MINERAL COMMODITY SUMMARIES 2020

Abrasives
Aluminum
Antimony
Arsenic
Asbestos
Barite
Bauxite
Beryllium
Bismuth
Boron
Bromine
Cadmium
Cement
Cesium
Chromium
Clays
Cobalt
Copper
Diamond
Diatomite
Feldspar
Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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Cover: Minerals play an integral part in all aspects of our lives. In this rural setting, minerals provide nutrients, such as nitrogen, phosphorus, potassium, and a host of micronutrients essential to maximize crop yields to ensure reliable food supplies. Various metals and other mineral materials are required to build the harvesters shown, in addition to the equipment needed to prepare the fields for and to plant these crops. Open spaces are ideal for wind farms, comprising myriad wind turbines that require numerous mineral materials for the actual structures as well as the infrastructure to transmit the electrical power produced to consumers across the nation. (Image provided as a courtesy of John Deere.)

U.S. Department of the Interior
U.S. Geological Survey

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Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
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U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
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KEY PUBLICATIONS

Minerals Yearbook—These annual publications review the mineral industries of the United States and of more than 180 other countries. They contain statistical data on minerals and materials and include information on economic and technical trends and developments and are available at https://www.usgs.gov/centers/nmic/publications. The three volumes that make up the Minerals Yearbook are Volume I, Metals and Minerals; Volume II, Area Reports, Domestic; and Volume III, Area Reports, International.

Mineral Commodity Summaries—Published on an annual basis, this report is the earliest Government publication to furnish estimates covering nonfuel mineral industry data and is available at https://www.usgs.gov/centers/nmic/mineral-commodity-summaries. Data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for more than 90 individual minerals and materials.

Mineral Industry Surveys—These periodic statistical and economic reports are designed to provide timely statistical data on production, shipments, stocks, and consumption of significant mineral commodities and are available at https://www.usgs.gov/centers/nmic/mineral-industry-surveys. The surveys are issued monthly, quarterly, or at other regular intervals.

Materials Flow Studies—These publications describe the flow of minerals and materials from extraction to ultimate disposition to help better understand the economy, manage the use of natural resources, and protect the environment and are available at https://www.usgs.gov/centers/nmic/materials-flow.

Recycling Reports—These studies illustrate the recycling of metal commodities and identify recycling trends and are available at https://www.usgs.gov/centers/nmic/recycling-statistics-and-information.

Historical Statistics for Mineral and Material Commodities in the United States (Data Series 140)—This report provides a compilation of statistics on production, trade, and use of approximately 90 mineral commodities since as far back as 1900 and is available at https://www.usgs.gov/centers/nmic/historical-statistics-mineral-and-material-commodities-united-states.

WHERE TO OBTAIN PUBLICATIONS

- *Mineral Commodity Summaries* and the *Minerals Yearbook* are sold by the U.S. Government Publishing Office. Orders are accepted over the internet at https://bookstore.gpo.gov, by email at ContactCenter@gpo.gov, by telephone toll free (866) 512–1800; Washington, DC area (202) 512–1800, by fax (202) 512–2104, or through the mail (P.O. Box 979050, St. Louis, MO 63197–9000).

- All current and many past publications are available in PDF format (and some are available in XLS format) through https://www.usgs.gov/centers/nmic.

INTRODUCTION

Each chapter of the 2020 edition of the U.S. Geological Survey (USGS) Mineral Commodity Summaries (MCS) includes information on events, trends, and issues for each mineral commodity as well as discussions and tabular presentations on domestic industry structure, Government programs, tariffs, 5-year salient statistics, and world production and resources. The MCS is the earliest comprehensive source of 2019 mineral production data for the world. More than 90 individual minerals and materials are covered by two-page synopses.

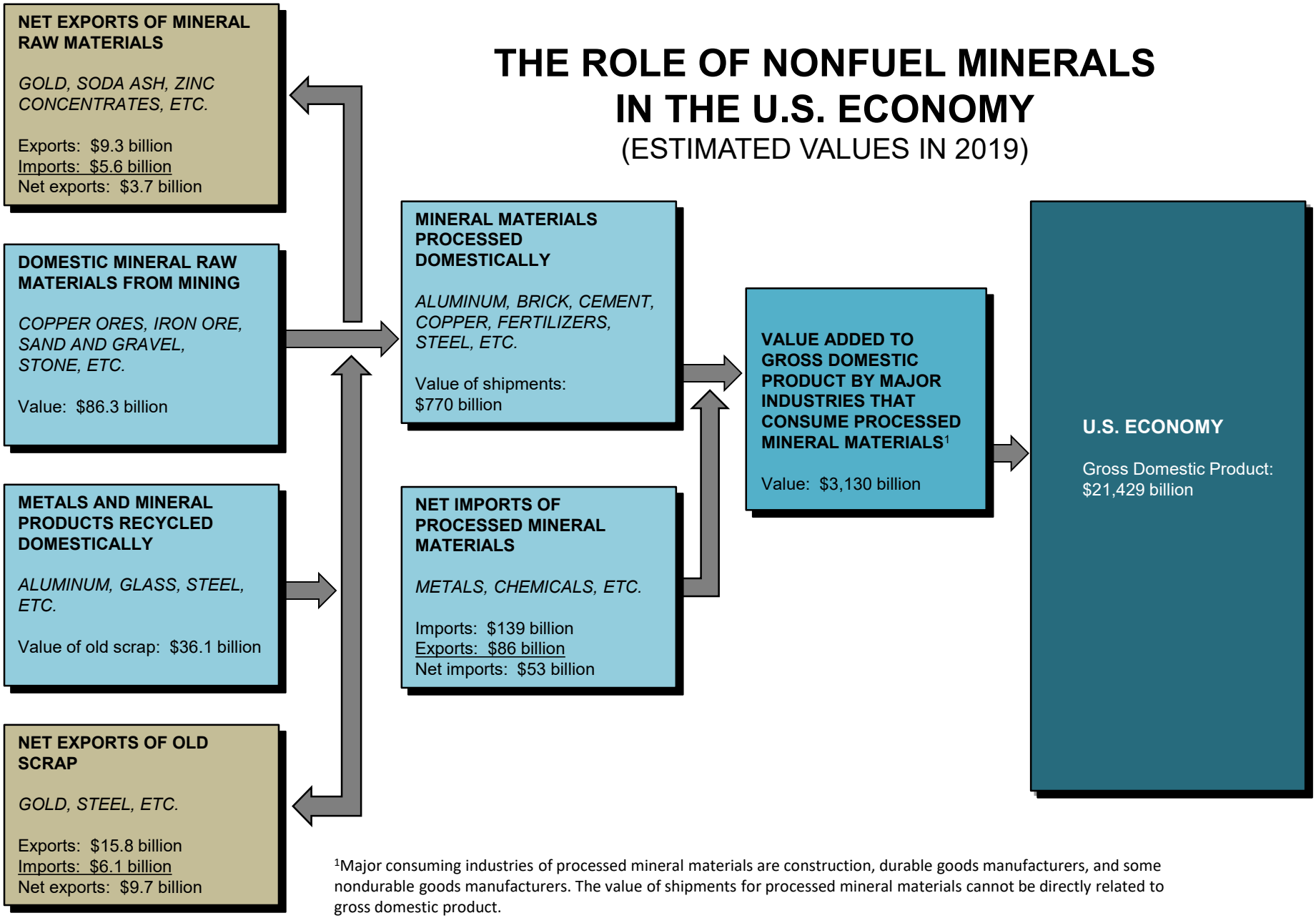
For mineral commodities for which there is a Government stockpile, detailed information concerning the stockpile status is included in the two-page synopsis.

Abbreviations and units of measure and definitions of selected terms used in the report are in Appendix A and Appendix B, respectively. “Appendix C—Reserves and Resources” includes “Part A—Resource/Reserve Classification for Minerals” and “Part B—Sources of Reserves Data.” A directory of USGS minerals information country specialists and their responsibilities is Appendix D.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the MCS 2020 are welcomed.

THE ROLE OF NONFUEL MINERALS IN THE U.S. ECONOMY

(ESTIMATED VALUES IN 2019)



[1]Major consuming industries of processed mineral materials are construction, durable goods manufacturers, and some nondurable goods manufacturers. The value of shipments for processed mineral materials cannot be directly related to gross domestic product.

Sources: U.S. Geological Survey and the U.S. Department of Commerce.

SIGNIFICANT EVENTS, TRENDS, AND ISSUES

In 2019, the estimated total value of nonfuel mineral production in the United States was $86.3 billion, an increase of 3% from the revised total of $84 billion in 2018. The estimated value of metals production increased slightly to $28.1 billion. Lower production of some metals was offset by increased values. Byproduct vanadium was produced in Utah for the first time since 2013. The total value of industrial minerals production was $58.2 billion, a 3% increase from that of 2018. Of this total, $27.7 billion was construction aggregates production (construction sand and gravel and crushed stone). Crushed stone was the leading nonfuel mineral commodity in 2019 accounting for 22% of the total value of U.S. nonfuel mineral production. Increased construction activity resulted in increased prices and production of some industrial minerals.

In 2018, as a result of U.S. Department of Commerce findings of harm to national security under Section 232 of the Trade Expansion Act of 1962, as amended (19 U.S.C. 1862), additional import duties for aluminum articles and steel articles were put into place. Several Presidential Proclamations were issued in 2019 modifying either the tariff rates or the countries affected. After the United States, Canada, and Mexico reached an agreement on trade terms in May, the ad valorem duties for aluminum and steel imports were removed for Canada and Mexico. As of December 2019, aluminum imports from all countries except Argentina, Australia, Canada, and Mexico remained subject to a 10% ad valorem tariff, and steel imports from all countries except Argentina, Australia, Brazil, Canada, the Republic of Korea, and Mexico remained subject to a 25% ad valorem tariff.

Under Section 301 (b) of the Trade Act of 1974, as amended, the Office of the United States Trade Representative (USTR) determined that acts, policies and practices of China related to technology transfer, intellectual property, and innovation were discriminatory or unreasonable and those actions burdened or restricted United States commerce (83 FR 14906) in 2018. Several lists of tariff lines (Lists 1, 2, 3) were compiled, and imports of those materials became subject to an additional import duty for products from China. Lists 1 and 2 had duty rates of 25% implemented in July 2018 and August 2018, respectively. List 3, which included nonfuel mineral commodities, had a duty rate of 10% imposed in late September 2018. The rate was scheduled to increase to 25% on January 1, 2019; however, that action was delayed. From January through May 2019, trade discussions between the United States and China were ongoing. In May 2019, because a trade agreement was not reached, the United States increased tariffs for List 3 items to 25% (84 FR 20459). China likewise imposed additional import duties for certain items originating in the United States. In December, a phase one trade agreement was reached between the United States and China, which reduced some tariff rates and resulted in additional tariffs not being implemented. At yearend 2019, the United States had a 25% tariff on approximately $250 billion of imports from China, including nonfuel mineral commodities, and a 7.5% tariff on approximately $120 billion of imports from China. China had additional tariffs ranging from 5% to 30% on approximately $110 billion of imports from the United States.

Also under Section 301 (b) of the Trade Act of 1974, as amended, the USTR published a request for comments in December (84 FR 67992) on proposed additional ad valorem duty rates of up to 100% for items from specified European countries, including several ferroalloys and other nonfuel mineral commodities. The critical minerals niobium, palladium, rhenium, and vanadium were on the list of proposed items.

Executive Order 13817, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (EO), was issued on December 20, 2017. Several actions were required of Federal agencies to address critical minerals. Pursuant to the EO, the Secretary of the Interior, in coordination with the Secretary of Defense, and in consultation with the heads of other relevant executive departments and agencies, was tasked with developing and submitting a list of minerals defined as critical minerals to the Federal Register. The final list of critical minerals was published in the Federal Register on May 18, 2018 (83 FR 23295), which included 35 minerals or mineral material groups. These were aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum-group metals, potash, the rare-earth-elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium.

The EO also directed the Secretary of Commerce, in coordination with heads of selected executive branch agencies and offices, to submit a report to the President that includes: “a strategy to reduce the Nation’s reliance on critical minerals; an assessment of progress toward developing critical minerals recycling and reprocessing technologies, and technological alternatives to critical minerals; options for accessing and developing critical minerals through investment and trade with our allies and partners; a plan to improve the topographic, geologic, and geophysical mapping of the United States and make the resulting data and metadata electronically accessible, to the extent permitted by law and subject to appropriate limitations for purposes of privacy and security, to support private sector mineral exploration of critical minerals; and recommendations to streamline permitting and review processes related to developing leases; enhancing access to critical mineral resources; and increasing discovery, production, and domestic refining of critical minerals.” In June 2019, the U.S. Department of Commerce issued the report,

which presented 6 Calls to Action, 24 goals, and 61 recommendations that describe specific steps that the Federal Government will take to achieve the objectives outlined in the EO.

As shown in the figure on page 4, minerals remained fundamental to the U.S. economy, contributing to the real gross domestic product at several levels, including mining, processing, and manufacturing finished products. The estimated value of nonfuel minerals produced at mines in the United States in 2019 was $86.3 billion. The value of net exports of mineral raw materials increased to $3.7 billion from $2.9 billion in 2018. Domestic raw materials and domestically recycled materials were used to produce mineral materials worth $770 billion. Of the $36.1 billion of domestically recycled products, iron and steel scrap contributed $17.6 billion. These mineral materials as well as imports of processed mineral materials, which decreased by 8% in 2019, were, in turn, consumed by downstream industries with an estimated value of $3.13 trillion in 2019, a 2.5% increase from the revised figure of $3.05 trillion in 2018.

The figure on page 7 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2019, imports made up more than one-half of the U.S. apparent consumption for 46 nonfuel mineral commodities, and the United States was 100% net import reliant for 17 of those. Critical minerals comprised 14 of the 17 mineral commodities with 100% net import reliance and comprised 17 of the 29 remaining mineral commodities with imports greater than 50% of annual consumption.

The figure on page 8 shows the countries from which the majority of these mineral commodities were imported and the number of mineral commodities for which each highlighted country was a leading supplier. China, followed by Canada, supplied the largest number of nonfuel mineral commodities. The United States was import reliant for an additional 30 commodities and was a net exporter of 17 nonfuel mineral commodities.

The estimated value of U.S. metal mine production in 2019 was $28.1 billion, slightly more than that of 2018 (table 1). Principal contributors to the total value of metal mine production in 2019 were gold (32%), copper (28%), iron ore (19%), and zinc (7%). The estimated value of U.S. industrial minerals production in 2019, including construction aggregates, was $58.2 billion, about 3% more than the revised value of 2018 (table 1). The value of industrial minerals production in 2019 was dominated by crushed stone (32%), cement (masonry and portland) (19%), construction sand and gravel (16%) and industrial sand and gravel (10%).

In 2019, U.S. production of 13 mineral commodities was valued at more than $1 billion each. These commodities were, in decreasing order of value, crushed stone, cement, construction sand and gravel, gold, copper, industrial sand and gravel, iron ore, lime, salt, zinc, soda ash, phosphate rock, and molybdenum concentrates.

In 2019, 13 States each produced more than $2 billion worth of nonfuel mineral commodities. These States were, in descending order of production value, Nevada, Arizona, Texas, Minnesota, California, Florida, Utah, Alaska, Missouri, Michigan, Wyoming, Georgia, and Pennsylvania (table 3 and figure on page 12).

The Defense Logistics Agency (DLA) Strategic Materials is responsible for providing safe, secure, and environmentally sound stewardship for strategic and critical materials in the U.S. National Defense Stockpile (NDS). DLA Strategic Materials stores 48 commodities at 12 locations in the United States. In fiscal year 2019, DLA Strategic Materials acquired approximately $14.5 million of new stock and sold $37.14 million of excess materials from the NDS. At the end of fiscal year 2019, materials valued at $1.03 billion remained in the NDS. Of the remaining material, portions were held in reserve, offered for sale, or sales were suspended. Additional detailed information can be found in the “Government Stockpile” sections in the mineral commodity chapters that follow. Under the authority of the Defense Production Act of 1950, the U.S. Geological Survey advises the DLA on acquisitions and disposals of NDS mineral materials.

2019 U.S. NET IMPORT RELIANCE[1]

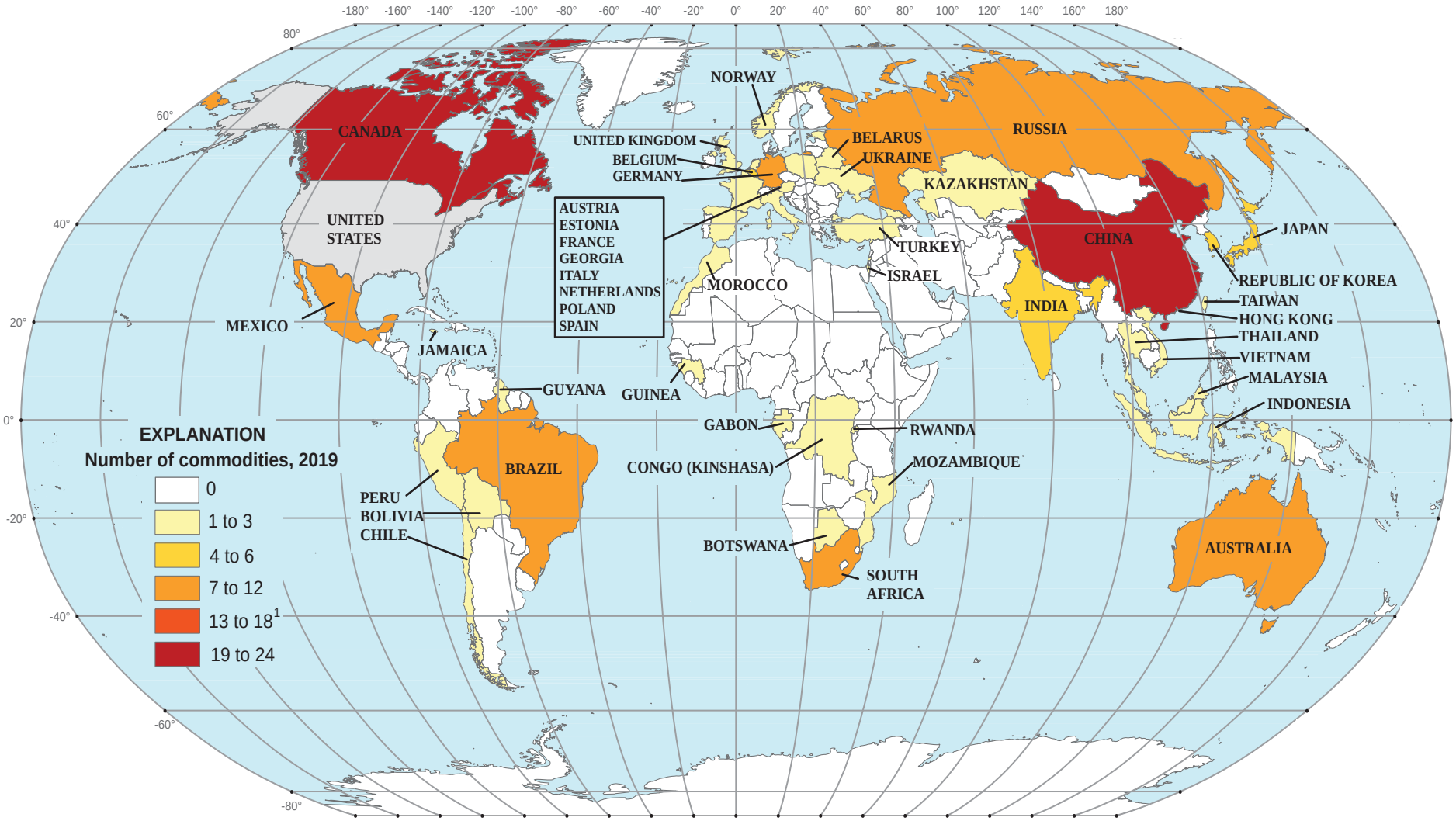
Commodity	Percent	Major import sources (2015–18)[2]
ARSENIC (all forms)	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, Vietnam, South Africa, China
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, Taiwan
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA, sheet (natural)	100	China, Brazil, Belgium, Austria
NEPHELINE SYENITE	100	Canada
NIOBIUM (columbium)	100	Brazil, Canada, Russia, Germany
RARE EARTHS[3] (compounds and metal)	100	China, Estonia, Japan, Malaysia
RUBIDIUM	100	Canada
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	Rwanda, Brazil, Australia, Congo (Kinshasa)
YTTRIUM	100	China, Estonia, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
BISMUTH	96	China, Belgium, Mexico, Republic of Korea
TELLURIUM	>95	Canada, China, Germany
VANADIUM	94	Austria, Canada, Russia, Republic of Korea
TITANIUM MINERAL CONCENTRATES	93	South Africa, Australia, Canada, Mozambique
POTASH	91	Canada, Russia, Belarus, Israel
DIAMOND (industrial stones)	88	India, South Africa, Botswana, Australia
BARITE	87	China, India, Morocco, Mexico
ZINC (refined)	87	Canada, Mexico, Australia, Peru
TITANIUM (sponge)	86	Japan, Kazakhstan, Ukraine, China, Russia
ANTIMONY (metal and oxide)	84	China, Thailand, Belgium, India
RHENIUM	82	Chile, Germany, Kazakhstan, Canada
STONE (dimension)	81	China, Brazil, Italy, Turkey
COBALT	78	Norway, Japan, China, Canada
TIN (refined)	77	Indonesia, Malaysia, Peru, Bolivia
ABRASIVES, fused Al oxide (crude)	>75	China, Hong Kong, France, Canada
BAUXITE	>75	Jamaica, Brazil, Guinea, Guyana
CHROMIUM	72	South Africa, Kazakhstan, Russia
PEAT	70	Canada
SILVER	68	Mexico, Canada, Peru, Poland
GARNET (industrial)	64	Australia, India, South Africa, China
PLATINUM	64	South Africa, Germany, Italy, Russia
ALUMINA	54	Brazil, Australia, Jamaica, Canada
MAGNESIUM COMPOUNDS	52	China, Canada, Australia, Hong Kong
ABRASIVES, silicon carbide (crude)	>50	China, South Africa, Netherlands, Hong Kong
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
IRON OXIDE PIGMENTS (natural and synthetic)	>50	China, Germany, Brazil, Canada
TUNGSTEN	>50	China, Bolivia, Germany, Spain
DIAMOND (industrial dust, grit, and powder)	50	China, Ireland, Republic of Korea, Russia
CADMIUM	<50	China, Australia, Canada, Peru
MAGNESIUM METAL	<50	Israel, Canada, Mexico, United Kingdom
NICKEL	47	Canada, Norway, Australia, Finland
SILICON (metal and ferrosilicon)	41	Russia, Brazil, Canada
MICA, scrap and flake (natural)	37	Canada, China, India, Finland
COPPER (refined)	35	Chile, Canada, Mexico
PALLADIUM	32	South Africa, Russia, Germany, Italy
LEAD (refined)	30	Canada, Mexico, Republic of Korea, India
SALT	29	Chile, Canada, Mexico, Egypt
PERLITE	28	Greece, China, Mexico
LITHIUM	>25	Argentina, Chile, China
BROMINE	<25	Israel, Jordan, China
SELENIUM	<25	China, Philippines, Mexico, Germany
ALUMINUM	22	Canada, Russia, United Arab Emirates, China
IRON and STEEL	21	Canada, Brazil, Republic of Korea

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (abrasives, metallic; boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zirconium mineral concentrates) or less than 21% import reliant (beryllium; cement; feldspar; gypsum; iron and steel slag; lime; nitrogen (fixed)–ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; talc and pyrophyllite; and vermiculite.). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]In descending order of import share.

[3]Data include lanthanides.

MAJOR IMPORT SOURCES OF NONFUEL MINERAL COMMODITIES FOR WHICH THE UNITED STATES WAS GREATER THAN 50% NET IMPORT RELIANT IN 2019



[1]In 2019, no countries qualified for the "13 to 18 commodities" category.

Source: U.S. Geological Survey

TABLE 1.—U.S. MINERAL INDUSTRY TRENDS

	2015	2016	2017	2018	2019[e]
Total mine production (million dollars):					
Metals	24,400	23,800	26,500	27,700	28,100
Industrial minerals	48,600	47,700	52,700	56,300	58,200
Coal	28,500	22,300	26,100	27,200	25,100
Employment (thousands of production workers):					
Coal mining	54	42	43	44	45
Nonfuel mineral mining	99	95	97	101	101
Chemicals and allied products	507	516	525	548	563
Stone, clay, and glass products	296	306	305	310	311
Primary metal industries	307	293	292	294	296
Average weekly earnings of production workers (dollars):					
Coal mining	1,383	1,336	1,432	1,437	1,520
Chemicals and allied products	927	920	1,011	1,072	1,069
Stone, clay, and glass products	843	850	873	945	967
Primary metal industries	987	1,002	995	1,035	1,025

[e]Estimated.

Sources: U.S. Geological Survey, U.S. Department of Energy, and U.S. Department of Labor.

TABLE 2.—U.S. MINERAL-RELATED ECONOMIC TRENDS

	2015	2016	2017	2018	2019[e]
Gross domestic product (billion dollars)	18,225	18,715	19,519	20,580	21,429
Industrial production (2012=100):					
Total index:	104	102	104	109	109
Manufacturing:	102	101	103	106	106
Nonmetallic mineral products	110	111	115	120	120
Primary metals:	97	93	94	98	98
Iron and steel	92	87	92	97	98
Aluminum	107	106	103	107	109
Nonferrous metals (except aluminum)	98	95	91	91	88
Chemicals	95	95	97	100	101
Mining:	114	103	110	124	132
Coal	87	70	75	74	70
Oil and gas extraction	134	129	135	156	171
Metals	100	100	98	93	94
Nonmetallic minerals	116	114	118	119	125
Capacity utilization (percent):					
Total industry:	77	75	76	79	78
Mining:	84	78	84	90	91
Metals	75	75	71	69	69
Nonmetallic minerals	90	87	88	88	91
Housing starts (thousands)	1,107	1,178	1,209	1,250	1,260
Light vehicle sales (thousands)	17,396	17,465	17,136	17,214	17,000
Highway construction, value, put in place (billion dollars)	91	94	90	91	100

[e]Estimated.

Sources: U.S. Department of Commerce, Federal Reserve Board, and U.S. Department of Transportation.

TABLE 3.—VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2019[e, 1]

State	Value (millions)	Rank[2]	Percent of U.S. total	Principal commodities[3]
Alabama	$1,690	19	1.96	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Alaska	3,130	8	3.63	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	6,970	2	8.08	Cement (portland), copper, molybdenum concentrates, sand and gravel (construction), stone (crushed).
Arkansas	901	31	1.04	Bromine, cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California	4,490	5	5.20	Boron minerals, cement (portland), gold, sand and gravel (construction), stone (crushed).
Colorado	1,790	17	2.07	Cement (portland), gold, molybdenum concentrates, sand and gravel (construction), stone (crushed).
Connecticut[4]	191	43	0.22	Clay (common clay), sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[4]	30	50	0.03	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida	3,370	6	3.91	Cement (portland), phosphate rock, sand and gravel (construction), stone (crushed), zirconium mineral concentrates.
Georgia	2,170	12	2.52	Cement (portland), clay (kaolin and montmorillonite), sand and gravel (construction), stone (crushed).
Hawaii	134	46	0.16	Sand and gravel (construction), stone (crushed).
Idaho[4]	185	35	0.21	Lead, phosphate rock, sand and gravel (construction), silver, stone (crushed).
Illinois[4]	1,470	20	1.17	Cement (portland), sand and gravel (construction), sand and gravel (industrial), silica (tripoli), stone (crushed).
Indiana	695	26	0.81	Cement (portland), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa[4]	836	27	0.97	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[4]	1,070	24	1.24	Cement (portland), helium (Grade-A), salt, sand and gravel (construction), stone (crushed).
Kentucky[4]	591	30	0.68	Cement (portland), clay (common clay), lime, sand and gravel (construction), stone (crushed).
Louisiana[4]	614	34	0.71	Clay (common clay), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[4]	102	45	0.12	Cement (portland), peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[4]	575	32	0.67	Cement (masonry and portland), sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[4]	289	42	0.34	Clay (common clay), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	2,750	10	3.18	Cement (portland), iron ore, salt, sand and gravel (construction), stone (crushed).
Minnesota[4]	5,300	4	6.14	Iron ore, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Mississippi	504	37	0.58	Clay (ball clay and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	3,050	9	3.53	Cement (portland), lead, lime, sand and gravel (industrial), stone (crushed).
Montana	1,280	23	1.49	Copper, molybdenum concentrates, palladium, platinum, sand and gravel (construction).

See footnotes at end of table.

TABLE 3.—VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2019[e, 1]—Continued

State	Value (millions)	Rank[2]	Percent of U.S. total	Principal commodities[3]
Nebraska[4]	$214	39	0.25	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	8,190	1	9.49	Copper, diatomite, gold, lime, sand and gravel (construction).
New Hampshire	156	44	0.18	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	377	40	0.44	Peat, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	1,090	28	1.26	Cement (portland), copper, potash, sand and gravel (construction), stone (crushed).
New York	1,870	16	2.16	Cement (portland), salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina[4]	1,420	18	1.64	Clay (common clay), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[4]	58	48	0.07	Clay (common clay), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Ohio[4]	1,400	15	1.62	Cement (portland), lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	1,070	29	1.24	Cement (portland), iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon	499	38	0.58	Cement (portland), diatomite, perlite (crude), sand and gravel (construction), stone (crushed).
Pennsylvania[4]	2,100	13	2.44	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Rhode Island[4]	54	49	0.06	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina[4]	1,140	25	1.32	Cement (masonry and portland), gold, sand and gravel (construction), stone (crushed).
South Dakota	312	41	0.36	Cement (portland), gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,420	22	1.64	Cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	6,470	3	7.49	Cement (portland), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	3,320	7	3.85	Copper, gold, molybdenum concentrates, salt, sand and gravel (construction).
Vermont[4]	95	47	0.11	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,520	21	1.76	Cement (portland), kyanite, lime, sand and gravel (construction), stone (crushed).
Washington	869	33	1.01	Cement (portland), diatomite, sand and gravel (construction), stone (crushed), zinc.
West Virginia[4]	332	36	0.38	Cement (masonry and portland), lime, sand and gravel (industrial), stone (crushed).
Wisconsin[4]	1,950	14	2.26	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	2,630	11	3.05	Cement (portland), clay (bentonite), helium (Grade-A), sand and gravel (construction), soda ash.
Undistributed	3,580	XX	4.15	
Total	86,300	XX	100.00	

[e]Estimated. XX Not applicable.

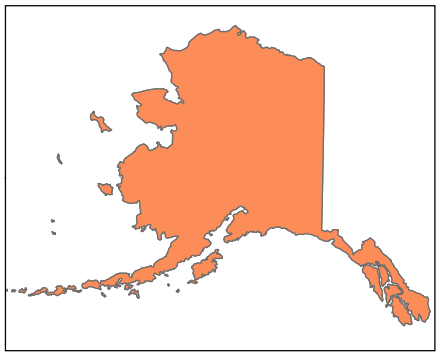
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

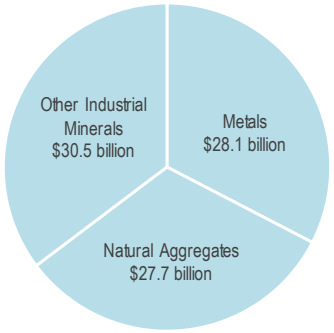
[2]Rank based on total, unadjusted State values.

[3]Listed in alphabetical order for each State.

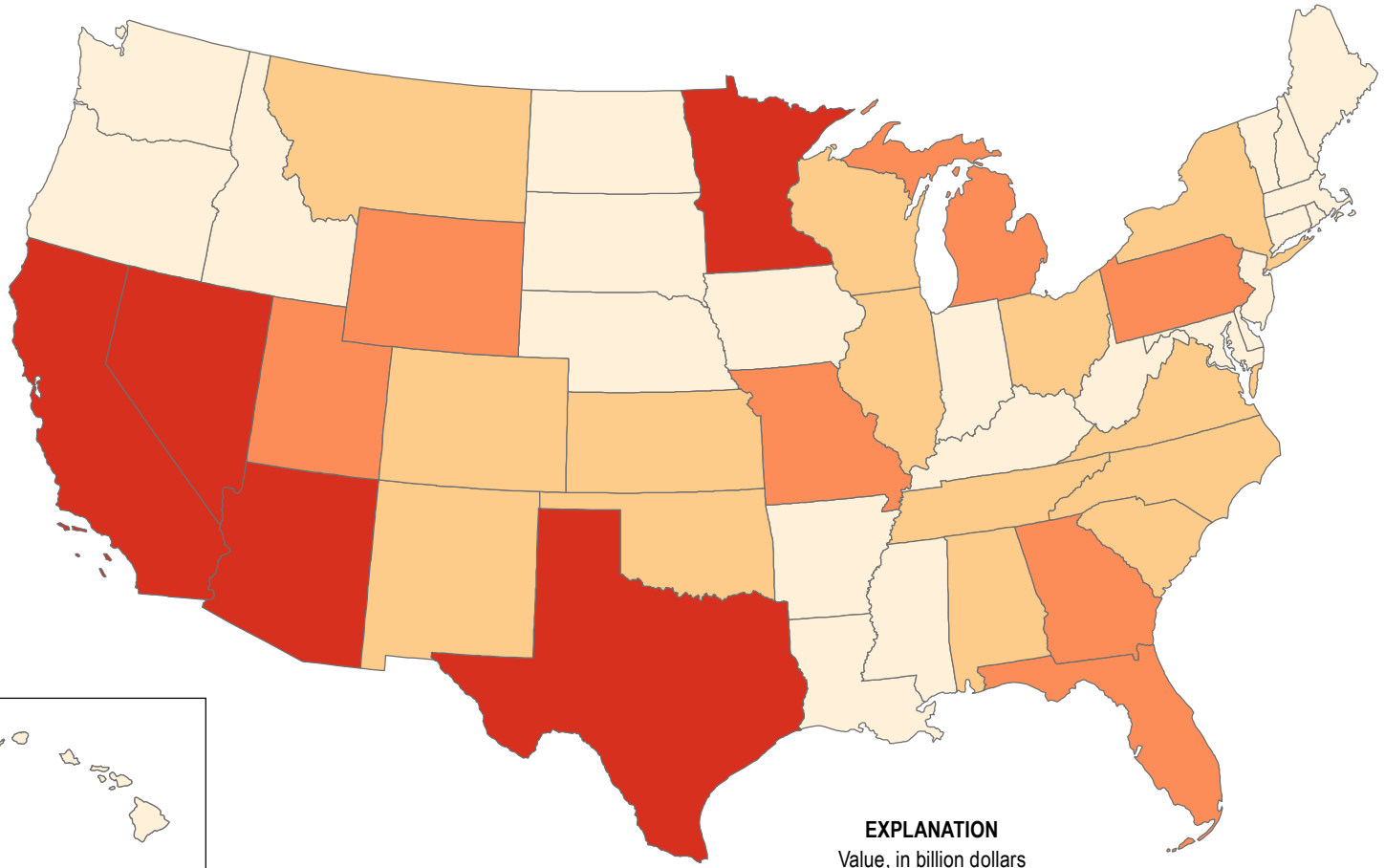
[4]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included in "Undistributed."

VALUE OF NONFUEL MINERALS PRODUCED IN 2019, BY STATE





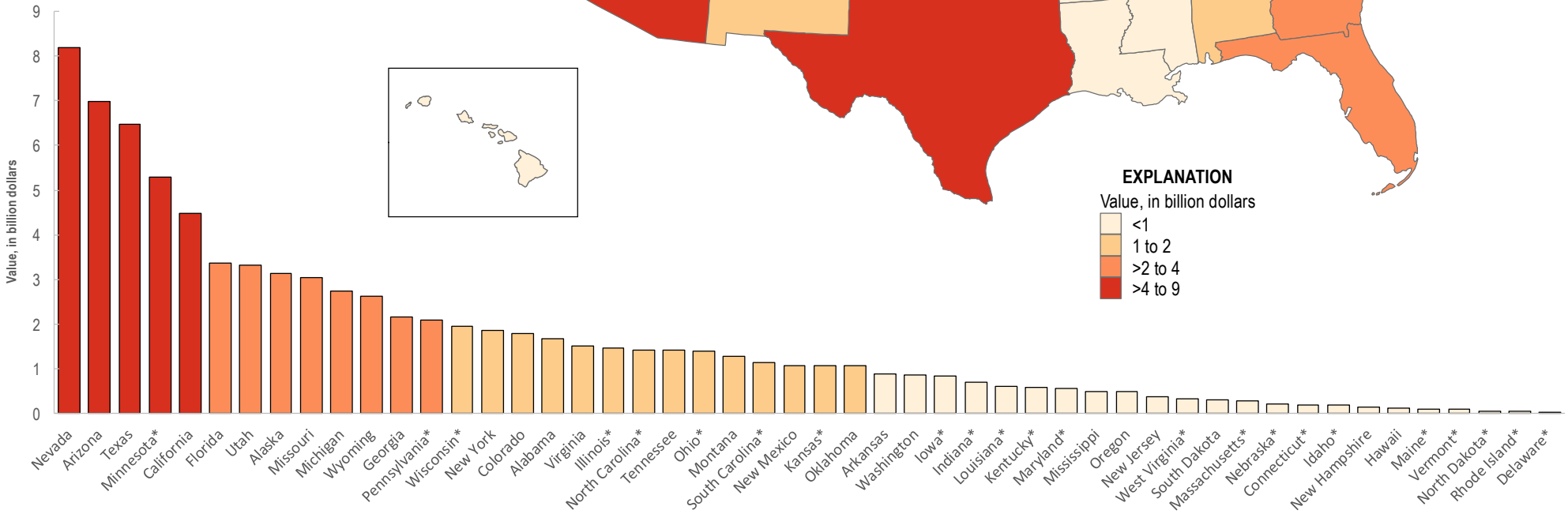
U.S. total: $86.3 billion



EXPLANATION

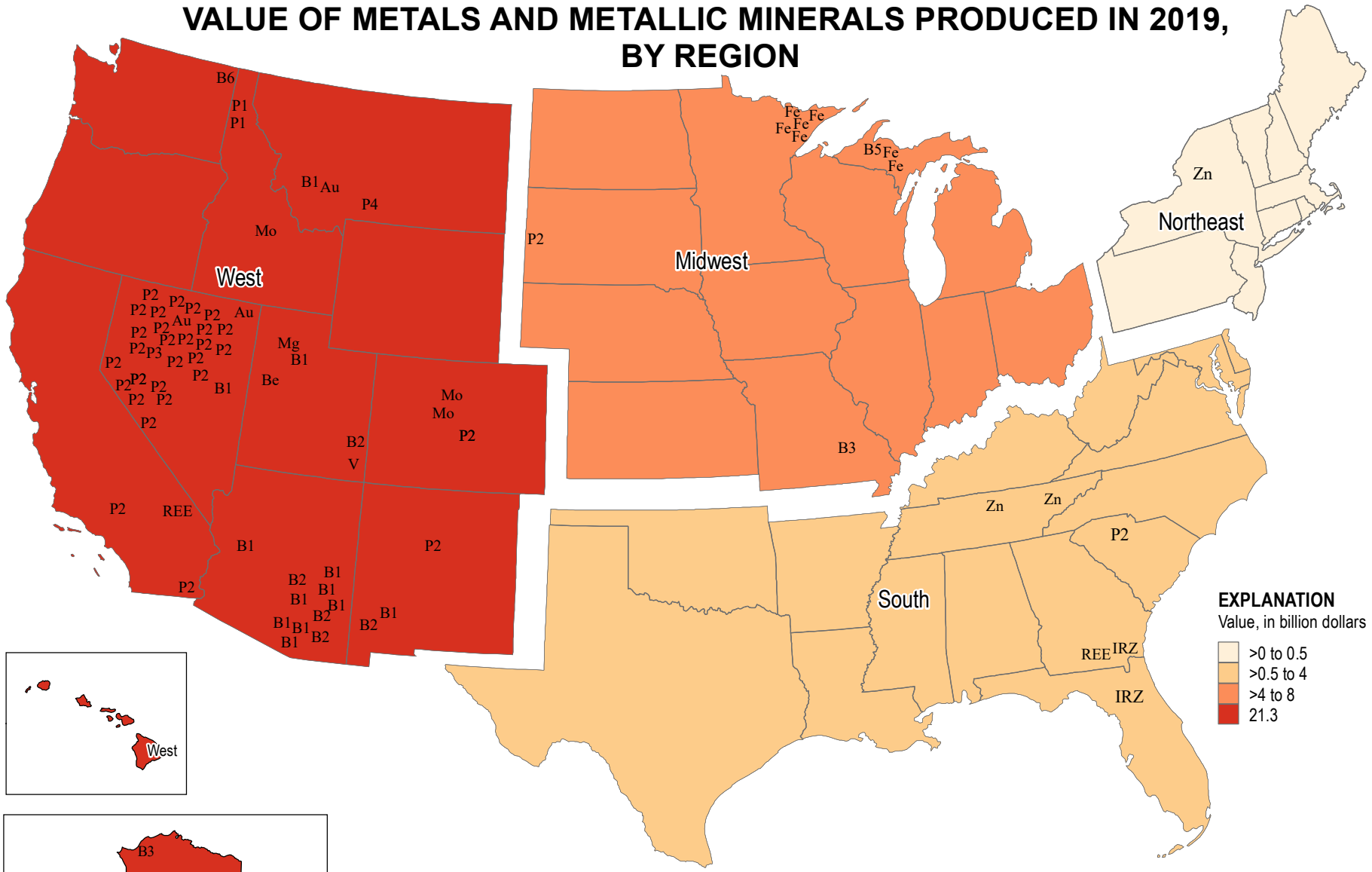
Value, in billion dollars

- <1
- 1 to 2
- >2 to 4
- >4 to 9



*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

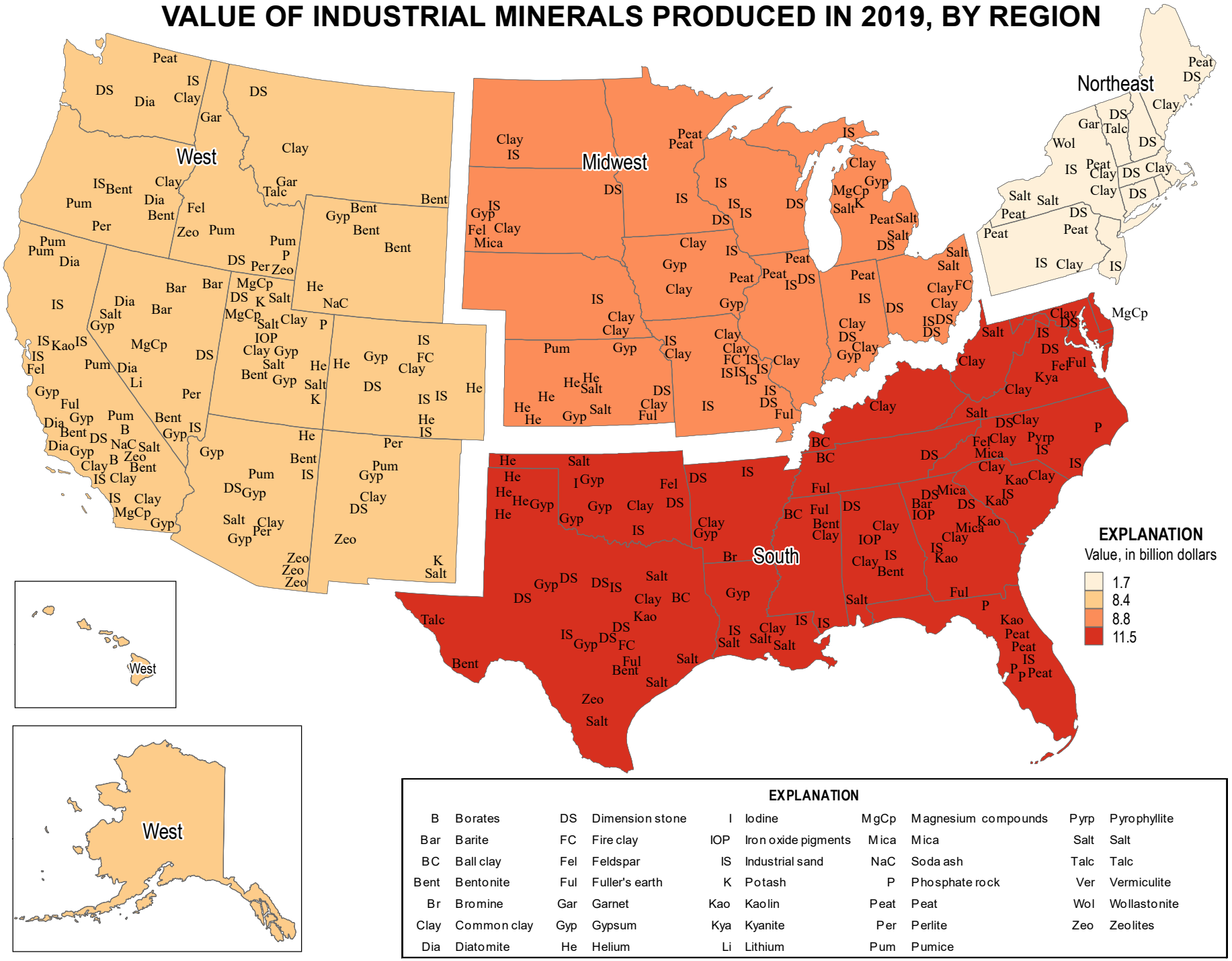
VALUE OF METALS AND METALLIC MINERALS PRODUCED IN 2019, BY REGION



EXPLANATION

Au	Gold	B5	Nickel, copper, and cobalt	Mg	Magnesium	P4	Platinum and palladium ± gold and silver
B1	Copper ± molybdenum ± gold and silver	B6	Lead and zinc	Mo	Molybdenum	REE	Rare-earth elements
B2	Copper ± silver	Be	Beryllium	P1	Silver ± base metals ± gold	V	Vanadium
B3	Lead and zinc ± copper ± silver	Fe	Iron ore	P2	Gold and silver	Zn	Zinc
B4	Silver and zinc ± lead and gold	IRZ	Ilmenite, rutile, and zircon	P3	Gold and silver ± base metals		

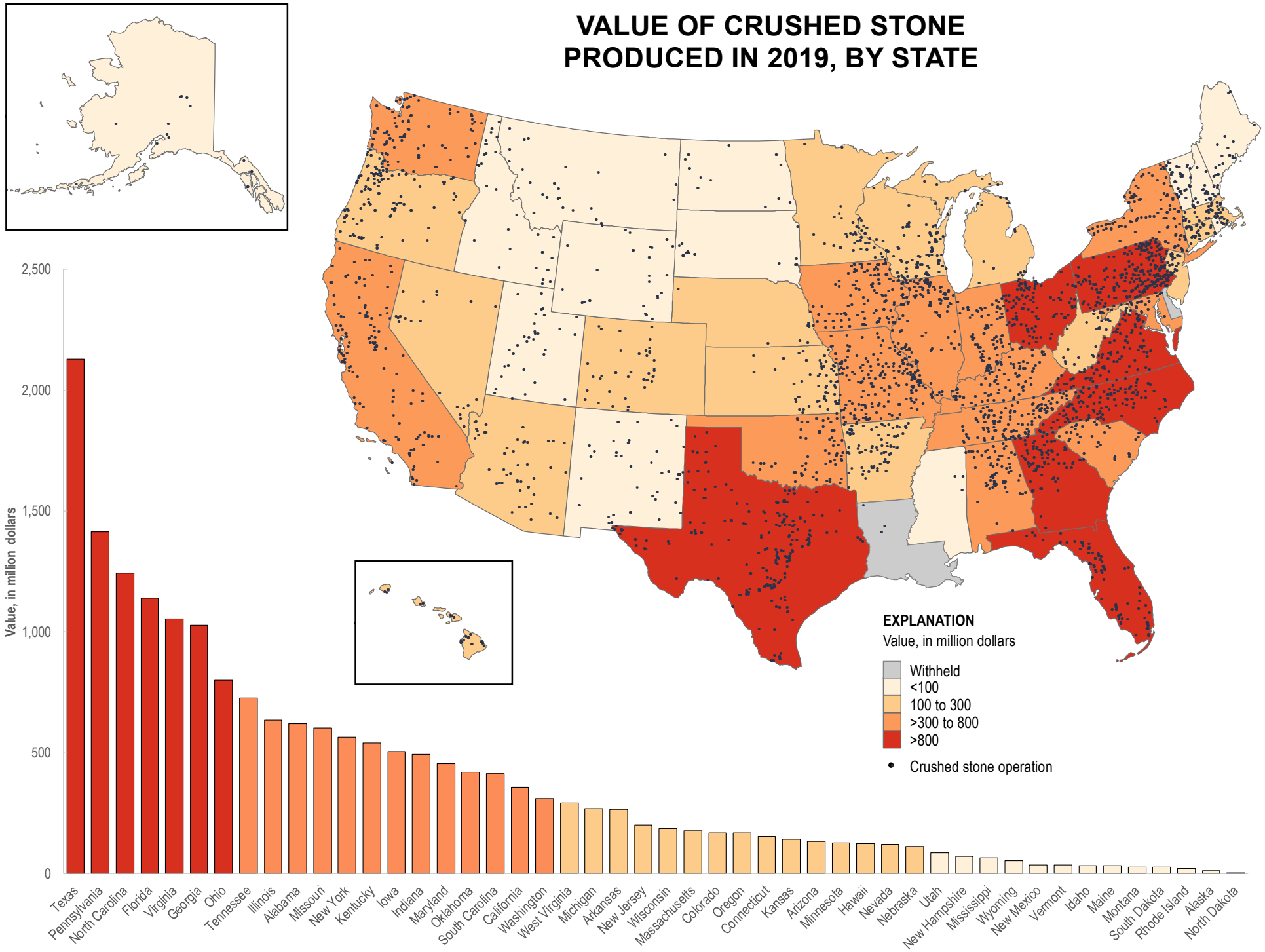
VALUE OF INDUSTRIAL MINERALS PRODUCED IN 2019, BY REGION



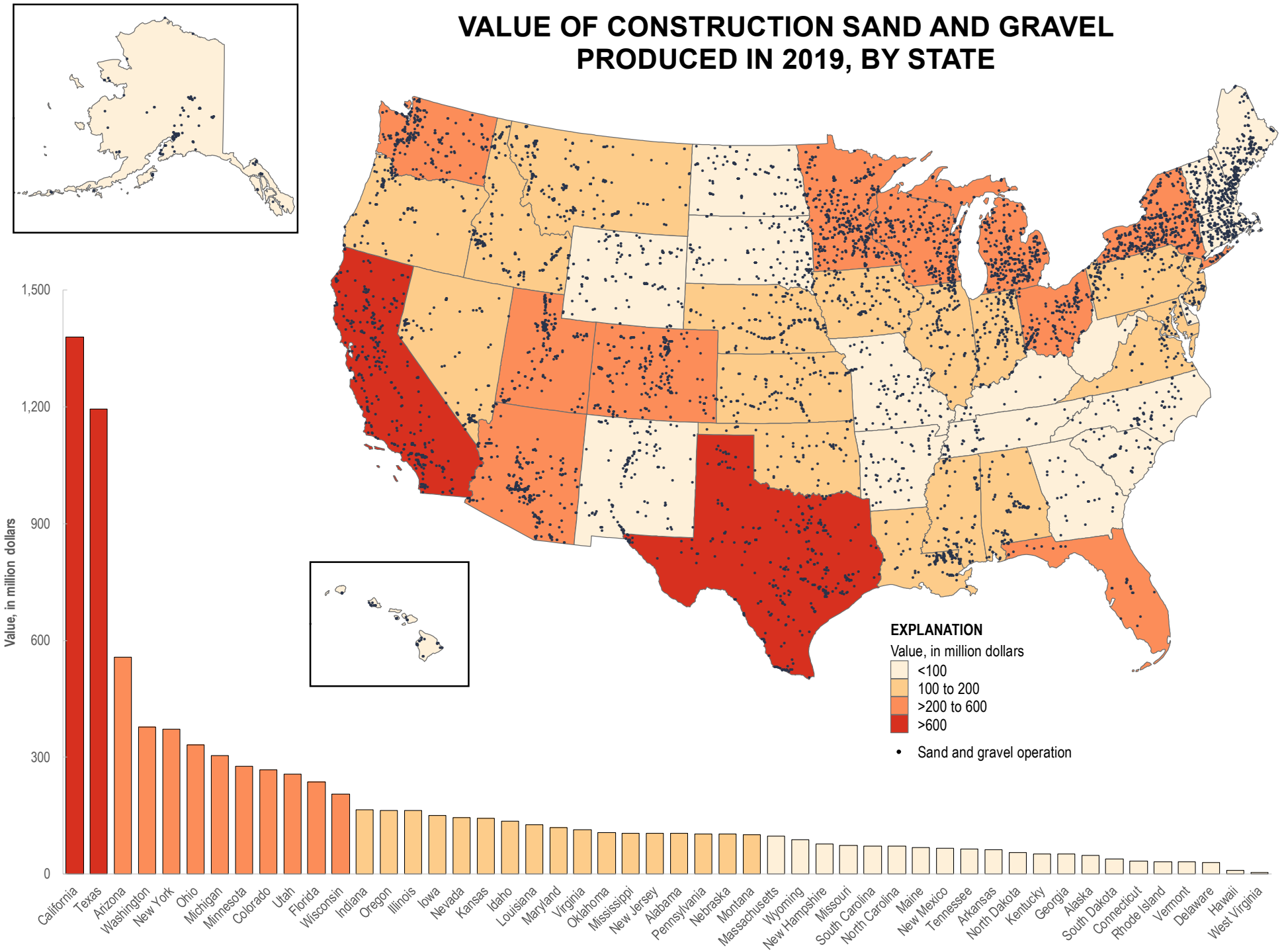
EXPLANATION

B	Borates	DS	Dimension stone	I	Iodine	MgCp	Magnesium compounds	Pyrp	Pyrophyllite
Bar	Barite	FC	Fire clay	IOP	Iron oxide pigments	Mica	Mica	Salt	Salt
BC	Ball clay	Fel	Feldspar	IS	Industrial sand	NaC	Soda ash	Talc	Talc
Bent	Bentonite	Ful	Fuller's earth	K	Potash	P	Phosphate rock	Ver	Vermiculite
Br	Bromine	Gar	Garnet	Kao	Kaolin	Peat	Peat	Wol	Wollastonite
Clay	Common clay	Gyp	Gypsum	Kya	Kyanite	Per	Perlite	Zeo	Zeolites
Dia	Diatomite	He	Helium	Li	Lithium	Pum	Pumice		

VALUE OF CRUSHED STONE PRODUCED IN 2019, BY STATE



VALUE OF CONSTRUCTION SAND AND GRAVEL PRODUCED IN 2019, BY STATE



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ABRASIVES (MANUFACTURED)

(Fused aluminum oxide, silicon carbide, and metallic abrasives)
(Data in metric tons unless otherwise noted)

Domestic Production and Use: Fused aluminum oxide was produced by two companies at three plants in the United States and Canada. Production of crude fused aluminum oxide had an estimated value of $7 million. Silicon carbide was produced by two companies at two plants in the United States. Production of crude silicon carbide had an estimated value of about $26 million. Metallic abrasives were produced by 11 companies in 8 States. Production of metallic abrasives had an estimated value of about $190 million. Bonded and coated abrasive products accounted for most abrasive uses of fused aluminum oxide and silicon carbide. Metallic abrasives are used primarily for steel shot and grit and cut wire shot, which are used for sandblasting, peening, and stonecutting applications.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	10,000	10,000
Silicon carbide[2]	35,000	35,000	35,000	35,000	35,000
Metallic abrasives	206,000	188,000	179,000	180,000	180,000
Shipments, metallic abrasives	224,000	204,000	197,000	196,000	190,000
Imports for consumption:					
Fused aluminum oxide	164,000	155,000	206,000	193,000	170,000
Silicon carbide	139,000	116,000	137,000	146,000	110,000
Metallic abrasives	52,800	54,100	29,600	29,900	30,000
Exports:					
Fused aluminum oxide	15,000	14,300	15,500	19,300	22,000
Silicon carbide	19,700	6,820	6,100	10,100	12,000
Metallic abrasives	35,900	28,600	31,000	33,600	32,000
Consumption, apparent:					
Fused aluminum oxide[3]	159,000	151,000	201,000	184,000	160,000
Silicon carbide[4]	154,000	144,000	166,000	171,000	130,000
Metallic abrasives[5]	241,000	230,000	196,000	192,000	190,000
Price, average unit value of imports, dollars per ton:					
Fused aluminum oxide, regular	579	418	489	692	730
Fused aluminum oxide, high-purity	1,290	1,360	1,220	1,280	1,300
Silicon carbide, crude	552	452	479	670	800
Metallic abrasives	584	543	1,020	1,180	1,300
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>75	>75	>75	>75	>75
Silicon carbide	>75	>75	>75	>75	>50
Metallic abrasives	7	11	E	E	E

Recycling: Up to 30% of fused aluminum oxide may be recycled, and about 5% of silicon carbide is recycled.

Import Sources (2015–18): Fused aluminum oxide, crude: China, 69%; Hong Kong, 14%; France, 8%; Canada, 4%; and other, 5%. Fused aluminum oxide, grain: Austria, 19%; Brazil, 17%; Canada, 16%; Germany, 14%; and other, 34%. Silicon carbide, crude: China, 80%; South Africa, 7%; Netherlands, 5%; Hong Kong, 4%; and other, 4%. Silicon carbide, grain: China, 52%; Brazil, 19%; Russia, 10%; Norway, 5%; and other, 14%. Metallic abrasives: Sweden, 32%; Canada, 24%; China, 13%; Germany, 9%; and other, 22%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Artificial corundum, crude	2818.10.1000	Free.
White, pink, ruby artificial corundum, greater than 97.5% aluminum oxide, grain	2818.10.2010	1.3% ad val.
Artificial corundum, not elsewhere specified or included, fused aluminum oxide, grain	2818.10.2090	1.3% ad val.
Silicon carbide, crude	2849.20.1000	Free.
Silicon carbide, grain	2849.20.2000	0.5% ad val.
Iron, pig iron, or steel granules	7205.10.0000	Free.

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ABRASIVES (MANUFACTURED)

Depletion Allowance: None.

Government Stockpile: None.

Events, Trends, and Issues: In 2019, China was the world's leading producer of abrasive fused aluminum oxide and abrasive silicon carbide. Imports, especially from China where operating costs were lower, continued to challenge abrasives producers in the United States and Canada. In recent years, imports of abrasives from Hong Kong have also increased. Foreign competition is expected to persist and continue to limit production in North America. The average unit value of imports has increased every year since 2016 for regular fused aluminum oxide and crude silicon carbide. The average unit values of imports of regular fused aluminum oxide and crude silicon carbide during the first 6 months of 2019 were 5% and 20% higher, respectively, than those in 2018 and 49% and 60% higher, respectively, than those in 2017.

Abrasives consumption in the United States is greatly influenced by activity in the manufacturing sectors, in particular the aerospace, automotive, furniture, housing, and steel industries. Steel grit can be reclaimed and used multiple times. The use of reclaimed metallic abrasives increased potentially owing to rising surcharges on scrap and waste disposal and increasing prices for new material.

One of the leading abrasives producers in the world divested its silicon carbide business to a private equity firm during 2019.

World Production Capacity:

	Fused aluminum oxide[e]		Silicon carbide[e]	
	2018	2019	2018	2019
United States	60,000	60,000	40,000	40,000
Argentina	—	—	5,000	5,000
Australia	50,000	50,000	—	—
Austria	60,000	60,000	—	—
Brazil	50,000	50,000	40,000	40,000
China	800,000	800,000	450,000	450,000
France	40,000	40,000	20,000	20,000
Germany	80,000	80,000	35,000	35,000
India	40,000	40,000	5,000	5,000
Japan	15,000	15,000	60,000	60,000
Mexico	—	—	45,000	45,000
Norway	—	—	80,000	80,000
Venezuela	—	—	30,000	30,000
Other countries	80,000	80,000	190,000	190,000
World total (rounded)	1,300,000	1,300,000	1,000,000	1,000,000

World Resources: Although domestic resources of raw materials for the production of fused aluminum oxide are rather limited, adequate resources are available in the Western Hemisphere. Domestic resources are more than adequate for the production of silicon carbide.

Substitutes: Natural and manufactured abrasives, such as garnet, emery, or metallic abrasives, can be substituted for fused aluminum oxide and silicon carbide in various applications.

[e]Estimated. E Net exporter. — Zero.

[1]Production data for aluminum oxide are combined production data from the United States and Canada to avoid disclosing company proprietary data.

[2]Rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.

[3]Defined as imports – exports because production includes data from Canada; actual consumption is higher than that shown.

[4]Defined as production + imports – exports.

[5]Defined as shipments + imports – exports.

[6]Defined as imports – exports.

ALUMINUM[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, three companies operated seven primary aluminum smelters in six States. Two smelters operated at full capacity and five smelters operated at reduced capacity throughout the year. One other smelter remained on standby throughout the year. Domestic smelters were operating at about 60% of capacity of 1.79 million tons per year in 2019. Production increased for the second year in a row after declining each year since 2012 and was 22% more than that in 2018. Based on published prices, the value of primary aluminum production was about $2.4 billion, 7% more than the value in 2018. The average annual U.S. market price declined by about 13% from that in 2018, partially offsetting the value of the increased production. Transportation applications accounted for 39% of domestic consumption; in descending order of consumption, the remainder was used in packaging, 19%; building, 14%; electrical, 9%; consumer durables, 8%; machinery, 8%; and other, 3%.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Primary	1,587	818	741	891	1,100
Secondary (from old scrap)	1,470	1,570	1,590	1,570	1,500
Secondary (from new scrap)	1,910	2,010	2,050	2,140	1,900
Imports for consumption:					
Crude and semimanufactures	4,560	5,410	6,220	5,540	3,700
Scrap	521	609	700	695	600
Exports:					
Crude and semimanufactures	1,460	1,470	1,330	1,340	1,100
Scrap	1,550	1,350	1,570	1,760	1,900
Consumption, apparent[2]	5,220	5,090	5,680	4,860	3,400
Supply, apparent[3]	7,120	7,100	7,730	7,000	5,300
Price, ingot, average U.S. market (spot), cents per pound	88.2	80.4	98.3	114.7	100
Stocks, yearend:					
Aluminum industry	1,350	1,400	1,470	1,570	1,600
London Metal Exchange (LME), U.S. warehouses[4]	507	362	254	186	65
Employment, number[5]	31,000	31,900	31,700	31,600	31,600
Net import reliance[6] as a percentage of apparent consumption	41	53	59	49	22

Recycling: In 2019, aluminum recovered from purchased scrap in the United States was about 3.4 million tons, of which about 56% came from new (manufacturing) scrap and 44% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 45% of apparent consumption.

Import Sources (2015–18): Canada, 48%; Russia 9%; United Arab Emirates, 9%; China, 6%; and other, 28%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Aluminum, not alloyed:		
Unwrought (in coils)	7601.10.3000	2.6% ad val.
Unwrought (other than aluminum alloys)	7601.10.6000	Free.
Aluminum alloys:		
Unwrought (billet)	7601.20.9045	Free.
Aluminum waste and scrap:		
Used beverage container scrap	7602.00.0030	Free.
Other	7602.00.0090	Free.

Depletion Allowance: Not applicable.[1]

Government Stockpile: None.

Events, Trends, and Issues: A 252,000-ton-per-year smelter in Hawesville, KY, shut down one potline with 50,000 tons per year of capacity in June for scheduled maintenance work. Another 50,000-ton-per-year potline at the Hawesville smelter was shut down for maintenance work in October ahead of a scheduled shutdown. Both potlines were scheduled to be restarted in 2020.

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ALUMINUM

In January, a 2-year power supply agreement took effect between a primary aluminum smelter in Mt. Holly, SC, and its power provider. In March, a 7-year power supply agreement between the owner of the 130,000-metric-ton-per-year Massena, NY, smelter and its power provider was signed. In September, workers represented by the United Steelworkers union ratified a 4-year contract covering about 1,700 employees, most of whom were located at a 269,000-metric-ton-per-year smelter in Evansville, IN, the smelter in Massena, NY, and a rolling mill in Gum Springs, AR. The new contract was retroactive to May 15 when the prior contract expired, and production was not disrupted during the negotiations.

In January, the U.S. Department of the Treasury lifted sanctions that were imposed against a Russian producer of aluminum, alumina, and bauxite in April 2018 in response to activities of the Government of Russia. Prior to the sanctions being lifted, a winddown period was granted to companies with contracts with the sanctioned company. The winddown period was extended several times until the sanctions were lifted and deliveries to consumers in the United States were not disrupted.

After the United States, Canada, and Mexico reached an agreement on trade terms, Presidential Proclamation 9893, issued in May 2019, removed the 10% ad valorem tariff on imports of aluminum from Canada and Mexico. The tariff on aluminum imports for Canada and Mexico was imposed under the authority of Section 232 of the Trade Expansion Act of 1962 in 2018. Canada and Mexico agreed to remove retaliatory measures that were imposed on United States products. Under the agreement, a quota on aluminum imports was not imposed, but if imports increased dramatically compared with historical volumes, the United States reserved the right to reimpose the tariff and Canada and Mexico reserved the right to reimpose retaliatory measures. Aluminum imports from all countries except Argentina, Australia, Canada, and Mexico remained subject to the 10% ad valorem tariff as of early December.

On October 22, the U.S. Department of Commerce announced its final determination in an antidumping investigation of imports of aluminum wire from China, which affirmed the preliminary finding announced May 30. The finding determined that aluminum cable and wire from China was sold below fair market value and antidumping rates of duty ranging from 58.51% to 63.47% were assigned.

World Smelter Production and Capacity: Capacity data for China in 2018 was revised based on Government data.

	Production		Yearend capacity	
	2018	2019[e]	2018	2019[e]
United States	891	1,100	1,790	1,790
Australia	1,580	1,600	1,720	1,720
Bahrain	1,010	1,400	1,050	1,540
Canada	2,920	2,900	3,270	3,270
China	35,800	36,000	44,000	44,400
Iceland	885	850	890	890
India	3,680	3,700	4,060	4,060
Norway	[e]1,300	1,300	1,430	1,430
Russia	3,630	3,600	3,900	3,900
United Arab Emirates	2,640	2,700	2,700	2,700
Other countries	9,260	9,200	12,200	12,200
World total (rounded)	63,600	64,000	77,000	77,900

World Resources: Global resources of bauxite are estimated to be between 55 billion to 75 billion tons and are sufficient to meet world demand for metal well into the future.[1]

Substitutes: Composites can substitute for aluminum in aircraft fuselages and wings. Glass, paper, plastics, and steel can substitute for aluminum in packaging. Composites, magnesium, steel, and titanium can substitute for aluminum in ground transportation uses. Composites, steel, vinyl, and wood can substitute for aluminum in construction. Copper can replace aluminum in electrical and heat-exchange applications.

[e]Estimated.

[1]See also Bauxite and Alumina.

[2]Defined as domestic primary metal production + recovery from old aluminum scrap + net import reliance; excludes imported scrap.

[3]Defined as domestic primary metal production + recovery from all aluminum scrap + net import reliance; excludes imported scrap.

[4]Includes aluminum alloy.

[5]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.

[6]Defined as imports – exports + adjustments for industry stock changes.

ANTIMONY

(Data in metric tons of antimony content unless otherwise noted)

Domestic Production and Use: In 2019, no marketable antimony was mined in the United States. A mine in Nevada that had extracted about 800 tons of stibnite ore from 2013 through 2014 was placed on care-and-maintenance status in 2015 and had no reported production in 2019. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced in 2019, based on the average New York dealer price for antimony, was about $34 million. Recycling supplied about 14% of estimated domestic consumption, and the remainder came mostly from imports. The value of antimony consumption in 2019, based on the average New York dealer price, was about $234 million. The estimated distribution of domestic primary antimony consumption was as follows: nonmetal products, including ceramics and glass and rubber products, 22%; flame retardants, 40%; and metal products, including antimonial lead and ammunition, 39%.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	645	664	621	331	370
Secondary	3,740	3,810	[e]3,800	[e]4,000	4,000
Imports for consumption:					
Ore and concentrates	308	119	61	96	140
Oxide	16,700	16,100	17,900	19,200	17,000
Unwrought, powder, waste and scrap[1]	5,790	7,150	6,830	6,500	7,200
Exports:					
Ore and concentrates[1]	31	12	46	38	10
Oxide	1,760	1,330	1,600	1,750	1,500
Unwrought, powder, waste and scrap[1]	1,440	623	653	506	280
Consumption, apparent[2]	23,500	28,500	28,700	28,400	27,000
Price, metal, average, dollars per pound[3]	3.27	3.35	3.98	3.88	3.90
Stocks, yearend	11,100	8,360	6,540	6,080	6,000
Employment, plant, number (yearend)[e]	27	27	27	27	27
Net import reliance[4] as a percentage of apparent consumption	81	84	85	84	84

Recycling: The bulk of secondary antimony is recovered at secondary lead smelters as antimonial lead, most of which was generated by, and then consumed by, the lead-acid battery industry.

Import Sources (2015–18): Metal: China, 52%; India, 20%; Vietnam, 8%; United Kingdom, 6%; and other, 14%. Ore and concentrate: Italy, 76%; China, 17%; Mexico, 4%; Bosnia and Herzegovina, 1%; and other, 2%. Oxide: China, 64%; Belgium, 10%; Thailand, 10%; Bolivia, 7%; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Ore and concentrates	2617.10.0000	Free.
Antimony oxide	2825.80.0000	Free.
Antimony and articles thereof:		
Unwrought antimony; powder	8110.10.0000	Free.
Waste and scrap	8110.20.0000	Free.
Other	8110.90.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[5] Antimony was added to the National Defense Stockpile in December 2018.

		FY 2019		**FY 2020**	
Material	**Inventory As of 9–30–19**	**Potential Acquisitions**	**Potential Disposals**	**Potential Acquisitions**	**Potential Disposals**
Antimony	73.5	1,100	—	1,100	—

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ANTIMONY

Events, Trends, and Issues: One company operated a smelter in Montana that produced antimony metal and oxides from imported intermediate products (antimony oxide and sodium antimonate) primarily from a smelter in Mexico that processed concentrates from mines in Australia and Mexico.

China continued to be the leading global antimony producer in 2019 and accounted for more than 60% of global mine production. Beginning in 2018, many large-scale producers reduced production, and many small-scale producers were put on care-and-maintenance status in response to stricter environmental standards from Provincial and National Governments. In 2019, producers in Guizhou, Hunan, and Yunnan Provinces maintained a steady production rate after their smelters completed upgrades to meet the environmental standards. However, it was reported some mines had begun stockpiling concentrates, which lead to the suspension of operations at several smelters in Lengshuijiang area, Hunan Province, in August 2019. In September 2019, one of China's largest mining and metal-producing state-owned companies was the only bidder on the inventory of 18,600 tons of antimony and rare earths from the defunct Fanya Metal Exchange.

World Mine Production and Reserves: Reserves for Pakistan were revised based on Government reports.

	Mine production		Reserves[6]
	2018	2019[e]	
United States	—	—	[7]60,000
Australia	2,170	2,000	[8]140,000
Bolivia	3,110	3,000	310,000
Burma	2,640	3,000	NA
China	89,600	100,000	480,000
Ecuador	50	50	NA
Guatemala	25	25	NA
Honduras	12	10	NA
Iran	600	600	NA
Kazakhstan	300	300	NA
Kyrgyzstan	370	400	NA
Laos	300	300	NA
Mexico	260	300	18,000
Pakistan	28	30	26,000
Russia (recoverable)	30,000	30,000	350,000
Tajikistan	15,200	16,000	50,000
Turkey	2,400	3,000	100,000
Vietnam	240	240	NA
World total (rounded)	147,000	160,000	1,500,000

World Resources: U.S. resources of antimony are mainly in Alaska, Idaho, Montana, and Nevada. Principal identified world resources are in Australia, Bolivia, China, Mexico, Russia, South Africa, and Tajikistan. Additional antimony resources may occur in Mississippi Valley-type lead deposits in the Eastern United States.

Substitutes: Selected organic compounds and hydrated aluminum oxide are substitutes as flame retardants. Chromium, tin, titanium, zinc, and zirconium compounds substitute for antimony chemicals in enamels, paint, and pigments. Combinations of calcium, copper, selenium, sulfur, and tin are substitutes for alloys in lead-acid batteries.

[e]Estimated. NA Not available. — Zero.

[1]Gross weight.

[2]Defined as primary production + secondary production from old scrap + net import reliance.

[3]New York dealer price for 99.65% metal, cost, insurance, freight U.S. ports. Source: Platts Metal Week.

[4]Defined as imports of antimony in oxide, unwrought metal, powder, waste and scrap – exports of antimony in oxide, unwrought metal, powder, waste and scrap + adjustments for industry stock changes.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Company-reported probable reserves for the Stibnite Gold Project in Idaho.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 64,300 tons.

ARSENIC

(Data in metric tons of arsenic content[1] unless otherwise noted)

Domestic Production and Use: Arsenic trioxide and primary arsenic metal have not been produced in the United States since 1985. The principal use for arsenic trioxide was for the production of arsenic acid used in the formulation of chromated copper arsenide (CCA) preservatives for the pressure treating of lumber used primarily in nonresidential applications. Three companies produced CCA preservatives in the United States in 2019. The grids in lead-acid storage batteries were strengthened by the addition of arsenic metal. Arsenic metal was also used as an antifriction additive for bearings, to harden lead shot, and in clip-on wheel weights. Arsenic compounds were used in herbicides and insecticides. High-purity arsenic (99.9999%) was used to produce gallium-arsenide (GaAs) semiconductors for solar cells, space research, and telecommunications. Arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide (InGaAs) was used for short-wave infrared technology. The value of arsenic compounds and metal imported domestically in 2019 was estimated to be about $7.2 million. Given that arsenic metal has not been produced domestically since 1985, it is likely that only a small portion of the material reported by the U.S. Census Bureau as arsenic exports was pure arsenic metal, and most of the material that has been reported under this category reflects the gross weight of alloys, compounds, residues, scrap, and waste containing arsenic. Therefore, the estimated consumption reported under salient U.S. statistics reflects only imports of arsenic products.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Imports for consumption:					
Arsenic metal	514	793	942	929	400
Compounds	5,920	5,320	5,980	5,540	7,000
Exports, all forms of arsenic (gross weight)[2]	1,670	1,760	698	107	20
Estimated consumption, all forms of arsenic[3]	6,430	6,120	6,920	6,470	7,400
Value, dollars per kilogram, average[4]					
Arsenic metal (China)	1.85	1.89	1.56	1.43	2.10
Trioxide (China)	0.45	0.46	0.45	0.44	0.44
Trioxide (Morocco)	0.64	0.68	0.68	0.75	0.77
Net import reliance[5] as a percentage of.					
estimated consumption, all forms of arsenic	100	100	100	100	100

Recycling: Arsenic metal was contained in new scrap recycled during GaAs semiconductor manufacturing. Arsenic-containing process water was internally recycled at wood treatment plants where CCA was used. Although scrap electronic circuit boards, relays, and switches may contain arsenic, no arsenic was known to have been recovered during the recycling process to recover other contained metals. No arsenic was recovered domestically from arsenic-containing residues and dusts generated at nonferrous smelters in the United States.

Import Sources (2015–18): Arsenic metal: China, 93%; Japan, 4%; Hong Kong, 3%, and other, <1%. Arsenic trioxide: China, 50%; Morocco, 47%; Belgium, 2%; and other, 1%. All forms of arsenic: China, 55%; Morocco, 42%; Belgium, 2%; other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Arsenic metal	2804.80.0000	Free.
Arsenic acid	2811.19.1000	2.3% ad val.
Arsenic trioxide	2811.29.1000	Free.
Arsenic sulfide	2813.90.1000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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ARSENIC

Events, Trends, and Issues: China and Morocco continued to be the leading global producers of arsenic trioxide, accounting for about 90% of estimated world production and supplied almost all of United States imports of arsenic trioxide in 2019. China was the leading world producer of arsenic metal and supplied about 90% of United States arsenic metal imports in 2019.

High-purity (99.9999%) arsenic metal was used to produce GaAs, indium-arsenide, and InGaAs semiconductors that were used in biomedical, communications, computer, electronics, and photovoltaic applications. Almost one-half of global GaAs wafer production took place in China. See the Gallium chapter for additional details.

World Production and Reserves (gross weight):

	Production[e, 6] (arsenic trioxide)		Reserves[7]
	2018	2019	
United States	—	—	
Belgium	1,000	1,000	World reserves data are unavailable but are thought to be more than 20 times world production.
Bolivia	40	40	
China	24,000	24,000	
Iran	110	110	
Japan	45	40	
Morocco	6,000	6,000	
Namibia	700	700	
Russia	1,500	1,500	
World total (rounded)	33,400	33,000	

World Resources: Arsenic may be obtained from copper, gold, and lead smelter flue dust, as well as from roasting arsenopyrite, the most abundant ore mineral of arsenic. Arsenic has been recovered from orpiment and realgar in China, Peru, and the Philippines; has been recovered from copper-gold ores in Chile; and was associated with gold occurrences in Canada. Orpiment and realgar from gold mines in Sichuan Province, China, were stockpiled for later recovery of arsenic. Arsenic also may be recovered from enargite, a copper mineral. Arsenic trioxide was produced at the hydrometallurgical complex of Guemassa, near Marrakech, Morocco, from cobalt arsenide ore from the Bou-Azzer Mine.

Substitutes: Substitutes for CCA in wood treatment include alkaline copper quaternary, ammoniacal copper quaternary, ammoniacal copper zinc arsenate, alkaline copper quaternary boron-based preservatives, copper azole, copper citrate, and copper naphthenate. Treated wood substitutes include concrete, plastic composite material, plasticized wood scrap, or steel. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third generation cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. GaAs-based integrated circuits are used in many defense-related applications because of their unique properties, and no effective substitutes exist for GaAs in these applications. GaAs in heterojunction bipolar transistors is being replaced in some applications by silicon-germanium.

[e]Estimated. — Zero.

[1]Arsenic content of arsenic metal is 100%; arsenic content of arsenic compounds is calculated at 77.7% for arsenic acids, 60.7% for arsenic sulfides, and 75.71% for arsenic trioxide.

[2]Most of the materials reported to the U.S. Census Bureau as arsenic exports are thought to be arsenic-containing compounds (such as arsenic acids, sulfides, and trioxides) or residues, waste, and scrap and was reported as gross weight.

[3]Estimated to be the same as imports.

[4]Calculated from U.S. Census Bureau import data.

[5]Defined as imports - exports.

[6]Includes calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide; inclusion of such materials would not duplicate reported arsenic trioxide production. Chile, Mexico, and Peru were thought to be significant producers of commercial-grade arsenic trioxide but have reported no production in recent years.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

ASBESTOS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: The last U.S. producer of asbestos ceased operations in 2002 as a result of the decline in domestic and international asbestos markets associated with health and liability issues. The United States has since been wholly dependent on imports to meet manufacturing needs. In 2019, all of the asbestos minerals imported into and used within the United States consisted of chrysotile and were shipped from Russia. Domestic consumption of chrysotile in 2019 was estimated to be 100 tons, based on import data available through August. Actual consumption may have been higher owing to companies drawing from stockpiles, but information regarding industry stocks was unavailable. The chloralkali industry, which uses asbestos to manufacture semipermeable diaphragms that prevent chlorine generated at the anode of an electrolytic cell from reacting with sodium hydroxide generated at the cathode, accounted for 100% of asbestos consumption in 2019, based on bill of lading information from a commercial trade database. In addition to asbestos minerals, a small, but unknown, quantity of asbestos was imported within manufactured products, including brake blocks for use in the oil industry, rubber sheets for gaskets used to create a chemical containment seal in the production of titanium dioxide, certain other types of preformed gaskets, and some vehicle friction products.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Imports for consumption[1]	325	747	332	681	[2]100
Exports[3]	—	—	—	—	—
Consumption, estimated[4]	325	747	332	681	100
Price, average U.S. Customs value, dollars per ton	1,880	1,910	1,870	1,670	1,500
Net import reliance[5] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2015–18): Brazil, 96%; and Russia, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Crocidolite	2524.10.0000	Free.
Amosite	2524.90.0010	Free.
Chrysotile:		
Crudes	2524.90.0030	Free.
Milled fibers, group 3 grades	2524.90.0040	Free.
Milled fibers, group 4 and 5 grades	2524.90.0045	Free.
Other	2524.90.0055	Free.
Other, asbestos	2524.90.0060	Free.

Depletion Allowance: 22% (Domestic), 10% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of asbestos in the United States (excluding asbestos contained within imported manufactured products) has decreased during the past several decades, falling from a record high of 803,000 tons in 1973 to less than 775 tons in each year since 2013. From 2013 through 2018, consumption fluctuated between 325 tons and roughly 775 tons, likely owing to stockpiling by companies in certain years, and averaged about 550 t, less than 0.1% of peak consumption in the 1970s. This decline has taken place as a result of health and liability issues associated with asbestos use, leading to the displacement of asbestos from traditional domestic markets by substitutes, alternative materials, and new technology. The chloralkali industry is the only remaining domestic consumer of asbestos in mineral form. Asbestos diaphragms are used in 11 chloralkali plants in the United States and account for about one-third of domestic chlorine production.

Estimated worldwide consumption of asbestos minerals decreased from approximately 2 million tons in 2010 to approximately 1 million tons in 2019. Asbestos-cement products, such as corrugated roofing tiles, pipes, and wall panels, are expected to continue to be the leading global market for asbestos.

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ASBESTOS

The U.S. Environmental Protection Agency (EPA) issued a significant new use rule (SNUR) under Section 5 of the Toxic Substances Control Act of 1976. The regulation, which went into effect on June 24, prohibits discontinued uses of asbestos from restarting without the EPA having an opportunity to evaluate each intended use for potential risks to health and the environment and take any necessary regulatory action, which may include a ban. The SNUR requires manufacturers to request approval before importing, manufacturing, or processing asbestos for adhesives, arc chutes, beater-add gaskets, building materials (insulation, plastics, textured paints, etc.), cement products, coatings, extruded sealant tape and other tape, filler for acetylene cylinders, friction materials (except brake blocks used in oil drilling equipment and vehicle brakes and linings), high-grade electrical paper, millboard, missile liner, packings, pipeline wrap, reinforced plastics, roofing felt, sealants, separators in fuel cells and batteries, vinyl-asbestos floor tile, woven products, and any other applications that are not currently in use in the United States.

The only asbestos producer in Brazil suspended mining activities on February 11. A comprehensive national ban on asbestos was enacted in November 2017, but the company had previously been allowed to continue operating owing to a judicial injunction. As of the end of September, the company was awaiting a decision from the Supreme Federal Court on a petition to restart mining for export purposes only.

At the former Mashaba Mine in Zimbabwe, which closed in 2007, a company began producing asbestos from tailings and was working to dewater the mining shafts and procure equipment to restart underground production. At full capacity, the mine was expected to produce 75,000 tons of asbestos per year. Asbestos was last produced in Zimbabwe in 2013.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2018	2019[e]	
United States	—	—	Small
Brazil	[e]110,000	15,000	12,000,000
China	[e]125,000	125,000	96,000,000
Kazakhstan	203,000	200,000	Large
Russia	[e]710,000	750,000	110,000,000
Zimbabwe	—	2,500	Large
World total (rounded)	1,150,000	1,100,000	Large

World Resources: Reliable evaluations of global asbestos resources have not been published recently, and the available information is insufficient to make accurate estimates for many countries. However, world resources are large and more than adequate to meet anticipated demand in the foreseeable future. Resources in the United States are composed mostly of short-fiber asbestos for which use in asbestos-based products is more limited than long-fiber asbestos.

Substitutes: Numerous materials substitute for asbestos. Substitutes include calcium silicate, carbon fiber, cellulose fiber, ceramic fiber, glass fiber, steel fiber, wollastonite, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene. Several nonfibrous minerals or rocks, such as perlite, serpentine, silica, and talc, are also considered to be possible asbestos substitutes for products in which the reinforcement properties of fibers are not required. Membrane cells and mercury cells are alternatives to asbestos diaphragms used in the chloralkali industry.

[e]Estimated. — Zero.

[1]Additional imports were reported by the U.S. Census Bureau in some years, but bill of lading information from a commercial trade database suggests that some shipments were misclassified.

[2]According to the U.S. Census Bureau, imports of asbestos minerals (chrysotile) totaled 100 tons through November 2019. Final 2019 imports may differ significantly from the provided estimate because imports of chrysotile typically do not follow a predictable pattern throughout the year.

[3]Exports of asbestos reported by the U.S. Census Bureau were 517 tons in 2015, 587 tons in 2016, 143 tons in 2017, 235 tons in 2018, and an estimated 200 tons in 2019. These shipments likely consisted of materials misclassified as asbestos, reexports, and (or) waste products because the United States no longer mines asbestos.

[4]Assumed to equal imports. Actual consumption in each year may have been higher or lower owing to stockpiling by companies, but information regarding industry stocks was unavailable.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, domestic mine production increased by approximately 6%, to an estimated 390,000 tons valued at an estimated $44 million. Most of the production came from Nevada and a single mine in Georgia. An estimated 2.5 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in seven States. The United States is the world's leading barite consumer, with more than 90% of the barite sold in the United States used as a weighting agent in fluids used in the drilling of oil and natural gas wells. The majority of Nevada crude barite was ground in Nevada and then sold to companies drilling in the Central and Western United States. Offshore drilling operations in the Gulf of Mexico and onshore drilling operations in other regions primarily used imported barite.

Barite also is used as a filler, extender, or weighting agent in products such as paints, plastics, and rubber. Some specific applications include use in automobile brake and clutch pads, automobile paint primer for metal protection and gloss, use as a weighting agent in rubber, and in the cement jacket around underwater petroleum pipelines. In the metal-casting industry, barite is part of the mold-release compounds. Because barite significantly blocks x-ray and gamma-ray emissions, it is used as aggregate in high-density concrete for radiation shielding around x-ray units in hospitals, nuclear powerplants, and university nuclear research facilities. Ultrapure barite is used as a contrast medium in x-ray and computed tomography examinations of the gastrointestinal tract.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Sold or used, mine	433	232	334	366	390
Ground and crushed[1]	2,010	1,420	2,030	2,420	2,500
Imports for consumption[2]	1,660	1,260	2,470	2,460	2,600
Exports[3]	147	78	116	67	34
Consumption, apparent (crude and ground)[4]	1,950	1,410	2,680	2,760	3,000
Estimated price, ground, average value, dollars per ton, ex-works	194	187	179	176	180
Employment, mine and mill, number	458	300	350	440	440
Net import reliance[5] as a percentage of apparent consumption	78	84	88	87	87

Recycling: None.

Import Sources (2015–18): China, 58%; India, 17%; Morocco, 12%; Mexico, 11%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Ground barite	2511.10.1000	Free.
Crude barite	2511.10.5000	$1.25 per metric ton.
Barium compounds:		
Barium oxide, hydroxide, and peroxide	2816.40.2000	2% ad val.
Barium chloride	2827.39.4500	4.2% ad val.
Barium sulfate, precipitated	2833.27.0000	0.6% ad val.
Barium carbonate, precipitated	2836.60.0000	2.3% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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BARITE

Events, Trends, and Issues: Although the U.S. monthly average count of active rigs dropped throughout 2019, sales of ground barite were estimated to have increased slightly. Nearly one-half of sales were from plants in Texas, reflecting increased domestic drilling activity, which has been concentrated in the Permian Basin in recent years.

Beginning in the 1980s, China emerged as the world's leading producer of barite and the United States has been its leading customer. Although that remains true, in recent years, owing partially to industry consolidation and increased barite consumption in China, domestic consumers have diversified import sources. A higher percentage of United States imports has been supplied by other leading exporting countries such as India and Morocco. This trend has also apparently stimulated increased production and exports in other countries, particularly Laos and Mexico.

Beginning in 2018, the U.S. Census Bureau reported increased quantities of barite imports from Vietnam. However, imports from Vietnam were more likely mined in Laos, where a new mine reportedly exported ore through the Port of Cua Lo in Vietnam. Domestic grinding plants reported importing more than 100,000 tons of barite from Laos in 2018 and, in 2019, this quantity was estimated to have increased to approximately 300,000 tons.

Production increases in Mexico in recent years corresponded with increased truck and rail shipments to key drilling areas in the Permian Basin. Most barite imports have been crude barite, which was processed at domestic grinding plants but, in 2019, an increasing proportion of barite from Mexico was reportedly ground barite shipped to warehouses or to onshore drilling sites.

World Mine Production and Reserves: In response to concerns about dwindling global reserves of 4.2-specific-gravity barite used by the oil and gas drilling industry, the American Petroleum Institute issued an alternate specification for 4.1-specific-gravity barite in 2010. This has likely stimulated exploration and expansion of global barite resources. Estimated reserves data are included only if developed since the adoption of the 4.1-specific-gravity standard. Reserves data for Pakistan were revised based on Government information.

	Mine production		Reserves[6]
	2018	2019[e]	
United States	366	390	NA
China	2,900	2,900	36,000
India	2,390	2,200	51,000
Iran	490	490	24,000
Kazakhstan	620	620	85,000
Laos	90	420	NA
Mexico	380	400	NA
Morocco	940	1,100	NA
Pakistan	110	110	26,000
Russia	163	160	12,000
Turkey	245	250	35,000
Other countries	482	480	30,000
World total (rounded)	9,180	9,500	300,000

World Resources: In the United States, identified resources of barite are estimated to be 150 million tons, and undiscovered resources contribute an additional 150 million tons. The world's barite resources in all categories are about 2 billion tons, but only about 740 million tons are identified resources. However, no known systematic assessment of either U.S. or global barite resources has been conducted since the 1980s.

Substitutes: In the drilling mud market, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. None of these substitutes, however, has had a major impact on the barite drilling mud industry.

[e]Estimated. NA Not available.

[1]Imported and domestic barite, crushed and ground, sold or used by domestic grinding establishments.

[2]Imports calculated from Harmonized Tariff Schedule of the United States codes 2511.10.1000, 2511.10.5000, and 2833.27.0000.

[3]Exports calculated from Schedule B numbers 2511.10.1000 and 2833.27.0000.

[4]Defined as sold or used by domestic mines + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise noted)

Domestic Production and Use: In 2019, the quantity of bauxite consumed was estimated to be 5.1 million tons, 30% more than that reported in 2018, with an estimated value of about $162 million. About 73% of the bauxite was refined by the Bayer process for alumina or aluminum hydroxide, and the remainder went to products such as abrasives, cement, chemicals, proppants, refractories, and as a slag adjuster in steel mills. Two domestic Bayer-process refineries with a combined alumina production capacity of 1.7 million tons per year produced an estimated 1.6 million tons in 2019, slightly more than that in 2018. One other refinery with 2.3 million tons per year of capacity that had been on care-and-maintenance status since 2016 was permanently shut down in December. About 66% of the alumina produced went to primary aluminum smelters, and the remainder went to nonmetallurgical products, such as abrasives, ceramics, chemicals, and refractories.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	11,500	6,050	4,360	4,200	5,100
Exports[2]	21	40	29	17	20
Stocks, industry, yearend[2]	1,500	880	880	600	300
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	9,660	5,360	3,510	3,890	5,100
Price, average value, U.S. imports (f.a.s.), dollars per ton	28	28	31	31	32
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[5]	4,550	2,360	1,430	1,570	1,600
Imports for consumption[5]	1,570	1,140	1,330	1,530	2,100
Exports[5]	2,210	1,330	481	288	200
Stocks, industry, yearend[5]	274	320	264	275	300
Consumption, apparent[3]	3,920	2,130	2,340	2,800	3,500
Price, average value, U.S. imports (f.a.s.), dollars per ton	400	362	486	592	500
Net import reliance[4] as a percentage of apparent consumption	E	E	38	44	54

Recycling: None.

Import Sources (2015–18): Bauxite:[2] Jamaica, 51%; Brazil, 23%; Guinea, 10%; Guyana, 7%; and other, 9%. Alumina:[5] Brazil, 39%; Australia, 31%; Jamaica, 9%; Canada, 5%; and other, 16%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Bauxite, calcined (refractory grade)	2606.00.0030	Free.
Bauxite, calcined (other)	2606.00.0060	Free.
Bauxite, crude dry (metallurgical grade)	2606.00.0090	Free.
Aluminum oxide (alumina)	2818.20.0000	Free.
Aluminum hydroxide	2818.30.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None

Events, Trends, and Issues: In 2019, two domestic alumina refineries produced alumina from imported bauxite. A 500,000-ton-per-year alumina refinery in Burnside, LA, produced specialty-grade alumina. A 1.2-million-ton-per-year alumina refinery in Gramercy, LA, produced alumina principally for aluminum smelting. A project at the Gramercy refinery was adding another production line for specialty-grade alumina but the amount of additional capacity and a projected completion date were not announced. A 2.3-million-ton-per-year alumina refinery in Point Comfort, TX, was permanently shut down in December. The average prices free alongside ship (f.a.s.) for U.S. imports for consumption of crude-dry bauxite and metallurgical-grade alumina during the first 8 months of 2019 were $32 per ton, slightly more than that of the same period in 2018, and $497 per ton, 12% lower than that in the same period of 2018, respectively.

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BAUXITE AND ALUMINA

In April, the Government of Malaysia ended its ban on bauxite mining that was imposed in January 2016 because of concerns about pollution from mines and uncovered stockpiles at ports. During the mining ban, exports of stockpiled bauxite were allowed and media sources reported that some mines continued illegal mining. In May, a court in Brazil lifted restrictions on production at a 6.3-million-ton-per-year alumina refinery. In February 2018, the Government of Brazil ordered the alumina refinery and a nearby 10-million-ton-per-year bauxite mine to shut down one-half of their capacities, citing concerns that leaks from disposal areas may have taken place after heavy rainfall in the area. The mine and refinery were ramped up to their full capacities by yearend. In March, a new 22.8-million-ton-per-year bauxite mine was commissioned in Queensland, Australia. In April, a new 2-million-ton-per-year alumina refinery in the United Arab Emirates was commissioned. In August, a new 12-million-ton-per-year bauxite mine in Guinea was commissioned and started exporting bauxite to the alumina refinery in the United Arab Emirates for which it would be the principal bauxite source. In October, a 1.65-million-ton-per-year alumina refinery in Jamaica shut down for a modernization project that would take about 2 years to complete.

In January, the U.S. Department of the Treasury lifted sanctions that were imposed in April 2018 against several Russian individuals and businesses in response to activities of the Government of Russia. Among the designated companies was a producer of bauxite, alumina, and aluminum. Prior to the sanctions being lifted, a winddown period was granted to companies with contracts with the sanctioned company. The winddown period was extended several times until the sanctions were lifted and deliveries to consumers in the United States were not disrupted.

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves:

	Alumina[5]		Bauxite		Reserves[6]
	2018	2019[e]	2018	2019[e]	
United States	1,570	1,600	W	W	20,000
Australia	20,400	20,000	86,400	100,000	[7]6,000,000
Brazil	8,100	8,900	29,000	29,000	2,600,000
Canada	1,570	1,500	—	—	—
China	72,500	73,000	79,000	75,000	1,000,000
Guinea	180	300	57,000	82,000	7,400,000
India	6,430	6,700	23,000	26,000	660,000
Indonesia	1,000	1,000	11,000	16,000	1,200,000
Jamaica	2,480	2,100	10,100	8,900	2,000,000
Malaysia	—	—	500	900	110,000
Russia	2,760	2,700	5,650	5,400	500,000
Saudi Arabia	1,770	1,800	3,890	4,100	200,000
Vietnam	1,310	1,300	4,100	4,500	3,700,000
Other countries	11,400	12,000	17,000	15,000	5,000,000
World total (rounded)	131,000	130,000	[8]327,000	[8]370,000	30,000,000

World Resources: Bauxite resources are estimated to be 55 billion to 75 billion tons, in Africa (32%), Oceania (23%), South America and the Caribbean (21%), Asia (18%), and elsewhere (6%). Domestic resources of bauxite are inadequate to meet long-term U.S. demand, but the United States and most other major aluminum-producing countries have essentially inexhaustible subeconomic resources of aluminum in materials other than bauxite.

Substitutes: Bauxite is the only raw material used in the production of alumina on a commercial scale in the United States. Although currently not economically competitive with bauxite, vast resources of clay are technically feasible sources of alumina. Other raw materials, such as alunite, anorthosite, coal wastes, and oil shales, offer additional potential alumina sources. Synthetic mullite, produced from kaolin, bauxitic kaolin, kyanite, and sillimanite, substitutes for bauxite-based refractories. Silicon carbide and alumina-zirconia can substitute for abrasives but cost more.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also Aluminum. As a general rule, 4 tons of dried bauxite is required to produce 2 tons of alumina, which, in turn, produces 1 ton of aluminum.

[2]Includes all forms of bauxite, expressed as dry equivalent weights.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]Calcined equivalent weights.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were 2.2 billion tons.

[8]Excludes U.S. production.

BERYLLIUM

(Data in metric tons of beryllium content unless otherwise noted)

Domestic Production and Use: One company in Utah mined bertrandite ore and converted it, along with imported beryl, into beryllium hydroxide. Some of the beryllium hydroxide was shipped to the company's plant in Ohio, where it was converted into metal, oxide, and downstream beryllium-copper master alloy, and some was sold. Based on the estimated unit value for beryllium in imported beryllium-copper master alloy, beryllium apparent consumption of 180 tons was valued at about $113 million. Based on sales revenues, approximately 21% of beryllium products were used in industrial components; 20% in aerospace and defense applications; 14% each in automotive electronics, consumer electronics, and telecommunications infrastructure; 9% in energy applications; 1% in semiconductor applications; and 7% in other applications. Beryllium alloy strip and bulk products, the most common forms of processed beryllium, were used in all application areas. The majority of unalloyed beryllium metal and beryllium composite products were used in defense and scientific applications.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, mine shipments	205	155	150	165	170
Imports for consumption[1]	66	68	60	67	45
Exports[2]	29	34	38	30	40
Shipments from Government stockpile[3]	1	3	2	—	—
Consumption:					
Apparent[4]	233	182	179	202	180
Reported, ore	220	160	160	170	170
Unit value, annual average, beryllium-copper master alloy, dollars per kilogram contained beryllium[5]	490	510	640	590	660
Stocks, ore, consumer, yearend	25	35	30	30	30
Net import reliance[6] as a percentage of apparent consumption	12	15	16	18	3

Recycling: Beryllium was recovered from new scrap generated during the manufacture of beryllium products and from old scrap. Detailed data on the quantities of beryllium recycled are not available but may account for as much as 20% to 25% of total beryllium consumption. The leading U.S. beryllium producer established a comprehensive recycling program for all of its beryllium products, recovering approximately 40% of the beryllium content of the new and old beryllium alloy scrap.

Import Sources (2015–18):[1] Kazakhstan, 39%; Japan, 15%; Brazil, 13%; United Kingdom, 5%; and other, 28%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Beryllium ores and concentrates	2617.90.0030	Free.
Beryllium oxide and hydroxide	2825.90.1000	3.7% ad val.
Beryllium-copper master alloy	7405.00.6030	Free.
Beryllium-copper plates, sheets, and strip:		
Thickness of 5 millimeters (mm) or more	7409.90.1030	3.0% ad val.
Thickness of less than 5 mm:		
Width of 500 mm or more	7409.90.5030	1.7% ad val.
Width of less than 500 mm	7409.90.9030	3.0% ad val.
Beryllium:		
Unwrought, including powders	8112.12.0000	8.5% ad val.
Waste and scrap	8112.13.0000	Free.
Other	8112.19.0000	5.5% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[7] The Defense Logistics Agency Strategic Materials had a goal of retaining 47 tons of beryllium metal in the National Defense Stockpile.

		FY 2019		**FY 2020**	
Material	**Inventory As of 9–30–19**	**Potential Acquisitions**	**Potential Disposals**	**Potential Acquisitions**	**Potential Disposals**
Beryl ore (gross weight)	1	—	—	—	—
Metal	67	—	5	—	7
Structured powder	7	—	—	—	—

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BERYLLIUM

Events, Trends, and Issues: Apparent consumption of beryllium-based products was estimated to have decreased by about 11% in 2019 from that of 2018 owing primarily to a 33% decrease in beryllium imports and a 33% increase in beryllium exports. Imported beryl concentrate has decreased substantially since 2015. Domestic beryllium production and consumption in 2019 were estimated to be close to that of 2018. During the first 6 months of 2019, the leading U.S. beryllium producer reported that net sales of its beryllium alloy strip and bulk products and beryllium metal and composite products were 6% higher than those during the first 6 months of 2018. Value-added sales of beryllium products increased primarily in the aerospace and defense, consumer electronics, energy, and telecommunications markets.

Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium in air, water, and other media. Industry is required to carefully control the quantity of beryllium dust, fumes, and mists in the workplace.

World Mine Production and Reserves: Reserves for the United States were revised based on updated company information.

	Mine production[8, 9]		Reserves[10]
	2018	2019[e]	
United States	165	170	The United States has very little beryl that can be economically hand sorted from pegmatite deposits. The Spor Mountain area in Utah, an epithermal deposit, contains a large bertrandite resource, which is being mined. Proven and probable bertrandite reserves in Utah total about 20,000 tons of contained beryllium. World beryllium reserves are not available.
Brazil	[e]3	3	
China	[e]48	70	
Madagascar	[e]6	1	
Mozambique	[e]16	15	
Nigeria	[e]4	1	
Rwanda	[e]1	1	
World total (rounded)	240	260	

World Resources: The world's identified resources of beryllium have been estimated to be more than 100,000 tons. About 60% of these resources are in the United States; by size, the Spor Mountain area in Utah, the McCullough Butte area in Nevada, the Black Hills area in South Dakota, the Sierra Blanca area in Texas, the Seward Peninsula in Alaska, and the Gold Hill area in Utah account for most of the total.

Substitutes: Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. In some applications, certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium may be substituted for beryllium metal or beryllium composites. Copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys (copper-tin-phosphorus) may be substituted for beryllium-copper alloys, but these substitutions can result in substantially reduced performance. Aluminum nitride or boron nitride may be substituted for beryllium oxide.

[e]Estimated. — Zero.

[1]Includes estimated beryllium content of imported ores and concentrates, oxide and hydroxide, unwrought metal (including powders), beryllium articles, waste and scrap, beryllium-copper master alloy, and beryllium-copper plates, sheets, and strip.

[2]Includes estimated beryllium content of exported unwrought metal (including powders), beryllium articles, and waste and scrap.

[3]Change in total inventory level from prior yearend inventory.

[4]Defined as production + net import reliance.

[5]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%. Rounded to two significant figures.

[6]Defined as imports – exports + adjustments for Government and industry stock changes.

[7]See Appendix B for definitions.

[8]In addition to the countries listed, Kazakhstan, Portugal, and Uganda may have produced beryl ore, but available information was inadequate to make reliable estimates of output. Other nations that produced gemstone beryl ore may also have produced some industrial beryl ore.

[9]Based on a beryllium content of 4% from bertrandite and beryl sources.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons gross weight unless otherwise noted)

Domestic Production and Use: The United States ceased production of primary refined bismuth in 1997 and is highly import dependent for its supply. Bismuth is contained in some lead ores mined domestically. However, the last domestic primary lead smelter closed at yearend 2013; since then all lead concentrates have been exported for smelting.

About two-thirds of domestic bismuth consumption was for chemicals used in cosmetic, industrial, laboratory, and pharmaceutical applications. Bismuth use in pharmaceuticals included bismuth salicylate (the active ingredient in over-the-counter stomach remedies) and other compounds used to treat burns, intestinal disorders, and stomach ulcers. Bismuth is also used in the manufacture of ceramic glazes, crystalware, and pearlescent pigments.

Bismuth has a wide variety of metallurgical applications, including use as an additive to enhance metallurgical quality in the foundry industry and as a nontoxic replacement for lead in brass, free-machining steels, and solders. The use of bismuth in brass for pipe fittings, fixtures, and water meters increased after 2014 when the definition of “lead-free” under the Safe Drinking Water Act was modified to reduce the maximum lead content of “lead free” pipes and plumbing fixtures to 0.25% from 8%. The melting point of bismuth is relatively low at 271 °C, and it is an important component of various fusible alloys, some of which have melting points below that of boiling water. These bismuth-containing alloys can be used in holding devices for grinding optical lenses, as a temporary filler to prevent damage to tubes in bending operations, as a triggering mechanism for fire sprinklers, and in other applications in which a low melting point is ideal. Bismuth-tellurium-oxide alloy film paste is used in the manufacture of semiconductor devices.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap	1,950	2,190	2,820	2,510	2,400
Exports, metal, alloys, and scrap	519	431	392	653	580
Consumption:					
Apparent[1]	1,490	1,780	2,520	1,900	1,900
Reported	621	710	756	566	600
Price, average, dollars per pound[2]	6.43	4.53	4.93	4.64	3.40
Stocks, yearend, consumer	456	512	494	533	500
Net import reliance[3] as a percentage of apparent consumption	95	96	97	96	96

Recycling: Bismuth-containing alloy scrap was recycled and thought to compose less than 5% of U.S. bismuth apparent consumption.

Import Sources (2015–18): China, 76%; Belgium, 6%; Mexico, 6%; Republic of Korea, 5%; and other, 7%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Bismuth and articles thereof, including waste and scrap	8106.00.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

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BISMUTH

Events, Trends, and Issues: Bismuth prices continued a significant downward trend that began in 2014, when the annual average domestic dealer price was $11.14 per pound. Bismuth was one of the metals held in significant quantities by the defunct Fanya Nonferrous Metals Exchange in China, which closed in 2015. In 2019, sales of the exchange's assets began, and though bismuth was not among the limited initial offerings the potential sale was a factor on the price of bismuth throughout the year.

In 2019, a stable bismuth-based perovskite oxide semiconductor was discovered that could potentially be used in thin-film solar technology. The discovery was the product of a National Science Foundation grant for development of high-performance semiconductors that could replace lead-halide perovskites in applications such as perovskite solar cells, the commercial production of which was not feasible because of stability issues as well as the toxicity of the lead-based perovskite material. Additional research to improve the photovoltaic efficiency of the bismuth-based perovskites is needed before their use would be feasible.

World Refinery Production and Reserves: Available information was inadequate to make reliable estimates for mine production and reserves data.

	Refinery production		Reserves[4]
	2018	2019[e]	
United States	—	—	Quantitative estimates of reserves are not available.
Bulgaria	50	50	
Canada	25	25	
China	14,000	14,000	
Japan	571	540	
Kazakhstan	290	270	
Korea, Republic of	900	900	
Laos	3,010	3,000	
Mexico	333	400	
World total (rounded)	19,200	19,000	

World Resources: Bismuth ranks 65th in elemental abundance in the Earth's continental crust, at an estimated 85 parts per billion by weight, constituting much less than 0.001%. World reserves of bismuth are usually estimated based on the bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores. In China and Vietnam, bismuth production is a byproduct or coproduct of tungsten and other metal ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines where bismuth has been the primary product. The Tasna Mine in Bolivia has been inactive since 1996.

Substitutes: Bismuth compounds can be replaced in pharmaceutical applications by alumina, antibiotics, calcium carbonate, and magnesia. Titanium dioxide-coated mica flakes and fish-scale extracts are substitutes in pigment uses. Cadmium, indium, lead, and tin can partially replace bismuth in low-temperature solders. Resins can replace bismuth alloys for holding metal shapes during machining, and glycerine-filled glass bulbs can replace bismuth alloys in triggering devices for fire sprinklers. Free-machining alloys can contain lead, selenium, or tellurium as a replacement for bismuth. Bismuth is an environmentally friendly substitute for lead in plumbing and many other applications, including fishing weights, hunting ammunition, lubricating greases, and soldering alloys.

[e]Estimated. — Zero.

[1]Defined as secondary production + imports – exports + adjustments for industry stock changes.

[2]Price in 2015 is based on New York dealer price for 99.99%-purity metal in minimum lots of 1 ton; source: Platts Metals Week. Prices in 2016–19 are based on 99.99%-purity metal at warehouse (Rotterdam) in minimum lots of 1 ton; source: American Metal Market (Fastmarkets AMM).

[3]Defined as imports – exports + adjustments for industry stock changes.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

BORON

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies in southern California produced borates in 2019, and most of the boron products consumed in the United States were manufactured domestically. U.S. boron production and consumption data were withheld to avoid disclosing company proprietary data. The leading boron producer mined borate ores, which contain the minerals kernite, tincal, and ulexite, by open pit methods and operated associated compound plants. Kernite was used to produce boric acid, tincal was used to produce sodium borate, and ulexite was used as a primary ingredient in the manufacture of a variety of specialty glasses and ceramics. A second company produced borates from brines extracted through solution-mining techniques. Boron minerals and chemicals were principally consumed in the North Central United States and the Eastern United States. In 2019, the glass and ceramics industries remained the leading domestic users of boron products, accounting for an estimated 80% of total borates consumption. Boron also was used as a component in abrasives, cleaning products, insecticides, and insulation and in the production of semiconductors.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	136	173	158	133	150
Boric acid	40	46	40	51	50
Colemanite (calcium borates)	35	35	58	73	40
Ulexite (sodium borates)	70	43	24	34	35
Exports:					
Boric acid	195	237	227	260	270
Refined borax	528	581	572	610	590
Consumption, apparent[1]	W	W	W	W	W
Price, average value of imports					
Cost, insurance, and freight, dollars per ton	327	352	392	404	377
Employment, number	1,380	1,340	1,300	1,350	1,350
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2015–18): All forms: Turkey, 80%; Bolivia, 13%; Chile, 3%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Natural borates:		
Sodium (ulexite)	2528.00.0005	Free.
Calcium (colemanite)	2528.00.0010	Free.
Boric acids	2810.00.0000	1.5% ad val.
Borates:		
Refined borax:		
Anhydrous	2840.11.0000	0.3% ad val.
Non-anhydrous	2840.19.0000	0.1% ad val.

Depletion Allowance: Borax, 14% (Domestic and foreign).

Government Stockpile: None.

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BORON

Events, Trends, and Issues: Elemental boron is a metalloid with limited commercial applications. Although the term "boron" is commonly referenced, it does not occur in nature in an elemental state. Boron combines with oxygen and other elements to form boric acid, or inorganic salts called borates. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on their boric oxide (B_2O_3) content, varying by ore and compound and by the absence or presence of calcium and sodium. The four borate minerals—colemanite, kernite, tincal, and ulexite—account for 90% of the borate minerals used by industry worldwide. Although borates were used in more than 300 applications, more than three-quarters of world consumption was used in ceramics, detergents, fertilizers, and glass.

China, India, Indonesia, Malaysia, and the Netherlands are the countries that imported the largest quantities of refined borates from the United States in 2019. Because China has low-grade boron reserves and demand for boron is anticipated to rise in that country, imports to China from Chile, Russia, Turkey, and the United States were expected to remain steady during the next several years.

Continued investment in new borate refineries and the continued rise in demand were expected to fuel growth in world production for the next few years. Two Australia-based mine developers confirmed that production of high-quality boron products is possible from their projects in California and Nevada. These companies have the potential to become substantial boron producers when they are fully developed. Both companies expect production to begin in 2021, with construction beginning at one site by late 2019.

World Production and Reserves: Reserves for Turkey were updated based on company information.

	Production—All forms		Reserves[3]
	2018	2019[e]	
United States	W	W	40,000
Argentina, crude ore	200	100	NA
Bolivia, ulexite	150	210	NA
Chile, ulexite	600	400	35,000
China, boric oxide equivalent	75	250	24,000
Germany, compounds	143	140	NA
Kazakhstan, unspecified	500	—	NA
Peru, crude borates	101	100	4,000
Russia, datolite ore	80	80	40,000
Turkey, refined borates	2,000	2,500	1,100,000
World total[4]	XX	XX	XX

World Resources: Deposits of borates are associated with volcanic activity and arid climates, with the largest economically viable deposits in the Mojave Desert of the United States, the Alpide belt in southern Asia, and the Andean belt of South America. U.S. deposits consist primarily of tincal, kernite, and borates contained in brines, and to a lesser extent, ulexite and colemanite. About 70% of all deposits in Turkey are colemanite, primarily used in the production of heat-resistant glass. At current levels of consumption, world resources are adequate for the foreseeable future.

Substitutes: The substitution of other materials for boron is possible in detergents, enamels, insulation, and soaps. Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamels can use other glass-producing substances, such as phosphates. Insulation substitutes include cellulose, foams, and mineral wools. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable. — Zero.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]World totals cannot be calculated because production and reserves are not reported in a consistent manner by all countries.

BROMINE

(Data in metric tons of bromine content unless otherwise noted)

Domestic Production and Use: Bromine was recovered from underground brines by two companies in Arkansas. Bromine is one of the leading mineral commodities, in terms of value, produced in Arkansas. The two bromine companies in the United States account for a large percentage of world production capacity.

The leading global applications of bromine are for the production of brominated flame retardants, and intermediates and industrial uses. Bromine compounds are also used in a variety of other applications, including drilling fluids and industrial water treatment. U.S. apparent consumption of bromine in 2019 was estimated to be greater than that in 2018.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	61,200	58,400	52,700	56,200	66,000
Exports, elemental bromine and compounds[2]	29,600	28,300	43,400	40,500	44,000
Consumption, apparent[3]	W	W	W	W	W
Price, average value of imports, Cost, insurance, and freight, dollars per kilogram	2.27	2.19	2.30	2.21	2.19
Employment, number[e]	1,100	1,100	1,100	1,100	1,100
Net import reliance[4] as a percentage of apparent consumption	<25	<25	<25	<25	<25

Recycling: Some bromide solutions were recycled to obtain elemental bromine and to prevent the solutions from being disposed of as hazardous waste. For example, hydrogen bromide is emitted as a byproduct in many organic reactions. This byproduct waste can be recycled with virgin bromine brines and used as a source of bromine production. Bromine contained in plastics can be incinerated as solid organic waste, and the bromine can be recovered.

Import Sources (2015–18):[5] Israel, 79%; Jordan, 11%; China, 7%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Bromine	2801.30.2000	5.5% ad val.
Hydrobromic acid	2811.19.3000	Free.
Potassium or sodium bromide	2827.51.0000	Free.
Ammonium, calcium, or zinc bromide	2827.59.2500	Free.
Potassium bromate	2829.90.0500	Free.
Sodium bromate	2829.90.2500	Free.
Ethylene dibromide	2903.31.0000	5.4% ad val.
Methyl bromide	2903.39.1520	Free.
Dibromoneopentyl glycol	2905.59.3000	Free.
Tetrabromobisphenol A	2908.19.2500	5.5% ad val.
Decabromodiphenyl and octabromodiphenyl oxide	2909.30.0700	5.5% ad val.

Depletion Allowance: Brine wells, 5% (Domestic and foreign).

Government Stockpile: None.

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BROMINE

Events, Trends, and Issues: The United States maintained its position as one of the leading bromine producers in the world. China, Israel, and Jordan also are major producers of elemental bromine. In 2019, U.S. net imports of bromine and bromine compounds increased compared with those in 2018. The average import value of elemental bromine increased by about 20% in 2019 compared with that in 2018. The leading source of imports of bromine and bromide compound (gross weight) was Israel. The leading imported bromine products in terms of both gross weight and bromine content were bromides and bromide oxides of ammonium, calcium, or zinc (79%) and bromides of potassium or sodium (17%). The leading exported bromine product was methyl bromide (45%).

Global consumption of elemental bromine and brominated flame retardants was strong in 2019. The price of bromine compounds also increased in 2019. The amount of clear brine fluids consumed in the oil-well and gas-well drilling industries continued to mirror global changes in oil prices and the number of active drilling rigs. In 2019, the monthly average number of active drilling rigs was about the same as in 2018.

Many bromine facilities in Shandong Province, China, remained closed in the first half of 2019 while rectifications and improvements were completed to meet new environmental regulations initiated by the Government of China in late 2017. Some plants restarted operations in the spring of 2019 following approval by the local government while others, especially small-scale unofficial plants, remained closed until they could meet the new guidelines.

In order to meet growing demand, a company in Jordan began an expansion project in 2018 to increase production capacity. The increased capacity was expected to have increased the country's 2019 bromine production.

World Production and Reserves:

	Production		Reserves[6]
	2018	2019[e]	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	60,000	60,000	NA
India	2,300	2,300	NA
Israel	175,000	180,000	Large
Japan	20,000	20,000	NA
Jordan	100,000	150,000	Large
Ukraine	4,500	4,500	NA
World total (rounded)	[7]362,000	[7]420,000	Large

World Resources: Bromine is found principally in seawater, evaporitic (salt) lakes, and underground brines associated with petroleum deposits. The Dead Sea, in the Middle East, is estimated to contain 1 billion tons of bromine. Seawater contains about 65 parts per million of bromine, or an estimated 100 trillion tons. Bromine is also recovered from seawater as a coproduct during evaporation to produce salt.

Substitutes: Chlorine and iodine may be substituted for bromine in a few chemical reactions and for sanitation purposes. There are no comparable substitutes for bromine in various oil-well and gas-well completion and packer applications. Because plastics have a low ignition temperature, aluminum hydroxide, magnesium hydroxide, organic chlorine compounds, and phosphorus compounds can be substituted for bromine as fire retardants in some uses.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Imports calculated from items shown in Tariff section.

[2]Exports calculated from Schedule B numbers 2801.30.2000, 2827.51.0000, 2827.59.0000, 2903.31.0000, and 2903.39.1520.

[3]Defined as production (sold or used) + imports – exports.

[4]Defined as imports – exports.

[5]Calculated using the gross weight of imports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production.

CADMIUM

(Data in metric tons of cadmium content unless otherwise noted)

Domestic Production and Use: Two companies in the United States produced refined cadmium in 2019. One company, operating in Tennessee, recovered primary refined cadmium as a byproduct of zinc leaching from roasted sulfide concentrates. The other company, operating in Ohio, recovered secondary cadmium metal from spent nickel-cadmium (NiCd) batteries. Domestic production and consumption of cadmium were withheld to avoid disclosing company proprietary data. Cadmium metal and compounds are mainly consumed for alloys, coatings, NiCd batteries, pigments, and plastic stabilizers. For the past 4 years, the United States has been a net importer of unwrought cadmium metal and cadmium metal powders and a net exporter of wrought cadmium products and cadmium pigments.

Salient Statistics—United States:	2015	2016	2017	2018	2019e
Production, refined[1]	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	237	240	274	273	350
Wrought cadmium and other articles (gross weight)	18	(2)	2	1	20
Cadmium waste and scrap (gross weight)	71	52	20	20	70
Exports:					
Unwrought cadmium and powders	350	157	223	41	20
Wrought cadmium and other articles (gross weight)	246	371	205	99	70
Cadmium waste and scrap (gross weight)	(2)	12	(2)	(2)	6
Consumption, reported, refined	W	W	W	W	W
Price, metal, annual average, dollars per kilogram[3]	1.47	1.34	1.75	2.89	2.60
Stocks, yearend, producer and distributor	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	E	<25	<25	<50	<50

Recycling: Secondary cadmium is mainly recovered from spent consumer and industrial NiCd batteries. Other waste and scrap from which cadmium can be recycled includes copper-cadmium alloy scrap, some complex nonferrous alloy scrap, cadmium-containing dust from electric arc furnaces, and cadmium telluride (CdTe) solar panels.

Import Sources (2015–18):[5] China, 25%; Australia, 22%; Canada, 21%; Peru, 10%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Cadmium oxide	2825.90.7500	Free.
Cadmium sulfide	2830.90.2000	3.1% ad val.
Pigments and preparations based on cadmium compounds	3206.49.6010	3.1% ad val.
Unwrought cadmium and powders	8107.20.0000	Free.
Cadmium waste and scrap	8107.30.0000	Free.
Wrought cadmium and other articles	8107.90.0000	4.4% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

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CADMIUM

Events, Trends, and Issues: Most of the world's primary cadmium metal was produced in Asia, and leading global producers, in descending order of production, were China, the Republic of Korea, and Japan. A smaller amount of secondary cadmium metal was recovered from recycling NiCd batteries. Although detailed data on the global consumption of primary cadmium were not available, NiCd battery production was thought to have continued to account for most global cadmium consumption. Other end uses for cadmium and cadmium compounds included alloys, anticorrosive coatings, pigments, polyvinyl chloride (PVC) stabilizers, and semiconductors for solar cells.

The average monthly cadmium price began 2019 averaging $2.80 per kilogram in January and trended upward to about $3.06 per kilogram in March. Prices began decreasing in May, falling to an average of about $2.40 per kilogram in August.

In 2019, a U.S.-based CdTe thin-film solar-cell producer continued constructing a second manufacturing plant in Ohio. The facility was expected to be completed in 2019 and reach its full production rate in 2020. The plant would triple the company's U.S. CdTe solar cell manufacturing capacity to 1.8 gigawatts per year.

World Refinery Production and Reserves:

	Refinery production		Reserves[6]
	2018	2019[e]	
United States[1]	W	W	Quantitative estimates of reserves are not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Canada	1,680	1,600	
China	8,200	8,200	
Japan	1,980	1,900	
Kazakhstan	1,500	1,400	
Korea, Republic of	5,000	5,000	
Mexico	1,360	1,400	
Netherlands	1,100	1,100	
Peru	765	770	
Russia	1,200	1,000	
Other countries	2,310	2,300	
World total (rounded)	[7]25,100	[7]25,000	

World Resources: Cadmium is generally recovered from zinc ores and concentrates. Sphalerite, the most economically significant zinc ore mineral, commonly contains minor amounts of cadmium, which shares certain similar chemical properties with zinc and often substitutes for zinc in the sphalerite crystal lattice. The cadmium mineral greenockite is frequently associated with weathered sphalerite and wurtzite.

Substitutes: Lithium-ion and nickel-metal hydride batteries can replace NiCd batteries in many applications. Except where the surface characteristics of a coating are critical (for example, fasteners for aircraft), coatings of zinc, zinc-nickel, aluminum, or tin can be substituted for cadmium in many plating applications. Cerium sulfide is used as a replacement for cadmium pigments, mostly in plastics. Barium-zinc or calcium-zinc stabilizers can replace barium-cadmium stabilizers in flexible PVC applications. Amorphous silicon and copper-indium-gallium-selenide photovoltaic cells compete with cadmium telluride in the thin-film solar-cell market. Research efforts continued to advance new thin-film technology based on perovskite material as a potential substitute.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data.
[1]Cadmium metal produced as a byproduct of zinc refining plus metal from recycling.
[2]Less than ½ unit.
[3]Average New York dealer price for 99.95% purity in 5-short-ton lots (2015). Source: Platts Metals Week. Average free market price for 99.95% purity in 10-ton lots; cost, insurance, and freight; global ports (2016–18). Source: Metal Bulletin.
[4]Defined as imports of unwrought metal and metal powders – exports of unwrought metal and metal powders + adjustments for industry stock changes.
[5]Imports for consumption of unwrought metal and metal powders (Harmonized Tariff Schedule of the United States code 8107.20.0000).
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Excludes U.S. production.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, U.S. portland cement production increased by 2.5% to 86 million tons, and masonry cement production continued to remain steady at 2.4 million tons. Cement was produced at 96 plants in 34 States, and at 2 plants in Puerto Rico. U.S. cement production continued to be limited by closed or idle plants, underutilized capacity at others, production disruptions from plant upgrades, and relatively inexpensive imports. In 2019, sales of cement increased slightly and were valued at $12.5 billion. Most cement sales were to make concrete, worth at least $65 billion. In 2019, it was estimated that 70% to 75% of sales were to ready-mixed concrete producers, 10% to concrete product manufactures, 8% to 10% to contractors, and 5% to 12% to other customer types. Texas, California, Missouri, Florida, Alabama, Michigan, and Pennsylvania were, in descending order of production, the seven leading cement-producing States and accounted for nearly 60% of U.S. production.

Salient Statistics—United States:[1]	2015	2016	2017	2018	2019[e]
Production:					
Portland and masonry cement[2]	84,405	84,695	86,356	86,368	88,500
Clinker	76,043	75,633	76,678	77,112	78,000
Shipments to final customers, includes exports	93,543	95,397	97,935	99,406	100,000
Imports of hydraulic cement for consumption	10,376	11,742	12,288	13,764	15,000
Imports of clinker for consumption	879	1,496	1,209	967	1,100
Exports of hydraulic cement and clinker	1,543	1,097	1,035	940	1,000
Consumption, apparent[3]	92,150	95,150	97,160	98,480	102,000
Price, average mill value, dollars per ton	106.50	111.00	117.00	121.00	123.50
Stocks, cement, yearend	7,230	7,420	7,870	8,580	8,850
Employment, mine and mill, number[e]	12,300	12,700	12,500	12,300	12,500
Net import reliance[4] as a percentage of apparent consumption	11	13	13	14	15

Recycling: Cement is not recycled, but significant quantities of concrete are recycled for use as a construction aggregate. Cement kilns can use waste fuels, recycled cement kiln dust, and recycled raw materials such as slags and fly ash. Various secondary materials can be incorporated as supplementary cementitious materials (SCMs) in blended cements and in the cement paste in concrete.

Import Sources (2015–18):[5] Canada, 35%; Greece, 16%; China, 14%; Turkey, 11%; and other, 24%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Cement clinker	2523.10.0000	Free.
White portland cement	2523.21.0000	Free.
Other portland cement	2523.29.0000	Free.
Aluminous cement	2523.30.0000	Free.
Other hydraulic cement	2523.90.0000	Free.

Depletion Allowance: Not applicable. Certain raw materials for cement production have depletion allowances.

Government Stockpile: None.

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CEMENT

Events, Trends, and Issues: Construction spending decreased in 2019, owing to a decline in private residential and nonresidential spending. Cement shipments into North Carolina and South Carolina increased owing to reconstruction following a hurricane in 2018. The leading cement-consuming States were Texas, California, and Florida, in descending order by tonnage.

No new company mergers were reported in 2019, but one European cement company entered into an agreement to purchase a Mexican cement company's plant in Pennsylvania, pending regulatory approval.

No major cement plant upgrades were completed during the year, but several minor upgrades were ongoing at a few domestic plants. One cement company began work on an upgrade to one of its plants in Indiana, with completion expected in 2022. Another company continued to work on securing permits for a new white cement plant in Texas, which would be the third white cement plant in the country. Many plants have installed emissions-reduction equipment to comply with the 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP). It remains possible that some kilns could be shut, idled, or used in a reduced capacity to comply with NESHAP, which would constrain U.S. clinker capacity.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2018	2019	2018	2019
United States (includes Puerto Rico)	87,000	89,000	103,000	103,000
Brazil	53,000	55,000	60,000	60,000
China	2,200,000	2,200,000	2,000,000	1,970,000
Egypt	81,200	76,000	48,000	48,000
India	300,000	320,000	280,000	280,000
Indonesia	75,200	74,000	78,000	78,000
Iran	58,000	60,000	80,000	81,000
Japan	55,300	54,000	53,000	53,000
Korea, Republic of	57,500	55,000	50,000	50,000
Russia	53,700	57,000	80,000	80,000
Turkey	72,500	51,000	90,000	92,000
Vietnam	90,200	95,000	90,000	90,000
Other countries (rounded)	870,000	900,000	720,000	720,000
World total (rounded)	4,050,000	4,100,000	3,700,000	3,700,000

World Resources: Although reserves at individual plants are subject to exhaustion, limestone and other cement raw materials are geologically widespread and abundant, and overall shortages are unlikely in the future.

Substitutes: Most portland cement is used to make concrete, mortars, or stuccos, and competes in the construction sector with concrete substitutes, such as aluminum, asphalt, clay brick, fiberglass, glass, gypsum (plaster), steel, stone, and wood. Certain materials, especially fly ash and ground granulated blast furnace slag, develop good hydraulic cementitious properties by reacting with lime, such as that released by the hydration of portland cement. Where readily available (including as imports), these SCMs are increasingly being used as partial substitutes for portland cement in many concrete applications and are components of finished blended cements.

[e]Estimated.

[1]Portland plus masonry cement unless otherwise noted; excludes Puerto Rico unless otherwise noted.

[2]Includes cement made from imported clinker.

[3]Defined as production of cement (including from imported clinker) + imports (excluding clinker) - exports + adjustments for stock changes.

[4]Defined as imports (cement and clinker) – exports.

[5]Hydraulic cement and clinker; includes imports into Puerto Rico.

CESIUM

(Data in metric tons of cesium oxide unless otherwise noted)

Domestic Production and Use: In 2019, no cesium was mined domestically, and the United States was 100% import reliant for cesium minerals. Pollucite, mainly found in association with lithium-rich, lepidolite-bearing or petalite-bearing zoned granite pegmatites, is the principal cesium ore mineral. Cesium minerals are used as feedstocks to produce a variety of cesium compounds and cesium metal. The primary application for cesium, by gross weight, is in cesium formate brines used for high-pressure, high-temperature well drilling for oil and gas production and exploration.

Cesium metal is used in the production of cesium compounds and potentially in photoelectric cells. Cesium bromide is used in infrared detectors, optics, photoelectric cells, scintillation counters, and spectrophotometers. Cesium carbonate is used in the alkylation of organic compounds and in energy conversion devices, such as fuel cells, magneto-hydrodynamic generators, and polymer solar cells. Cesium chloride is used in analytical chemistry applications as a reagent, in high-temperature solders, as an intermediate in cesium metal production, in isopycnic centrifugation, as a radioisotope in nuclear medicine, as an insect repellent in agricultural applications, and in specialty glasses. Cesium hydroxide is used as an electrolyte in alkaline storage batteries. Cesium iodide is used in fluoroscopy equipment—Fourier-transform infrared spectrometers—as the input phosphor of x-ray image intensifier tubes, and in scintillators. Cesium nitrate is used as a colorant and oxidizer in the pyrotechnic industry, in petroleum cracking, in scintillation counters, and in x-ray phosphors. Cesium sulfates are soluble in water and are thought to be used primarily in water treatment, fuel cells, and to improve optical quality for scientific instruments.

Cesium isotopes, which are obtained as a byproduct in nuclear fission or formed from other isotopes, such as barium-131, are used in electronic, medical, metallurgical, and research applications. Cesium isotopes are used as an atomic resonance frequency standard in atomic clocks, which plays a vital role in aircraft guidance systems, global positioning satellites, and internet and cellular telephone transmissions. Cesium clocks monitor the cycles of microwave radiation emitted by cesium's electrons and use these cycles as a time reference. Owing to the high accuracy of the cesium atomic clock, the international definition of 1 second is based on the cesium atom. The U.S. civilian time and frequency standard is based on a cesium fountain clock at the National Institute of Standards and Technology in Boulder, CO. The U.S. military frequency standard, the United States Naval Observatory Time Scale, is based on 48 weighted atomic clocks, including 25 cesium fountain clocks.

A company in Richland, WA, produced a range of cesium-131 medical products for treatment of various cancers. Cesium-137 may be used in industrial gauges, in mining and geophysical instruments, and for sterilization of food, sewage, and surgical equipment. Because of the danger posed by the radiological properties of cesium-137, efforts to find substitutes in its applications continued.

Salient Statistics—United States: Consumption, import, and export data for cesium have not been available since the late 1980s. Because cesium metal is not traded in commercial quantities, a market price is unavailable. Only a few thousand kilograms of cesium chemicals are thought to be consumed in the United States every year. The United States was 100% import reliant for its cesium needs.

In 2019, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $63.00, a slight increase from $61.80 in 2018, and 99.98% (metal basis) cesium for $81.10, a 3% increase from $78.70 in 2018.

In 2019, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, cesium chloride, and cesium iodide were $118.20, $71.90, $101.80, $103.60, and $117.00 respectively, a 3% increase from prices in 2018. The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $81.90 for 50 milliliters and $125.00 for 100 milliliters, and the price for 25 grams of cesium formate, 98% basis, was $39.90.

Recycling: Cesium formate brines are typically rented by oil and gas exploration clients. After completion of the well, the used cesium formate brine is returned and reprocessed for subsequent drilling operations. The formate brines are recycled with an estimated recovery rate of 85%, which can be reprocessed for further use.

Import Sources (2015–18): No reliable data have been available to determine the source of cesium ore imported by the United States since 1988. Previously, Canada was thought to be the primary supplier of cesium ore.

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CESIUM

Tariff: Item	Number	Normal Trade Relations 12–31–19
Alkali metals, other	2805.19.9000	5.5% ad val.
Chlorides, other	2827.39.9000	3.7% ad val.
Bromides, other	2827.59.5100	3.6% ad val.
Iodides, other	2827.60.5100	4.2% ad val.
Sulfates, other	2833.29.5100	3.7% ad val.
Nitrates, other	2834.29.5100	3.5% ad val.
Carbonates, other	2836.99.5000	3.7% ad val.
Cesium-137, other	2844.40.0021	Free

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic cesium occurrences will likely remain uneconomic unless market conditions change. No known human health issues are associated with naturally occurring cesium, and its use has minimal environmental impact. Radioactive isotopes of cesium have been known to cause adverse health effects. Certain cesium compounds may be toxic if consumed. Food that has been irradiated using the radioisotope Cesium-137 has been found to be safe by the U.S. Food and Drug Administration.

During 2019, projects that were primarily aimed at developing lithium resources with cesium content were at various stages of development. One United States-based company sold its cesium mine in Manitoba, Canada, and its specialty fluids division, including cesium formate, in Norway, Scotland, and Singapore to a company in China. Operations commenced at a pollucite mine in Western Australia in December 2018, with cesium being exported to the United States as contracted with a cesium chemical producer. The company reported that the first stage of mining produced 19,000 tons of pollucite with an average grade of 9.1% cesium oxide. The U.S. Food and Drug Administration issued a notice of significant health and safety risks associated with compounded cesium chloride, which had been used as an alternative cancer treatment. In May 2019, a blood irradiator that used cesium-137 spilled while being moved from a medical research center to a secure disposal site. The National Nuclear Security Administration managed the cleanup efforts and an investigation. Congressional budget proposals recommended increased funding for the National Nuclear Security Administration's Cesium Irradiator Replacement Project to assist in replacing cesium-137 blood irradiators.

World Mine Production and Reserves: There were no official sources for cesium production data. In addition to production of pollucite in Australia, Namibia and Zimbabwe were thought to have produced cesium in small quantities as a byproduct of lithium mining operations. Cesium reserves are, therefore, estimated based on the occurrence of pollucite, which is mined as a byproduct of the lithium mineral lepidolite. Most pollucite contains 5% to 32% cesium oxide. Reserves data for Australia and Canada were added based on industry information.

	Reserves[1]
Australia	7,100
Canada	120,000
Namibia	30,000
Zimbabwe	60,000
World total (rounded)	220,000

World Resources: Cesium is associated with lithium-bearing pegmatites worldwide, and cesium resources have been identified in Australia, Canada, Namibia, the United States, and Zimbabwe. In the United States, pollucite occurs in pegmatites in Alaska, Maine, and South Dakota. Lower concentrations occur in brines in Chile and China and in geothermal systems in Germany, India, and Tibet. China was thought to have cesium-rich deposits of geyserite, lepidolite, and pollucite, with concentrations highest in Yichun, Jiangxi Province, although no resource, reserves, or production estimates were available.

Substitutes: Cesium and rubidium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications. However, rubidium is mined from similar deposits, in relatively smaller quantities, as a byproduct of cesium production in pegmatites and as a byproduct of lithium production from lepidolite (hard-rock) mining and processing, making it no more readily available than cesium.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

CHROMIUM

(Data in thousand metric tons of chromium content unless otherwise noted)

Domestic Production and Use: In 2019, the United States was expected to consume 4% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, chromium ferroalloys, chromium metal, and stainless steel. Imported chromite ore was consumed by one chemical firm to produce chromium chemicals. Stainless-steel and heat-resisting-steel producers were the leading consumers of ferrochromium. Stainless steels and superalloys require the addition of chromium via ferrochromium or chromium-containing scrap. The value of chromium material consumption in 2018 was $1.2 billion as measured by the value of net imports, excluding stainless steel, and was expected to be about $810 million in 2019.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Mine	—	—	—	—	—
Recycling[1]	159	156	156	143	140
Imports for consumption	511	528	615	621	520
Exports	238	253	256	230	150
Shipments from Government stockpile	9	5	8	4	3
Consumption:					
Reported (includes recycling)	486	475	483	464	460
Apparent (includes recycling)[2]	441	436	523	538	510
Unit value, average annual import (dollars per ton):					
Chromite ore (gross weight)	216	198	259	279	270
Ferrochromium (chromium content)[3]	2,606	2,227	3,212	2,933	2,200
Chromium metal (gross weight)	11,386	9,827	9,682	11,344	11,000
Stocks, yearend, held by U.S. consumers	8	8	8	8	8
Net import reliance[4] as a percentage of apparent consumption	64	64	70	73	72

Recycling: In 2019, recycled chromium (contained in reported stainless steel scrap receipts) accounted for 28% of apparent consumption.

Import Sources (2015–18): Chromite (mineral): South Africa, 99%; and Canada, 1%. Chromium-containing scrap:[5] Canada, 49%; Mexico, 43%; and other, 8%. Chromium (primary metal):[6] South Africa, 34%; Kazakhstan, 9%; Russia, 8%; and other, 49%. Total imports: South Africa, 38%; Kazakhstan, 7%; Russia, 6%; and other, 49%.

Tariff:[7] Item	Number	Normal Trade Relations 12–31–19
Chromium ores and concentrates:		
Cr_2O_3 not more than 40%	2610.00.0020	Free.
Cr_2O_3 more than 40% and less than 46%	2610.00.0040	Free.
Cr_2O_3 more than or equal to 46%	2610.00.0060	Free.
Chromium oxides and hydroxides:		
Chromium trioxide	2819.10.0000	3.7% ad val.
Other	2819.90.0000	3.7% ad val.
Sodium dichromate	2841.30.0000	2.4% ad val.
Potassium dichromate	2841.50.1000	1.5% ad val.
Other chromates and dichromates	2841.50.9100	3.1% ad val.
Carbides of chromium	2849.90.2000	4.2% ad val.
Ferrochromium:		
Carbon more than 4%	7202.41.0000	1.9% ad val.
Carbon more than 3%	7202.49.1000	1.9% ad val.
Carbon more than 0.5%	7202.49.5010	3.1% ad val.
Other	7202.49.5090	3.1% ad val.
Ferrosilicon chromium	7202.50.0000	10% ad val.
Chromium metal:		
Unwrought, powder	8112.21.0000	3% ad val.
Waste and scrap	8112.22.0000	Free.
Other	8112.29.0000	3% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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CHROMIUM

Government Stockpile:[8]

Material[9]	Inventory As of 9–30–19	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals	FY 2020 Potential Acquisitions	FY 2020 Potential Disposals
Ferrochromium:					
High-carbon	39.6	—	[10]21.3	—	[10]21.3
Low-carbon	27.4	—	—	—	—
Chromium metal	3.85	—	0.181	—	0.181

Events, Trends, and Issues: Chromium is consumed in the form of ferrochromium to produce stainless steel. South Africa was the leading chromite ore producer. Increased labor costs, increased costs for electricity, an unreliable supply of electricity, and challenges related to deep level mining, together with the decreasing cost of chromite ore, could affect production in South Africa.

China was the leading chromium-consuming country. China was also the leading stainless-steel- and ferrochromium-producing country. South Africa was the second-leading country in ferrochromium production. Ferrochromium production is electrical-energy intensive, so constrained electrical power supply and rising costs for electricity in South Africa could also impact ferrochromium production.

From September 2018 to September 2019, high-carbon ferrochromium prices decreased by 43%. Prices in September 2019 were below the prior low in October 2016.

World Mine Production and Reserves:

	Mine production[11] 2018	Mine production[11] 2019[e]	Reserves[12] (shipping grade)[13]
United States	—	—	620
Finland	2,210	2,200	13,000
India	4,300	4,100	100,000
Kazakhstan	6,690	6,700	230,000
South Africa	17,600	17,000	200,000
Turkey	8,000	10,000	26,000
Other countries	4,250	4,000	NA
World total (rounded)	43,100	44,000	570,000

World Resources: World resources are greater than 12 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries. The world's chromium resources are heavily geographically concentrated (95%) in Kazakhstan and southern Africa; United States chromium resources are mostly in the Stillwater Complex in Montana.

Substitutes: Chromium has no substitute in stainless steel, the leading end use, or in superalloys, the major strategic end use. Chromium-containing scrap can substitute for ferrochromium in some metallurgical uses.

[e]Estimated. NA Not available. — Zero.

[1]Recycling production is based on reported receipts of all types of stainless steel scrap.

[2]Defined as production (from mines and recycling) + imports – exports + adjustments for Government and industry stock changes.

[3]Excludes ferrochromium silicon.

[4]Defined as imports – exports + adjustments for Government and industry stock changes.

[5]Includes chromium metal scrap and stainless steel scrap.

[6]Includes chromium metal, ferrochromium, and stainless steel.

[7]In addition to the tariff items listed, certain imported chromium materials (see 26 U.S.C. sec. 4661, 4662, and 4672) are subject to excise tax.

[8]See Appendix B for definitions.

[9]Units are thousand tons of material by gross weight.

[10]High-carbon and low-carbon ferrochromium, combined.

[11]Mine production units are thousand tons, gross weight, of marketable chromite ore.

[12]See Appendix C for resource and reserve definitions and information concerning data sources.

[13]Reserves units are thousand tons of shipping-grade chromite ore, which is deposit quantity and grade normalized to 45% Cr_2O_3, except for the United States where grade is normalized to 7% Cr_2O_3 and Finland where grade is normalized to 26% Cr_2O_3.

CLAYS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Production of clays (sold or used) in the United States was estimated to be 26 million tons valued at $1.8 billion in 2019, with about 145 companies operating clay and shale mines in 40 States. The leading 20 firms produced approximately 50% of the U.S. tonnage and 85% of the value for all types of clay. Principal uses for specific clays were estimated to be as follows: ball clay—50% floor and wall tile and 15% sanitaryware; bentonite—52% pet waste absorbents and 31% drilling mud; common clay—34% brick, 29% lightweight aggregate, and 24% cement; fire clay—70% heavy clay products (for example, brick and cement) and 30% refractory products and miscellaneous uses; fuller's earth—98% pet waste absorbents; and kaolin—60% paper coating and filling, 12% paint, and 9% catalysts. Lightweight ceramic proppants for use in hydraulic fracturing are also a significant market for kaolin, but data were insufficient to estimate market size.

Exports of clay and shale were estimated to have increased by 4% in 2019 after remaining essentially unchanged in 2018. In 2019, the United States exported 820,000 tons of bentonite mainly for pet waste absorbent, drilling mud, foundry sand bond, and iron ore pelletizing applications, with Canada, Japan, and Mexico being the leading destinations. About 2.5 million tons of kaolin were exported mainly as a paper coating and filler; a component in ceramic bodies; and fillers and extenders in paint, plastic, and rubber products, with China, Japan, and Mexico being the leading destinations. Lesser quantities of ball clay, fire clay, and fuller's earth were exported for ceramic, refractory, and absorbent uses, respectively.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production (sold or used):					
Ball clay	1,220	1,270	1,270	1,120	1,100
Bentonite	4,080	4,000	4,430	4,670	4,700
Common clay	12,000	13,000	13,300	12,700	12,000
Fire clay	398	534	575	567	560
Fuller's earth[1]	1,960	1,860	1,840	1,880	2,000
Kaolin	5,810	5,290	5,560	5,530	5,500
Total[1, 2]	25,500	26,000	27,000	26,400	26,000
Imports for consumption:					
Artificially activated clays and earths	24	26	28	23	16
Kaolin	426	389	316	330	260
Other	71	57	86	68	58
Total[2]	520	473	430	421	330
Exports:					
Artificially activated clays and earths	173	143	147	149	160
Ball clay	48	41	83	90	93
Bentonite	938	801	961	845	820
Clays, not elsewhere classified	268	256	244	244	290
Fire clay[3]	217	184	225	250	300
Fuller's earth	77	86	78	70	67
Kaolin	2,420	2,290	2,310	2,390	2,500
Total[2]	4,140	3,800	4,040	4,030	4,200
Consumption, apparent[4]	21,800	22,600	23,400	22,800	22,000
Price, ex-works, average, dollars per ton:					
Ball clay	50	39	49	54	55
Bentonite	98	99	99	99	100
Common clay	14	14	15	16	17
Fire clay	13	13	13	12	11
Fuller's earth[1]	86	89	93	88	89
Kaolin	151	157	156	156	158
Employment (excludes office workers):					
Mine (may not include contract workers)	1,130	1,120	1,220	1,110	1,110
Mill	4,730	4,440	4,370	4,360	4,360
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2015–18): All clay types combined: Brazil, 75%; China, 7%; Mexico, 6%; and other, 12%.

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CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–19
Kaolin and other kaolinic clays, whether or not calcined	2507.00.0000	Free.
Bentonite	2508.10.0000	Free.
Fire clay	2508.30.0000	Free.
Common blue clay and other ball clays	2508.40.0110	Free.
Decolorizing earths and fuller's earth	2508.40.0120	Free.
Other clays	2508.40.0150	Free.
Chamotte or dinas earth	2508.70.0000	Free.
Activated clays and activated earths	3802.90.2000	2.5% ad val.
Expanded clays and other mixtures	6806.20.0000	Free.

Depletion Allowance: Ball clay, bentonite, fire clay, fuller's earth, and kaolin, 14% (Domestic and foreign); clay used in the manufacture of common brick, lightweight aggregate, and sewer pipe, 7.5% (Domestic and foreign); clay used in the manufacture of drain and roofing tile, flower pots, and kindred products, 5% (Domestic and foreign); clay from which alumina and aluminum compounds are extracted, 22% (Domestic).

Government Stockpile: None.

Events, Trends, and Issues: Total U.S. sales of clays decreased slightly in 2018 and again in 2019 compared with those of the previous year. Over the past 2 years, other industrial minerals associated with construction activity have been estimated to have increased. Ball clay and common clay experienced decreases during this period and sales of bentonite increased in 2018 and were essentially unchanged in 2019.

World Mine Production and Reserves:[6] Global reserves are large, but country-specific data are not available.

	Mine production					
	Bentonite		Fuller's earth		Kaolin	
	2018	2019[e]	2018	2019[e]	2018	2019[e]
United States	4,670	4,700	[1]1,880	[1]2,000	5,530	5,500
Brazil (beneficiated)	520	520	—	—	1,800	1,800
China	5,600	5,600	—	—	3,200	3,200
Czechia	277	280	—	—	[7]3,620	[7]3,600
Germany	395	390	—	—	4,300	4,300
Greece	[7]1,360	[7]1,400	53	60	—	—
India	800	810	6	6	[7]4,000	[7]4,000
Iran	360	360	—	—	790	790
Mexico	470	470	110	110	330	330
Senegal	—	—	178	180	—	—
Spain	175	180	625	630	[7]450	[7]450
Turkey	1,500	1,500	20	—	1,400	1,400
Ukraine	110	110	—	—	2,400	2,400
United Kingdom	—	—	—	—	1,000	1,000
Other countries	2,230	2,200	345	350	13,400	13,000
World total (rounded)	18,500	18,500	[1]3,220	[1]3,300	42,200	42,000

World Resources: Resources of all clays are extremely large.

Substitutes: Clays compete with calcium carbonate in filler and extender applications; diatomite, organic pet litters, polymers, silica gel, and zeolites as absorbents; and various siding and roofing types in building construction.

[e]Estimated. E Net exporter. — Zero.

[1]Does not include U.S. production of attapulgite.

[2]Data may not add to totals shown because of independent rounding.

[3]Includes refractory-grade kaolin.

[4]Defined as production (sold or used) + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Includes production of crude ore.

COBALT

(Data in metric tons of cobalt content unless otherwise noted)

Domestic Production and Use: In 2019, the nickel-copper Eagle Mine in Michigan produced cobalt-bearing nickel concentrate. In Missouri, a company built a flotation plant and produced nickel-copper-cobalt concentrate from historic mine tailings. Most U.S. cobalt supply comprised imports and secondary (scrap) materials. Approximately six companies in the United States produced cobalt chemicals. About 46% of the cobalt consumed in the United States was used in superalloys, mainly in aircraft gas turbine engines; 9% in cemented carbides for cutting and wear-resistant applications; 14% in various other metallic applications; and 31% in a variety of chemical applications. The total estimated value of cobalt consumed in 2019 was $400 million.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Mine[e]	760	690	640	490	500
Secondary	2,750	2,750	2,750	2,740	2,700
Imports for consumption	11,400	12,800	11,900	11,800	13,600
Exports	3,830	4,160	5,710	6,960	4,000
Consumption:					
Reported (includes secondary)	8,830	9,010	9,240	9,270	9,300
Apparent (includes secondary)[1]	10,300	11,500	8,920	7,580	12,400
Price, average, dollars per pound:					
U.S. spot, cathode[2]	13.44	12.01	26.97	37.43	17.00
London Metal Exchange (LME), cash	12.90	11.57	25.28	32.94	15.00
Stocks, yearend:					
Industry[3]	1,070	969	1,020	1,040	1,000
LME, U.S. warehouse	165	195	160	130	110
Net import reliance[4] as a percentage of apparent consumption	73	76	69	64	78

Recycling: In 2019, cobalt contained in purchased scrap represented an estimated 29% of cobalt reported consumption.

Import Sources (2015–18): Cobalt contained in metal, oxide, and salts: Norway, 17%; Japan, 13%; China, 11%; Canada, 11%; and other, 48%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Cobalt ores and concentrates	2605.00.0000	Free.
Chemical compounds:		
Cobalt oxides and hydroxides	2822.00.0000	0.1% ad val.
Cobalt chlorides	2827.39.6000	4.2% ad val.
Cobalt sulfates	2833.29.1000	1.4% ad val.
Cobalt carbonates	2836.99.1000	4.2% ad val.
Cobalt acetates	2915.29.3000	4.2% ad val.
Unwrought cobalt, alloys	8105.20.3000	4.4% ad val.
Unwrought cobalt, other	8105.20.6000	Free.
Cobalt mattes and other intermediate products; cobalt powders	8105.20.9000	Free.
Cobalt waste and scrap	8105.30.0000	Free.
Wrought cobalt and cobalt articles	8105.90.0000	3.7% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[5] See the Lithium chapter for statistics on lithium-cobalt oxide and lithium-nickel-cobalt-aluminum oxide.

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Cobalt	302	—	—	—	—
Cobalt alloys, gross weight	3	—	—	—	—

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COBALT

Events, Trends, and Issues: Congo (Kinshasa) continued to be the world's leading source of mined cobalt, supplying approximately 70% of world cobalt mine production. With the exception of production in Morocco and artisanally mined cobalt in Congo (Kinshasa), most cobalt is mined as a byproduct of copper or nickel. China was the world's leading producer of refined cobalt, most of which it produced from partially refined cobalt imported from Congo (Kinshasa). China was the world's leading consumer of cobalt, with more than 80% of its consumption being used by the rechargeable battery industry.

During the first 7 months of 2019, cobalt prices generally trended downward, which analysts attributed to oversupply and consumer destocking and deferral of purchases. In early August, a Switzerland-based producer and marketer of commodities announced that, owing to low cobalt prices, it planned to place its world-leading cobalt mine on care-and-maintenance status by yearend 2019. Following the announcement, cobalt prices increased, then stabilized.

World Mine Production and Reserves: Reserves for multiple countries were revised based on industry reports.

	Mine production		Reserves[6]
	2018	2019[e]	
United States	490	500	55,000
Australia	4,880	5,100	[7]1,200,000
Canada	3,520	3,000	230,000
China	2,000	2,000	80,000
Congo (Kinshasa)	104,000	100,000	3,600,000
Cuba	3,500	3,500	500,000
Madagascar	3,300	3,300	120,000
Morocco	2,100	2,100	18,000
New Caledonia[8]	2,100	1,600	—
Papua New Guinea	3,280	3,100	56,000
Philippines	4,600	4,600	260,000
Russia	6,100	6,100	250,000
South Africa	2,300	2,400	50,000
Other countries	5,540	5,700	570,000
World total (rounded)	148,000	140,000	7,000,000

World Resources: Identified cobalt resources of the United States are estimated to be about 1 million tons. Most of these resources are in Minnesota, but other important occurrences are in Alaska, California, Idaho, Michigan, Missouri, Montana, Oregon, and Pennsylvania. With the exception of resources in Idaho and Missouri, any future cobalt production from these deposits would be as a byproduct of another metal. Identified world terrestrial cobalt resources are about 25 million tons. The vast majority of these resources are in sediment-hosted stratiform copper deposits in Congo (Kinshasa) and Zambia; nickel-bearing laterite deposits in Australia and nearby island countries and Cuba; and magmatic nickel-copper sulfide deposits hosted in mafic and ultramafic rocks in Australia, Canada, Russia, and the United States. More than 120 million tons of cobalt resources have been identified in manganese nodules and crusts on the floor of the Atlantic, Indian, and Pacific Oceans.

Substitutes: Depending on the application, substitution for cobalt could result in a loss in product performance or an increase in cost. The cobalt contents of lithium-ion batteries, the leading global use for cobalt, are expected to be reduced rather than eliminated; nickel contents of lithium-ion batteries will increase as cobalt contents decrease. Potential substitutes in other applications include barium or strontium ferrites, neodymium-iron-boron, or nickel-iron alloys in magnets; cerium, iron, lead, manganese, or vanadium in paints; cobalt-iron-copper or iron-copper in diamond tools; copper-iron-manganese for curing unsaturated polyester resins; iron, iron-cobalt-nickel, nickel, cermets, or ceramics in cutting and wear-resistant materials; nickel-based alloys or ceramics in jet engines; nickel in petroleum catalysts; rhodium in hydroformylation catalysts; and titanium-based alloys in prosthetics.

[e]Estimated. — Zero.

[1]Defined as net import reliance + secondary production, as estimated from consumption of purchased scrap.

[2]As reported by Platts Metals Week. Cobalt cathode is refined cobalt metal produced by an electrolytic process.

[3]Stocks held by consumers and processors; excludes stocks held by trading companies and held for investment purposes.

[4]Defined as imports – exports + adjustments for Government and industry stock changes for refined cobalt.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were 310,000 tons.

[8]Overseas territory of France. Although nickel-cobalt mining and processing continued, the leading producer reported zero reserves based on recent nickel prices.

COPPER

(Data in thousand metric tons of copper content unless otherwise noted)

Domestic Production and Use: In 2019, U.S. mine production of recoverable copper increased by 6% to an estimated 1.3 million tons and was valued at an estimated $7.9 billion, slightly less than $8.05 billion in 2018. Arizona was the leading copper-producing State and accounted for an estimated 68% of domestic output, followed by, in descending order, Utah, New Mexico, Nevada, Montana, Michigan, and Missouri. Twenty-four mines recovered copper, 15 of which accounted for 99% of production. Three smelters, 3 electrolytic refineries, 4 fire refineries, and 14 electrowinning facilities operated during 2019. Refined copper and scrap were used at about 30 brass mills, 15 rod mills, and 500 foundries and miscellaneous consumers. Copper and copper alloy products were used in building construction, 43%; electrical and electronic products, 20%; transportation equipment, 20%; consumer and general products, 10%; and industrial machinery and equipment, 7%.[1]

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine, recoverable	1,380	1,430	1,260	1,220	1,300
Refinery:					
Primary (from ore)	1,090	1,180	1,040	1,070	1,000
Secondary (from scrap)	49	46	40	41	45
Copper recovered from old (post-consumer) scrap[2]	166	149	146	149	160
Imports for consumption:					
Ores and concentrates	([3])	([3])	14	32	35
Refined	687	708	813	778	650
Exports:					
Ores and concentrates	392	331	237	253	330
Refined	86	134	94	190	140
Consumption:					
Reported, refined metal	1,810	1,800	1,800	1,820	1,850
Apparent (primary refined and old scrap)[2, 4]	1,840	1,880	1,860	1,830	1,800
Price, annual average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	256.2	224.9	285.4	298.7	280.0
COMEX, high-grade, first position	250.8	219.7	280.4	292.6	270.0
London Metal Exchange, high-grade	249.5	220.6	279.5	296.0	270.0
Stocks, yearend, refined, held by U.S. producers, consumers, and metal exchanges	209	223	265	244	130
Employment, mine and plant, thousands	11.2	10.1	10.5	11.7	12.0
Net import reliance[5] as a percentage of apparent consumption	32	30	36	33	35

Recycling: Old (post-consumer) scrap, converted to refined metal and alloys, provided an estimated 160,000 tons of copper, equivalent to 9% of apparent consumption. Purchased new (manufacturing) scrap, derived from fabricating operations, yielded an estimated 710,000 tons of copper. Of the total copper recovered from scrap (including aluminum- and nickel-base scrap), brass and wire-rod mills recovered approximately 80%; copper smelters, refiners, and ingot makers, 15%; and miscellaneous chemical plants, foundries, and manufacturers, 5%. Copper in all scrap contributed about 35% of the U.S. copper supply.[6]

Import Sources (2015–18): Copper content of blister and anodes: South Africa, 61%; Finland, 29%; Malaysia, 8%; and other, 2%. Copper content of ores and concentrates: Mexico, 99%; and other, 1%. Copper content of scrap: Canada, 55%; Mexico, 33%; and other, 12%. Refined copper: Chile, 56%; Canada, 26%; Mexico, 11%; and other, 7%. Refined copper accounted for 85% of all unwrought copper imports.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Copper ores and concentrates, copper content	2603.00.0010	1.7¢/kg on lead content.
Unrefined copper anodes	7402.00.0000	Free.
Refined copper and alloys, unwrought	7403.00.0000	1.0% ad val.
Copper wire rod	7408.11.0000	1.0% or 3.0% ad val.

Depletion Allowance: 15% (Domestic), 14% (Foreign).

Government Stockpile: None.

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COPPER

Events, Trends, and Issues: In 2019, U.S. mine production of copper increased by an estimated 6% owing to higher ore grades and (or) higher mining and milling rates at several operations. Output from the Mission Mine rose from that in 2018, when production was significantly affected by a landslide early in the year. On October 11, about 75% of unionized workers at a company with mines and plants in Arizona and Texas voted to go on strike. The company announced that it would temporarily close its smelter and refinery but did not address the status of its Arizona mines. Non-striking workers may have continued to extract ore at some sites, based on media reports. Production of refined copper in the United States fell by an estimated 7% as a result of the strike, which had not been resolved as of early December, and maintenance shutdowns at two other smelters. Two projects (Gunnison in Arizona and Pumpkin Hollow in Nevada) planned to begin production by yearend but had not started up as of the end of November.

Estimated global mine production of copper decreased slightly to 20 million tons in 2019 from 20.4 million tons in 2018, owing primarily to reduced output from the Batu Hijau and Grasberg Mines in Indonesia, where mining was shifting to new ore zones. Production also declined in Chile as a result of lower ore grades, strikes, and weather-related disruptions. These decreases were partially offset by increased output from multiple other countries. Global refined production increased slightly to an estimated 25 million tons in 2019 from 24.4 million tons in 2018. Higher refinery capacity in China was mostly offset by smelter shutdowns for maintenance and upgrades in other countries. In Zambia, mined and refined copper output were affected by a new import duty on copper concentrates, which lowered smelter production and constrained the supply of sulfuric acid needed to produce electrowon copper.

Through November 2019, the monthly average COMEX spot copper price varied between $2.56 per pound (October) and $2.92 per pound (April). It was projected to average about $2.70 per pound for the full year, a decrease of 8% from $2.93 per pound in 2018.

World Mine Production and Reserves: Reserves for multiple countries were revised based on reported company data and (or) information from the Governments of those countries.

	Mine production		Reserves[7]
	2018	2019[e]	
United States	1,220	1,300	51,000
Australia	920	960	[8]87,000
Chile	5,830	5,600	200,000
China	1,590	1,600	26,000
Congo (Kinshasa)	1,230	1,300	19,000
Indonesia	651	340	28,000
Kazakhstan	603	700	20,000
Mexico	751	770	53,000
Peru	2,440	2,400	87,000
Russia	751	750	61,000
Zambia	854	790	19,000
Other countries	3,540	3,800	220,000
World total (rounded)	20,400	20,000	870,000

World Resources: A 2014 U.S. Geological Survey assessment of copper deposits indicated that identified resources contained about 2.1 billion tons of copper, and undiscovered resources contained an estimated 3.5 billion tons.[9]

Substitutes: Aluminum substitutes for copper in automobile radiators, cooling and refrigeration tube, electrical equipment, and power cable. Titanium and steel are used in heat exchangers. Optical fiber substitutes for copper in telecommunications applications, and plastics substitute for copper in drain pipe, plumbing fixtures, and water pipe.

[e]Estimated.

[1]Distribution reported by the Copper Development Association. Some electrical components are included in each end use.

[2]Includes copper converted to refined metal and alloys by brass and wire-rod mills, foundries, refineries, and other manufacturers.

[3]Less than ½ unit.

[4]Primary refined production + copper in old scrap converted to refined metal and alloys + refined imports – refined exports ± refined stock changes.

[5]Defined as refined imports – refined exports ± adjustments for refined copper stock changes.

[6]Primary refined production + copper recovered from old and new scrap + refined imports – refined exports ± refined stock changes.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 23 million tons.

[9]Johnson, K.M., Hammarstrom, J.M., Zientek, M.L., and Dicken, C.L., 2014, Estimate of undiscovered copper resources of the world, 2013: U.S. Geological Survey Fact Sheet 2014–3004, 3 p., *https://doi.org/10.3133/fs20143004.*

DIAMOND (INDUSTRIAL)[1]

(Data in million carats unless otherwise noted)

Domestic Production and Use: In 2019, total domestic primary production of manufactured industrial diamond bort, grit, and dust and powder was estimated to be 190 million carats with a value of $86 million. There was no domestic production of stone. One firm in Ohio and one firm in Pennsylvania accounted for all of the production. At least nine firms produced polycrystalline diamond from diamond powder. At least two companies recovered used industrial diamond as one of their principal operations. The major consuming sectors of industrial diamond are computer chip production; construction; drilling for minerals, natural gas, and oil; machinery manufacturing; stone cutting and polishing; and transportation (infrastructure and vehicles). Highway building, milling, and repair and stone cutting consumed most of the industrial diamond stone. About 99% of U.S. industrial diamond apparent consumption was synthetic industrial diamond because its quality can be controlled and its properties can be customized.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	40	42	41	184	190
Secondary	63	66	11	33	38
Imports for consumption	275	216	362	548	350
Exports	140	134	161	159	120
Consumption, apparent[2]	238	190	253	606	460
Price, value of imports, dollars per carat	0.20	0.23	0.16	0.12	0.13
Net import reliance[3] as a percentage of apparent consumption	57	43	79	64	50
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	79	83	87	—	—
Secondary	0.19	0.36	0.39	0.13	0.12
Imports for consumption	1.31	1.37	1.23	0.95	0.84
Exports	—	—	—	—	—
Sales from Government stockpile excesses	—	—	—	—	—
Consumption, apparent[2]	80.7	84.9	89.0	1.1	1.0
Price, value of imports, dollars per carat	17.50	13.60	12.90	7.60	7.20
Net import reliance[3] as a percentage of apparent consumption	2	2	1	88	88

Recycling: In 2019, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 38 million carats with an estimated value of $790,000. It was estimated that 120,000 carats of diamond stone was recycled with an estimated value of $190,000.

Import Sources (2015–18): Bort, grit, and dust and powder; natural and synthetic: China, 77%; Ireland, 8%; Republic of Korea, 5%; Russia, 4%; and other, 6%. Stones, primarily natural: India, 32%; South Africa, 31%; Botswana, 17%; Australia, 9%; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Industrial Miners' diamonds, carbonados	7102.21.1010	Free.
Industrial Miners' diamonds, other	7102.21.1020	Free.
Industrial diamonds, simply sawn, cleaved, or bruted	7102.21.3000	Free.
Industrial diamonds, not worked	7102.21.4000	Free.
Grit or dust and powder of natural diamonds, 80 mesh or finer	7105.10.0011	Free.
Grit or dust and powder of natural diamonds, over 80 mesh	7105.10.0015	Free.
Grit or dust and powder of synthetic diamonds, coated with metal	7105.10.0020	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, 80 mesh or finer	7105.10.0030	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, over 80 mesh	7105.10.0050	Free.

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DIAMOND (INDUSTRIAL)

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2019, China was the world's leading producer of synthetic industrial diamond, with annual production exceeding 14.6 billion carats. The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and is expected to remain a significant producer and exporter of synthetic industrial diamond as well. U.S. demand for industrial diamond is likely to be strong in the construction sector as the United States continues building, milling, and repairing the Nation's highway system. Industrial diamond coats the cutting edge of saws used to cut concrete in highway construction and repair work.

In 2018 and 2019, U.S. synthetic-industrial-diamond producers did not manufacture any diamond stone. This resulted in the large decrease in apparent consumption and the large increase in industrial diamond stone import reliance seen in the salient statistics table. Domestic and global demand for synthetic diamond grit and powder is expected to remain greater than that for natural diamond material.

Synthetic diamond production far exceeds natural industrial diamond output. Worldwide production of manufactured industrial diamond totaled at least 14.6 billion carats in 2019; the leading producers included China, France, Ireland, Japan, Russia, South Africa, Sweden, and the United States.

Global rough diamond production decreased by 14% during the first two quarters of 2019 driven by reductions in Botswana and South Africa. Globally, most natural industrial diamond is produced as a byproduct of mining gem-quality diamond.

World Natural Industrial Diamond Mine Production and Reserves:[4] Reserves for Australia and South Africa were revised based on Government and company information.

	Mine production		Reserves[5]
	2018	2019[e]	
United States	—	—	NA
Australia	14	13	[6]40
Botswana	7	6	90
Congo (Kinshasa)	12	12	150
Russia	19	19	650
South Africa	2	2	54
Zimbabwe	3	3	NA
Other countries	1	1	120
World total (rounded)	58	56	1,100

World Resources: Natural diamond deposits have been discovered in more than 35 countries. Natural diamond accounts for about 1% of all industrial diamond used; synthetic diamond accounts for the remainder. At least 15 countries have the technology to produce synthetic diamond.

Substitutes: Materials that can compete with industrial diamond in some applications include manufactured abrasives, such as cubic boron nitride, fused aluminum oxide, and silicon carbide. Globally, synthetic diamond, rather than natural diamond, is used for about 99% of industrial applications.

[e]Estimated. NA Not available. — Zero.

[1]See Gemstones for information on gem-quality diamond.

[2]Defined as manufactured diamond production + secondary diamond production + imports – exports.

[3]Defined as imports – exports.

[4]Natural industrial diamond only.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant reserves were 39 million carats.

DIATOMITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, production of diatomite was estimated to be 980,000 tons with an estimated processed value of $330 million, f.o.b. plant. Six companies produced diatomite at 12 mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Approximately 60% of diatomite is used in filtration products. The remaining 40% is used in absorbents, fillers, lightweight aggregates, and other applications. A small amount, less than 1%, is used for specialized pharmaceutical and biomedical purposes. The unit value of diatomite varied widely in 2019, from approximately $10 per ton when used as a lightweight aggregate in portland cement concrete to more than $1,000 per ton for limited specialty markets, including art supplies, cosmetics, and DNA extraction.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production[1]	832	686	768	957	980
Imports for consumption	7	8	9	9	10
Exports	74	66	87	68	72
Consumption, apparent[2]	765	628	690	898	920
Price, average value, dollars per ton, f.o.b. plant	290	280	360	330	340
Employment, mine and plant, number[e]	345	350	360	370	370
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2015–18): Canada, 75%; Mexico, 11%; Germany, 9%; Japan, 2%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Siliceous fossil meals, including diatomite	2512.00.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced diatomite sold or used by producers in 2019 increased slightly compared with that of 2018. Apparent domestic consumption increased slightly in 2019 to an estimated 920,000 tons; exports increased by an estimated 6%. The United States remained the leading global producer and consumer of diatomite. Filtration (including the purification of beer, liquors, and wine and the cleansing of greases and oils) continued to be the leading end use for diatomite, also known as diatomaceous earth. An important application for diatomite is the removal of microbial contaminants, such as bacteria, protozoa, and viruses in public water systems. Other applications for diatomite include filtration of human blood plasma, pharmaceutical processing, and use as a nontoxic insecticide. Domestically, diatomite used in the production of cement was the second-ranked use.

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DIATOMITE

In 2019, the United States was the leading producer of diatomite, accounting for an estimated 34% of total world production, followed by Denmark and China with 15% each, Turkey with 6%, the Republic of Korea with 5%, Peru with 4%, and Mexico with 3%. Smaller quantities of diatomite were mined in 23 additional countries.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2018	2019[e]	
United States[1]	957	980	250,000
Argentina	70	70	NA
China	420	420	110,000
Denmark[5] (processed)	440	440	NA
France	75	80	NA
Germany	52	50	NA
Japan	40	40	NA
Korea, Republic of	134	130	NA
Mexico	96	100	NA
New Zealand	40	40	NA
Peru	110	110	NA
Russia	47	50	NA
Spain	50	50	NA
Turkey	170	170	44,000
Other countries	143	170	NA
World total (rounded)	2,840	2,900	Large

World Resources: Diatomite deposits form from an accumulation of amorphous hydrous silica cell walls of dead diatoms in oceanic and fresh waters. Diatomite is also known as kieselguhr (Germany), tripolite (after an occurrence near Tripoli, Libya), and moler (an impure Danish form). Because U.S. diatomite occurrences are at or near Earth's surface, recovery from most deposits is achieved through low-cost, open pit mining. Outside the United States, however, underground mining is fairly common owing to deposit location and topographic constraints. World resources of crude diatomite are adequate for the foreseeable future.

Substitutes: Many materials can be substituted for diatomite. However, the unique properties of diatomite assure its continued use in many applications. Expanded perlite and silica sand compete for filtration. Filters made from manufactured materials, notably ceramic, polymeric, or carbon membrane filters and filters made with cellulose fibers, are becoming competitive as filter media. Alternate filler materials include clay, ground limestone, ground mica, ground silica sand, perlite, talc, and vermiculite. For thermal insulation, materials such as various clays, exfoliated vermiculite, expanded perlite, mineral wool, and special brick can be used. Transportation costs will continue to determine the maximum economic distance that most forms of diatomite may be shipped and still remain competitive with alternative materials.

[e]Estimated. E Net exporter. NA Not available.

[1]Processed ore sold or used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes sales of moler production.

FELDSPAR AND NEPHELINE SYENITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: U.S. feldspar production in 2019 had an estimated value of $46 million. The three leading companies mined and processed about 80% of production; four other companies supplied the remainder. Producing States were North Carolina, California, Oklahoma, Virginia, and Idaho, in descending order of estimated tonnage. Feldspar processors reported joint product recovery of mica and silica sand. Nepheline syenite produced in the United States was not included in production figures because the material was not considered to be marketable as a flux and was mostly used in construction applications.

Feldspar is ground to about 20 mesh for glassmaking and to 200 mesh or finer for most ceramic and filler applications. It was estimated that domestically produced feldspar was transported by ship, rail, or truck to at least 30 States and to foreign destinations, including Canada and Mexico. In pottery and glass, feldspar and nepheline syenite function as a flux. The estimated 2019 end-use distribution of domestic feldspar and nepheline syenite was glass, about 65%, and ceramic tile, pottery, and other uses, 35%.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, marketable[1]	520	470	440	550	470
Imports for consumption:					
Feldspar	120	37	290	181	75
Nepheline syenite	449	572	1,460	1,070	500
Exports, feldspar	15	6	5	4	5
Consumption, apparent[1, 2]					
Feldspar only	630	510	730	720	540
Feldspar and nepheline syenite	1,100	1,100	2,200	1,800	1,000
Price, average value, dollars per ton:					
Feldspar only, marketable production	71	69	64	97	97
Nepheline syenite, import value	150	128	61	76	157
Employment, mine, preparation plant, and office, number[e]	270	250	240	240	240
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	17	6	39	24	13
Nepheline syenite	100	100	100	100	100

Recycling: Feldspar and nepheline syenite are not recycled by producers; however, glass container producers use cullet (recycled container glass), thereby reducing feldspar and nepheline syenite consumption.

Import Sources (2015–18): Feldspar: Turkey, 98%; and other, 2%. Nepheline syenite: Canada, 100%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Feldspar	2529.10.0000	Free.
Nepheline syenite	2529.30.0010	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2019, domestic production and sales of feldspar decreased by almost 15% and the average unit value of sales was virtually unchanged from that of 2018. Imports of feldspar and nepheline syenite decreased substantially in 2019 and appear to have returned to the levels of imports prior to the unusually high level of 2017. A company based in Canada continued development of a feldspar-quartz-kaolin project in Idaho that contained high-grade potassium feldspar. In March 2019, the company amended project development plans to open a smaller than initially planned operation, with production expected to be about 30,000 tons per year of potassium feldspar during a 25-year mine life. For several years, the operation has produced a low-iron and trace-element feldspathic sand product from old mine tailings, which was sold to ceramic tile producers.

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FELDSPAR AND NEPHELINE SYENITE

Domestic feldspar consumption has been gradually shifting toward glass from ceramics. A growing segment in the glass industry was solar glass, used in the production of solar panels. Glass, including beverage containers (more than one-half of the feldspar consumed by the glass industry), plate glass, and fiberglass insulation for housing and building construction, continued to be the leading end use of feldspar in the United States.

In the United States, residential construction, in which feldspar is a raw material commonly used in the manufacture of plate glass, ceramic tiles and sanitaryware, and insulation, slowed down during the first 9 months of 2019 compared with the same period in 2018.

A company based in Canada continued development of its White Mountain high-purity calcium feldspar (anorthosite) deposit in southwestern Greenland; the construction of all necessary facilities was finished in 2018. Upon completion of the electrical components and the road to the port facility, the company began shipping products to customers in August 2019. Owing to the feldspar's purity and tests, which indicate an alumina recovery of greater than 90%, the company is targeting its product as a replacement for bauxite as a primary source of alumina. In addition, this high-purity calcium feldspar is targeted to compete with kaolin in the production of electrical-grade glass (E-glass) fiberglass and kaolin and premium nepheline syenite in the filler market for paint and clear-coating formulations and polymers.

World Mine Production and Reserves:[4] Reserves data for Thailand were revised based on Government information.

	Mine production		Reserves[5]
	2018	2019[e]	
United States[1]	550	470	NA
Brazil (beneficiated marketable)	400	400	150,000
China	2,000	2,000	NA
Czechia	449	460	23,000
Egypt	400	400	1,000,000
India	4,000	4,000	320,000
Iran	750	750	630,000
Italy	4,000	4,000	NA
Korea, Republic of	617	650	240,000
Malaysia	420	420	NA
Spain (includes pegmatites)	600	600	NA
Thailand	1,500	1,600	235,000
Turkey	7,500	7,500	240,000
Other countries	2,380	2,400	NA
World total (rounded)	25,600	26,000	Large

World Resources: Identified and undiscovered resources of feldspar are more than adequate to meet anticipated world demand. Quantitative data on resources of feldspar existing in feldspathic sands, granites, and pegmatites generally have not been compiled. Ample geologic evidence indicates that resources are large, although not always conveniently accessible to the principal centers of consumption.

Substitutes: Imported nepheline syenite was the major alternative material for feldspar. Feldspar can be replaced in some of its end uses by clays, electric furnace slag, feldspar-silica mixtures, pyrophyllite, spodumene, or talc.

[e]Estimated. NA Not available.

[1]Rounded to two significant digits to avoid disclosing company proprietary data.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]Feldspar only.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

FLUORSPAR

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, minimal fluorspar (calcium fluoride, CaF_2) was produced in the United States. One company sold fluorspar from stockpiles produced as a byproduct of its limestone quarrying operation in Cave-in-Rock, IL. Synthetic fluorspar may have been recovered as a byproduct of petroleum alkylation, stainless steel pickling, or uranium processing, but no data were collected from any of these operations. An estimated 17,000 tons of fluorosilicic acid (FSA), equivalent to about 27,000 tons of fluorspar grading 100%, was recovered from four phosphoric acid plants processing phosphate rock. Fluorosilicic acid was used primarily in water fluoridation.

U.S. fluorspar consumption was satisfied by imports and small quantities of byproduct synthetic fluorspar. Domestically, production of hydrofluoric acid (HF) in Louisiana and Texas was by far the leading use for acid-grade fluorspar. Hydrofluoric acid is the primary feedstock for the manufacture of virtually all fluorine-bearing chemicals, particularly refrigerants and fluoropolymers, and is also a key ingredient in the processing of aluminum and uranium. Fluorspar was also used in cement production, in enamels, as a flux in steelmaking, in glass manufacture, in iron and steel casting, and in welding rod coatings.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorspar equivalent from phosphate rock	105	72	64	27	27
Imports for consumption:					
Acid grade	328	328	331	381	370
Metallurgical grade	48	55	70	78	70
Total fluorspar imports	376	383	401	459	440
Hydrofluoric acid	120	126	123	122	130
Aluminum fluoride	32	20	21	26	39
Cryolite	19	16	10	17	22
Exports, all grades	14	12	11	9	7
Consumption					
Apparent[1]	362	371	390	450	430
Reported	W	W	W	W	W
Price, average value of imports					
Cost, insurance, and freight, dollars per ton:					
Acid grade	289	273	267	276	300
Metallurgical grade	249	233	237	258	270
Stocks, yearend, consumer and dealer[2]	[e]150	[e]150	NA	NA	NA
Employment, mine, number[e]	5	4	4	3	3
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Synthetic fluorspar may be produced from neutralization of waste in the enrichment of uranium, petroleum alkylation, and stainless steel pickling; however, undesirable impurities constrain use. Primary aluminum producers recycle HF and fluorides from smelting operations.

Import Sources (2015–18): Mexico, 66%; Vietnam, 13%; South Africa, 8%; China, 6%; and other, 7%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Metallurgical grade (less than 97% CaF_2)	2529.21.0000	Free.
Acid grade (97% or more CaF_2)	2529.22.0000	Free.
Natural cryolite	2530.90.1000	Free.
Hydrogen fluoride (hydrofluoric acid)	2811.11.0000	Free.
Aluminum fluoride	2826.12.0000	Free.
Synthetic cryolite	2826.30.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

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FLUORSPAR

Events, Trends, and Issues: In recent years, several of the world's leading mines have been operating at or near full capacity. Further, there have been increasing concerns about the possibility of China becoming a net fluorspar importer owing to increased environmental regulation of its mining industry. Although there is little reliable information on China's fluorspar production, China's reported imports of fluorspar increased by approximately 350,000 tons from 2017 to 2018, and by an estimated 100,000 tons in 2019; imports were primarily from Mongolia and new production in Burma. New producers in Canada, Morocco, and South Africa were also ramping up production in 2019.

A hydrofluoroolefin (HFO) plant in Corpus Christi, TX, went into operation in February. HFO manufacturers continued to introduce HFOs and blends as low global-warming-potential alternatives to hydrofluorocarbon-based foam-blowing agents, propellants, and refrigerants, which are subject to increased restrictions under the Montreal Protocol. Because refrigerant gases are a leading downstream use of HF, the HFO plant, along with a similar plant in Baton Rouge, LA, that went into operation in 2017, were expected to support strong demand for fluorspar in the United States.

World Mine Production and Reserves: Reserves for Brazil and Spain were revised based on updated data from Government sources, and reserves for Morocco were revised based on company-reported information.

	Mine production		Reserves[4, 5]
	2018	2019[e]	
United States	NA	NA	4,000
Argentina	14	14	NA
Brazil	26	18	1,400
Burma	70	44	NA
Canada	20	110	NA
China	4,000	4,000	42,000
Germany	45	45	NA
Iran	70	55	3,400
Mexico	1,080	1,200	68,000
Mongolia	605	670	22,000
Morocco	65	100	320
South Africa	242	240	41,000
Spain	145	140	10,000
Thailand	48	50	3,600
United Kingdom	11	21	4,000
Vietnam	239	240	5,000
Other countries	40	41	110,000
World total (rounded)	6,720	7,000	310,000

World Resources: Enormous quantities of fluorine are present in phosphate rock. Current U.S. reserves of phosphate rock are estimated to be 1 billion tons, containing about 72 million tons of 100% fluorspar equivalent assuming an average fluorine content of 3.5% in the phosphate rock. World reserves of phosphate rock are estimated to be 70 billion tons, equivalent to about 5 billion tons of 100% fluorspar equivalent.

Substitutes: Fluorosilicic acid is used to produce aluminum fluoride (AlF_3), but because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. Fluorosilicic acid has been used to produce HF, but this practice has not been widely adopted. Synthetic fluorspar could potentially be recovered by the Department of Energy's two depleted uranium hexafluoride conversion plants in Paducah, KY, and Portsmouth, OH. However, the preferred product is currently aqueous HF rather than fluorspar. Aluminum smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand, and titanium dioxide have been used as substitutes for fluorspar fluxes.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Defined as total fluorspar imports – exports.

[2]Industry stocks for leading consumers and fluorspar distributors.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Measured as 100% calcium fluoride.

GALLIUM

(Data in kilograms of gallium content unless otherwise noted)

Domestic Production and Use: No domestic primary (low-grade, unrefined) gallium has been recovered since 1987. Globally, primary gallium is recovered as a byproduct of processing bauxite and zinc ores. One company in Utah recovered and refined high-purity gallium from imported low-grade primary gallium metal and new scrap. Imports of gallium metal and gallium arsenide (GaAs) wafers were valued at about $700,000 and $170 million, respectively. GaAs was used to manufacture integrated circuits (ICs) and optoelectronic devices, which include laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells. Gallium nitride (GaN) principally was used to manufacture optoelectronic devices. ICs accounted for 73% of domestic gallium consumption, optoelectronic devices accounted for 25%, and research and development accounted for 2%. About 81% of the gallium consumed in the United States was contained in GaAs, GaN, and gallium phosphide (GaP) wafers. Gallium metal, triethyl gallium, and trimethyl gallium, used in the epitaxial layering process to fabricate epiwafers for the production of LEDs and ICs, accounted for most of the remainder. Optoelectronic devices were used in aerospace applications, consumer goods, industrial equipment, medical equipment, and telecommunications equipment. Uses of ICs included defense applications, high-performance computers, and telecommunications equipment.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	28,600	10,500	20,200	32,000	3,000
Gallium arsenide wafers (gross weight)	2,690,000	1,290,000	804,000	446,000	340,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	29,700	18,100	17,900	15,000	15,000
Price, imports, dollars per kilogram:					
High-purity, refined[1]	317	690	477	508	570
Low-purity, primary[2]	188	125	124	185	150
Stocks, consumer, yearend	3,280	2,720	2,840	2,920	1,920
Net import reliance[3] as a percentage of reported consumption	100	100	100	100	100

Recycling: Old scrap, none. Substantial quantities of new scrap generated in the manufacture of GaAs-based devices were reprocessed to recover high-purity gallium at one facility in Utah.

Import Sources (2015–18): Metal: China[4], 50%; United Kingdom, 18%; Germany, 10%; Ukraine, 9%; and other, 13%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3.0% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Imports of gallium metal and GaAs wafers continued to account for all U.S. consumption of gallium. In 2019, gallium metal imports decreased by about 90% from those of 2018, most likely owing to the introduction of higher import tariffs on gallium from China and the 300% increase of gallium imports from China in 2018 before the tariffs were introduced. Gallium stockpiling in 2018 may have been prompted by the discussion of China's potential tariffs.

Primary low-grade (99.99%-pure) gallium prices in China decreased by about 7% in 2019. Low-grade gallium prices worldwide continued to decline as China's primary low-grade gallium production continued to exceed worldwide consumption despite reduced production. The average monthly price for low-grade gallium in China decreased to $145 per kilogram throughout 2019 from approximately $155 per kilogram at yearend 2018. China's primary low-grade gallium production capacity has expanded to approximately 600 tons per year since 2016 from 140 tons per year in 2010. China accounted for more than 80% of worldwide low-grade gallium capacity.

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GALLIUM

Low-grade primary gallium producers outside of China most likely restricted output owing to a large surplus of primary gallium. These producers included Japan, the Republic of Korea, Russia, and Ukraine. Germany and Kazakhstan ceased primary production in 2016 and 2013, respectively.

Primary high-purity refined gallium production in 2019 was estimated to be about 205 tons. China, Japan, Slovakia, and the United States were the known principal producers of high-purity refined gallium. The United Kingdom ceased high-purity gallium production in 2018. Gallium was recovered from new scrap in Canada, China, Germany, Japan, Slovakia, and the United States. World primary low-grade gallium production capacity in 2019 was estimated to be 720 tons per year; high-purity refinery capacity, 330 tons per year; and secondary capacity, 270 tons per year.

In 2018, the value of worldwide radio frequency (RF) GaAs device consumption increased slightly to $8.9 billion owing to a growing wireless telecommunications infrastructure in Asia; growth of third- and fourth-generation (3G and 4G) “smartphones,” which employ up to 10 times the amount of GaAs in standard cellular handsets; and robust use in military radar and communications applications. Global GaAs wafer consumption by volume increased by 17% in 2019, with an estimated 50% and 40% of wafers used in LED and RF applications, respectively. Countries within the Asia and the Pacific region dominated the GaAs wafer market. Owing to their large power-handling capabilities, high-switching frequencies, and higher voltage capabilities, GaN-based products, which historically have been used in defense applications, continued to be used in cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets. The GaN RF device market was estimated to be $750 million in 2019, an increase of 15% from the revised $650 million in 2018.

The global high-power LED market was estimated to be $13.3 billion in 2019, an increase of 5.3% from that in 2018. LED manufacturing capacity in Asia increased significantly in 2018 and 2019 owing to China’s Government-instituted incentives to increase LED production. China’s increased LED production outpaced worldwide consumption and LED prices declined.

World Production and Reserves:

	Primary production		Reserves[5]
	2018	2019[e]	
United States	—	—	Quantitative estimates of reserves are not available.
China	397,000	310,000	
Japan	3,000	3,000	
Korea, Republic of	3,000	3,000	
Russia	6,000	4,000	
Ukraine	4,000	4,000	
World total (rounded)	413,000	320,000	

World Resources: Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of processing bauxite and the remainder is produced from zinc-processing residues. The average gallium content of bauxite is 50 parts per million. U.S. bauxite deposits consist mainly of subeconomic resources that are not generally suitable for alumina production owing to their high silica content. Some domestic zinc ores contain up to 50 parts per million gallium and could be a significant resource, although no gallium is currently recovered from domestic ores. Gallium contained in world resources of bauxite is estimated to exceed 1 million tons, and a considerable quantity could be contained in world zinc resources. However, less than 10% of the gallium in bauxite and zinc resources is potentially recoverable.

Substitutes: Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier 3G cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. GaAs-based ICs are used in many defense-related applications because of their unique properties, and no effective substitutes exist for GaAs in these applications. GaAs in heterojunction bipolar transistors is being replaced in some applications by silicon-germanium.

[e]Estimated. NA Not available. — Zero.

[1]Estimated based on the average values of U.S. imports for 99.9999%- and 99.99999%-pure gallium.

[2]Estimated based on the average values of U.S. imports for 99.99%-pure gallium.

[3]Defined as imports – exports. Excludes gallium arsenide wafers.

[4]Includes Hong Kong.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: In 2019, garnet for industrial use was mined by four firms—one in Idaho, one in Montana, and two in New York. One processing facility operated in Pennsylvania and another opened in Oregon in June. The estimated value of crude garnet production was about $21 million, and refined material sold or used had an estimated value of $62 million. The major end uses of garnet were, in descending percentage of consumption, for abrasive blasting, water-filtration media, water-jet-assisted cutting, and other end uses, such as in abrasive powders, nonslip coatings, and sandpaper. Domestic industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, filtration plants, glass polishing, the petroleum industry, shipbuilders, textile stonewashing, and wood-furniture-finishing operations.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production (crude)	77,200	81,300	92,900	101,000	93,000
Production (refined, sold or used)	47,200	46,600	84,100	166,000	140,000
Imports for consumption[e, 2]	212,000	156,000	54,200	254,000	180,000
Exports[e]	11,000	10,100	17,700	14,200	12,000
Consumption, apparent[e, 3]	278,000	227,000	129,000	341,000	260,000
Price, average value, dollars per ton, import	230	200	300	210	250
Stocks, yearend	NA	NA	NA	NA	NA
Employment, mine and mill, number[e]	110	110	140	170	160
Net import reliance[4] as a percentage of apparent consumption	72	64	28	70	64

Recycling: Garnet was recycled in Pennsylvania at a plant with a recycling capacity of 25,000 tons per year and at a new plant in Oregon, with a recycling capacity of 16,000 tons per year, that opened in June 2019. Garnet can be recycled multiple times without degradation of its quality. Most recycled garnet is from blast cleaning and water-jet-assisted cutting operations.

Import Sources (2015–18):[e] Australia, 30%; India, 30%; South Africa, 26%; China, 10%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Emery, natural corundum, natural garnet, and other natural abrasives, crude	2513.20.1000	Free.
Emery, natural corundum, natural garnet, and other natural abrasives, other than crude	2513.20.9000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2019, estimated domestic production of crude garnet concentrates decreased by 8% compared with production in 2018. U.S. garnet production was estimated to be about 8% of total global garnet production. The 2019 estimated domestic sales or use of refined garnet decreased by 12% compared with sales in 2018. This decrease was thought to have taken place because of high quantities of industry stocks of garnet and decreased crude garnet production and imports into the United States.

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GARNET (INDUSTRIAL)

Garnet imports in 2019 were estimated to have decreased by 29% compared with those in 2018. Most of the decrease was attributed to a lack of imports of garnet from South Africa, owing to the Pennsylvania processing facility reaching its storage capacity. Imports from India remained steady and continued to recover from previous export restrictions. Imports from China increased and somewhat offset the decrease from South Africa. In 2019, the average unit value of garnet imports was $250 per ton, an increase of 19% compared with the average unit value in 2018. In the United States, most domestically produced crude garnet concentrate was priced at about $230 per ton. U.S. exports in 2019 were estimated to have decreased by 15%.

The United States consumed about 22% of global garnet production and world production of garnet decreased by 4% in 2019. Garnet production increased in Australia and China; garnet production decreased in India and South Africa.

The garnet market is very competitive. To increase profitability and remain competitive with imported material, production may be restricted to only high-grade garnet ores or as a byproduct of other salable mineral products that occur with garnet, such as kyanite, marble, metallic ores, mica minerals, sillimanite, staurolite, or wollastonite.

World Mine Production and Reserves: Data for China were revised based on a new data source, which nearly tripled estimated production compared with previously published data.

	Mine production		Reserves[5]
	2018	2019[e]	
United States	101,000	93,000	5,000,000
Australia	360,000	400,000	Moderate to Large
China	290,000	310,000	Moderate to Large
India	162,000	150,000	13,000,000
South Africa	278,000	190,000	NA
Other countries	60,000	60,000	6,500,000
World total (rounded)	1,250,000	1,200,000	Moderate to Large

World Resources: World resources of garnet are large and occur in a wide variety of rocks, particularly gneisses and schists. Garnet also occurs in contact-metamorphic deposits in crystalline limestones, pegmatites, serpentinites, and vein deposits. In addition, alluvial garnet is present in many heavy-mineral sand and gravel deposits throughout the world. Large domestic resources of garnet also are concentrated in coarsely crystalline gneiss near North Creek, NY; other significant domestic resources of garnet occur in Idaho, Maine, Montana, New Hampshire, North Carolina, and Oregon. In addition to those in the United States, major garnet deposits exist in Australia, Canada, China, India, and South Africa, where they are mined for foreign and domestic markets; deposits in Russia and Turkey also have been mined in recent years, primarily for internal markets. Additional garnet resources are in Chile, Czechia, Pakistan, Spain, Thailand, and Ukraine; small mining operations have been reported in most of these countries.

Substitutes: Other natural and manufactured abrasives can substitute to some extent for all major end uses of garnet. In many cases, however, using the substitutes would entail sacrifices in quality or cost. Fused aluminum oxide and staurolite compete with garnet as a sandblasting material. Ilmenite, magnetite, and plastics compete as filtration media. Corundum, diamond, and fused aluminum oxide compete for lens grinding and for many lapping operations. Emery is a substitute in nonskid surfaces. Fused aluminum oxide, quartz sand, and silicon carbide compete for the finishing of plastics, wood furniture, and other products.

[e]Estimated. NA Not available.

[1]Excludes gem and synthetic garnet.

[2]Source: U.S. Census Bureau and Trade Mining, LLC; adjusted by U.S. Geological Survey.

[3]Defined as crude production + imports – exports.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

GEMSTONES[1]

(Data in million dollars unless otherwise noted)

Domestic Production and Use: The combined value of U.S. natural and synthetic gemstone output in 2019 was an estimated $65 million, a 9% increase compared with that of 2018. Domestic gemstone production included agate, beryl, coral, diamond, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise, and many other gem materials. In decreasing order of production value, Arizona, Oregon, Nevada, California, Montana, Maine, Arkansas, Colorado, Utah, Idaho, North Carolina, Tennessee, and New York produced 96% of U.S. natural gemstones. Synthetic gemstones were manufactured by four firms in North Carolina, California, Maryland, and Arizona, in decreasing order of production value. Major gemstone uses were carvings, gem and mineral collections, and jewelry.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:[2]					
Natural[3]	8.5	11.7	9.2	9.5	10
Laboratory-created (synthetic)	55.1	54.9	55.1	50.0	55
Imports for consumption	25,100	25,200	24,900	27,700	26,000
Exports, excluding reexports	3,030	2,940	2,440	1,850	1,200
Consumption, apparent[4]	22,100	22,300	22,500	25,900	25,000
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,100	1,120	1,120	1,120	1,120
Net import reliance[5] as a percentage of apparent consumption	99	99	99	99	99

Recycling: Gemstones are often recycled by being resold as estate jewelry, reset, or recut, but this report does not account for those stones.

Import Sources (2015–18 by value): Diamond: India, 37%; Israel, 33%; Belgium, 14%; South Africa, 4%; and other, 12%. Typically, diamond imports account for 90% to 95% of the total value of gem imports.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–19**
Coral and similar materials, unworked	0508.00.0000	Free.
Imitation gemstones	3926.90.4000	2.8% ad val.
Pearls, imitation, pearl beads, not strung	7018.10.1000	4.0% ad val.
Imitation gemstones, glass beads	7018.10.2000	Free.
Pearls, natural, graded and temporarily strung	7101.10.3000	Free.
Pearls, natural, other	7101.10.6000	Free.
Pearls, cultured	7101.21.0000	Free.
Diamonds, unworked or sawn	7102.31.0000	Free.
Diamonds, ½ carat or less	7102.39.0010	Free.
Diamonds, cut, more than ½ carat	7102.39.0050	Free.
Other nondiamond gemstones, unworked	7103.10.2000	Free.
Other nondiamond gemstones, uncut	7103.10.4000	10.5% ad val.
Rubies, cut	7103.91.0010	Free.
Sapphires, cut	7103.91.0020	Free.
Emeralds, cut	7103.91.0030	Free.
Other nondiamond gemstones, cut	7103.99.1000	Free.
Other nondiamond gemstones, worked	7103.99.5000	10.5% ad val.
Synthetic gemstones, cut but not set	7104.90.1000	Free.
Synthetic gemstones, other	7104.90.5000	6.4% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2019, U.S. imports for consumption of gem-quality diamonds were estimated to be about $23 billion, which was an 8% decrease compared with $25.1 billion in 2018. U.S. imports for consumption of natural, nondiamond gemstones were estimated to be about $3.0 billion, which was a 14% increase compared with $2.64 billion in 2018. U.S. synthetic gemstone production increased by 10% compared with that in 2018. The increase

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GEMSTONES

in synthetic production was because of the combination of a 5% increase in the value of U.S. synthetic diamond production and a 16% increase in the value of U.S. synthetic moissanite production compared with those of 2018. No synthetic diamond production was reported in South Carolina during 2019.

The United States accounted for more than 35% of the world's diamond consumption and was once again the leading global market in terms of consumer demand. The United States is expected to continue to dominate global gemstone demand. Consumption also increased in Asia. During the first three quarters of 2019, globally, the leading gemstone sales by value were diamond, emerald, ruby, sapphire, and tanzanite. Worldwide rough gem-grade diamond sales decreased by 39% during the first three quarters compared with the same period of 2018.

Total world diamond production during 2019 increased slightly from 2018 levels. Production is expected to continue to remain steady in the near term and then decline slightly, until 2025, when several large mines are expected to reach the end of their mine life, and only a few new projects are being developed.

World Gem Diamond Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2018	2019[e]	
United States	(8)	(8)	World reserves of diamond-bearing deposits are substantial. No reserves data are available for other gemstones.
Angola	7,570	7,500	
Australia	281	280	
Botswana	17,100	18,000	
Brazil	251	250	
Canada	23,200	23,000	
China	99	100	
Congo (Kinshasa)	3,030	3,000	
Guinea	234	240	
Lesotho	1,290	1,300	
Namibia	2,400	2,500	
Russia	24,200	25,000	
Sierra Leone	590	600	
South Africa	7,930	8,000	
Tanzania	328	400	
Zimbabwe	326	400	
Other countries	242	400	
World total (rounded)	89,000	91,000	

World Resources: Most diamond-bearing ore bodies have a diamond content that ranges from less than 1 carat per ton to about 6 carats per ton of ore. The major diamond reserves are in southern Africa, Australia, Canada, and Russia.

Substitutes: Glass, plastics, and other materials are substituted for natural gemstones. Synthetic gemstones (manufactured materials that have the same chemical and physical properties as natural gemstones) are common substitutes. Simulants (materials that appear to be gems but differ in chemical and physical characteristics) also are frequently substituted for natural gemstones.

[e]Estimated.

[1]Excludes industrial diamond and industrial garnet. See Diamond (Industrial) and Garnet (Industrial).

[2]Estimated minimum production.

[3]Includes production of freshwater shell.

[4]Defined as production (natural and synthetic) + imports – exports (excluding reexports).

[5]Defined as imports – exports (excluding reexports).

[6]Data in thousands of carats of gem diamond.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Less than ½ unit.

GERMANIUM

(Data in kilograms of germanium content unless otherwise noted)

Domestic Production and Use: In 2019, zinc concentrates containing germanium were produced at mines in Alaska, Tennessee, and Washington. Germanium-containing concentrates in Alaska and Washington were exported to a refinery in Canada for processing and germanium recovery. A zinc smelter in Clarksville, TN, produced and exported germanium leach concentrates recovered from processing zinc concentrates from the Middle Tennessee Mines. Germanium in the form of compounds and metal was imported into the United States for further processing by industry. A company in Utah produced germanium wafers for solar cells used in satellites from imported and recycled germanium. A refinery in Oklahoma recovered germanium from industry-generated scrap and produced germanium tetrachloride for the production of fiber optics. Although the consumption quantity was estimated to have remained level in 2019 compared with that in 2018, the estimated value of germanium consumed in 2019, based on the annual average germanium metal price, was $37 million, about 20% less than that in 2018.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Primary refinery	—	—	—	—	—
Secondary refinery	W	W	W	W	W
Imports for consumption:					
Germanium metal	20,100	11,000	11,100	11,800	14,000
Germanium dioxide[1]	14,300	15,200	12,000	12,400	13,000
Total exports[2]	5,000	4,780	3,670	4,880	3,300
Shipments from Government stockpile	—	—	—	—	—
Consumption, estimated[3]	34,000	30,000	30,000	30,000	30,000
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,792	1,087	1,082	1,543	1,240
Germanium dioxide	1,211	830	731	1,084	920
Net import reliance[5] as a percentage of estimated consumption	>75%	>50%	>50%	>50%	>50%

Recycling: Worldwide, about 30% of the total germanium consumed is produced from recycled materials. During the manufacture of most optical devices, more than 60% of the germanium metal used is routinely recycled as new scrap. Germanium scrap is also recovered from the windows in decommissioned tanks and other military vehicles. The United States has the capability to recycle new and old scrap.

Import Sources (2015–18):[6] Germanium metal: China, 59%; Belgium, 22%; Germany, 9%; Russia, 7%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad val.
Metal, unwrought	8112.92.6000	2.6% ad val.
Metal, powder	8112.92.6500	4.4% ad val.
Metal, wrought	8112.99.1000	4.4% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile:[7]

		FY 2019		**FY 2020**	
Material	**Inventory As of 9–30–19**	**Potential Acquisitions**	**Potential Disposals**	**Potential Acquisitions**	**Potential Disposals**
Germanium metal	14,004	—	—	—	—
Germanium scrap (gross weight)	3,794	—	5,000	—	3,000
Germanium wafers (each)	68,671	—	—	—	—

Events, Trends, and Issues: The major global end uses for germanium were electronics and solar applications, fiber-optic systems, infrared optics, polymerization catalysts, and other uses (such as chemotherapy, metallurgy, and phosphors). Germanium-containing infrared optics were primarily for military use, but the commercial applications for thermal-imaging devices that use germanium lenses have increased during the past few years.

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GERMANIUM

The 2019 estimated average annual prices of germanium dioxide and germanium metal decreased by 15% and 20%, respectively, from prices in 2018; however, the 2019 average annual prices remained higher than those in 2016 and 2017. Global demand for fiber-optic cable was thought to have decreased in 2019 compared with that in 2018 owing to a slowdown in the rollout of fifth-generation cellular network technology and reduced spending on cable installation by major telecommunication companies. Fiber-optic cable manufacturing accounted for about one-third of global germanium consumption.

A Canada-based mining company lifted a partial force majeure on its germanium sales in February. The company imposed the partial force majeure in January 2018 after an explosion damaged a slag fuming furnace at its lead-zinc refinery in Canada. During the 13-month period, the company was able to fulfill about 60% of its contract sales for germanium.

According to China news sources, several germanium producers temporarily stopped production during the year either for maintenance or in response to low germanium prices. Most notably, a leading germanium producer in Yunnan Province reportedly shut down a 10,000-kilogram-per-year germanium metal production line in June. At full production, the company produced between 40,000 and 50,000 kilograms per year of germanium metal. The shutdown was expected to last 6 months. This company received nine Government subsidies totaling 3.6 million yuan between January 1, 2019, and June 27, 2019.

In October, the Government of Yunnan Province, China, auctioned 92,300 kilograms of germanium metal, which was previously held by the now-defunct Fanya Metal Exchange. Kunming Rongke New Material Co. Ltd. was awarded the full quantity.

World Refinery Production and Reserves:[8]

	Refinery production[e]		Reserves[9]
	2018	2019	
United States	W	W	Data on the recoverable germanium content of zinc ores are not available.
China	94,900	85,000	
Russia	6,000	6,000	
Other countries[10]	30,000	40,000	
World total (rounded)[11]	130,000	130,000	

World Resources: The available resources of germanium are associated with certain zinc and lead-zinc-copper sulfide ores. Substantial U.S. reserves of recoverable germanium are contained in zinc deposits in Alaska, Tennessee, and Washington. Based on an analysis of zinc concentrates, U.S. reserves of zinc may contain as much as 2,500 tons of germanium. Because zinc concentrates are shipped globally and blended at smelters, however, the recoverable germanium in zinc reserves cannot be determined. On a global scale, as little as 3% of the germanium contained in zinc concentrates is recovered. Significant amounts of germanium are contained in ash and flue dust generated in the combustion of certain coals for power generation.

Substitutes: Silicon can be a less-expensive substitute for germanium in certain electronic applications. Some metallic compounds can be substituted in high-frequency electronics applications and in some light-emitting-diode applications. Zinc selenide and germanium glass substitute for germanium metal in infrared applications systems, but often at the expense of performance. Antimony and titanium are substitutes for use as polymerization catalysts.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Data has been adjusted to exclude low-value shipments, then multiplied by 69% to account for germanium content.

[2]Includes Schedule B numbers: 8112.92.6100, 8112.99.1000, and 2825.60.0000. Data have been adjusted to exclude low-value shipments. Oxide data have been multiplied by 69% to account for germanium content.

[3]Estimated consumption of germanium contained in metal and germanium dioxide.

[4]Average European price for minimum 99.999% purity. Source: Argus Media group-Argus Metals International.

[5]Defined as imports – exports + adjustments for Government stock changes.

[6]Import sources are based on gross weight of wrought and unwrought germanium metal and germanium metal powders.

[7]See Appendix B for definitions.

[8]Includes primary and secondary production.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Includes Belgium, Canada, Germany, Japan, and Ukraine.

[11]Excludes U.S. production.

GOLD

(Data in metric tons[1] of gold content unless otherwise noted)

Domestic Production and Use: In 2019, domestic gold mine production was estimated to be about 200 tons, 11% less than that in 2018, and the value was estimated to be about $9.0 billion. Gold was produced in 12 States at more than 40 lode mines, at several large placer mines in Alaska, and numerous smaller placer mines (mostly in Alaska and in the Western States). About 7% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper ores. The top 27 operations yielded more than 99% of the mined gold produced in the United States. Commercial-grade gold was produced at about 15 refineries. A few dozen companies, out of several thousand companies and artisans, dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and Providence, RI, areas, with lesser concentrations in California, Florida, and Texas. Estimated domestic uses (excluding gold bullion bar) were jewelry, 50%; electrical and electronics, 37%; official coins, 8%; and other, 5%.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine	214	232	237	226	200
Refinery:					
Primary	244	242	207	205	200
Secondary (new and old scrap)	238	220	119	117	130
Imports for consumption[2]	265	374	255	213	170
Exports[2]	478	393	461	474	350
Consumption, reported	165	169	150	160	150
Stocks, yearend, Treasury[3]	8,140	8,140	8,140	8,140	8,140
Price, dollars per troy ounce[4]	1,163	1,252	1,261	1,272	1,400
Employment, mine and mill, number[5]	11,500	11,600	11,900	12,200	12,000
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

Recycling: In 2019, an estimated 130 tons of new and old scrap was recycled, equivalent to about 87% of reported consumption. The domestic supply of gold from recycling increased by 11% compared with that in 2018.

Import Sources (2015–18):[2] Mexico, 26%; Canada, 22%; Peru, 13%; Colombia, 9%; and other, 30%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Precious metal ore and concentrates:		
Gold content of silver ores	2616.10.0080	0.8¢/kg on lead content
Gold content of other ores	2616.90.0040	1.7¢/kg on lead content.
Gold bullion	7108.12.1013	Free.
Gold dore	7108.12.1020	Free.
Gold scrap	7112.91.0000	Free.

Depletion Allowance: 15% (Domestic), 14% (Foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of gold (see salient statistics above), and the U.S. Department of Defense administers a Governmentwide secondary precious-metals recovery program.

Events, Trends, and Issues: The estimated gold price in 2019 was 10% higher than the price in 2018 but was 16% lower than the record-high annual price in 2012. The Engelhard daily price of gold in 2019 fluctuated through several cycles. Early in the year the gold price was about $1,300 per troy ounce and started increasing at the end of May, reaching a projected annual high of $1,547 per troy ounce in September. During this time, several factors were reported to have spurred the increase in price: demand from central banks and investors increased; the U.S. Federal Reserve Board cut interest rates; and trade negotiations halted between the United States and China. The price started a downward trend in October and November.

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GOLD

The11% decrease in domestic mine production in 2019 was attributed to decreases in production from the Bald Mountain, Carlin, and Cortez Mines in Nevada and the Fort Knox and Pogo Mines in Alaska. In 2019, worldwide gold mine production was estimated to be unchanged from that in 2018. Increased mine production in Australia, China, and Indonesia offset decreased gold mine production in Peru, South Africa, the United States, and Zimbabwe.

In the first 9 months of 2019, domestic consumption of gold used in the production of coins and bars decreased by more than 19%; however, gold consumption for jewelry increased slightly. Globally, gold consumption by the jewelry industry decreased by 5% and gold used for the production of coins and bars decreased by 22% compared with that in the first 9 months of 2018. Investments in gold-based exchange-traded funds were significantly higher in the United States and globally during the same period. Also, gold holdings in central banks increased during the year.

World Mine Production and Reserves: Reserves for Australia, Canada, Indonesia, Papua New Guinea, Peru, and South Africa were revised based on Government and (or) industry reports.

	Mine production		Reserves[7]
	2018	2019[e]	
United States	226	200	3,000
Argentina	72	72	1,600
Australia	315	330	[8]10,000
Brazil	85	85	2,400
Canada	183	180	1,900
China	401	420	2,000
Ghana	127	130	1,000
Indonesia	135	160	2,600
Kazakhstan	100	100	1,000
Mexico	117	110	1,400
Papua New Guinea	67	70	1,000
Peru	143	130	2,100
Russia	311	310	5,300
South Africa	117	90	3,200
Uzbekistan	104	100	1,800
Other countries	797	800	10,000
World total (rounded)	3,300	3,300	50,000

World Resources: An assessment of U.S. gold resources indicated 33,000 tons of gold in identified (15,000 tons) and undiscovered (18,000 tons) resources.[9] Nearly one-quarter of the gold in undiscovered resources was estimated to be contained in porphyry copper deposits. The gold resources in the United States, however, are only a small portion of global gold resources.

Substitutes: Base metals clad with gold alloys are widely used in electrical and electronic products, and in jewelry to economize on gold; many of these products are continually redesigned to maintain high-utility standards with lower gold content. Generally, palladium, platinum, and silver may substitute for gold.

[e]Estimated. E Net exporter.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Refined bullion, dore, ores, concentrates, and precipitates. Excludes: Waste and scrap, official monetary gold, gold in fabricated items, gold in coins, and net bullion flow (in tons) to market from foreign stocks at the New York Federal Reserve Bank.

[3]Includes gold in Exchange Stabilization Fund. Stocks were valued at the official price of $42.22 per troy ounce.

[4]Engelhard's average gold price quotation for the year. In 2019, the price was estimated by the U.S. Geological Survey based on data from January through November.

[5]Data from the Mine Safety and Health Administration.

[6]Defined as imports – exports.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 3,900 tons.

[9]U.S. Geological Survey National Mineral Resource Assessment Team, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

GRAPHITE (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2019, natural graphite was not produced in the United States; however, approximately 95 U.S. firms, primarily in the Great Lakes and Northeastern regions and Alabama and Tennessee, consumed 52,000 tons valued at an estimated $44 million. The major uses of natural graphite were brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2019, U.S. natural graphite imports were an estimated 58,000 tons, which were about 65% flake and high-purity, 34% amorphous, and 1% lump and chip graphite.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, mine	—	—	—	—	—
Imports for consumption	46,700	38,900	51,900	70,700	58,000
Exports	11,600	14,300	13,900	10,400	6,600
Consumption, apparent[1]	35,100	24,700	38,000	60,300	52,000
Price, imports (average dollars per ton at foreign ports):					
Flake	1,710	1,920	1,390	1,520	1,300
Lump and chip (Sri Lankan)	1,800	1,880	1,900	1,890	2,370
Amorphous	454	571	451	310	438
Net import reliance[1] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Refractory brick and linings, alumina-graphite refractories for continuous metal castings, magnesia-graphite refractory brick for basic oxygen and electric arc furnaces, and insulation brick led the way in the recycling of graphite products. The market for recycled refractory graphite material is expanding, with material being recycled into products such as brake linings and thermal insulation. Recovering high-quality flake graphite from steelmaking kish is technically feasible, but currently not practiced. The abundance of graphite in the world market inhibits increased recycling efforts. Information on the quantity and value of recycled graphite is not available.

Import Sources (2015–18): China, 33%; Mexico, 24%; Canada, 16%; India, 9%; and other, 18%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Crystalline flake (not including flake dust)	2504.10.1000	Free.
Powder	2504.10.5000	Free.
Other	2504.90.0000	Free.

Depletion Allowance: 22% (Domestic lump and amorphous), 14% (Domestic flake), and 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Worldwide consumption of graphite has steadily increased since 2013 and into 2019. U.S. consumption has fluctuated over this time period. During 2015 and 2016, U.S. consumption decreased by 39% and by 30%, respectively. In 2017 and 2018, consumption increased by 54% and by 59%, respectively, to its highest point during the past 5 years. However, during 2019, consumption declined again by 14%.

In 2019, principal United States import sources of natural graphite were, in descending order of tonnage, China, Mexico, Canada, Madagascar, Brazil, Mozambique, the United Kingdom, Japan, Sri Lanka, and Austria, which combined accounted for 99% of the tonnage and 97% of the value of total United States imports. Mexico and China provided most of the amorphous graphite, and Sri Lanka provided all the lump and chip dust variety.

During 2019, China produced more than 60% of the world's graphite. Approximately 40% of production in China was amorphous graphite and about 60% was flake. China does produce some large flake graphite, but the majority of its flake graphite production is very small, in the +200-mesh range. North America produced only 4% of the world's graphite supply with production in Canada and Mexico. No production of natural graphite was reported in the United States, but two companies were developing graphite projects—one in Alabama and one in Alaska.

Large graphite deposits were being developed in Madagascar, northern Mozambique, Namibia, and south-central Tanzania. Some mines in Madagascar began ramping up production in 2018, and a mine in Tanzania started sampling production beginning in 2017. A graphite mine project in Mozambique commenced operations at the start of 2018 and was ramping up production during 2018 and 2019 at a high-grade graphite deposit, which was reportedly

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GRAPHITE (NATURAL)

the largest natural graphite mine globally. The mine cut back production during 2019 in an effort to stabilize graphite prices. The mine is expected to operate for 50 years.

During the first half of 2019, crystalline flake graphite prices declined to levels similar to those of midyear 2017. The price decline was the result of oversupply, and some graphite mining companies cut back production in an effort to stabilize and increase graphite prices.

A U.S. automaker continued to build a large plant to manufacture lithium-ion electric vehicle batteries. The plant's completion was projected for 2020. A portion of the plant was operational and battery packs were being assembled in 2018 and 2019. When the plant is complete, it was expected to require 35,200 tons per year of spherical graphite for use as anode material for lithium-ion batteries.

New thermal technology and acid-leaching techniques have enabled the production of higher purity graphite powders that are likely to lead to development of new applications for graphite in high-technology fields. Innovative refining techniques have made the use of graphite possible in carbon-graphite composites, electronics, foils, friction materials, and specialty lubricant applications. Flexible graphite product lines are likely to be the fastest growing market. Large-scale fuel-cell applications are being developed that could consume as much graphite as all other uses combined.

World Mine Production and Reserves: Reserves for Mozambique and Tanzania were revised based on information reported by graphite-producing companies and the Governments of those countries.

	Mine production		Reserves[2]
	2018	2019[e]	
United States	—	—	([3])
Austria	1,000	1,000	([3])
Brazil	95,000	96,000	72,000,000
Canada	40,000	40,000	([3])
China	693,000	700,000	73,000,000
Germany	800	800	([3])
India	35,000	35,000	8,000,000
Korea, North	6,000	6,000	2,000,000
Madagascar	46,900	47,000	1,600,000
Mexico	9,000	9,000	3,100,000
Mozambique	104,000	100,000	25,000,000
Namibia	3,460	3,500	([3])
Norway	16,000	16,000	600,000
Pakistan	14,000	14,000	([3])
Russia	25,200	25,000	([3])
Sri Lanka	4,000	4,000	([3])
Tanzania	150	150	18,000,000
Turkey	2,000	2,000	90,000,000
Ukraine	20,000	20,000	([3])
Vietnam	5,000	5,000	7,600,000
Zimbabwe	2,000	2,000	([3])
Other	200	200	([3])
World total (rounded)	1,120,000	1,100,000	300,000,000

World Resources: Domestic resources of graphite are relatively small, but the rest of the world's inferred resources exceed 800 million tons of recoverable graphite.

Substitutes: Synthetic graphite powder, scrap from discarded machined shapes, and calcined petroleum coke compete for use in iron and steel production. Synthetic graphite powder and secondary synthetic graphite from machining graphite shapes compete for use in battery applications. Finely ground coke with olivine is a potential competitor in foundry-facing applications. Molybdenum disulfide competes as a dry lubricant but is more sensitive to oxidizing conditions.

[e]Estimated. — Zero.

[1]Defined as imports – exports.

[2]See Appendix C for resource and reserve definitions and information concerning data sources.

[3]Included with "World total."

GYPSUM

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, domestic production of crude gypsum was estimated to be 20 million tons with a value of about $160 million. The leading crude gypsum-producing States, in alphabetical order, were estimated to be Iowa, Kansas, Nevada, Oklahoma, and Texas, which together accounted for an estimated 64% of total output. Overall, 47 companies produced or processed gypsum in the United States at 52 mines in 16 States. The majority of domestic consumption, which totaled approximately 42 million tons, was used by agriculture, cement production, and manufacturers of wallboard and plaster products. Small quantities of high-purity gypsum, used in a wide range of industrial processes, accounted for the remaining tonnage. At the beginning of 2019, the production capacity of 63 operating gypsum panel manufacturing plants in the United States was about 34.1 billion square feet[1] per year. Total wallboard sales were estimated to be 24.0 billion square feet.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Crude	18,800	19,800	20,700	21,100	20,000
Synthetic[2]	15,500	16,700	20,700	16,600	16,000
Calcined[3]	16,500	17,900	17,800	16,900	17,000
Wallboard products sold (million square feet[1])	22,100	24,400	25,000	23,700	24,000
Imports, crude, including anhydrite	4,030	4,340	4,800	5,190	6,100
Exports, crude, not ground or calcined	63	43	36	36	38
Consumption, apparent[4]	38,300	40,800	46,200	42,900	42,000
Price:					
Average crude, free on board (f.o.b.) mine, dollars per metric ton	7.80	8.00	7.50	8.30	8.00
Average calcined, f.o.b. plant, dollars per metric ton	28.00	30.00	30.00	32.00	32.00
Employment, mine and calcining plant, number[e]	4,500	4,500	4,500	4,500	4,500
Net import reliance[5] as a percentage of apparent consumption	10	11	10	12	14

Recycling: Approximately 700,000 tons of gypsum scrap that was generated by wallboard manufacturing was recycled onsite. The recycling of wallboard from new construction and demolition sources also took place, although those amounts are unknown. Recycled gypsum was used primarily for agricultural purposes and feedstock for the manufacture of new wallboard. Other potential markets for recycled gypsum include athletic field marking, cement production (as a stucco additive), grease absorption, sludge drying, and water treatment.

Import Sources (2015–18): Mexico, 41%; Spain, 29%; Canada, 28%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Gypsum; anhydrite	2520.10.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. gypsum production decreased by 5% compared with that of 2018. Apparent consumption decreased slightly compared with that of 2018. U.S. gypsum imports increased by 17% compared with those of 2018. Exports, although very low compared with imports and often subject to wide fluctuations, increased by 6%.

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GYPSUM

Demand for gypsum depends principally on construction industry activity, particularly in the United States, where the majority of gypsum consumed is used for building plasters, the manufacture of portland cement, and wallboard products. The construction of wallboard manufacturing plants designed to use synthetic gypsum from coal flue gas desulfurization (FGD) units as feedstock has resulted in less mining of natural gypsum. The availability of inexpensive natural gas, however, has limited the additional construction of FGD units and, therefore, the use of synthetic gypsum in wallboard.

The United States, the world's leading crude gypsum producer, produced an estimated 20 million tons. China and Iran were the second-leading producers each producing an estimated 16 million tons. Increased use of wallboard in Asia, coupled with new gypsum product plants, spurred increased production in that region. As wallboard becomes more widely used in other regions, worldwide production of gypsum is expected to increase.

World Mine Production and Reserves: Reserves for India, Iran, Oman, Pakistan, and Thailand were revised based on Government and other public data.

	Mine production		Reserves[6]
	2018	2019[e]	
United States	21,100	20,000	700,000
Algeria	2,500	2,500	NA
Brazil	3,200	3,200	340,000
Canada	3,000	3,000	450,000
China	15,500	16,000	NA
France	3,000	3,000	NA
Germany	3,200	3,200	NA
India	2,700	2,700	37,000
Iran	16,000	16,000	NA
Japan	4,700	4,700	NA
Mexico	5,400	5,400	NA
Oman	7,000	7,000	NA
Pakistan	2,200	2,200	4,900
Russia	3,800	3,800	NA
Saudi Arabia	3,310	3,300	NA
Spain	7,000	7,000	NA
Thailand	9,300	9,300	1,700
Turkey	10,000	10,000	200,000
Other countries	20,000	21,000	NA
World total (rounded)	143,000	140,000	Large

World Resources: Reserves are large in major producing countries, but data for most are not available. Domestic gypsum resources are adequate but unevenly distributed. Large imports from Canada augment domestic supplies for wallboard manufacturing in the United States, particularly in the eastern and southern coastal regions. Imports from Mexico supplement domestic supplies for wallboard manufacturing along portions of the U.S. western seaboard. Large gypsum deposits occur in the Great Lakes region, the midcontinent region, and several Western States. Foreign resources are large and widely distributed; 80 countries were thought to produce gypsum in 2019.

Substitutes: In such applications as stucco and plaster, cement and lime may be substituted for gypsum; brick, glass, metallic or plastic panels, and wood may be substituted for wallboard. Gypsum has no practical substitute in the manufacturing of portland cement. Synthetic gypsum generated by various industrial processes, including FGD of smokestack emissions, is very important as a substitute for mined gypsum in wallboard manufacturing, cement production, and agricultural applications (in descending order by tonnage). In 2019, synthetic gypsum was estimated to account for about 45% of the total domestic gypsum supply.

[e]Estimated. NA Not available.

[1]The standard unit used in the U.S. wallboard industry is square feet; multiply square feet by 9.29×10^{-2} to convert to square meters. Source: The Gypsum Association.

[2]Synthetic gypsum used; the majority of these data were obtained from the American Coal Ash Association.

[3]From domestic crude and synthetic gypsum.

[4]Defined as domestic crude production + synthetic used + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

HELIUM

(Data in million cubic meters of contained helium gas[1] unless otherwise noted)

Domestic Production and Use: The estimated value of Grade-A helium (99.997% or greater) extracted during 2019 by private industry was about $717 million. Fourteen plants (one in Arizona, two in Colorado, five in Kansas, one in Oklahoma, four in Texas, and one in Utah) extracted helium from natural gas and produced crude helium that ranged from 50% to 99% helium. One plant in Colorado and another in Wyoming extracted helium from natural gas and produced Grade-A helium. Three plants in Kansas and one in Oklahoma accepted crude helium from other producers and the Bureau of Land Management (BLM) pipeline and purified it to Grade-A helium. In 2019, estimated domestic consumption of Grade-A helium was 40 million cubic meters (1.4 billion cubic feet), and it was used for magnetic resonance imaging, 30%; lifting gas, 17%; analytical and laboratory applications, 14%; welding, 9%; engineering and scientific applications, 6%; leak detection and semiconductor manufacturing, 5% each; and various other minor applications, 14%.

Salient Statistics—United States:	2015	2016	2017	2018[e]	2019[e]
Helium extracted from natural gas[2]	71	66	63	64	68
Withdrawn from storage[3]	20	23	28	26	21
Grade-A helium sales	91	89	91	90	89
Imports for consumption	16	23	19	8	7
Exports	64	62	74	84	83
Consumption, apparent[4]	43	50	36	40	40
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

In fiscal year (FY) 2019, the price for crude helium to Government users was $3.10 per cubic meter ($86.00 per thousand cubic feet) and to nongovernment users was $4.29 per cubic meter ($119.00 per thousand cubic feet). The price for the Government-owned helium is mandated by the Helium Stewardship Act of 2013 (Public Law 113–40) and determined through public auctions and industry surveys. The last year helium prices were posted by the Federal Government was in 2018. The estimated price for private industry's Grade-A helium was about $7.57 per cubic meter ($210 per thousand cubic feet), with some producers posting surcharges to this price.

Recycling: In the United States, helium used in large-volume applications is seldom recycled. Some low-volume or liquid boil-off recovery systems are used. In the rest of the world, helium recycling is practiced more often.

Import Sources (2015–18): Qatar, 79%; Canada, 8%; Algeria, 5%; Portugal, 4%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Helium	2804.29.0010	3.7% ad val.

Depletion Allowance: Allowances are applicable to natural gas from which helium is extracted, but no allowance is granted directly to helium.

Government Stockpile: Under the Helium Stewardship Act of 2013, the BLM manages the Federal Helium Program, which includes all operations of the Cliffside Field helium storage reservoir, in Potter County, TX, and the Government's crude helium pipeline system. Private firms that sell Grade-A helium to Federal agencies are required to purchase a like amount of (in-kind) crude helium from the BLM. The law mandates that the BLM sell at auction Federal Conservation helium stored in Bush Dome at the Cliffside Field. The last auction was completed in the summer of 2018. Because the remaining conservation helium is less than 83.2 million cubic meters (3 billion cubic feet), the law requires that the BLM begin disposal of all helium assets including all operations of the Cliffside Field helium storage reservoir and pipeline system and complete the sale by yearend 2021. In the meantime, the BLM will continue to make in-kind helium available to Federal customers. In FY 2019, privately owned companies purchased about 4.8 million cubic meters (176 million cubic feet) of in-kind crude helium. During FY 2019, the BLM's Amarillo Field Office, Helium Operations, accepted about 3.0 million cubic meters (107 million cubic feet) of private helium for storage and redelivered nearly 24.2 million cubic meters (0.875 billion cubic feet). As of September 30, 2019, about 67.4 million cubic meters (2.43 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

Stockpile Status—9–30–19[6]

Material	Inventory	Authorized for disposal	Disposal plan FY 2019	Disposals FY 2019
Helium	68.0	51.4	4.8	4.8

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HELIUM

Events, Trends, and Issues: In 2019, the BLM continued implementation of the Helium Stewardship Act of 2013 by supplying helium to Federal agencies through the in-kind helium program from Federal helium storage at the Cliffside Field near Amarillo. The Bush Dome at the Cliffside Field is the only geologic structure in the United States that is used to store of helium. The Federal Government has stored helium in the Bush Dome since 1962. By about 2025, international helium extraction facilities are likely to become the main sources of supply for world helium users.

World Production and Reserves:[8]

	Production		Reserves[9]
	2018	2019[e]	
United States (extracted from natural gas)	64	68	3,900
United States (from Cliffside Field)	26	21	([10])
Algeria	14	14	1,800
Australia	4	4	NA
Canada	<1	<1	NA
China	NA	NA	NA
Poland	2	2	25
Qatar	45	51	NA
Russia	3	2	1,700
World total (rounded)	158	160	NA

World Resources: Section 16 of Public Law 113-40 requires the U.S. Geological Survey (USGS) to complete a national helium gas assessment. The USGS and the BLM coordinated efforts to complete this assessment. The USGS expects results to be published in 2020. The BLM plans to publish an update to its report of the Helium Resources of the United States by midyear 2020. Until then, the following estimates are still the best available.

As of December 31, 2006, the total helium reserves and resources of the United States were estimated to be 20.6 billion cubic meters (744 billion cubic feet). This includes 4.25 billion cubic meters (153 billion cubic feet) of measured reserves, 5.33 billion cubic meters (192 billion cubic feet) of probable resources, 5.93 billion cubic meters (214 billion cubic feet) of possible resources, and 5.11 billion cubic meters (184 billion cubic feet) of speculative resources. Included in the measured reserves are 670 million cubic meters (24.2 billion cubic feet) of helium stored in the Cliffside Field Government Reserve, and 65 million cubic meters (2.3 billion cubic feet) of helium contained in Cliffside Field native gas. The Hugoton (Kansas, Oklahoma, and Texas), Panhandle West, Panoma, Riley Ridge in Wyoming, and Cliffside Fields are the depleting fields from which most U.S.-produced helium is extracted. These fields contained an estimated 3.9 billion cubic meters (140 billion cubic feet) of helium.

Helium resources of the world, exclusive of the United States, were estimated to be about 31.3 billion cubic meters (1.13 trillion cubic feet). The locations and volumes of the major deposits, in billion cubic meters, are Qatar, 10.1; Algeria, 8.2; Russia, 6.8; Canada, 2.0; and China, 1.1. As of December 31, 2018, the BLM had analyzed about 22,300 gas samples from 26 countries and the United States, in a program to identify world helium resources.

Substitutes: There is no substitute for helium in cryogenic applications if temperatures below –429 °F are required. Argon can be substituted for helium in welding, and hydrogen can be substituted for helium in some lighter-than-air applications in which the flammable nature of hydrogen is not objectionable. Hydrogen is also being investigated as a substitute for helium in deep-sea diving applications below 1,000 feet.

[e]Estimated. E Net exporter. NA Not available.

[1]Measured at 101.325 kilopascals absolute (14.696 psia) and 15 °C; 27.737 cubic meters of helium = 1,000 cubic feet of helium at 70 °F and 14.7 psia.

[2]Both Grade-A and crude helium.

[3]Extracted from natural gas in prior years.

[4]Grade-A helium. Defined as Grade-A helium sales + imports – exports. However, substantial increases in exports reported in 2018 and 2019 suggest that domestic consumption declined, although no significant decline in U.S. helium consumption is thought to have taken place. For that reason, apparent consumption for 2018 and 2019 was estimated to have remained at about 40 million cubic meters.

[5]Defined as imports – exports.

[6]See Appendix B for definitions.

[7]Supervisory General Engineer, Helium Resources Division, Bureau of Land Management, Amarillo Field Office, Helium Operations, Amarillo, TX.

[8]Production and reserves outside of the United States are estimated.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Included in United States (extracted from natural gas) reserves.

INDIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Indium was not recovered from ores in the United States in 2019. Several companies produced indium products—including alloys, compounds, high-purity metal, and solders—from imported indium metal. Production of indium tin oxide (ITO) continued to account for most of global indium consumption. ITO thin-film coatings were primarily used for electrical conductive purposes in a variety of flat-panel displays—most commonly liquid crystal displays (LCDs). Other indium end uses included alloys and solders, compounds, electrical components and semiconductors, and research. Based on an average of recent annual import levels, estimated domestic consumption of refined indium was 110 tons in 2019. The estimated value of refined indium consumed domestically in 2019, based on the average New York dealer price, was about $43 million.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, refinery	—	—	—	—	—
Imports for consumption	140	160	127	125	110
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	140	160	127	125	110
Price, annual average, dollars per kilogram:					
New York dealer[2]	520	345	363	375	390
Duties unpaid in warehouse, Rotterdam[3]	410	240	225	291	210
Net import reliance[4] as a percentage of estimated consumption	100	100	100	100	100

Recycling: Indium is most commonly recovered from ITO scrap in Japan and the Republic of Korea. A significant quantity of scrap was recycled domestically; however, data on the quantity of secondary indium recovered from scrap were not available.

Import Sources (2015–18): China, 36%; Canada, 22%; Republic of Korea, 11%; Taiwan, 7%; and other, 24%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Unwrought indium, including powders, waste, and scrap	8112.92.3000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The 2019 estimated average New York dealer price of indium was $390 per kilogram, 4% more than that of 2018. The average monthly price in January was $390 per kilogram where it remained through September. The 2019 estimated average free market price of indium was $210 per kilogram, 28% less than in 2018. The average monthly free market price began the year at $232 per kilogram and decreased throughout the year to an average of $160 per kilogram in September.

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INDIUM

In January, the Fanya Metal Exchange attempted to auction two lots of indium, totaling 37.41 tons, with a starting price of $170 per kilogram, but no bids were received. A second auction for 34.64 tons of indium was held in April, and the total lot sold for about $5.5 million ($161 per kilogram) to the State-owned China National Corporation for Overseas Economic Cooperation (CCOEC). The Fanya Metal Exchange reportedly held 3,600 tons of indium, which is equivalent to 4 years of global primary indium production, before it closed in 2015.

New telecommunication networks have created a new demand for indium, which is used for indium phosphide (InP) lasers and receivers. InP lasers are used in telecommunications for fiber-optic networks that have connections between third-, fourth-, and fifth-generation (3G, 4G, and 5G) wireless antennas; have data transmission speeds of greater than 10 terabits per second; and have total transmission distances of more than 5,000 kilometers.

World Refinery Production and Reserves:

	Refinery production		Reserves[5]
	2018	2019[e]	
United States	—	—	Quantitative estimates of reserves are not available.
Belgium	22	20	
Canada	58	60	
China	300	300	
France	40	50	
Japan	70	75	
Korea, Republic of	235	240	
Peru	11	10	
Russia	5	5	
World total (rounded)	741	760	

World Resources: Indium is most commonly recovered from the zinc-sulfide ore mineral sphalerite. The indium content of zinc deposits from which it is recovered ranges from less than 1 part per million to 100 parts per million. Although the geochemical properties of indium are such that it occurs in trace amounts in other base-metal sulfides—particularly chalcopyrite and stannite—most deposits of these minerals are subeconomic for indium.

Substitutes: Antimony tin oxide coatings have been developed as an alternative to ITO coatings in LCDs and have been successfully annealed to LCD glass; carbon nanotube coatings have been developed as an alternative to ITO coatings in flexible displays, solar cells, and touch screens; PEDOT [poly(3,4-ethylene dioxythiophene)] has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes; and copper or silver nanowires have been explored as a substitute for ITO in touch screens. Graphene has been developed to replace ITO electrodes in solar cells and also has been explored as a replacement for ITO in flexible touch screens. Researchers have developed a more adhesive zinc oxide nanopowder to replace ITO in LCDs. Hafnium can replace indium in nuclear reactor control rod alloys.

[e]Estimated. NA Not available. — Zero.

[1]Estimated to equal imports.

[2]Price is based on 99.99%-minimum-purity indium; delivered duty paid U.S. buyers; in minimum lots of 50 kilograms. Source: Platts Metals Week.

[3]Price is based on 99.99%-minimum-purity indium, duties unpaid in warehouse (Rotterdam). Sources: Metal Bulletin (2015–2017) and Argus Media group–Argus Metals International (2018–2019).

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

IODINE

(Data in metric tons of elemental iodine unless otherwise noted)

Domestic Production and Use: Iodine was produced from brines in 2019 by three companies operating in Oklahoma. U.S. iodine production in 2019 was withheld to avoid disclosing company proprietary data. The average annual cost, insurance, and freight value of iodine imports in 2019 was estimated to be $26 per kilogram, a 16% increase from that of 2018.

Because domestic and imported iodine was used by downstream manufacturers to produce many intermediate iodine compounds, it was difficult to establish an accurate end-use pattern. Crude iodine and inorganic iodine compounds were thought to account for more than 50% of domestic iodine consumption in 2019. Worldwide, the leading uses of iodine and its compounds were x-ray contrast media, pharmaceuticals, liquid-crystal-displays (LCDs), and iodophors, in descending order of quantity consumed.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production	W	W	W	W	W
Imports for consumption	5,630	4,320	4,170	4,930	4,600
Exports	1,210	1,050	1,230	1,190	1,200
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	3,800	4,610	4,500	4,620	4,800
Price, crude, average value of imports, cost, insurance, and freight, dollars per kilogram	27.74	22.71	19.55	22.46	26
Employment, number[e]	60	60	60	60	60
Net import reliance[2] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled.

Import Sources (2015–18): Chile, 88%; Japan, 11%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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IODINE

Events, Trends, and Issues: According to trade publications, spot prices for iodine crystal averaged about $28 per kilogram during the first half of 2019. Although this was an increase from the 2018 annual average of about $25 per kilogram, prices were still considerably less than the historically high levels of $65 to $85 per kilogram in late 2012 and early 2013. The increase in the average spot price was attributed to an undersupply in the market. The estimated average annual value of crude iodine imported in the United States increased by about 16% in 2019 compared with that in 2018.

As in recent years, Chile was the world's leading producer of iodine, followed by Japan and the United States. Excluding production in the United States, Chile accounted for about 65% of world production in 2019. In Turkmenistan, a new iodine producer started operations and was thought to have contributed to an increase in the country's total iodine production in 2019. Most of the world's iodine supply comes from three areas: the Chilean desert nitrate mines, the oilfields and gasfields in Japan, and the iodine-rich brine wells in northwestern Oklahoma.

World Mine Production and Reserves: China and Iran also produce crude iodine, but output is not officially reported.

	Mine production		Reserves[3]
	2018	2019[e]	
United States	W	W	250,000
Azerbaijan	200	200	170,000
Chile	18,000	18,000	610,000
Indonesia	38	40	100,000
Japan	8,800	9,000	5,000,000
Russia	8	10	120,000
Turkmenistan	540	600	70,000
World total (rounded)	[4]27,600	[4]28,000	6,300,000

World Resources: Seawater contains 0.06 part per million iodine, and the oceans are estimated to contain approximately 90 billion tons of iodine. Seaweeds of the Laminaria family are able to extract and accumulate up to 0.45% iodine on a dry basis. Although not as economical as the production of iodine as a byproduct of gas, nitrates, and oil, the seaweed industry represented a major source of iodine prior to 1959 and remains a large resource.

Substitutes: No comparable substitutes exist for iodine in many of its principal applications, such as in animal feed, catalytic, nutritional, pharmaceutical, and photographic uses. Bromine and chlorine could be substituted for iodine in biocide, colorant, and ink, although they are usually considered less desirable than iodine. Antibiotics can be used as a substitute for iodine biocides.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Excludes U.S. production.

IRON AND STEEL[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: The U.S. iron and steel industry produced raw steel in 2019 with an estimated value of about $92 billion, an 11% decrease from $103 billion in 2018 and a 9% increase from $84 billion in 2017. Pig iron and raw steel was produced by three companies operating integrated steel mills in nine locations. Fifty companies produced raw steel at 98 minimills. Combined production capacity was about 111 million tons. Indiana accounted for an estimated 26% of total raw steel production, followed by Ohio, 12%; Michigan, 5%; and Pennsylvania, 5%, with no other State having more than 5% of total domestic raw steel production. Construction accounted for an estimated 44% of total domestic shipments by market classification, followed by transportation (predominantly automotive), 28%; machinery and equipment, 9%; energy, 6%; appliances, 5%; and other applications, 8%.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Pig iron production[2]	25.4	22.3	22.4	24.1	23
Raw steel production	78.8	78.5	81.6	86.6	87
Basic oxygen furnaces, percent	37.3	33.0	31.6	32.0	30
Electric arc furnaces, percent	62.7	67.0	68.4	68.0	70
Continuously cast steel, percent	99.0	99.4	99.6	98.2	99
Shipments, steel mill products	78.5	78.5	82.5	86.4	87
Imports:					
Finished steel mill products	28.6	23.9	26.8	23.3	20
Semifinished steel mill products	6.6	6.1	7.8	7.3	7.0
Total steel mill products	35.2	30.0	34.6	30.6	27.0
Exports:					
Finished steel mill products	8.9	8.3	9.5	7.9	6.7
Semifinished products	(3)	(3)	(3)	(3)	(3)
Total steel mill products	9.0	8.4	9.6	8.0	6.7
Stocks, service centers, yearend[4]	7.5	6.6	7.0	7.3	6.0
Consumption, apparent (steel)[5]	110	105	111	101	100
Producer price index for steel mill products (1982=100)[6]	177.1	167.8	187.4	211.1	207
Total employment, average, number[6]					
Blast furnaces and steel mills	87,000	83,900	80,600	82,100	83,000
Iron and steel foundries	64,900	65,000	65,000	65,200	63,000
Net import reliance[7] as a percentage of apparent consumption	29	25	26	22	21

Recycling: See Iron and Steel Scrap and Iron and Steel Slag.

Import Sources (2015–18): Canada, 17%; Brazil, 13%; Republic of Korea, 11%; and other, 59%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Carbon steel:		
Semifinished	7207.00.0000	Free.
Flat, hot-rolled	7208.00.0000	Free.
Flat, cold-rolled	7209.00.0000	Free.
Galvanized	7210.00.0000	Free.
Bars and rods, hot-rolled	7213.00.0000	Free.
Structural shapes	7216.00.0000	Free.
Stainless steel:		
Semifinished	7218.00.0000	Free.
Flat-rolled sheets	7219.00.0000	Free.
Bars and rods	7222.00.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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IRON AND STEEL

Events, Trends, and Issues: After several Presidential proclamations were issued in 2018 imposing 25% ad valorem tariffs on steel imports from most countries of origin under the authority of Section 232 of the Trade Expansion Act of 1962 (83 FR 11625), the President of the United States modified proclamation 9705 and issued two additional proclamations in 2019. Presidential Proclamation 9886, issued in May 2019, reduced the ad valorem tariff on steel imports from Turkey to 25% from 50%. Also, in May 2019, Proclamation 9894 removed the Section 232 tariffs for steel imports from Canada and Mexico. Steel imports from all countries except Argentina, Australia, Brazil, Canada, Mexico, and the Republic of Korea still required a 25% ad valorem tariff. In September 2018, March 2019, and June 2019, the U.S. Department of Commerce issued additional guidance in the Federal Register for companies to request product exemptions from the Section 232 tariffs.

The World Steel Association[8] forecast global finished steel demand to increase by 3.9% in 2019 and 1.7% in 2020, as a result of real estate investment in China and 4.1% growth in emerging and developing economies in 2020. Steel consumption in developed economies, except for China, was expected to remain the same or decrease slightly in 2019 despite growth in consumer and construction applications as potential and enacted trade policies affected investments and exports among the manufacturing sector. Growth of the construction sectors in 2019 and 2020 was expected to decrease slightly in the United States, as well as in the European Union, Latin America, Japan, and the Republic of Korea. In other countries in Asia, including India, Government stimulus was expected to increase demand in the construction sector. Automotive production rates were expected to decrease in 2019 in China, Germany, the Republic of Korea, and Turkey.

World Production:

	Pig iron		Raw steel	
	2018	2019[e]	2018	2019[e]
United States	24	23	87	87
Brazil	29	26	35	32
China	771	820	928	1,000
Germany	27	26	42	41
India	71	75	106	110
Iran	2	3	25	27
Italy	5	5	25	24
Japan	77	75	104	100
Korea, Republic of	47	48	72	72
Mexico	4	4	20	19
Russia	52	50	72	71
Taiwan	15	16	23	23
Turkey	11	10	37	34
Ukraine	21	21	21	22
Vietnam	6	10	18	27
Other countries	94	96	198	194
World total (rounded)	1,250	1,300	1,810	1,900

World Resources: Not applicable. See Iron Ore and Iron and Steel Scrap for steelmaking raw-material resources.

Substitutes: Iron is the least expensive and most widely used metal. In most applications, iron and steel compete either with less expensive nonmetallic materials or with more expensive materials that have a performance advantage. Iron and steel compete with lighter materials, such as aluminum and plastics, in the motor vehicle industry; aluminum, concrete, and wood in construction; and aluminum, glass, paper, and plastics in containers.

[e]Estimated.

[1]Production and shipments data source is the American Iron and Steel Institute; see also Iron and Steel Scrap and Iron Ore.

[2]More than 95% of iron made is transported in molten form to steelmaking furnaces located at the same site.

[3]Less than ½ unit.

[4]Steel mill products. Source: Metals Service Center Institute.

[5]Defined as steel shipments + imports of finished steel mill products – total exports of steel mill products + adjustments for industry stock changes.

[6]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331100.

[7]Defined as total imports – total exports + adjustments for industry stock changes.

[8]World Steel Association, 2019, Short range outlook October 2019: Brussels, Belgium, World Steel Association press release, October 14, 6 p.

IRON AND STEEL SCRAP[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: In 2019, the total value of domestic purchases of iron and steel scrap (receipts of ferrous scrap by all domestic consumers from brokers, dealers, and other outside sources) and exports was estimated to be $17.6 billion, approximately 17% less than the $21.1 billion in 2018 and 4% more than the $16.8 billion in 2017. U.S. apparent steel consumption, an indicator of economic growth, was estimated to have decreased slightly to 100 million tons in 2019 from 101 million tons in 2018. Manufacturers of pig iron, raw steel, and steel castings accounted for about 92% of scrap consumption by the domestic steel industry, using scrap together with pig iron and direct-reduced iron to produce steel products for the appliance, construction, container, machinery, oil and gas, transportation, and various other consumer industries. The ferrous castings industry consumed most of the remaining scrap to produce cast iron and steel products. Relatively small quantities of steel scrap were used for producing ferroalloys, for the precipitation of copper, and by the chemical industry; these uses collectively totaled less than 1 million tons.

During 2019, raw steel production was an estimated 87 million tons, up slightly from 86.6 million tons in 2018. Net shipments of steel mill products were an estimated 87 million tons, up slightly from 86.4 million tons in 2018.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Home scrap	6.3	5.9	5.6	5.8	5.8
Purchased scrap[2]	54	53	55	59	59
Imports for consumption[3]	3.5	3.9	4.6	5.0	4.5
Exports[3]	13	13	15	17	18
Consumption, reported	51	50	50	52	53
Consumption, apparent[4]	51	50	51	52	52
Price, average, dollars per metric ton delivered, No. 1 Heavy Melting composite price	213	196	266	323	266
Stocks, consumer, yearend	4.2	4.3	4.5	5.1	5.2
Employment, dealers, brokers, processors, number[e]	30,000	27,000	27,000	27,000	28,000
Net import reliance[5] as a percentage of reported consumption	E	E	E	E	E

Recycling: Recycled iron and steel scrap is a vital raw material for the production of new steel and cast iron products. The steel and foundry industries in the United States have been structured to recycle scrap, and, as a result, are highly dependent upon scrap. One ton of steel that is recycled conserves 1.1 tons of iron ore, 0.6 ton of coking coal, and 0.05 ton of limestone.

Overall, the scrap recycling rate in the United States has averaged between 80% and 90% during the past decade, with automobiles making up the primary source of old steel scrap. Recycling of automobiles is nearly 100% each year, with rates fluctuating slightly owing to the rate of new vehicle production and general economic trends. More than 15 million tons of steel is recycled from automobiles annually, the equivalent of approximately 12 million cars, from more than 7,000 vehicle dismantlers and 350 car shredders in North America. The recycling of steel from automobiles is estimated to save the equivalent energy necessary to power 18 million homes every year.

Recycling rates, which fluctuate annually, were estimated to be 98% for structural steel from construction, 88% for appliances, 71% for rebar and reinforcement steel, and 70% for steel packaging. The recycling rates for appliance, can, and construction steel are expected to increase in the United States and in emerging industrial countries at an even greater rate. Public interest in recycling continues, and recycling is becoming more profitable and convenient as environmental regulations for primary production increase.

Recycling of scrap plays an important role in the conservation of energy because the remelting of scrap requires much less energy than the production of iron or steel products from iron ore. Also, consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment. Recycled scrap consists of approximately 58% post-consumer (old, obsolete) scrap, 24% prompt scrap (produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

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IRON AND STEEL SCRAP

Import Sources (2015–18): Canada, 72%; Mexico, 9%; United Kingdom, 8%; Sweden, 5%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Ferrous waste and scrap:		
Stainless steel	7204.21.0000	Free.
Turnings, shavings, chips, milling waste, sawdust, filings, trimmings, and stampings:		
No. 1 bundles	7204.41.0020	Free.
No. 2 bundles	7204.41.0040	Free.
Borings, shovelings, and turnings	7204.41.0060	Free.
Other	7204.41.0080	Free.
Other:		
No. 1 heavy melting	7204.49.0020	Free.
No. 2 heavy melting	7204.49.0040	Free.
Cut plate and structural	7204.49.0060	Free.
Shredded	7204.49.0070	Free.
Remelting scrap ingots	7204.50.0000	Free.
Powders, of pig iron, spielgeleisen, iron, or steel:		
Alloy steel	7205.21.0000	Free.
Other	7205.29.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In 2019, steel mill production capacity utilization peaked to the highest rates since April 2012, reaching 82.4% in February 2019, with rates remaining over 80% between January and June. Composite prices published for No. 1 Heavy Melting steel scrap delivered averaged about $271 per ton during the first 8 months of 2019, a decrease from $323 per ton in 2018. The average monthly prices during this time fluctuated between a high of $309.87 per ton in March and a low of $225.91 per ton in July. In the first 8 months of 2019, Turkey was the primary destination for exports of ferrous scrap, by tonnage, accounting for 20% of total exports, followed by Canada (11%), Taiwan (10%), Vietnam (9%), and Mexico (7%). The value of exported scrap decreased to an estimated $5.3 billion in 2019 from $5.9 billion in 2018.

The World Steel Association[6] forecast global finished steel demand to increase by 3.9% in 2019 and 1.7% in 2020, as a result of real estate investment in China and 4.1% growth in emerging and developing economies in 2020. Steel demand among developed economies, except for China, was expected to remain the same or decrease slightly in 2019 despite growth in consumer and construction applications as potential and enacted trade policies affected investments and exports within the manufacturing sector. Growth of the construction sectors in 2019 and 2020 was expected to decrease slightly in the United States, as well as the European Union, Japan, Latin America, and the Republic of Korea. In other countries in Asia, including India, Government stimulus was expected to increase demand in the construction sector. Automotive production growth was also expected to decrease in 2019 in China, Germany, the Republic of Korea, and Turkey.

World Mine Production and Reserves: Not applicable.

World Resources: Not applicable.

Substitutes: An estimated 2.8 million tons of direct-reduced iron was used in the United States in 2019 as a substitute for iron and steel scrap, up from 2.4 million tons in 2018.

[e]Estimated. E Net exporter.

[1]See also Iron and Steel and Iron Ore.

[2]Defined as net receipts + exports – imports.

[3]Excludes used rails for rerolling and other uses, and ships, boats, and other vessels for scrapping.

[4]Defined as home scrap + purchased scrap + imports – exports + adjustments for industry stock changes.

[5]Defined as imports – exports + adjustments for industry stock changes.

[6]World Steel Association, 2019, Short range outlook October 2019: Brussels, Belgium, World Steel Association press release, October 14, 6 p.

IRON AND STEEL SLAG

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: Iron and steel (ferrous) slags are formed by the combination of slagging agents and impurities during the production of crude (or pig) iron and crude steel. The slags are tapped separately from the metals, cooled and processed, and are primarily used in the construction industry. Data are unavailable on actual U.S. ferrous slag production, but domestic slag sales[1] in 2019 were estimated to be 17 million tons valued at about $470 million. Blast furnace slag was about 50% of the tonnage sold and accounted for 88% of the total value of slag, most of which was granulated. Steel slag produced from basic oxygen and electric arc furnaces accounted for the remainder of sales. Slag was processed by 28 companies servicing active iron and steel facilities or reprocessing old slag piles at about 129 processing plants (including some iron and steel plants with more than one slag-processing facility) in 33 States, including facilities that import and grind unground slag to sell as ground granulated blast furnace slag (GGBFS).

Air-cooled iron slag and steel slag are used primarily as aggregates in concrete (air-cooled iron slag only); asphaltic paving, fill, and road bases; both slag types also can be used as a feed for cement kilns. Almost all GGBFS is used as a partial substitute for portland cement in concrete mixes or in blended cements. Pelletized slag is generally used for lightweight aggregate but can be ground into material similar to GGBFS. Actual prices per ton ranged in 2019 from a few cents for some steel slags at a few locations to about $120 or more for some GGBFS. Owing to low unit values, most slag types can be shipped only short distances by truck, but rail and waterborne transportation allow for greater travel distances. Because much higher unit values make it economic to ship GGBFS longer distances, much of the GGBFS consumed in the United States is imported.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production (sales)[1, 2]	17.7	15.7	16.2	16.8	17.0
Imports for consumption[3]	1.5	2.0	2.1	2.2	2.3
Exports	(4)	(4)	(4)	(4)	(4)
Consumption, apparent[5]	17.7	15.7	16.2	16.8	17.0
Price, average value, dollars per ton, f.o.b. plant[6]	19.50	22.00	24.50	26.50	27.50
Employment, number[e]	1,700	1,600	1,500	1,500	1,600
Net import reliance[7] as a percentage of apparent consumption	8	13	13	13	14

Recycling: Following removal of entrained metal, slag can be returned to the blast and steel furnaces as ferrous and flux feed, but data on these returns are incomplete. Entrained metal, particularly in steel slag, is routinely recovered during slag processing for return to the furnaces and is an important revenue source for slag processors; data on metal returns are unavailable.

Import Sources (2015–18): Japan, 24%; Canada, 20%; Brazil, 12%; Italy, 12%; and other, 32%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Granulated slag	2618.00.0000	Free.
Slag, dross, scale, from manufacture of iron and steel	2619.00.0000	Free.

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IRON AND STEEL SLAG

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In 2019, two blast furnaces were idled in the United States after two different blast furnaces were restarted in 2018. This continued the trend of U.S. blast furnaces being closed or idled in recent years (including four in 2015) and contributed to the reduction in the domestic supply of new blast furnace slag. However, many sites have large slag stockpiles, which can allow for processing to continue for several years after the furnaces are closed or idled. The majority of U.S steel slag production is from electric arc furnaces.

At yearend 2019, domestic GGBFS remained in limited supply because granulation cooling was available at only two active U.S. blast furnaces. It remained unclear if new granulation cooling installations at additional blast furnace sites would be economic. Another plant produced a limited supply of pelletized slag, but it was uncertain if additional pelletizing capacity would be added. Grinding of granulated blast furnace slag was only done domestically by cement companies. Supply constraints appear to have limited domestic consumption of GGBFS in recent years. Although prices have increased, sales of GGBFS have not correlated with the increases in the quantity of cement sold since 2010.

The domestic supply of fly ash, which is used as an additive in concrete production, has decreased, owing to new restrictions of mercury and carbon dioxide (CO_2) emissions at coal-fired powerplants, powerplant closures, and conversion of powerplants to natural gas. Mercury emission restrictions on cement plants, enacted in 2015, may reduce the demand for fly ash as a raw material in clinker manufacture, and air-cooled and steel slags could be used as substitute raw materials. Demand for GGBFS is likely to increase because its use in cement yields a superior product in many applications and reduces the unit CO_2 emissions in the production of the cement.

World Mine Production and Reserves: Because slag is not mined, the concept of reserves does not apply. World production data for slag were unavailable, but may be estimated as 25% to 30% of crude (pig) iron production and steel furnace slag as 10% to 15% of crude steel production. In 2019, world iron slag production was estimated to be between 320 million to 384 million tons, with steel slag production estimated to be between 190 million to 280 million tons.

World Resources: Not applicable.

Substitutes: In the construction sector, ferrous slags compete with natural aggregates (crushed stone and sand and gravel) but are far less widely available than the natural materials. As a cementitious additive in blended cements and concrete, GGBFS mainly competes with fly ash, metakaolin, and volcanic ash pozzolans. In this respect, GGBFS reduces the amount of portland cement per ton of concrete, thus allowing more concrete to be made per ton of portland cement. Slags (especially steel slag) can be used as a partial substitute for limestone and some other natural raw materials for clinker (cement) manufacture and compete in this use with fly ash and bottom ash. Some other metallurgical slags, such as copper slag, can compete with ferrous slags in some specialty markets, such as a ferrous feed in clinker manufacture, but are generally in much more restricted supply than ferrous slags.

[e]Estimated.

[1]Processed slag sold during the year, excluding entrained metal.

[2]Data include sales of imported granulated blast furnace slag and exclude sales of pelletized slag.

[3]U.S. Census Bureau data adjusted by the U.S. Geological Survey to remove nonslag materials (such as cenospheres, fly ash, and silica fume) and slags or other residues of other metallurgical industries (especially copper slag), whose unit values are outside the range expected for granulated slag. In some years, tonnages may be underreported.

[4]Less than 0.05 million tons.

[5]Defined as total sales of slag – exports.

[6]Rounded to the nearest $0.50 per ton.

[7]Defined as imports – exports.

IRON ORE[1]

(Data in thousand metric tons, usable ore, unless otherwise noted)

Domestic Production and Use: In 2019, mines in Michigan and Minnesota shipped 98% of the usable iron ore products consumed in the steel industry in the United States with an estimated value of $5.4 billion, an increase from $4.6 billion in 2018. The remaining 2% of domestic iron ore was produced for nonsteel end uses. Seven open-pit iron ore mines (each with associated concentration and pelletizing plants), and three iron metallic plants—one direct-reduced iron (DRI) plant in Louisiana and two hot-briquetted iron (HBI) plants in Indiana and Texas—operated during the year to supply steelmaking raw materials. The United States was estimated to have produced 1.9% and consumed 2.0% of the world's iron ore output.

Salient Statistics—United States:[2]	2015	2016	2017	2018	2019[e]
Production:					
Iron ore	46,100	41,800	47,900	49,500	48,000
Iron metallics	1,450	2,070	3,250	3,560	3,700
Shipments	43,500	46,600	46,900	50,400	50,000
Imports for consumption	4,550	3,010	3,710	3,810	5,100
Exports	7,500	8,710	10,600	13,000	13,000
Consumption:					
Reported	38,500	34,500	34,400	36,600	37,000
Apparent[3]	42,100	37,900	40,100	41,200	41,000
Value, U.S. dollars per metric ton	81.19	73.11	78.54	93.00	112.15
Stocks, mine, dock, and consuming plant, yearend, excluding byproduct ore	4,760	2,990	3,930	3,100	2,700
Employment, mine, concentrating and pelletizing plant, number	4,800	4,660	4,630	4,860	4,800
Net import reliance[4] as a percentage of apparent consumption (iron content of ore)	E	E	E	E	E

Recycling: None. See Iron and Steel Scrap.

Import Sources (2015–18): Brazil, 55%; Canada, 28%; Sweden, 6%, Chile, 4%; and other, 7%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Iron ores and concentrates:		
Concentrates	2601.11.0030	Free.
Coarse ores	2601.11.0060	Free.
Other ores	2601.11.0090	Free.
Pellets	2601.12.0030	Free.
Briquettes	2601.12.0060	Free.
Sinter	2601.12.0090	Free.
Roasted iron pyrites	2601.20.0000	Free.

Depletion Allowance: 15% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. iron ore production was estimated to have decreased slightly in 2019 owing to a decrease in domestic pig iron production and raw steel production from basic oxygen furnaces. Total raw steel production was estimated to have increased to 87 million tons in 2019 from 86.6 million tons in 2018. The share of steel produced by basic oxygen furnaces, the process that uses iron ore, continued to decline from 37.3% in 2015 to an estimated 30% in 2019 owing to increased use of electric arc furnaces because of their energy efficiency, reduced environmental impacts, and the ready supply of scrap.

Overall, global prices trended upwards in 2019 and the annual average value of $112.15 per ton was a 21% increase from $93.00 per ton in 2018. Based on reported prices for iron ore fines (62% iron content) imported into China (cost and freight into Tianjin port), the highest monthly average price during the first 10 months of 2019 was $120.24 per ton in July compared with the high of $77.46 per ton in February 2018. The lowest monthly average price during the same period in 2019 was $76.16 per ton in January compared with the low of $64.56 per ton in July 2018. The prices trended upwards owing to an estimated 4% increase in raw steel production and a reduced supply of higher grade iron ore products, spurred partially by closures of pelletizing plants in Brazil.

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IRON ORE

In August, one company completed a project at an iron-ore-processing facility in Minnesota enabling the plant to produce 3.5 million tons per year of direct-reduced-iron-grade pellets that will feed into a hot-briquetted plant under construction in Ohio, which was expected to open in mid-2020. Globally, iron ore production in 2019 was expected to increase by 5% from that of 2018, primarily owing to increased production in Australia, Brazil, China, and India.

Global finished steel demand was forecast by the World Steel Association[5] to increase by 3.9% in 2019 and 1.7% in 2020, as a result of real estate investment in China and 4.1% growth in emerging and developing economies in 2020. Steel demand among developed economies, except for China, was expected to remain the same or decrease slightly in 2019 despite growth in consumer and construction applications as potential and enacted trade policies impacted investments and exports among the manufacturing sector. Increased pressure on steel producers around the world to increase efficiency, reduce energy consumption, and meet environmental benchmarks continued the slow decline in use of low-grade iron ore and spurred investment in the production of iron metallics and high-grade iron ore products, such as pellets.

World Mine Production and Reserves: Reserves for Australia, Brazil, India, South Africa, and the United States were revised based on Government and industry sources.

	Mine production					
	Usable ore		Iron content		Reserves[6, 7]	
	2018	2019[e]	2018	2019[e]	Crude ore	Iron content
United States	49,500	48,000	31,300	31,000	3,000	1,000
Australia	900,000	930,000	557,000	580,000	[8]48,000	[8]23,000
Brazil	460,000	480,000	250,000	260,000	29,000	15,000
Canada	52,400	54,000	31,500	33,000	6,000	2,300
Chile	14,000	14,000	8,940	9,000	NA	NA
China	335,000	350,000	209,000	220,000	20,000	6,900
India	205,000	210,000	126,000	130,000	5,500	3,400
Iran	36,400	38,000	23,900	25,000	2,700	1,500
Kazakhstan	41,900	43,000	11,700	12,000	2,500	900
Mexico	22,300	23,000	14,000	14,000	NA	NA
Peru	14,200	15,000	9,530	10,000	NA	NA
Russia	96,100	99,000	56,700	59,000	25,000	14,000
South Africa	74,300	77,000	47,200	49,000	1,100	690
Sweden	35,800	37,000	22,200	23,000	1,300	600
Ukraine	60,300	62,000	37,700	39,000	[9]6,500	[9]2,300
Other countries	62,500	62,000	35,800	35,000	18,000	9,500
World total (rounded)	2,460,000	2,500,000	1,470,000	1,500,000	170,000	81,000

World Resources: U.S. resources are estimated to be 110 billion tons of iron ore containing about 27 billion tons of iron. U.S. resources are mainly low-grade taconite-type ores from the Lake Superior district that require beneficiation and agglomeration prior to commercial use. World resources are estimated to be greater than 800 billion tons of crude ore containing more than 230 billion tons of iron.

Substitutes: The only source of primary iron is iron ore, used directly as direct-shipping ore or converted to briquettes, concentrates, DRI, iron nuggets, pellets, or sinter. DRI, iron nuggets, and scrap are extensively used for steelmaking in electric arc furnaces and in iron and steel foundries. Technological advancements have been made, which allow hematite to be recovered from tailings basins and pelletized.

[e]Estimated. E Net exporter. NA Not available.

[1]Data are for iron ore used as a raw material in steelmaking unless otherwise noted. See also Iron and Steel and Iron and Steel Scrap.

[2]Except where noted, salient statistics are for all forms of iron ore used in steelmaking, and do not include iron metallics, which include DRI, hot-briquetted iron, and iron nuggets.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]World Steel Association, 2019, Short range outlook October 2019: Brussels, Belgium, World Steel Association press release, October 14, 6 p.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Million metric tons.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 24 billion tons for crude ore and 11 billion tons for iron content.

[9]For Ukraine, reserves consist of the A+B categories of the Soviet reserves classification system.

IRON OXIDE PIGMENTS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Iron oxide pigments (IOPs) were mined domestically by two companies in two States. Mine production, which was withheld to avoid disclosing company proprietary data, decreased in 2019 from that of 2018. Five companies, including the two producers of natural IOPs, processed and sold about 38,000 tons of finished natural and synthetic IOPs with an estimated value of $52 million, significantly below the most recent sales peak of 88,100 tons in 2007. About 59% of natural and synthetic finished IOPs were used in concrete and other construction materials; 11% in plastics; 7% in coatings and paints; 5% in foundry sands and other foundry uses; 3% each in animal food, industrial chemicals, and glass and ceramics; and 9% in other uses.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOP	53,500	48,500	47,300	48,200	38,000
Imports for consumption	176,000	179,000	179,000	179,000	160,000
Exports, pigment grade	8,930	15,800	13,500	11,100	9,900
Consumption, apparent[1]	221,000	212,000	213,000	216,000	190,000
Price, average value, dollars per kilogram[2]	1.46	1.46	1.46	1.58	1.40
Employment, mine and mill	55	60	60	60	55
Net import reliance[3] as a percentage of:					
Apparent consumption	W	W	W	W	W
Reported consumption	>50	>50	>50	>50	>50

Recycling: None.

Import Sources (2015–18): Natural: Spain, 43%; Cyprus, 36%; Austria, 10%; France, 9%; and other, 2%. Synthetic: China, 50%; Germany, 28%; Brazil, 6%, Canada, 4%, and other, 12%. Total: China, 48%; Germany, 28%; Brazil, 6%; Canada, 4%; and other, 14%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Natural:		
Micaceous iron oxides	2530.90.2000	2.9% ad val.
Earth colors	2530.90.8015	Free.
Iron oxides and hydroxides containing 70% or more by weight Fe_2O_3:		
Synthetic:		
Black	2821.10.0010	3.7% ad val.
Red	2821.10.0020	3.7% ad val.
Yellow	2821.10.0030	3.7% ad val.
Other	2821.10.0040	3.7% ad val.
Earth colors	2821.20.0000	5.5% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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IRON OXIDE PIGMENTS

Events, Trends, and Issues: In 2019, domestic mine production of crude ntural IOPs decreased owing to a major producer reducing mine output to draw down stocks after excess crude production in 2016 and 2017. Production and sales of finished natural and synthetic IOPs decreased by about 21%. Production and sales of synthetic IOPs also decreased in 2019, owing in part to a decrease in natural-disaster-related construction and refurbishment projects. In the United States, residential construction, in which IOPs are commonly used to color concrete block and brick, ready-mixed concrete, and roofing tiles, remained about the same during the first 9 months of 2019 compared with that of the same period in 2018. Housing starts decreased slightly.

Exports of pigment-grade IOPs decreased by about 11% during the first 9 months of 2019 compared with that during the same period in 2018, mostly owing to a significant decrease in exports to Malaysia, the Netherlands, and Thailand. More than 87% of pigment-grade IOPs went to Mexico, China, Belgium, Chile, Brazil, Thailand, the United Kingdom, and Germany, in descending order of quantity. Exports of other grades of iron oxides and hydroxides, nearly double those of pigment grade, increased by about 47% during the first 9 months of 2019 compared with those of the same period in 2018. About 98% of exports of other grades of iron oxides and hydroxides went to Spain, Canada, China, Mexico, Israel, Argentina, and Australia in descending order of quantity. Total imports of natural and synthetic IOPs decreased slightly in 2019 compared with those in 2018.

World Mine Production and Reserves: Reserves for Pakistan were revised based on Government information.

	Mine production		Reserves[4]
	2018	2019[e]	
United States	W	W	Moderate
Austria (micaceous IOP)	3,500	3,500	NA
Cyprus (umber)	3,300	4,000	Moderate
France	8,000	8,000	NA
Germany[5]	370,000	360,000	Moderate
India (ocher)	2,000,000	2,000,000	37,000,000
Italy	35,000	9,000	NA
Pakistan (ocher)	70,000	70,000	100,000
Spain (ocher and red iron oxide)	18,000	18,000	Large
World total	[6]NA	[6]NA	Large

World Resources: Domestic and world resources for production of IOPs are adequate. Adequate resources are available worldwide for the manufacture of synthetic IOPs.

Substitutes: Milled IOPs are thought to be the most commonly used natural minerals for pigments. Because IOPs are color stable, low cost, and nontoxic, they can be economically used for imparting black, brown, red, and yellow coloring in large and relatively low-value applications. Other minerals may be used as colorants, but they generally cannot compete with IOPs because of their higher costs and more limited availability. Synthetic IOPs are widely used as colorants and compete with natural IOPs in many color applications. Organic colorants are used for some colorant applications, but many of the organic compounds fade over time from exposure to sunlight.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Defined as sold or used finished natural and synthetic IOPs + imports – exports.

[2]Average unit value for finished iron oxide pigments sold or used by U.S. producers.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes natural and synthetic IOP.

[6]A significant number of other countries, including Azerbaijan, Brazil, China, Honduras, Iran, Kazakhstan, Lithuania, Paraguay, Russia, South Africa, Turkey, Ukraine, and the United Kingdom, are thought to produce IOPs, but output was not reported and no basis was available to make reliable estimates of production.

KYANITE AND RELATED MINERALS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In Virginia, one firm with integrated mining and processing operations produced an estimated 90,000 tons of kyanite worth $33 million from two hard-rock open pit mines and synthetic mullite by calcining kyanite. Two other companies, one in Alabama and another in Georgia, produced synthetic mullite from materials mined from four sites; each company sourced materials from one site in Alabama and one site in Georgia. Synthetic mullite production data are withheld to avoid disclosing company proprietary data. Commercially produced synthetic mullite is made by sintering or fusing such feedstock materials as kyanite, kaolin, bauxite, or bauxitic kaolin. Natural mullite occurrences typically are rare and uneconomic to mine. Of the kyanite-mullite output, 90% was estimated to have been used in refractories and 10% in other uses, including abrasive products, such as motor vehicle brake shoes and pads and grinding and cutting wheels; ceramic products, such as electrical insulating porcelains, sanitaryware, and whiteware; foundry products and precision casting molds; and other products. An estimated 60% to 65% of the refractory use was by the iron and steel industries, and the remainder was by industries that manufacture chemicals, glass, nonferrous metals, and other materials. Andalusite was commercially mined from an andalusite-pyrophyllite-sericite deposit in North Carolina and processed as a blend of primarily andalusite for use by producers of refractories in making firebrick.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine	[1]109,000	[1]79,700	[1]91,300	[1]89,200	90,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	11,500	2,510	7,420	8,590	9,000
Exports (kyanite)	39,900	37,100	42,400	43,000	40,000
Consumption, apparent[2]	W	W	W	W	W
Price, average, dollars per metric ton:[3]					
U.S. kyanite, raw concentrate	270	270	270	NA	NA
U.S. kyanite, calcined	410	420	420	NA	NA
Employment, kyanite mine, office, and plant, number[e]	155	150	140	150	150
Employment, mullite plant, office, and plant, number[e]	220	210	200	200	200
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2015–18): South Africa, 75%; Peru, 19%; France, 4%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

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KYANITE AND RELATED MINERALS

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, increased by about 4% in the first 8 months of 2019 compared with that of the same period in 2018, indicating a similar change in consumption of kyanite-mullite refractories. Total world steel production similarly increased by about 4% during the first 8 months of 2019 compared with that of the same period in 2018. The increase in world steel production during the first 8 months of 2019 was the result of sustained growth in China with a 9% increase in steel production. The steel industry continued to be the largest market for refractories.

In June 2019, a company in South Africa suspended production for more than 1 month after entering business rescue proceedings resulting from financial setbacks. The company accounted for almost one-third of global andalusite output. The complications were the result of low prices and weakening demand for refractories globally. Bauxite and mullite could receive increased consideration as alternatives to refractory andalusite, if andalusite producers are unable to meet demand in 2020.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2018	2019[e]	
United States (kyanite)	[1]89,200	90,000	Large
India (kyanite and sillimanite)	101,000	110,000	7,190,000
Peru (andalusite)	40,000	40,000	NA
South Africa (andalusite)	200,000	190,000	NA
World total (rounded)	[6]NA	[6]NA	NA

World Resources: Large resources of kyanite and related minerals are known to exist in the United States. The chief resources are in deposits of micaceous schist and gneiss, mostly in the Appalachian Mountains and in Idaho. Other resources are in aluminous gneiss in southern California. These resources are not economic to mine at present. The characteristics of kyanite resources in the rest of the world are thought to be similar to those in the United States. Significant resources of andalusite are known to exist in China, France, Peru, and South Africa; kyanite resources have been identified in Brazil, India, and Russia; and sillimanite has been identified in India.

Substitutes: Two types of synthetic mullite (fused and sintered), superduty fire clays, and high-alumina materials are substitutes for kyanite in refractories. Principal raw materials for synthetic mullite are bauxite, kaolin and other clays, and silica sand.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Source: Virginia Department of Mines, Minerals and Energy.

[2]Defined as production + imports – exports.

[3]Source: Average of prices reported in Industrial Minerals.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]In addition to the countries listed, France continued production of andalusite and Cameroon and China produced kyanite and related minerals. Output was not reported quantitatively, and no reliable basis was available for estimation of output levels.

LEAD

(Data in thousand metric tons of lead content unless otherwise noted)

Domestic Production and Use: Six lead mines in Missouri, plus five mines in Alaska, Idaho, and Washington that produced lead as a principal product or byproduct, accounted for all domestic lead mine production. The value of the lead in concentrates mined in 2019, based on the average North American Market price for refined lead, was about $630 million. Nearly all lead mine production has been exported since the last primary refinery closed in 2013. The 12 secondary refineries in 10 States accounted for more than 95% of the secondary lead produced in 2019. It was estimated that the lead-acid battery industry accounted for about 93% of reported U.S. lead consumption during 2019. Lead-acid batteries were primarily used as starting-lighting-ignition (SLI) batteries for automobiles, as industrial-type batteries for standby power for computer and telecommunications networks, and for motive power. During the first 9 months of 2019, 97 million lead-acid automotive batteries were shipped by North American producers, a 3% decrease from those shipped in the same period of 2018.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine, lead in concentrates	370	346	310	280	280
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,050	1,110	1,140	1,140	1,200
Imports for consumption:					
Lead in concentrates	—	—	(1)	—	(1)
Refined metal, unwrought (gross weight)	521	533	658	563	520
Exports:					
Lead in concentrates	350	341	269	251	260
Refined metal, unwrought (gross weight)	56	43	24	67	28
Consumption, apparent[2]	1,510	1,600	1,770	1,630	1,650
Price, average, cents per pound:[3]					
North American market	91.2	94.4	114.5	110.9	100.0
London Metal Exchange (LME), cash	81.0	84.8	105.1	101.8	91.0
Employment, number:					
Mine and mill (average)[4]	1,970	1,970	1,890	1,870	1,790
Net import reliance[5] as a percentage of apparent consumption, refined metal	31	31	36	30	30

Recycling: In 2019, about 1.2 million tons of secondary lead was produced, an amount equivalent to 73% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2015–18): Refined metal: Canada, 44%; Mexico, 18%; Republic of Korea, 17%; India, 5%; and other, 16%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Lead ores and concentrates, lead content	2607.00.0020	1.1¢/kg on lead content.
Refined lead	7801.10.0000	2.5% on the value of the lead content.
Antimonial lead	7801.91.0000	2.5% on the value of the lead content.
Alloys of lead	7801.99.9030	2.5% on the value of the lead content.
Other unwrought lead	7801.99.9050	2.5% on the value of the lead content.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

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LEAD

Events, Trends, and Issues: During the first 11 months of 2019, the average LME cash price for lead was 91 cents per pound, 11% less than the average price in 2018. Global stocks of lead in LME-approved warehouses were 67,275 tons in mid-December 2019, which was 37% less than those at yearend 2018.

In 2019, domestic mine production was estimated to be essentially unchanged from that in the previous year in all four lead-producing States. Production at one mine in Idaho continued to be relatively low owing to an employee strike, which began in March 2017. The United States has become more reliant on imported refined lead in recent years owing to the closure of the last primary lead smelter in 2013. In the first 10 months of 2019, 22.9 million spent SLI lead-acid batteries were exported, essentially unchanged compared with that in the same time period in 2018.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2019 decreased by 0.3% to 11.76 million tons, and metal consumption decreased by 0.5% to 11.81 million tons, resulting in a production-to-consumption deficit of about 50,000 tons of refined lead owing to the decline in automobile production and increased uses of lithium-ion batteries.

World Mine Production and Reserves: Reserves estimates for Australia, Peru, and Turkey were revised based on new information from company or Government reports.

	Mine production		Reserves[7]
	2018	2019[e]	
United States	280	280	5,000
Australia	432	430	[8]36,000
Bolivia	112	100	1,600
China	2,100	2,100	18,000
India	192	190	2,500
Kazakhstan	86	90	2,000
Mexico	240	240	5,600
Peru	289	290	6,300
Russia	220	220	6,400
Sweden	65	60	1,100
Turkey	76	70	860
Other countries	468	430	5,000
World total (rounded)	4,560	4,500	90,000

World Resources: Identified world lead resources total more than 2 billion tons. In recent years, significant lead resources have been identified in association with zinc and (or) silver or copper deposits in Australia, China, Ireland, Mexico, Peru, Portugal, Russia, and the United States (Alaska).

Substitutes: Substitution by plastics has reduced the use of lead in cable covering and cans. Tin has replaced lead in solder for potable water systems. The electronics industry has moved toward lead-free solders and flat-panel displays that do not require lead shielding. Steel and zinc are common substitutes for lead in wheel weights.

[e]Estimated. — Zero.

[1]Less than ½ unit.

[2]Defined as primary refined production + secondary refined production (old scrap) + refined imports – refined exports.

[3]Source: Platts Metal Week.

[4]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct.

[5]Defined as imports – exports.

[6]International Lead and Zinc Study Group, 2019, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group news release, October 28, 7 p.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 12 million tons.

LIME[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, an estimated 18 million tons of quicklime and hydrate was produced (excluding independent commercial hydrators[2]), valued at about $2.4 billion. At yearend, 28 companies were producing lime, which included 18 companies with commercial sales and 10 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 74 primary lime plants (plants operating quicklime kilns) in 28 States and Puerto Rico. Six of these 28 companies operated only hydrating plants in 11 States. In 2019, the five leading U.S. lime companies produced quicklime or hydrate in 21 States and accounted for about 80% of U.S. lime production. Principal producing States were, in alphabetical order, Alabama, Kentucky, Missouri, Ohio, and Texas. Major markets for lime were, in descending order of consumption, steelmaking, chemical and industrial applications (such as the manufacture of fertilizer, glass, paper and pulp, and precipitated calcium carbonate, and in sugar refining), flue gas treatment, construction, water treatment, and nonferrous mining.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production[3]	18,300	17,300	17,600	18,100	18,000
Imports for consumption	391	376	367	370	360
Exports	346	329	391	422	350
Consumption, apparent[4]	18,300	17,300	17,600	18,000	18,000
Quicklime average value, dollars per ton at plant	121.50	121.00	122.10	124.60	124.00
Hydrate average value, dollars per ton at plant	146.40	145.50	147.10	151.50	151.00
Employment, mine and plant, number	NA	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	<1	<1	E	E	<1

Recycling: Large quantities of lime are regenerated by paper mills. Some municipal water-treatment plants regenerate lime from softening sludge. Quicklime is regenerated from waste hydrated lime in the carbide industry. Data for these sources were not included as production in order to avoid duplication.

Import Sources (2015–18): Canada, 93%; Mexico, 6%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Calcined dolomite	2518.20.0000	3% ad val.
Quicklime	2522.10.0000	Free.
Slaked lime	2522.20.0000	Free.
Hydraulic lime	2522.30.0000	Free.

Depletion Allowance: Limestone produced and used for lime production, 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2019, domestic lime production was estimated to have remained essentially unchanged from that of 2018. In 2018, one sugar cooperative finalized its decision to close the sugar beet facility in Torrington, WY, in 2019, thereby removing one quicklime kiln from production. Another company sold its quicklime and hydrate production plant in Calera, AL, which reduced the number of companies producing lime. As a result, the total number of operating quicklime plants remained at 74 in 2019. Hydrated lime is a dry calcium hydroxide powder made from reacting quicklime with a controlled amount of water in a hydrator. It is used in chemical and industrial, construction, and environmental applications. In 2019, the leading uses of hydrated lime were chemical and industrial, and construction applications; flue gas desulfurization; and water treatment.

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LIME

World Lime Production and Limestone Reserves:

	Production[e, 6]		Reserves[7]
	2018	2019	
United States	18,100	18,000	Adequate for all countries listed.
Australia	2,000	2,100	
Belgium[8]	1,330	1,300	
Brazil	8,300	8,400	
Bulgaria	1,500	1,500	
Canada (shipments)	1,810	1,800	
China	300,000	300,000	
Czechia	1,040	1,100	
France	2,600	2,600	
Germany	7,000	7,100	
India	16,000	16,000	
Iran	3,300	3,300	
Italy[8]	3,600	3,600	
Japan (quicklime only)	7,580	7,600	
Kazakhstan	1,050	1,100	
Korea, Republic of	5,200	5,200	
Malaysia	1,600	1,600	
Poland (hydrated and quicklime)	2,680	2,700	
Romania	2,210	2,200	
Russia (industrial and construction)	11,100	11,000	
Slovenia	1,060	1,200	
South Africa	1,200	1,200	
Spain	1,820	1,800	
Turkey	4,700	4,700	
Ukraine	2,100	2,100	
United Kingdom	1,400	1,400	
Other countries	13,400	14,000	
World total (rounded)	424,000	430,000	

World Resources: Domestic and world resources of limestone and dolomite suitable for lime manufacture are very large.

Substitutes: Limestone is a substitute for lime in many applications, such as agriculture, fluxing, and sulfur removal. Limestone, which contains less reactive material, is slower to react and may have other disadvantages compared with lime, depending on the application; however, limestone is considerably less expensive than lime. Calcined gypsum is an alternative material in industrial plasters and mortars. Cement, cement kiln dust, fly ash, and lime kiln dust are potential substitutes for some construction uses of lime. Magnesium hydroxide is a substitute for lime in pH control, and magnesium oxide is a substitute for dolomitic lime as a flux in steelmaking.

[e]Estimated. E Net exporter, NA Not available.

[1]Data are for quicklime, hydrated lime, and refractory dead-burned dolomite. Includes Puerto Rico.

[2]To avoid double counting quicklime production, excludes independent commercial hydrators that purchase quicklime for hydration.

[3]Sold or used by producers.

[4]Defined as production + imports – exports. Includes some double counting based on nominal, undifferentiated reporting of company export sales as U.S. production.

[5]Defined as imports – exports.

[6]Only countries that produced 1 million tons of lime or more are listed separately.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Includes hydraulic lime.

LITHIUM

(Data in metric tons of lithium content unless otherwise noted)

Domestic Production and Use: The only lithium production in the United States was from a brine operation in Nevada. Two companies produced a wide range of downstream lithium compounds in the United States from domestic or imported lithium carbonate, lithium chloride, and lithium hydroxide. Domestic production data were withheld to avoid disclosing company proprietary data.

Although lithium markets vary by location, global end-use markets are estimated as follows: batteries, 65%; ceramics and glass, 18%; lubricating greases, 5%; polymer production, 3%; continuous casting mold flux powders, 3%; air treatment, 1%; and other uses, 5%. Lithium consumption for batteries has increased significantly in recent years because rechargeable lithium batteries are used extensively in the growing market for portable electronic devices and increasingly are used in electric tools, electric vehicles, and grid storage applications. Lithium minerals were used directly as ore concentrates in ceramics and glass applications.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production	W	W	W	W	W
Imports for consumption	2,750	3,140	3,330	3,420	2,500
Exports	1,790	1,520	1,960	1,660	1,700
Consumption, estimated[1]	2,000	3,000	3,000	3,000	2,000
Price, annual average, battery-grade lithium carbonate, dollars per metric ton[2]	6,500	8,650	15,000	17,000	13,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>25	>50	>50	>50	>25

Recycling: One domestic company has recycled lithium metal and lithium-ion batteries since 1992 at its facility in British Columbia, Canada. In 2015, the company began operating the first U.S. recycling facility for lithium-ion vehicle batteries in Lancaster, OH.

Import Sources (2015–18): Argentina, 53%; Chile, 40%; China, 3%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Other alkali metals	2805.19.9000	5.5% ad val.
Lithium oxide and hydroxide	2825.20.0000	3.7% ad val.
Lithium carbonate:		
U.S. pharmaceutical grade	2836.91.0010	3.7% ad val.
Other	2836.91.0050	3.7% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[4]

		FY 2019		**FY 2020**	
Material	**Inventory As of 9–30–19**	**Potential Acquisitions**	**Potential Disposals**	**Potential Acquisitions**	**Potential Disposals**
Lithium cobalt oxide (kilograms, gross weight)	750	—	—	—	—
Lithium nickel cobalt aluminum oxide (kilograms, gross weight)	1,620	—	—	—	—
Lithium-ion precursors (kilograms, gross weight)	—	19,000	—	—	—

Events, Trends, and Issues: Excluding U.S. production, worldwide lithium production in 2019 decreased by 19% to 77,000 tons of lithium content from 95,000 tons of lithium content in 2018 in response to lithium production exceeding consumption and decreasing lithium prices. Global consumption of lithium in 2019 was estimated to be about 57,700 tons of lithium content, an increase of 18% from 49,100 tons of lithium content in 2018. However, consumption was lower than anticipated by the lithium industry owing to China scaling back subsidies on electric vehicles, consumers reducing lithium inventories, and lower electric vehicle sales volumes.

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LITHIUM

Spot lithium carbonate prices in China decreased from approximately $11,600 per ton at the beginning of the year to about $7,300 per ton in December. For large fixed contracts, the annual average U.S. lithium carbonate price was $13,000 per metric ton in 2019, a 24% decrease from that of 2018. Spot lithium hydroxide prices in China decreased from approximately $15,500 per ton at the beginning of the year to about $8,000 per ton in December. Spot lithium metal (99.9% Li) prices in China decreased from approximately $120,000 per ton at the beginning of the year to about $82,000 per ton in December.

Six mineral operations in Australia, two brine operations each in Argentina and Chile, and one brine and one mineral operation in China accounted for the majority of world lithium production. Owing to overproduction and decreased prices, several established lithium operations postponed capacity expansion plans. Junior mining operations in Australia, Canada, and Namibia ceased production altogether.

Lithium supply security has become a top priority for technology companies in the United States and Asia. Strategic alliances and joint ventures among technology companies and exploration companies continued to be established to ensure a reliable, diversified supply of lithium for battery suppliers and vehicle manufacturers. Brine-based lithium sources were in various stages of development in Argentina, Bolivia, Chile, China, and the United States; mineral-based lithium sources were in various stages of development in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Finland, Germany, Mali, Namibia, Portugal, Serbia, Spain, and Zimbabwe; and lithium-clay sources were in various stages of development in Mexico and the United States.

World Mine Production and Reserves: Reserves for Argentina, Australia, Brazil, Chile, the United States, and Zimbabwe were revised based on new information from Government and industry sources.

	Mine production		Reserves[5]
	2018	2019[e]	
United States	W	W	630,000
Argentina	6,400	6,400	1,700,000
Australia	58,800	42,000	[6]2,800,000
Brazil	300	300	95,000
Canada	2,400	200	370,000
Chile	17,000	18,000	8,600,000
China	7,100	7,500	1,000,000
Namibia	500	—	NA
Portugal	800	1,200	60,000
Zimbabwe	1,600	1,600	230,000
Other[7]	—	—	1,100,000
World total (rounded)	[8]95,000	[8]77,000	17,000,000

World Resources: Owing to continuing exploration, identified lithium resources have increased substantially worldwide and total about 80 million tons. Lithium resources in the United States—from continental brines, geothermal brines, hectorite, oilfield brines, and pegmatites—are 6.8 million tons. Lithium resources in other countries have been revised to 73 million tons. Lithium resources, in descending order, are: Bolivia, 21 million tons; Argentina, 17 million tons; Chile, 9 million tons; Australia, 6.3 million tons; China, 4.5 million tons; Congo (Kinshasa), 3 million tons; Germany, 2.5 million tons; Canada and Mexico, 1.7 million tons each; Czechia, 1.3 million tons; Mali, Russia, and Serbia, 1 million tons each; Zimbabwe, 540,000 tons; Brazil, 400,000 tons; Spain, 300,000 tons; Portugal, 250,000 tons; Peru, 130,000 tons; Austria, Finland and Kazakhstan, 50,000 tons each; and Namibia, 9,000 tons.

Substitutes: Substitution for lithium compounds is possible in batteries, ceramics, greases, and manufactured glass. Examples are calcium, magnesium, mercury, and zinc as anode material in primary batteries; calcium and aluminum soaps as substitutes for stearates in greases; and sodic and potassic fluxes in ceramics and glass manufacture.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. NA Not available. — Zero.

[1]Defined as production + imports – exports. Rounded to one significant digit to avoid disclosing company proprietary data.

[2]Source: Industrial Minerals, IM prices: Lithium carbonate, large contracts, delivered continental United States.

[3]Defined as imports – exports + adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant reserves were 1.7 million tons.

[7]Other countries with reported reserves include Finland, Mali, and Mexico.

[8]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

[Data in thousand metric tons of magnesium oxide (MgO) content unless otherwise noted][2]

Domestic Production and Use: Seawater and natural brines accounted for about 73% of U.S. magnesium compound production in 2019. The value of production of all types of magnesium compounds was estimated to be $276 million. Magnesium oxide and other compounds were recovered from seawater by one company in California and another company in Delaware, from well brines by one company in Michigan, and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada. One company in Washington processed olivine that was mined previously for use as foundry sand. About 72% of the magnesium compounds consumed in the United States were used in agricultural, chemical, construction, deicing, environmental, and industrial applications in the form of caustic-calcined magnesia, magnesium chloride, magnesium hydroxide, and magnesium sulfates. The remaining 28% was used for refractories in the form of dead-burned magnesia, fused magnesia, and olivine.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production (shipments)	394	408	438	405	410
Shipments (gross weight)	561	579	616	610	620
Imports for consumption	602	370	436	551	570
Exports	71	88	103	116	120
Consumption, apparent[3]	925	690	771	840	860
Employment, plant, number[e]	260	260	260	270	270
Net import reliance[4] as a percentage of apparent consumption	57	41	43	52	52

Recycling: Some magnesia-based refractories are recycled, either for reuse as refractory material or for use as construction aggregate.

Import Sources (2015–18): Caustic-calcined magnesia: China, 60%; Canada, 20%; Australia, 8%; Hong Kong, 4%; and other, 8%. Dead-burned and fused magnesia: China, 60%; Brazil, 15%; Turkey, 6%; Ukraine, 6%; and other, 13%. Magnesium chloride: Israel, 60%; Netherlands, 28%; China, 4%; India, 4%; and other, 4%. Magnesium hydroxide: Mexico, 50%; Netherlands, 15%; Israel, 14%; Austria, 10%; and other, 11%. Magnesium sulfates: China, 53%; Germany, 27%; Canada, 6%; Mexico, 4%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Crude magnesite	2519.10.0000	Free.
Dead-burned and fused magnesia	2519.90.1000	Free.
Caustic-calcined magnesia	2519.90.2000	Free.
Kieserite	2530.20.1000	Free.
Epsom salts	2530.20.2000	Free.
Magnesium hydroxide and peroxide	2816.10.0000	3.1% ad val.
Magnesium chloride	2827.31.0000	1.5% ad val.
Magnesium sulfate (synthetic)	2833.21.0000	3.7% ad val.

Depletion Allowance: Brucite, 10% (Domestic and foreign); dolomite, magnesite, and magnesium carbonate, 14% (Domestic and foreign); magnesium chloride (from brine wells), 5% (Domestic and foreign); and olivine, 22% (Domestic) and 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of dead-burned and fused magnesia in the United States increased slightly in 2019 compared with that in 2018. Global consumption of dead-burned and fused magnesia increased by about 4% during the first 8 months of 2019 compared with that in the same period of 2018, as world steel production increased in 2019. However, sales of magnesia-based refractory products by major producers lagged as many consumers in the steel industry started the year with high stock levels and destocked during the first half of the year, especially in Europe. Consumption by nonferrous metal producers and other consumers of magnesia refractory products offset some of the decreased consumption by the steel industry. Although world prices for dead-burned and fused magnesia started the year high, by March import prices were declining and by August, prices were about 50% lower than at the start of the year as producers in China sought to sell surplus supplies. Import prices for caustic-calcined magnesia were more stable during the year and the average price of imports through August was 14% higher than that for the same period in 2018.

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MAGNESIUM COMPOUNDS

Consumption of caustic-calcined magnesia continued to increase for animal feed supplements and fertilizer as the importance of magnesium as a nutrient gained recognition. Environmental applications, such as wastewater treatment, also accounted for increasing consumption of magnesium compounds, including caustic-calcined magnesia and magnesium hydroxide.

Because China was the leading producing country for magnesia and magnesite, policy changes in China affected prices and availability of all grades of magnesia in the world market. Stricter enforcement of environmental regulations in Henan and Shandong Provinces that forced some refractory producers to decrease production was cited for decreased consumption of fused magnesia. Decreased demand in China resulted in lower prices as producers in China increased exports. Lower prices for fused magnesia caused prices for dead-burned magnesia to also decrease; the export price range for dead-burned magnesia from China decreased by about 33% from the start of the year to the end of June. Magnesite mines in Liaoning Province were shut down from August 1 to October 31 owing to high stocks, low prices, and environmental regulations. The temporary closure of mines in China did not cause magnesia prices to increase significantly as stocks were high before the announcement. The Government of China announced mandatory shutdowns of capacity in several industries, including steelmaking, in certain areas during the winter months, which would likely decrease demand for fused and dead-burned magnesia.

World Magnesite Mine Production and Reserves:[5] In addition to magnesite, vast reserves exist in well and lake brines and seawater from which magnesium compounds can be recovered.

	Mine production		Reserves[6]
	2018	2019[e]	
United States	W	W	35,000
Australia	265	300	[7]320,000
Austria	750	740	50,000
Brazil	1,700	1,700	390,000
China	18,500	19,000	1,000,000
Greece	450	470	280,000
India	175	140	82,000
Korea, North	70	50	2,300,000
Russia	1,500	1,500	2,300,000
Slovakia	475	500	120,000
Spain	550	580	35,000
Turkey	1,800	2,000	230,000
Other countries	865	600	1,400,000
World total (rounded)	[8]27,100	[8]28,000	8,500,000

World Resources: Resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread. Identified world magnesite and brucite resources total 12 billion tons and several million tons, respectively. Resources of dolomite, forsterite, magnesium-bearing evaporite minerals, and magnesia-bearing brines are estimated to constitute a resource of billions of tons. Magnesium hydroxide can be recovered from seawater. Serpentine could be used as a source of magnesia but global resources, including in tailings of asbestos mines, have not been quantified but are thought to be very large.

Substitutes: Alumina, chromite, and silica substitute for magnesia in some refractory applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See also Magnesium Metal.

[2]Previously reported as magnesium content. Based on input from consumers, producers, and others involved in the industry, it was determined that reporting magnesium compound data in terms of contained magnesia was more useful than reporting in terms of magnesium content. Conversion factors used: magnesite, 47.8% MgO; magnesium chloride, 42.3% MgO; magnesium hydroxide, 69.1% MgO; and magnesium sulfate, 33.5% MgO.

[3]Defined as shipments + imports – exports.

[4]Defined as imports – exports.

[5]Gross weight of magnesite (magnesium carbonate) in thousand tons.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were 37 million tons.

[8]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, primary magnesium was produced by one company in Utah at an electrolytic process plant that recovered magnesium from brines from the Great Salt Lake. Secondary magnesium was recovered from scrap at plants that produced magnesium ingot and castings, and from aluminum alloy scrap at secondary aluminum smelters. Primary magnesium production in 2019 was estimated to have decreased from that of 2018. Information regarding U.S. primary magnesium production was withheld to avoid disclosing company proprietary data. The leading use for primary magnesium metal, which accounted for 55% of reported consumption, was in castings, principally used for the automotive industry. Aluminum-base alloys that were used for packaging, transportation, and other applications accounted for 28% of primary magnesium metal consumption; desulfurization of iron and steel, 13%; and other uses, 4%. About 33% of the secondary magnesium was consumed for structural uses and about 67% was used in aluminum alloys.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	88	102	114	109	110
Imports for consumption	49	46	42	47	55
Exports	15	19	14	11	10
Consumption:					
Reported, primary	64	69	65	46	55
Apparent[2]	W	W	W	W	W
Price, annual average:[3]					
U.S. spot Western, dollars per pound	2.15	2.15	2.15	2.17	2.35
China, free on board, dollars per metric ton	2,131	2,195	2,262	2,530	NA[4]
Stocks, producer, yearend	W	W	W	W	W
Employment, number[e]	420	420	400	400	400
Net import reliance[5] as a percentage of apparent consumption	<50	<25	<25	<50	<50

Recycling: In 2019, about 25,000 tons of secondary magnesium was recovered from old scrap and 85,000 tons were recovered from new scrap. Aluminum-base alloys accounted for 67% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 33%.

Import Sources (2015–18): Israel, 25%; Canada, 24%; Mexico, 10%; United Kingdom, 10%; and other, 31%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Unwrought metal	8104.11.0000	8.0% ad val.
Unwrought alloys	8104.19.0000	6.5% ad val.
Scrap	8104.20.0000	Free.
Powders and granules	8104.30.0000	4.4% ad val.
Wrought metal	8104.90.0000	14.8¢/kg on Mg content + 3.5% ad val.

Depletion Allowance: Dolomite, 14% (Domestic and foreign); magnesium chloride (from brine wells), 5% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The sole U.S. producer of primary magnesium temporarily shut down some capacity at the end of 2016 citing the shutdown of a titanium sponge plant that had been a major customer, and this capacity was not expected to restart in the foreseeable future. In May, the U.S. Department of Commerce assigned a preliminary countervailing duty rate of 7.48% on magnesium produced by one company in Israel. In July, the U.S. International Trade Commission issued a preliminary determination that magnesium produced by the same company in Israel would be subject to an antidumping duty rate of 193.24%. In November, an affirmative final determination was announced that found magnesium from Israel was sold at less than fair value in the United States. The final determinations on the antidumping and countervailing duty rates were expected in January 2020. The investigations into magnesium imports from Israel were initiated in November 2018 after a complaint was filed by the sole domestic primary magnesium producer. The investigations and preliminary determinations were cited for price increases and tight supplies of magnesium throughout the year.

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MAGNESIUM METAL

Producers in China dominate global magnesium metal production, but several projects were under development to increase primary magnesium metal capacity elsewhere and in China. In the United States, one company was evaluating a location in Washington for a facility to produce magnesium from a dolomite deposit in Nevada. A company in Quebec, Canada, produced a limited amount of magnesium from serpentine contained in asbestos tailings at its 25-kilogram-per-day pilot plant and planned to start construction of a 16,700-ton-per-year plant in 2020, with completion in about 1 year. Another company was testing its process for producing magnesium from serpentine-bearing asbestos tailings in the same region of Quebec. In August, a company in Australia completed a feasibility study for a 3,000-ton-per-year plant to recover magnesium from coal fly ash and planned to complete construction by yearend 2020. A magnesium smelter in Turkey restarted production in May under new ownership after being closed for 1 year. In China, a 100,000-ton-per-year plant to produce magnesium from lake brines in Qinghai Province continued ramping up to commercial production in 2019. Construction of the facility was completed in 2017.

The use of magnesium in automobile parts continued to increase as automobile manufacturers sought to decrease vehicle weight in response to consumer desires for increased fuel efficiency. Magnesium castings have substituted for aluminum, iron, and steel in some automobiles. The substitution of aluminum for steel in automobile sheet was expected to increase consumption of magnesium in aluminum alloy sheet. Although some magnesium sheet applications have been developed for automobiles, these were generally limited to expensive sports cars and luxury vehicles, automobiles where the higher price of magnesium is not a deterrent to its use.

World Primary Production and Reserves:

	Primary production		Reserves[6]
	2018	2019[e]	
United States	W	W	Magnesium metal is derived from seawater, natural brines, dolomite, serpentine, and other minerals. The reserves for this metal are sufficient to supply current and future requirements.
Brazil	15	15	
Canada	(7)	(7)	
China	860	900	
Iran	1	—	
Israel	21	20	
Kazakhstan	17	25	
Russia	70	80	
Turkey	4	5	
Ukraine	8	10	
World total (rounded)	[8]996	[8]1,100	

World Resources: Resources from which magnesium may be recovered range from large to virtually unlimited and are globally widespread. Resources of dolomite, serpentine, and magnesium-bearing evaporite minerals are enormous. Magnesium-bearing brines are estimated to constitute a resource in the billions of tons, and magnesium could be recovered from seawater along world coastlines.

Substitutes: Aluminum and zinc may substitute for magnesium in castings and wrought products. The relatively light weight of magnesium is an advantage over aluminum and zinc in castings and wrought products in most applications; however, its high cost is a disadvantage relative to these substitutes. For iron and steel desulfurization, calcium carbide may be used instead of magnesium. Magnesium is preferred to calcium carbide for desulfurization of iron and steel because calcium carbide produces acetylene in the presence of water.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also Magnesium Compounds.

[2]Defined as primary production + secondary production from old scrap + imports – exports + adjustments for industry stock changes.

[3]Source: Platts Metals Week.

[4]Discontinued.

[5]Defined as imports – exports + adjustments for industry stock changes.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Less than ½ unit.

[8]Excludes U.S. production.

MANGANESE

(Data in thousand metric tons gross weight unless otherwise noted)

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by eight firms with plants principally in the East and Midwest. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Additional quantities of ore were used for such nonmetallurgical purposes as production of dry cell batteries, in fertilizers and animal feed, and as a brick colorant. Manganese ferroalloys were produced at two plants. Construction, transportation, and machinery end uses accounted for about 43%, 13%, and 11%, respectively, of manganese consumption on a manganese-content basis. Most of the rest went to a variety of other iron and steel applications. In 2019, the value of domestic consumption, estimated from foreign trade data on a manganese-content basis, was about $1.2 billion.

Salient Statistics—United States:[1]	2015	2016	2017	2018	2019[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ore	441	282	297	440	340
Ferromanganese	292	229	331	427	370
Silicomanganese[2]	301	264	351	412	370
Exports:					
Manganese ore	1	1	1	3	1
Ferromanganese	5	7	9	10	7
Silicomanganese	1	2	8	4	1
Shipments from Government stockpile:[3]					
Manganese ore	—	—	—	—	—
Ferromanganese	32	42	9	10	5
Consumption, reported:					
Manganese ore[4]	451	410	378	370	380
Ferromanganese	344	342	345	348	360
Silicomanganese	138	139	141	139	140
Consumption, apparent, manganese[5]	693	545	714	793	740
Price, average, 46% to 48% Mn metallurgical ore, dollars per metric ton unit, contained Mn:					
Cost, insurance, and freight (c.i.f.), U.S. ports[e]	3.53	3.41	6.43	7.17	6.60
China spot market (c.i.f.)	3.22	4.48	[6]5.62	[6]6.91	[7]6.16
Stocks, producer and consumer, yearend:[4]					
Manganese ore	187	207	148	185	150
Ferromanganese	21	21	17	27	28
Silicomanganese	21	10	11	21	22
Net import reliance[8] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.

Import Sources (2015–18): Manganese ore: Gabon, 70%; South Africa, 17%; Australia, 6%; Mexico, 5%; and other, 2%. Ferromanganese: South Africa, 27%; Australia, 19%; Norway, 16%; Republic of Korea, 13%; and other, 25%. Silicomanganese: Georgia, 27%; South Africa, 24%; Australia, 20%; Mexico, 8%; and other, 21%. Manganese contained in principal manganese imports:[9] South Africa, 22%; Gabon, 21%; Australia, 15%; Georgia, 10%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Ores and concentrates	2602.00.0040/60	Free.
Manganese dioxide	2820.10.0000	4.7% ad val.
High-carbon ferromanganese	7202.11.5000	1.5% ad val.
Ferrosilicon manganese (silicomanganese)	7202.30.0000	3.9% ad val.
Metal, unwrought	8111.00.4700/4900	14% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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MANGANESE

Government Stockpile:[10]

Material	Inventory As of 9–30–19	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals	FY 2020 Potential Acquisitions	FY 2020 Potential Disposals
Manganese ore, metallurgical grade	292	—	292	—	292
Ferromanganese, high-carbon	193	—	45	—	45
Manganese metal, electrolytic	0.432	3	—	5	—

Events, Trends, and Issues: U.S. manganese apparent consumption was estimated to have decreased by 7% to 740,000 tons in 2019 compared with that in 2018 as a result of decreases in U.S. ferromanganese and silicomanganese imports. Electrolytic manganese metal was newly added to the National Defense Stockpile in 2019 as a critical material for defense purposes; the last time electrolytic manganese metal was held in the Government stockpile was in 2004.

World Mine Production and Reserves (manganese content): Reserves for Australia, Brazil, Gabon, India, and South Africa were revised based on Government and industry sources.

	Mine production 2018	Mine production 2019[e]	Reserves[11]
United States	—	—	—
Australia	3,480	3,200	[12]100,000
Brazil	1,310	1,200	140,000
Burma	207	210	NA
China	1,200	1,300	54,000
Cote d'Ivoire	395	400	NA
Gabon	2,330	2,400	61,000
Georgia	200	200	NA
Ghana	1,360	1,400	13,000
India	961	1,000	34,000
Kazakhstan, concentrate	140	130	5,000
Malaysia	390	420	NA
Mexico	210	190	5,000
South Africa	5,800	5,500	260,000
Ukraine, concentrate	517	540	140,000
Other countries	397	910	Small
World total (rounded)	18,900	19,000	810,000

World Resources: Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs. South Africa accounts for about 74% of the world's identified manganese resources, and Ukraine accounts for about 10%.

Substitutes: Manganese has no satisfactory substitute in its major applications.

[e]Estimated. NA Not available. — Zero.

[1]Manganese content typically ranges from 35% to 54% for manganese ore and from 74% to 95% for ferromanganese.

[2]Imports more nearly represent amount consumed than does reported consumption.

[3]Defined as stockpile shipments – receipts, thousand tons, manganese content. If receipts, a negative quantity is shown.

[4]Exclusive of ore consumed directly at iron and steel plants and associated yearend stocks.

[5]Defined as imports – exports + adjustments for Government and industry stock changes, thousand tons, manganese content. Based on estimates of average content for all significant components—including ore, manganese dioxide, ferromanganese, silicomanganese, and manganese metal—except imports, for which content is reported.

[6]For average metallurgical-grade ore containing 44% manganese, as reported by CRU Group.

[7]Average weekly price through September 2019 for average metallurgical-grade ore containing 44% manganese, as reported by CRU Group.

[8]Defined as imports – exports + adjustments for Government and industry stock changes, thousand tons, manganese content.

[9]Includes imports of ferromanganese, manganese ore, silicomanganese, synthetic manganese dioxide, and unwrought manganese metal.

[10]See Appendix B for definitions.

[11]See Appendix C for resource and reserve definitions and information concerning data sources.

[12]For Australia, Joint Ore Reserves Committee-compliant reserves were 45 million tons of manganese content.

MERCURY

(Data in metric tons of mercury content unless otherwise noted)

Domestic Production and Use: Mercury has not been produced as a principal mineral commodity in the United States since 1992. In 2019, mercury was recovered as a byproduct from processing gold-silver ore at several mines in Nevada; however, production data were not reported. Secondary, or recycled, mercury was recovered from batteries, compact and traditional fluorescent lamps, dental amalgam, medical devices, and thermostats, as well as mercury-contaminated soils. It was estimated that less than 40 tons per year of mercury was consumed domestically. The leading domestic end users of mercury were the chlorine-caustic soda (chloralkali), dental, electronics, and fluorescent-lighting manufacturing industries. Only two mercury cell chloralkali plants operated in the United States in 2019. Until December 31, 2012, domestic- and foreign-sourced mercury was refined and then exported for global use, primarily for small-scale gold mining in many parts of the world. Beginning January 1, 2013, export of elemental mercury from the United States was banned, with some exceptions, under the Mercury Export Ban Act of 2008. Effective January 1, 2020, exports of five additional mercury compounds will be banned. The U.S. Environmental Protection Agency issued the final rule for mercury reporting requirements for the Toxic Substances Control Act. The requirements applied to anyone who manufactured (including imports) mercury or mercury-added products, or otherwise intentionally used mercury in a manufacturing process.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption (gross weight), metal	26	24	20	6	10
Exports (gross weight), metal	([1])	—	—	—	—
Price, average value, dollars per flask 99.99%:					
European Union[2, 3]	1,954	1,402	1,041	1,100	NA
Global locations[2, 4]	2,465	1,275	1,273	2,709	2,550
Net import reliance[5] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: In 2019, eight facilities operated by six companies in the United States accounted for the majority of secondary mercury produced and were authorized by the U.S. Department of Energy to temporarily store mercury. Mercury-containing automobile convenience switches, barometers, compact and traditional fluorescent bulbs, computers, dental amalgam, medical devices, and thermostats were collected by smaller companies and shipped to the refining companies for retorting to reclaim the mercury. In addition, many collection companies recovered mercury when retorting was not required. With the rapid phasing out of compact and traditional fluorescent lighting for light-emitting-diode (LED) lighting, there has been an increased amount of mercury being recycled.

Import Sources (2015–18): Canada, 39%; France, 32%; Switzerland, 13%; China, 8%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Mercury	2805.40.0000	1.7% ad val.
Amalgams	2843.90.0000	3.7% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[6] An inventory of 4,437 tons of mercury was held in storage at the Hawthorne Army Depot in Hawthorne, NV. The Mercury Export Ban Act of 2008 required the U.S. Department of Energy to establish long-term management and storage capabilities for domestically produced elemental mercury. Sales of mercury from the stockpiles remained suspended.

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Mercury	4,437	—	—	—	—

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MERCURY

Events, Trends, and Issues: Owing to mercury toxicity and concerns for the environment and human health, overall mercury use has declined in the United States. Mercury continues to be released to the environment from numerous sources, including mercury-containing car switches when automobiles (those produced prior to 2003) are scrapped without recovering them for recycling, coal-fired powerplant emissions, incineration of mercury-containing medical devices, and from naturally occurring sources. Mercury is no longer used in most batteries and paints manufactured in the United States. Some button-type batteries, cleansers, fireworks, folk medicines, grandfather clocks, pesticides, and skin-lightening creams and soaps may still contain mercury. Mercury compounds were used as catalysts in the coal-based manufacture of vinyl chloride monomer in China. In some parts of the world, mercury was used in the recovery of gold in small-scale mining operations. Conversion to nonmercury technology for chloralkali production and the ultimate closure of the world's mercury-cell chloralkali plants may release a large quantity of mercury to the global market for recycling, sale, or, owing to export bans in Europe and the United States, storage.

Byproduct mercury production is expected to continue from large-scale domestic and foreign gold-silver mining and processing, as is secondary production of mercury from an ever-diminishing supply of mercury-containing products. Domestic mercury consumption will continue to decline owing to increased use of LED lighting and consequent reduced use of conventional fluorescent tubes and compact fluorescent bulbs, and continued substitution of nonmercury-containing products in control, dental, and measuring applications.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2018[e]	2019[e]	
United States	NA	NA	Quantitative estimates of reserves are not available. China, Kyrgyzstan, and Peru are thought to have the largest reserves.
Argentina	25	30	
China	3,600	3,500	
Kyrgyzstan	20	20	
Mexico (net exports)	234	240	
Norway	20	20	
Peru (exports)	40	40	
Tajikistan	100	100	
Other countries	20	20	
World total (rounded)	4,060	4,000	

World Resources: China, Kyrgyzstan, Mexico, Peru, Russia, Slovenia, Spain, and Ukraine have most of the world's estimated 600,000 tons of mercury resources. Mexico reclaims mercury from Spanish colonial silver-mining waste. In Spain, once a leading producer of mercury, mining at its centuries-old Almaden Mine stopped in 2003. In the United States, there are mercury occurrences in Alaska, Arkansas, California, Nevada, and Texas; however, mercury has not been mined as a principal mineral commodity since 1992. The declining consumption of mercury, except for small-scale gold mining, indicates that these resources are sufficient for centuries of use.

Substitutes: Ceramic composites substitute for the dark-gray mercury-containing dental amalgam. "Galistan," an alloy of gallium, indium, and tin, replaces the mercury used in traditional mercury thermometers, and digital thermometers have replaced traditional thermometers. At chloralkali plants around the world, mercury-cell technology is being replaced by newer diaphragm and membrane cell technology. LEDs that contain indium substitute for mercury-containing fluorescent lamps. Lithium, nickel-cadmium, and zinc-air batteries replace mercury-zinc batteries in the United States; indium compounds substitute for mercury in alkaline batteries; and organic compounds have been substituted for mercury fungicides in latex paint.

[e]Estimated. NA Not available. — Zero.

[1]Less than ½ unit.

[2]Some international data and dealer prices are reported in flasks. One metric ton (1,000 kilograms) = 29.0082 flasks, and 1 flask = 76 pounds, or 34.47 kilograms, or 0.03447 ton.

[3]Average annual price of minimum 99.99% mercury published by Argus Media group–Argus Metals International. Price discontinued on May 1, 2018.

[4]Average midpoint of free market 99.99% mercury in warehouse, global locations, price published by Metal Bulletin.

[5]Defined as imports – exports + adjustments for Government stock changes.

[6]See Appendix B for definitions.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

MICA (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Scrap and flake mica production, excluding low-quality sericite, was estimated to be 38,000 tons valued at $4.6 million. Mica was mined in Georgia, North Carolina, and South Dakota. Scrap mica was recovered principally from mica and sericite schist and as a byproduct from feldspar, industrial sand beneficiation, and kaolin. Eight companies produced an estimated 63,000 tons of ground mica valued at about $22 million from domestic and imported scrap and flake mica. The majority of domestic production was processed into small-particle-size mica by either wet or dry grinding. Primary uses were joint compound, oil-well-drilling additives, paint, roofing, and rubber products.

A minor amount of sheet mica was produced as incidental production from feldspar mining in North Carolina. Data was withheld to avoid disclosing company proprietary data. The domestic consuming industry was dependent on imports to meet demand for sheet mica. Most sheet mica was fabricated into parts for electrical and electronic equipment.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Scrap and flake:					
Production:[1]					
Sold and used	32,600	28,000	40,000	44,000	38,000
Ground	65,800	59,500	69,700	65,300	63,000
Imports[2]	33,200	31,500	29,700	28,100	29,000
Exports[3]	7,440	6,340	6,790	6,000	5,900
Consumption, apparent[4]	58,400	53,200	62,900	66,100	61,000
Price, average, dollars per metric ton, reported:					
Scrap and flake	142	152	165	122	120
Ground:					
Dry	305	320	292	308	310
Wet	423	435	424	454	480
Employment, mine, number	NA	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	44	47	36	33	37
Sheet:					
Sold and used	W	W	W	W	W
Imports[6]	2,390	2,120	1,850	1,860	2,500
Exports[7]	911	689	704	686	950
Consumption, apparent[5]	1,480	1,430	1,150	1,170	1,600
Price, average value, dollars per kilogram, muscovite and phlogopite mica, reported:					
Block	W	W	W	W	W
Splittings	1.61	1.61	1.66	1.65	1.65
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2015–18): Scrap and flake: Canada, 45%; China, 31%; India, 10%; Finland, 4%; and other, 10%. Sheet: China, 48%; Brazil, 22%; Belgium, 8%; Austria, 5%; and other, 17%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Split block mica	2525.10.0010	Free.
Mica splittings	2525.10.0020	Free.
Unworked, other	2525.10.0050	Free.
Mica powder	2525.20.0000	Free.
Mica waste	2525.30.0000	Free.
Plates, sheets, and strips of agglomerated or reconstructed mica	6814.10.0000	2.7% ad val.
Worked mica and articles of mica, other	6814.90.0000	2.6% ad val.

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MICA (NATURAL)

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic production of scrap and flake mica was estimated to have decreased by 14% in 2019. Apparent consumption of scrap and flake mica decreased by 8%. Apparent consumption of sheet mica was estimated to have increased by 32% in 2019 as a result of increased imports of sheet mica from China. No environmental concerns are associated with the manufacture and use of mica products. Future supplies of sheet mica for United States consumption were expected to come increasingly from imports, primarily from Brazil, China, and India.

World Mine Production and Reserves: World production of sheet mica is shown to have remained steady; however, reliable production numbers for some countries that may influence that world total were unavailable.

	Scrap and flake			Sheet		
	Mine production		Reserves[8]	Mine production[e]		Reserves[8]
	2018	2019[e]		2018	2019	
United States	44,000	38,000	Large	W	W	Very small
Canada	23,000	23,000	Large	NA	NA	NA
China	100,000	100,000	Large	NA	NA	NA
Finland	62,600	64,000	Large	NA	NA	NA
France	20,000	22,000	Large	NA	NA	NA
India	15,000	16,000	Large	1,000	1,000	110,000
Korea, Republic of	16,600	17,000	12,000,000	—	—	NA
Madagascar	35,000	36,000	Large	—	—	NA
Turkey	6,500	7,000	620,000	—	—	NA
Other countries	52,800	53,000	Large	200	200	Moderate
World total (rounded)	375,000	380,000	Large	NA	NA	Very large

World Resources: Resources of scrap and flake mica are available in clay deposits, granite, pegmatite, and schist, and are considered more than adequate to meet anticipated world demand in the foreseeable future. World resources of sheet mica have not been formally evaluated because of the sporadic occurrence of this material. Large deposits of mica-bearing rock are known to exist in countries such as Brazil, India, and Madagascar. Limited resources of sheet mica are available in the United States. Domestic resources are uneconomic because of the high cost of the hand labor required to mine and process sheet mica from pegmatites.

Substitutes: Some lightweight aggregates, such as diatomite, perlite, and vermiculite, may be substituted for ground mica when used as filler. Ground synthetic fluorophlogopite, a fluorine-rich mica, may replace natural ground mica for uses that require thermal and electrical properties of mica. Many materials can be substituted for mica in numerous electrical, electronic, and insulation uses. Substitutes include acrylic, cellulose acetate, fiberglass, fishpaper, nylatron, nylon, phenolics, polycarbonate, polyester, styrene, polyvinyl chloride, and vulcanized fiber. Mica paper made from scrap mica can be substituted for sheet mica in electrical and insulation applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Excludes low-quality sericite used primarily for brick manufacturing.

[2]Includes Harmonized Tariff Schedule of the United States codes: 2525.10.0050, <$6.00/kg; 2525.20.0000; and 2525.30.0000.

[3]Includes Schedule B numbers: 2525.10.0000, <$6.00/kg; 2525.20.0000; and 2525.30.0000.

[4]Defined as sold or used by producing companies + imports – exports.

[5]Defined as imports – exports.

[6]Includes Harmonized Tariff Schedule of the United States codes: 2525.10.0010; 2525.10.0020; 2525.10.0050, >$6.00/kg; 6814.10.0000; and 6814.90.0000.

[7]Includes Schedule B numbers: 2525.10.0000, >$6.00/kg; 6814.10.0000; and 6814.90.0000.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

MOLYBDENUM

(Data in metric tons of molybdenum content unless otherwise noted)

Domestic Production and Use: U.S. mine production of molybdenum in 2019 increased by 7% to 44,000 tons compared with the previous year. Molybdenum ore was produced as a primary product at two mines—both in Colorado—whereas seven copper mines (four in Arizona and one each in Montana, Nevada, and Utah) recovered molybdenite concentrate as a byproduct. Three roasting plants converted molybdenite concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced. Metallurgical applications accounted for about 88% of the total molybdenum consumed.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, mine	47,400	36,200	40,700	41,400	44,000
Imports for consumption	17,500	22,800	36,000	37,600	37,000
Exports	41,500	31,200	43,200	48,400	57,000
Consumption:					
Reported[1]	17,600	15,800	17,200	16,900	17,000
Apparent[2]	23,800	27,900	34,100	31,400	24,000
Price, average value, dollars per kilogram[3]	15.10	14.40	18.06	27.04	26
Stocks, consumer materials	1,880	1,910	2,010	1,940	1,700
Employment, mine and plant, number	950	920	940	940	950
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Molybdenum is recycled as a component of catalysts, ferrous scrap, and superalloy scrap. Ferrous scrap comprises revert scrap, and new and old scrap. Revert scrap refers to remnants manufactured in the steelmaking process. New scrap is generated by steel mill customers and recycled by scrap collectors and processors. Old scrap is largely molybdenum-bearing alloys recycled after serving their useful life. The amount of molybdenum recycled as part of new and old steel and other scrap may be as much as 30% of the apparent supply of molybdenum. There are no processes for the separate recovery and refining of secondary molybdenum from its alloys. Molybdenum is not recovered separately from recycled steel and superalloys, but the molybdenum content of the recycled alloys is significant, and the molybdenum content is reused. Recycling of molybdenum-bearing scrap will continue to be dependent on the markets for the principal alloy metals in which molybdenum is contained, such as iron, nickel, and chromium.

Import Sources (2015–18): Ferromolybdenum: Chile, 54%; Republic of Korea, 33%; Canada, 8%; and other, 5%. Molybdenum ores and concentrates: Peru, 53%; Chile, 27%; Canada, 11%; Mexico, 8%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Molybdenum ore and concentrates, roasted	2613.10.0000	12.8¢/kg + 1.8% ad val.
Molybdenum ore and concentrates, other	2613.90.0000	17.8¢/kg.
Molybdenum chemicals:		
Molybdenum oxides and hydroxides	2825.70.0000	3.2% ad val.
Molybdates of ammonium	2841.70.1000	4.3% ad val.
Molybdates, all others	2841.70.5000	3.7% ad val.
Molybdenum pigments, molybdenum orange	3206.20.0020	3.7% ad val.
Ferroalloys, ferromolybdenum	7202.70.0000	4.5% ad val.
Molybdenum metals:		
Powders	8102.10.0000	9.1¢/kg + 1.2% ad val.
Unwrought	8102.94.0000	13.9¢/kg + 1.9% ad val.
Wrought bars and rods	8102.95.3000	6.6% ad val.
Wrought plates, sheets, strips, etc.	8102.95.6000	6.6% ad val.
Wire	8102.96.0000	4.4% ad val.
Waste and scrap	8102.97.0000	Free.
Other	8102.99.0000	3.7% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

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MOLYBDENUM

Events, Trends, and Issues: In 2019, the estimated average molybdic oxide price decreased by 4% compared with that of 2018, and U.S. estimated mine output of molybdenum increased by 7% from that of 2018. The increase in production was seen mainly at byproduct mines. Byproduct molybdenum production continued at the Bagdad, Morenci, Pinto Valley, and Sierrita Mines in Arizona; the Continental Pit Mine in Montana; the Robinson Mine in Nevada; and the Bingham Canyon Mine in Utah. Primary molybdenum production continued at the Climax and Henderson Mines in Colorado. The Thompson Creek Mine in Idaho continued to be on care-and-maintenance status in 2019.

Estimated U.S. imports for consumption decreased slightly from those of 2018. U.S. exports increased by 17% from those of 2018. Roasted and unroasted concentrate exports increased by 26% and 13%, respectively, compared with those during the same period in 2018. Apparent consumption decreased by 22% compared with that of 2018.

Global molybdenum production in 2019 decreased slightly compared with 2018. In descending order of production, China, Chile, the United States, Peru, and Mexico provided more than 90% of total global production.

World Mine Production and Reserves: The reserves estimate for Peru was revised based on new information from Government reports.

	Mine production		Reserves[5]
	2018	2019[e]	(thousand metric tons)
United States	41,400	44,000	2,700
Argentina[e]	600	600	100
Armenia[e]	5,000	5,400	150
Canada	4,680	4,700	100
Chile	60,200	54,000	1,400
China[e]	133,000	130,000	8,300
Iran[e]	3,500	3,500	43
Mexico	15,100	16,000	130
Mongolia	1,800	1,800	210
Peru	28,000	28,000	2,900
Russia[e]	2,800	2,800	1,000
Turkey[e]	900	900	700
Uzbekistan[e]	200	200	60
World total (rounded)	297,000	290,000	18,000

World Resources: Identified resources of molybdenum in the United States are about 5.4 million tons, and in the rest of the world, about 20 million tons. Molybdenum occurs as the principal metal sulfide in large low-grade porphyry molybdenum deposits and as an associated metal sulfide in low-grade porphyry copper deposits. Resources of molybdenum are adequate to supply world needs for the foreseeable future.

Substitutes: There is little substitution for molybdenum in its major application in steels and cast irons. In fact, because of the availability and versatility of molybdenum, industry has sought to develop new materials that benefit from its alloying properties. Potential substitutes include boron, chromium, niobium (columbium), and vanadium in alloy steels; tungsten in tool steels; graphite, tantalum, and tungsten for refractory materials in high-temperature electric furnaces; and cadmium-red, chrome-orange, and organic-orange pigments for molybdenum orange.

[e]Estimated. E Net exporter.

[1]Reported consumption of primary molybdenum products.

[2]Defined as production + imports – exports + adjustments for concentrate, consumer, and product producer stock changes.

[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide, as reported by CRU Group.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

NICKEL

(Data in metric tons of nickel content unless otherwise noted)

Domestic Production and Use: In 2019, the underground Eagle Mine in Michigan produced approximately 14,000 tons of nickel in concentrate, which was exported to smelters in Canada and overseas. In October, the mine processed the first ore from the newly developed Eagle East extension. As part of the Superfund Redevelopment Initiative, a company in Missouri constructed a facility to recover metals, including nickel, from mine tailings. Nickel in crystalline sulfate was produced as a byproduct of smelting and refining platinum-group-metal ores mined in Montana.

In the United States, the leading uses for primary nickel are stainless and alloy steels, nonferrous alloys and superalloys, electroplating, and other uses including catalysts and chemicals. Domestic production of stainless steel was estimated to have decreased by approximately 10% in 2019. Consumption of nickel used in alloys for jet turbine engines continued to increase.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine	27,200	24,100	22,100	17,600	14,000
Refinery, byproduct	W	W	W	W	W
Imports:					
Ores and concentrates	24	([1])	64	3	—
Primary	130,000	111,000	150,000	144,000	120,000
Secondary	27,100	32,300	38,100	45,100	38,000
Exports:					
Ores and concentrates	25,400	22,400	20,000	[2]19,000	19,000
Primary	9,610	10,300	11,000	9,780	13,000
Secondary	51,900	63,700	51,500	67,200	49,000
Consumption:					
Estimated, primary metal	110,000	98,000	100,000	110,000	110,000
Estimated, secondary	120,000	130,000	130,000	120,000	120,000
Apparent, primary metal[3]	118,000	104,000	140,000	136,000	110,000
Apparent, total[4]	234,000	235,000	273,000	259,000	230,000
Price, average annual, London Metal Exchange (LME):					
Cash, dollars per metric ton	11,831	9,594	10,403	13,114	14,000
Cash, dollars per pound	5.367	4.352	4.719	5.977	6.30
Stocks, yearend:					
Consumer	19,200	15,100	14,600	16,300	16,000
LME U.S. warehouses	4,212	5,232	3,780	2,268	2,000
Net import reliance[5] as a percentage of total apparent consumption	50	44	51	52	47

Recycling: Nickel in alloyed form was recovered from the processing of nickel-containing waste, including flue dust, grinding swarf, mill scale, and shot blast generated during the manufacturing of stainless steel; filter cakes, plating solutions, spent catalysts, spent pickle liquor, sludges, and all types of spent nickel-containing batteries. Nickel-containing alloys and stainless steel scrap were also melted and used to produce new alloys and stainless steel. In 2019, recycled nickel in all forms accounted for approximately 47% of apparent consumption.

Import Sources (2015–18): Nickel contained in ferronickel, metal, oxides, and salt: Canada, 41%; Norway, 11%; Australia, 8%; Finland, 8%; and other, 32%. Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 38%; Mexico, 28%; United Kingdom, 9%; and other, 25%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Nickel ores and concentrates, nickel content	2604.00.0040	Free.
Ferronickel	7202.60.0000	Free.
Unwrought nickel, not alloyed	7502.10.0000	Free.
Nickel waste and scrap	7503.00.0000	Free.
Nickel powders	7504.00.0010	Free.
Nickel flakes	7504.00.0050	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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NICKEL

Government Stockpile:[6] The U.S. Department of Energy is holding nickel ingot contaminated by low-level radioactivity at Paducah, KY, and shredded nickel scrap at Oak Ridge, TN. Ongoing decommissioning activities at former nuclear defense sites were expected to generate additional nickel in scrap. See the Lithium chapter for statistics on lithium-nickel-cobalt-aluminum oxide.

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Nickel alloys, gross weight	592	—	68	—	272

Events, Trends, and Issues: The Government of Indonesia decided to reinstate its ban on direct-shipping nickel ore beginning in January 2020, 2 years earlier than previously announced. The Government had relaxed enforcement of the ban in 2017 following rapid development of the country's nickel-processing capacity, primarily smelters producing nickel pig iron. The return to the regulation was reportedly in order to conserve ore for the domestic processing industry.

In January 2019, a company in Indonesia's Central Sulawesi Province broke ground on a project to produce nickel and cobalt for use in batteries. Globally, numerous idled facilities and delayed development projects resumed activity in anticipation of growing demand for nickel in electric vehicle batteries.

World Mine Production and Reserves: Reserves for Australia, Canada, and Russia were revised based on new information from company or Government reports.

	Mine production		Reserves[7]
	2018	2019[e]	
United States	17,600	14,000	110,000
Australia	170,000	180,000	[8]20,000,000
Brazil	74,400	67,000	11,000,000
Canada	176,000	180,000	2,600,000
China	110,000	110,000	2,800,000
Cuba	51,000	51,000	5,500,000
Indonesia	606,000	800,000	21,000,000
New Caledonia[9]	216,000	220,000	NA
Philippines	345,000	420,000	4,800,000
Russia	272,000	270,000	6,900,000
Other countries	366,000	370,000	14,000,000
World total (rounded)	2,400,000	2,700,000	89,000,000

World Resources: Identified land-based resources averaging 1% nickel or greater contain at least 130 million tons of nickel, with about 60% in laterites and 40% in sulfide deposits. Extensive nickel resources also are found in manganese crusts and nodules on the ocean floor. The decline in discovery of new sulfide deposits in traditional mining districts has led to exploration in more challenging locations such as east-central Africa and the subarctic.

Substitutes: Low-nickel, duplex, or ultrahigh-chromium stainless steels are being substituted for austenitic grades in construction. Nickel-free specialty steels are sometimes used in place of stainless steel in the power-generating and petrochemical industries. Titanium alloys can substitute for nickel metal or nickel-base alloys in corrosive chemical environments. Lithium-ion batteries may be used instead of nickel metal hydride batteries in certain applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Less than ½ unit.

[2]Estimated. The U.S. Census Bureau reported that exports of nickel in ores and concentrates were 54,600 tons in 2018; all or part of these data have been referred to the U.S. Census Bureau for verification.

[3]Defined as primary imports – primary exports + adjustments for industry stock changes, excluding secondary consumer stocks.

[4]Defined as apparent primary metal consumption + estimated secondary consumption.

[5]Defined as imports – exports + adjustments for consumer stock changes.

[6]See Appendix B for definitions.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 5.4 million tons.

[9]Overseas territory of France.

NIOBIUM (COLUMBIUM)

(Data in metric tons of niobium content unless otherwise noted)

Domestic Production and Use: Significant U.S. niobium mine production has not been reported since 1959. Companies in the United States produced niobium-containing materials from imported niobium concentrates, oxides, and ferroniobium. Niobium was consumed mostly in the form of ferroniobium by the steel industry and as niobium alloys and metal by the aerospace industry. In 2019, there was a decrease in reported consumption of niobium for high-strength low alloy steel and superalloy applications. Major end-use distribution of reported niobium consumption was as follows: steels, about 78%, and superalloys, about 22%. The estimated value of niobium consumption was $460 million, as measured by the value of imports.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, mine	—	—	—	—	—
Imports for consumption[1]	8,520	8,250	9,330	11,200	11,000
Exports[1]	1,430	1,480	1,490	955	570
Shipments from Government stockpile	—	—	—	—	—
Consumption:[e]					
Apparent[2]	7,080	6,730	7,780	10,100	9,900
Reported[3]	7,510	7,370	7,640	7,130	6,000
Unit value, ferroniobium, dollars per kilogram[4]	24	21	20	21	23
Net import reliance[2] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Niobium was recycled when niobium-bearing steels and superalloys were recycled; scrap recovery, specifically for niobium content, was negligible. The amount of niobium recycled is not available, but it may be as much as 20% of apparent consumption.

Import Sources (2015–18): Niobium ore and concentrate: Rwanda, 39%; Brazil, 19%; Australia, 16%; Congo (Kinshasa), 10%; and other, 16%. Niobium oxide: Brazil, 48%; Russia, 25%; Thailand, 10%; Estonia, 9%; and other, 8%. Ferroniobium and niobium metal: Brazil, 70%; Canada, 26%; Germany, 2%; and other, 2%. Total imports: Brazil, 67%; Canada, 23%; Russia, 3%; Germany, 2%; and other, 5%. Of the U.S. niobium material imports (by contained weight), 75% was ferroniobium, 14% was niobium metal, 10% was niobium oxide, and 1% was niobium ores and concentrates.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Niobium oxide	2825.90.1500	3.7% ad val.
Ferroniobium:		
Less than 0.02% P or S, or less than 0.4% Si	7202.93.4000	5% ad val.
Other	7202.93.8000	5% ad val.
Niobium:		
Waste and scrap[5]	8112.92.0600	Free.
Powders and unwrought metal	8112.92.4000	4.9% ad val.
Niobium, other[5]	8112.99.9000	4% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[6]

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Ferroniobium (gross weight)	407	209	—	—	—
Niobium metal (gross weight)	10	—	—	—	—

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NIOBIUM (COLUMBIUM)

Events, Trends, and Issues: Niobium principally was imported in the form of ferroniobium. Based on data through August 2019, U.S. niobium apparent consumption (measured in contained niobium) for 2019 was estimated to be 9,900 tons, slightly less than that of 2018. Brazil continued to be the world's leading niobium producer with 88% of global production, followed by Canada with 10%. Global niobium production is thought to have increased in 2019 owing to anticipated growing demand for ferroniobium from steel manufacturers in China following the country's implementation of higher rebar strength standards beginning in November 2018. Niobium was increasingly substituted for vanadium as a microalloying additive in high-strength rebar owing to the supply deficit and high price volatility of ferrovanadium. Based on data through August 2019, ferroniobium imports into China were estimated to have increased by 50% in 2019 compared with the previous year.

One domestic company developing its Elk Creek project in Nebraska announced a new mine design that was expected to increase the mine life by 4 years and reduce the environmental impacts of its operation. The new design included an onsite water treatment system that would eliminate the need to discharge excess process water into the nearby Missouri River, more efficient recycling of mineral-processing reagents, and the use of advanced emission control technologies that would result in reduced air emissions. The company submitted its construction air permit to the State of Nebraska in July. The project would be the only niobium mine and primary niobium processing facility in the United States. It was expected to begin production after 2020.

In January, a leading niobium producer in Brazil announced plans to increase its annual ferroniobium production capacity by 50% to 150,000 tons (approximately 98,000 tons of contained niobium). The company expected to invest $200 million in the expansion which would be completed before the end of 2020.

World Mine Production and Reserves: The reserves data for the United States and Brazil were revised based on information reported by niobium-producing companies and the Governments of those countries.

	Mine production		Reserves[7]
	2018	2019[e]	
United States	—	—	210,000
Brazil	59,000	65,000	11,000,000
Canada	7,700	7,600	1,600,000
Other countries	1,460	1,500	NA
World total (rounded)	68,200	74,000	>13,000,000

World Resources: World resources of niobium are more than adequate to supply projected needs. Most of the world's identified resources of niobium occur as pyrochlore in carbonatite (igneous rocks that contain more than 50%-by-volume carbonate minerals) deposits and are outside the United States. The United States has approximately 1,400,000 tons of niobium in identified resources, most of which were considered subeconomic at 2019 prices for niobium.

Substitutes: The following materials can be substituted for niobium, but a performance loss or higher cost may ensue: ceramic matrix composites, molybdenum, tantalum, and tungsten in high-temperature (superalloy) applications; molybdenum, tantalum, and titanium as alloying elements in stainless and high-strength steels; and molybdenum and vanadium as alloying elements in high-strength low-alloy steels.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated niobium content of ferroniobium, niobium and tantalum ores and concentrates, niobium oxide, and niobium powders and unwrought metal.

[2]Defined as imports – exports + adjustments for Government stock changes.

[3]Only includes ferroniobium and nickel niobium.

[4]Unit value is weighted average unit value of gross weight of U.S. ferroniobium trade. (Trade is imports plus exports.)

[5]This category includes niobium-containing material and other material.

[6]See Appendix B for definitions.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

NITROGEN (FIXED)—AMMONIA

(Data in thousand metric tons of contained nitrogen unless otherwise noted)

Domestic Production and Use: Ammonia was produced by 16 companies at 35 plants in 16 States in the United States during 2019; 2 additional plants were idle for the entire year. About 60% of total U.S. ammonia production capacity was in Louisiana, Oklahoma, and Texas because of their large reserves of natural gas, the dominant domestic feedstock for ammonia. In 2019, U.S. producers operated at about 90% of rated capacity. The United States was one of the world's leading producers and consumers of ammonia. Urea, ammonium nitrate, nitric acid, ammonium phosphates, and ammonium sulfate were, in descending order of importance, the major derivatives of ammonia produced in the United States.

Approximately 88% of apparent domestic ammonia consumption was for fertilizer use, including anhydrous ammonia for direct application, urea, ammonium nitrates, ammonium phosphates, and other nitrogen compounds. Ammonia also was used to produce explosives, plastics, synthetic fibers and resins, and numerous other chemical compounds.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production	[1]9,590	[1]10,200	[1]11,600	[1]13,100	14,000
Imports for consumption	4,320	3,840	3,090	2,530	2,000
Exports	93	183	612	281	240
Consumption, apparent[2]	13,700	13,800	14,100	15,200	16,000
Stocks, producer, yearend	420	400	320	490	400
Price, dollars per short ton, average, f.o.b. Gulf Coast[3]	481	267	247	281	230
Employment, plant, number[e]	1,200	1,300	1,500	1,600	1,600
Net import reliance[4] as a percentage of apparent consumption	30	26	18	14	12

Recycling: None.

Import Sources (2015–18): Trinidad and Tobago, 65%; Canada, 26%; Russia, 3%; Venezuela, 3%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Ammonia, anhydrous	2814.10.0000	Free.
Urea	3102.10.0000	Free.
Ammonium sulfate	3102.21.0000	Free.
Ammonium nitrate	3102.30.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The Henry Hub spot natural gas price ranged between $2.03 and $4.12 per million British thermal units for most of the year, with an average of about $2.60 per million British thermal units. Natural gas prices in 2019 were lower than those in 2018; a result of strong supply growth and warmer winter weather compared with that in 2018. The U.S. Department of Energy, Energy Information Administration, projected that Henry Hub natural gas spot prices would average $2.52 per million British thermal units in 2020.

The weekly average Gulf Coast ammonia price was $259 per short ton at the beginning of 2019, decreased to $200 per short ton in mid-April, and then increased to $235 per short ton in mid-August. The average ammonia price for 2019 was estimated to be $230 per short ton. In 2019, low natural gas prices resulted in lower ammonia prices.

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NITROGEN (FIXED)—AMMONIA

A long period of stable and low natural gas prices in the United States has made it economical for companies to upgrade existing ammonia plants and construct new nitrogen facilities. The additional capacity has reduced ammonia imports. Expansion in the ammonia industry took place throughout the past 5 years; however, no additional ammonia plants are expected to be commissioned before 2022. The newest U.S. ammonia plant located in Freeport, TX, became operational in 2018.

Global ammonia capacity is expected to increase by a total of 4% during the next 4 years. Capacity additions are expected in Africa, Eastern Europe, and south Asia; however, ongoing plant closures will decrease capacity in east Asia. Demand for ammonia is expected to increase in all regions with the largest increases expected in Africa and Eastern Europe.

Large corn plantings maintain the continued demand for nitrogen fertilizers. According to the U.S. Department of Agriculture, U.S. corn growers planted 37.1 million hectares of corn in the 2019 crop-year (July 1, 2018, through June 30, 2019), which was 3% greater than the area planted in 2018. Corn acreage in the 2020 crop-year is expected to increase because of anticipated higher returns for corn compared with those of other crops.

World Ammonia Production and Reserves:

	Plant production		Reserves[5]
	2018	2019[e]	
United States	13,100	14,000	Available atmospheric nitrogen and sources of natural gas for production of ammonia are considered adequate for all listed countries.
Algeria	1,600	2,300	
Australia	1,300	1,300	
Belarus	1,050	1,100	
Brazil	1,000	1,000	
Canada	3,830	3,800	
China	41,000	40,000	
Egypt	3,700	4,100	
Germany	2,600	2,600	
India	11,400	12,000	
Indonesia	5,000	5,000	
Iran	3,400	3,400	
Netherlands	2,400	2,400	
Oman	1,700	1,700	
Pakistan	3,100	3,100	
Poland	2,170	2,200	
Qatar	3,100	3,100	
Russia	14,900	15,000	
Saudi Arabia	4,000	4,300	
Trinidad and Tobago	4,000	4,000	
Ukraine	1,620	1,600	
Uzbekistan	1,200	1,200	
Vietnam	1,100	1,100	
Other countries	15,800	15,000	
World total (rounded)	144,000	150,000	

World Resources: The availability of nitrogen from the atmosphere for fixed nitrogen production is unlimited. Mineralized occurrences of sodium and potassium nitrates, such as those found in the Atacama Desert of Chile, contribute minimally to the global nitrogen supply.

Substitutes: Nitrogen is an essential plant nutrient that has no substitute. No practical substitutes for nitrogen explosives and blasting agents are known.

[e]Estimated.

[1]Source: The Fertilizer Institute; data adjusted by the U.S. Geological Survey.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]Source: Green Markets.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

PEAT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The estimated free on board (f.o.b.) mine value of marketable peat production in the conterminous United States was $14 million in 2019. Peat was harvested and processed by about 28 companies in 12 conterminous States. Florida, Michigan, and Minnesota were the leading producing States, in order of quantity harvested. Reed-sedge peat accounted for approximately 87% of the total volume produced, followed by sphagnum moss with 10%. Domestic peat applications included earthworm culture medium, golf course construction, mixed fertilizers, mushroom culture, nurseries, packing for flowers and plants, seed inoculants, and vegetable cultivation. In the industrial sector, peat was used as an oil absorbent and as an efficient filtration medium for the removal of waterborne contaminants in mine waste streams, municipal storm drainage, and septic systems.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production	455	441	498	479	470
Sales by producers	460	443	515	545	540
Imports for consumption	1,150	1,130	1,150	1,200	1,100
Exports	28	30	30	37	40
Consumption, apparent[1]	1,620	1,590	1,520	1,670	1,600
Price, average value, f.o.b. mine, dollars per ton	28.39	31.97	27.55	25.88	28.50
Stocks, producer, yearend	179	125	222	196	180
Employment, mine and plant, number[e]	550	550	540	540	500
Net import reliance[2] as a percentage of apparent consumption	72	72	67	71	70

Recycling: None.

Import Sources (2015–18): Canada, 95%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Peat	2703.00.0000	Free.

Depletion Allowance: 5% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Peat is an important component of plant-growing media, and the demand for peat generally follows that of horticultural applications. In the United States, the short-term outlook is for production to average about 470,000 tons per year and imported peat from Canada is expected to continue to account for more than 70% of domestic consumption. Imports for 2019 were estimated to have decreased to 1.1 million tons from 1.2 million tons in 2018, and exports were estimated to have increased to about 40,000 tons from 37,000 tons in 2018. Peat stocks were estimated to have decreased in 2019 owing to a wet peat harvesting season causing a decrease in peat production in some parts of the country. Based on estimated world production for 2019, the world's leading peat producers were, in descending order of production, Finland, Germany, Ireland, Belarus, and Sweden.

Africa's first peat-fired powerplant in Gishoma, Rwanda, produced energy at its 15-megawatt-capacity facility, which added to the national power grid in 2019. Another peat-fired powerplant was under construction in Gisagara, Rwanda, and was expected to be operational in 2020. The peat-fired powerplants are anticipated to increase the national power capacity by about 40% when fully operational, bringing Rwanda closer to its goal of energy independence.

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PEAT

In other parts of the world, concerns about climate change prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's ability to act as a carbon sink. Ireland's peat production was expected to decrease over the coming years owing to its transition to alternative fuel sources. The country was aiming to have at least 80% of its fossil fuel sector employment transitioned to the renewable energy sector by 2025. Ireland announced in 2019 that it planned to stop all peat harvesting by 2028, 2 years ahead of the previously announced schedule. In 2019, Finland announced its goal of becoming carbon neutral by 2035. To achieve this, peat production will be phased out in favor for other forms of noncarbon energy. Presently, about 40% of Finland's energy consumption is supplied by peat and other fossil fuels. Several European countries, including Belarus, Ireland, and Sweden, were planning or implementing peatland restoration projects to help combat greenhouse gas emissions and restore wildlife habitats. These initiatives were expected to decrease peat production across Europe in the future.

World Mine Production and Reserves: Reserves for countries that reported by volume only and had insufficient data for conversion to tons were combined and included with "Other countries." Reserves for Latvia were updated with information from company reports.

	Mine production		Reserves[3]
	2018	2019[e]	
United States	479	470	150,000
Belarus	2,620	2,600	2,600,000
Canada	1,240	1,300	720,000
Estonia	1,030	1,000	60,000
Finland	9,970	10,000	6,000,000
Germany	3,800	4,000	(4)
Ireland	3,000	3,000	(4)
Latvia	1,900	1,900	230,000
Lithuania	510	500	210,000
Poland	700	700	(4)
Russia	800	800	1,000,000
Sweden	2,450	2,500	(4)
Ukraine	590	600	(4)
United Kingdom	700	—	(4)
Other countries[e]	610	600	1,400,000
World total (rounded)	30,400	30,000	12,000,000

World Resources: Peat is a renewable resource, continuing to accumulate on 60% of global peatlands. However, the volume of global peatlands has been decreasing at a rate of 0.05% annually owing to harvesting and land development. Many countries evaluate peat resources based on volume or area because the variations in densities and thickness of peat deposits make it difficult to estimate tonnage. Volume data have been converted using the average bulk density of peat produced in that country. Reserves data were estimated based on data from International Peat Society publications and the percentage of peat resources available for peat extraction. More than 50% of the U.S. peat resources are located in undisturbed areas of Alaska.

Substitutes: Natural organic materials, such as composted yard waste and coir (coconut fiber), compete with peat in horticultural applications. Shredded paper and straw are used to hold moisture for some grass-seeding applications. The superior water-holding capacity and physiochemical properties of peat limit substitution alternatives in most applications.

[e]Estimated. — Zero.

[1]Defined as production + imports – exports + adjustments for industry stock changes.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Included with "Other countries."

PERLITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, the quantity of domestic processed crude perlite sold and used was estimated to be 480,000 tons with a value of $35 million. Crude ore production was from eight mines operated by six companies in five Western States. New Mexico and Oregon continued to be the leading producing States. Processed crude perlite was expanded at 56 plants in 27 States. Domestic apparent consumption was 670,000 tons. The applications for expanded perlite were building construction products, 58%; fillers, 18%; horticultural aggregate, 16%; filter aid, 4%; and other, 4%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Mine production, crude ore	501	521	570	[e]510	520
Sold and used, processed crude perlite	444	437	479	[e]460	480
Imports for consumption[1]	154	199	171	204	200
Exports[1]	18	16	18	16	13
Consumption, apparent[2]	580	620	632	[e]620	670
Price, average value, dollars per ton, f.o.b. mine	61	65	73	72	72
Employment, mine and mill, number	142	135	139	130	140
Net import reliance[3] as a percentage of apparent consumption	23	30	24	30	28

Recycling: Not available.

Import Sources (2015–18): Greece, 89%; China, 8%; Mexico, 2%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Vermiculite, perlite and chlorites, unexpanded	2530.10.0000	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Perlite is a siliceous volcanic glass that expands up to 20 times its original volume when rapidly heated. In horticultural uses, expanded perlite is used to provide moisture retention and aeration without compaction when added to soil. Owing primarily to cost, some commercial greenhouse growers in the United States have recently switched to a wood fiber material over perlite. Perlite, however, remained a preferred soil amendment for segments of greenhouse growers because it does not degrade or compact over lengthy growing times and is inert. Construction applications for expanded perlite are numerous because it is lightweight, fire resistant, and an excellent insulator. Novel and small markets for perlite have increased during the past 10 years; cosmetics, environmental remediation, personal care products, and marijuana growing have become increasing markets for perlite. Exploration continued at a perlite deposit in Nevada that could be developed as a potential supplier of crude perlite ore for industrial and household applications.

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PERLITE

Domestic perlite mining generally takes place in remote areas, and its environmental impact is not severe. The mineral fines, overburden, and reject ore produced during ore mining and processing are used to reclaim the mined-out areas, and, therefore, little waste remains. Airborne dust is captured by baghouses, and virtually no runoff contributes to water pollution.

Based on estimated world production for 2019, the world's leading producers were, in descending order of production, China, Greece, Turkey, and the United States, with about 47%, 20%, 16%, and 13%, respectively, of world production. Although China was the leading producer, most of its perlite production was thought to be consumed internally. Greece and Turkey remained the leading exporters of perlite.

World Perlite Production and Reserves:

	Production		Reserves[4]
	2018	2019[e]	
United States	[e, 5]510	[5]520	50,000
Argentina	20	20	NA
Armenia	45	45	NA
China	1,900	1,900	NA
Greece	750	800	120,000
Hungary	39	40	49,000
Iran	20	20	NA
Mexico	20	20	NA
New Zealand	20	20	NA
Turkey	650	650	57,000
Other countries	50	50	NA
World total (rounded)	4,020	4,100	NA

World Resources: Perlite occurrences in Arizona, Idaho, Nevada, New Mexico, and Oregon are thought to contain large resources. Significant deposits have been reported in China, Greece, Hungary, and Turkey, and a few other countries. Insufficient information is available to make reliable estimates of resources in many perlite-producing countries.

Substitutes: In construction applications, diatomite, expanded clay and shale, pumice, and slag can be substituted for perlite. For horticultural uses, vermiculite, coco coir, wood pulp, and pumice are alternative soil additives and are sometimes used in conjunction with perlite.

[e]Estimated. NA Not available.

[1]Exports and imports were estimated by the U.S. Geological Survey from U.S. Census Bureau combined data for vermiculite, perlite, and chlorites, unexpanded.

[2]Defined as sold or used processed perlite + imports – exports.

[3]Defined as imports − exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Mine production of crude ore.

PHOSPHATE ROCK

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, phosphate rock ore was mined by five firms at 10 mines in four States and processed into an estimated 23 million tons of marketable product, valued at $1.6 billion, free on board (f.o.b.) mine. Florida and North Carolina accounted for more than 75% of total domestic output; the remainder was produced in Idaho and Utah. Marketable product refers to beneficiated phosphate rock with phosphorus pentoxide (P_2O_5) content suitable for phosphoric acid or elemental phosphorus production. More than 95% of the phosphate rock mined in the United States was used to manufacture wet-process phosphoric acid and superphosphoric acid, which were used as intermediate feedstocks in the manufacture of granular and liquid ammonium phosphate fertilizers and animal feed supplements. Approximately 50% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium (DAP) and monoammonium phosphate (MAP) fertilizer, and merchant-grade phosphoric acid. The balance of the phosphate rock mined was for the manufacture of elemental phosphorus, which was used to produce phosphorus compounds for industrial applications, primarily glyphosate herbicide.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, marketable	27,400	27,100	27,900	25,800	23,000
Sold or used by producers	26,200	26,700	26,300	23,300	23,000
Imports for consumption	1,960	1,590	2,470	2,770	2,000
Consumption, apparent[1]	28,100	28,200	28,800	26,000	25,000
Price, average value, dollars per ton, f.o.b. mine[2]	72.41	76.90	73.67	70.77	70.00
Stocks, producer, yearend	6,730	7,450	8,440	10,600	10,000
Employment, mine and beneficiation plant, number[e]	2,000	2,000	2,000	2,000	2,000
Net import reliance[3] as a percentage of apparent consumption	4	4	5	2	10

Recycling: None.

Import Sources (2015–18): Peru, 79%; Morocco, 20%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Natural calcium phosphates:		
Unground	2510.10.0000	Free.
Ground	2510.20.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic phosphate rock production was lower in 2019 owing to the temporary closure of one mine in Florida and companies reducing stocks of phosphate rock. Domestic consumption was 4% lower because of lower production of phosphoric acid and fertilizers. Imports were lower as the result of the permanent closure at the end of 2018 of a phosphoric acid plant in Louisiana that used imported phosphate rock and the temporary closure of another plant in Louisiana in the fourth quarter of 2019.

The leading phosphate rock producer in the United States permanently closed a phosphoric acid and fertilizer plant in June 2019 as part of corporate restructuring. The facility had been idled since 2017 and the phosphate rock mine that supplied the plant closed in late 2018. Another company planned to use the facility to manufacture organic fertilizers.

The only U.S. producer of elemental phosphorus received approval for a new phosphate rock mine in Idaho. The new mine would replace the current mine when the ore is depleted in about 10 years. U.S. phosphate rock annual mine production capacity was expected to remain at 31.1 million tons in 2020.

According to industry analysts, the rated capacity of global phosphate rock mines was projected to increase to 177 million tons in 2023 from 157 million tons in 2019, not including official capacity data for China. Production of marketable phosphate rock in China was thought to be between 80 and 85 million tons per year, compared with official production statistics of 110 million tons per year that included some crude ore production. Most of the increases in production capacity were planned for Africa and the Middle East, where major expansion projects were in progress in Jordan, Morocco, Saudi Arabia, Senegal, and Togo.

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PHOSPHATE ROCK

A Russian company restarted production of phosphate rock in Syria in 2018. The mine had been closed since late 2015 because of the conflicts in the region. The Russian company signed a 50-year operating agreement with the Government of Syria to operate the mine. The company planned to produce about 2.2 million tons per year. Production data for Syria have not been verified.

World consumption of P_2O_5, contained in phosphoric acid, fertilizers, and other products, was projected to increase to 50 million tons in 2023 from 47 million tons in 2019. Africa, India, and South America accounted for about 75% of the projected growth. U.S. consumption of P_2O_5 was expected to remain between 4.0 and 4.5 million tons per year.

World Mine Production and Reserves: Reserves for Israel, Peru, and South Africa were revised based on industry reports. Reserves for Australia were revised based on Government information.

	Mine production		Reserves[4]
	2018	2019[e]	
United States	25,800	23,000	1,000,000
Algeria	1,200	1,200	2,200,000
Australia	2,800	2,700	[5]1,200,000
Brazil	5,740	5,300	1,700,000
China[6]	120,000	110,000	3,200,000
Egypt	5,000	5,000	1,300,000
Finland	989	1,000	1,000,000
India	1,600	1,600	46,000
Israel	3,550	3,500	62,000
Jordan	8,020	8,000	1,000,000
Kazakhstan	1,300	1,300	260,000
Mexico	1,540	1,500	30,000
Morocco and Western Sahara	34,800	36,000	50,000,000
Peru	3,900	3,700	210,000
Russia	14,000	14,000	600,000
Saudi Arabia	6,090	6,200	1,400,000
Senegal	1,650	1,600	50,000
South Africa	2,100	1,900	1,400,000
Syria	100	2,000	1,800,000
Togo	800	800	30,000
Tunisia	3,340	3,000	100,000
Uzbekistan	900	900	100,000
Vietnam	3,300	5,500	30,000
Other countries	970	1,000	770,000
World total (rounded)	249,000	240,000	69,000,000

World Resources: Some world reserves were reported only in terms of ore tonnage and grade. Phosphate rock resources occur principally as sedimentary marine phosphorites. The largest sedimentary deposits are found in northern Africa, China, the Middle East, and the United States. Significant igneous occurrences are found in Brazil, Canada, Finland, Russia, and South Africa. Large phosphate resources have been identified on the continental shelves and on seamounts in the Atlantic Ocean and the Pacific Ocean. World resources of phosphate rock are more than 300 billion tons. There are no imminent shortages of phosphate rock.

Substitutes: There are no substitutes for phosphorus in agriculture.

[e]Estimated.

[1]Defined as phosphate rock sold or used by producers + imports. U.S. producers stopped exporting phosphate rock in 2003.

[2]Marketable phosphate rock, weighted value, all grades.

[3]Defined as imports + adjustments for industry stock changes.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]For Australia, Joint Ore Reserves Committee-compliant reserves were 81 million tons.

[6]Production data for large mines only, as reported by the National Bureau of Statistics of China.

PLATINUM-GROUP METALS

(Palladium, platinum, iridium, osmium, rhodium, and ruthenium)
(Data in kilograms of platinum-group-metal content unless otherwise noted)

Domestic Production and Use: One company in Montana produced over 15,000 kilograms of platinum-group metals (PGMs) with an estimated value of about $680 million. Small quantities of primary PGMs also were recovered as byproducts of copper-nickel mining in Michigan; however, this material was sold to foreign companies for refining. The leading domestic use for PGMs was in catalytic converters to decrease harmful emissions from automobiles. Platinum-group metals are also used in catalysts for bulk-chemical production and petroleum refining; dental and medical devices; electronic applications, such as in computer hard disks, hybridized integrated circuits, and multilayer ceramic capacitors; glass manufacturing; investment; jewelry; and laboratory equipment.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Mine production:[1]					
Palladium	12,500	13,100	13,600	14,300	12,000
Platinum	3,670	3,890	3,980	4,160	3,600
Imports for consumption:[2]					
Palladium	85,300	80,400	86,000	92,900	76,000
Platinum	42,700	42,300	53,200	58,500	38,000
PGM waste and scrap	123,000	154,000	354,000	40,700	38,000
Iridium	1,010	1,300	1,420	1,020	910
Osmium	8	27	856	25	—
Rhodium	10,600	10,700	11,600	14,500	14,000
Ruthenium	8,230	8,410	14,600	17,900	9,900
Exports:[3]					
Palladium	23,000	17,500	52,300	53,300	50,000
Platinum	14,400	14,000	16,700	18,900	17,000
PGM waste and scrap	246,000	48,100	55,500	31,800	19,000
Rhodium	759	794	844	2,010	1,600
Other PGMs	781	736	939	2,600	1,300
Consumption, apparent[4, 5]					
Palladium	117,000	118,000	89,300	95,900	80,000
Platinum	40,800	43,200	51,500	53,800	33,000
Price, dollars per troy ounce:[6]					
Palladium	694.99	617.39	874.30	1,036.43	1,500.00
Platinum	1,056.09	989.52	951.23	882.66	850.00
Iridium	544.19	586.90	908.35	1,293.27	1,500.00
Rhodium	954.90	696.84	1,112.59	2,225.30	3,300.00
Ruthenium	47.63	42.00	76.86	244.41	270.00
Employment, mine, number[1]	1,439	1,432	1,432	1,628	1,400
Net import reliance [5, 7] as a percentage of apparent consumption:					
Palladium	53	53	38	41	32
Platinum	66	66	71	74	64

Recycling: About 116,000 kilograms of palladium and platinum was recovered globally from new and old scrap in 2018, including about 49,000 kilograms recovered from automobile catalytic converters in the United States.

Import Sources (2015–18): Palladium: South Africa, 33%; Russia, 33%; Germany, 7%; Italy, 7%; and other, 20%. Platinum: South Africa, 46%; Germany, 16%; Italy, 7%; Russia, 6%; and other, 25%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free. See footnotes for specific Harmonized Tariff Schedule of the United States codes.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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PLATINUM-GROUP METALS

Government Stockpile:[8]

Material	Inventory As of 9–30–19	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals	FY 2020 Potential Acquisitions	FY 2020 Potential Disposals
Iridium	15	—	15	—	15
Platinum	261	—	261	—	261

Events, Trends, and Issues: Progress continued at a domestic mine expansion project; full production from the project was expected by late 2021. Based on platinum content, imports of PGM waste and scrap decreased by 89% in 2018 compared with imports in 2017 and remained at similarly low levels in 2019; however, imports of PGM waste and scrap based on gross weight only decreased by 12% during the same time period. This indicates that imported PGM waste and scrap has increased in content of PGMs other than platinum.

Production of PGMs in South Africa, the world's leading supplier of mined material, decreased by 4% compared with that of 2018 owing to increased labor costs, increased costs for electricity, an unreliable supply of electricity, and challenges related to deep-level mining.

The estimated annual average prices of iridium, palladium, rhodium, and ruthenium increased by 15%, 41%, 50%, and 8%, respectively, compared with those of 2018. The estimated average annual price of platinum was 3% lower than that of 2018, continuing a 5-year trend of declining prices. The price of palladium remained higher than that of platinum in 2019, with palladium prices exceeding a previous high of $1,036.82 in January 2013 and platinum prices decreasing to their lowest level in a decade.

World Mine Production and Reserves:

	Mine production				PGM
	Palladium		Platinum		Reserves[9]
	2018	2019[e]	2018	2019[e]	
United States	14,300	12,000	4,160	3,600	900,000
Canada	20,000	20,000	7,400	7,400	310,000
Russia	90,000	86,000	22,000	22,000	3,900,000
South Africa	80,600	80,000	137,000	130,000	63,000,000
Zimbabwe	12,000	12,000	15,000	15,000	1,200,000
Other countries	2,920	3,000	4,470	4,300	NA
World total (rounded)	220,000	210,000	190,000	180,000	69,000,000

World Resources: World resources of PGMs are estimated to total more than 100 million kilograms. The largest reserves are in the Bushveld Complex in South Africa.

Substitutes: Palladium has been substituted for platinum in most gasoline-engine catalytic converters because of the historically lower price for palladium relative to that of platinum. About 25% of palladium can routinely be substituted for platinum in diesel catalytic converters; the proportion can be as much as 50% in some applications. For some industrial end uses, one PGM can substitute for another, but with losses in efficiency.

[e]Estimated. NA Not available. — Zero.

[1]Estimates from published sources.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 7110.11.0010, 7110.11.0020, 7110.11.0050, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0010, 7110.41.0020, 7110.41.0030, 7110.49.0010, 7112.92.0000, and 7118.90.0020.

[3]Includes data for the following Schedule B codes: 7110.11.0000, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0000, 7110.49.0000, and 7112.92.0000.

[4]Defined as primary production + secondary production + imports – exports.

[5]Excludes imports and (or) exports of waste and scrap.

[6]Engelhard Corp. unfabricated metal.

[7]Defined as imports – exports.

[8]See Appendix B for definitions.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

POTASH

(Data in thousand metric tons of K_2O equivalent unless otherwise noted)

Domestic Production and Use: In 2019, the estimated sales value of marketable potash, f.o.b. mine, was $400 million, which was about the same as that in 2018. Potash denotes a variety of mined and manufactured salts, which contain the element potassium in water-soluble form. In agriculture, the term potash refers to potassic fertilizers, which are potassium chloride (KCl), potassium sulfate or sulfate of potash (SOP), and potassium magnesium sulfate (SOPM) or langbeinite. Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride for fertilizer use. The majority of U.S. production was from southeastern New Mexico, where two companies operated two underground mines and one deep-well solution mine. Sylvinite and langbeinite ores in New Mexico were beneficiated by flotation, dissolution-recrystallization, heavy-media separation, solar evaporation, and (or) combinations of these processes, and accounted for about 50% of total U.S. producer sales. In Utah, two companies operated three facilities. One company extracted underground sylvinite ore by deep-well solution mining. Solar evaporation crystallized the sylvinite ore from the brine solution, and a flotation process separated the MOP from byproduct sodium chloride. The firm also processed subsurface brines by solar evaporation and flotation to produce MOP at its other facility. Another company processed brine from the Great Salt Lake by solar evaporation to produce SOP and other byproducts.

The fertilizer industry used about 85% of U.S. potash sales, and the remainder was used for chemical and industrial applications. About 80% of the potash produced was SOPM and SOP, which are required to fertilize certain chloride-sensitive crops. Muriate of potash accounted for the remaining 20% of production and was used for agricultural and chemical applications.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, marketable[1]	740	510	480	520	510
Sales by producers, marketable[1]	620	600	490	520	510
Imports for consumption	5,190	4,550	5,870	5,710	5,000
Exports	106	96	128	105	90
Consumption, apparent[1, 2]	5,700	5,100	6,200	6,100	5,400
Price, dollars per ton of K_2O, average, all products, f.o.b. mine[3]	880	680	770	750	800
Price, dollars per ton of K_2O, average, muriate, f.o.b. mine	580	350	410	440	480
Employment, number, mine and mill	1,300	1,150	900	900	900
Net import reliance[4] as a percentage of apparent consumption	89	88	92	92	91

Recycling: None.

Import Sources (2015–18): Canada, 81%; Russia, 8%; Belarus, 5%; Israel, 2%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Potassium nitrate	2834.21.0000	Free.
Potassium chloride	3104.20.0000	Free.
Potassium sulfate	3104.30.0000	Free.
Potassic fertilizers, other	3104.90.0100	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic and world consumption of potash fertilizers was affected by wet conditions during the planting seasons in many countries during the first half of 2019. This resulted in lower potash sales and higher inventories worldwide. In the United States, production and sales of all forms of potash decreased slightly as sales of SOP, SOPM, and MOP for nonfertilizer uses offset some of the lower MOP fertilizer sales. Domestic imports and consumption fell by more than 12% owing to the poor weather conditions during the spring planting season.

High inventories caused the major world producers to reduce production during the second half of the year. Belarus, Canada, Chile, Germany, and Israel all had temporary mine and plant closures.

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POTASH

World consumption of potash was estimated to have remained about the same as in 2018 at 43 million tons, owing to increased nonagricultural uses and regional seasonal consumption during the second half of 2019. World production was estimated to have fallen by 5% compared with 2018, owing to high inventories.

Development of a SOP facility in Utah continued in 2019. The Sevier Playa project, which is about 225 kilometers southwest of Salt Lake City, would produce SOP from solar evaporation of surface brines. The operating company received final permits in 2019 and was expected to begin construction in 2020. Production was scheduled to begin in 2022 at 30,000 tons of SOP and ramp up to full capacity of 372,000 tons per year of SOP in 2025.

Global annual potash production capacity was estimated to be 61 million tons in 2019. New mines in Belarus and Russia, and expansions to existing facilities in Canada and Israel were expected to be completed in 2020. Other projects in Belarus, Canada, China, Jordan, and the United Kingdom could increase capacity to about 68 million tons in 2023; however, these projects were dependent on potash market conditions or securing financing for the projects.

World Mine Production and Reserves: Reserves for Canada, Spain, and the United Kingdom were revised based on official Government information. Reserves for Russia were revised based on information reported by the producers. The previously reported reserve information was based on official Government data, which included some deposits that are considered resources by USGS reserve definition.

	Mine production		Reserves[5]	
	2018	2019[e]	Recoverable ore	K_2O equivalent
United States[1]	520	510	970,000	220,000
Belarus	7,200	7,000	3,300,000	750,000
Brazil	200	200	310,000	24,000
Canada	13,800	13,300	4,200,000	1,000,000
Chile	1,200	950	NA	100,000
China	5,000	5,000	NA	350,000
Germany	3,200	3,000	NA	150,000
Israel	2,200	2,000	NA	[6]Large
Jordan	1,480	1,500	NA	[6]Large
Laos	200	200	NA	20,000
Russia	7,170	6,800	NA	600,000
Spain	700	600	NA	68,000
Other countries	351	270	1,500,000	300,000
World total (rounded)	43,300	41,000	NA	>3,600,000

World Resources: Estimated domestic potash resources total about 7 billion tons. Most of these lie at depths between 1,800 and 3,100 meters in a 3,110-square-kilometer area of Montana and North Dakota as an extension of the Williston Basin deposits in Manitoba and Saskatchewan, Canada. The Paradox Basin in Utah contains resources of about 2 billion tons, mostly at depths of more than 1,200 meters. The Holbrook Basin of Arizona contains resources of about 0.7 to 2.5 billion tons. A large potash resource lies about 2,100 meters under central Michigan and contains more than 75 million tons. Estimated world resources total about 250 billion tons.

Substitutes: No substitutes exist for potassium as an essential plant nutrient and as an essential nutritional requirement for animals and humans. Manure and glauconite (greensand) are low-potassium-content sources that can be profitably transported only short distances to crop fields.

[e]Estimated. NA Not available.

[1]Data are rounded to no more than two significant digits to avoid disclosing company proprietary data.

[2]Defined as sales + imports – exports.

[3]Includes MOP, SOP, and SOPM. Does not include other chemical compounds that contain potassium.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Israel and Jordan recover potash from the Dead Sea, which contains nearly 2 billion tons of potassium chloride.

PUMICE AND PUMICITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 510,000 tons with an estimated processed value of about $17 million, free on board (f.o.b.) plant. Pumice and pumicite were mined in California, Oregon, Idaho, New Mexico, and Kansas, in descending order of production. The porous, lightweight properties of pumice are well suited for its main uses. Mined pumice was used in the production of abrasives, concrete admixtures and aggregates, lightweight building blocks, horticultural purposes, and other uses, including absorbent, filtration, laundry stone washing, and road use.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, mine[1]	310	374	383	496	510
Imports for consumption	64	170	166	159	110
Exports[e]	11	9	11	11	12
Consumption, apparent[2]	363	535	538	644	610
Price, average value, dollars per ton, f.o.b. mine or mill	33	38	39	32	33
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	15	30	29	23	17

Recycling: Little to no known recycling.

Import Sources (2015–18): Greece, 93%; Iceland, 5%; and Mexico, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Pumice, crude or in irregular pieces, including crushed	2513.10.0010	Free.
Pumice, other	2513.10.0080	Free.

Depletion Allowance: 5% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced pumice and pumicite sold or used in 2019 was estimated to be 3% more than that in 2018. Imports were estimated to have decreased, and exports increased compared with those of 2018. Since 2015, apparent consumption and quantity of pumice that was sold or used had followed an upward trend until 2019. Almost all imported pumice originated from Greece in 2019, and primarily supplied markets in the eastern and Gulf Coast regions of the United States. Turkey, followed by Greece, was the leading global producer of pumice and pumicite. Although the domestic mill price for pumice was approximately $33 per ton, the average imported value of pumice was approximately $44 per ton.

Pumice and pumicite are plentiful in the Western United States, but legal challenges and public land designations could limit access to known deposits. Pumice and pumicite production is sensitive to mining and transportation costs. Although unlikely in the short term, an increase in fuel prices would likely lead to increases in production costs, making imports and competing materials attractive substitutes for domestic products.

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PUMICE AND PUMICITE

All known domestic pumice and pumicite mining in 2019 was accomplished through open pit methods, generally in remote areas, away from major population centers. Although the generation and disposal of reject fines in mining and milling may result in local dust issues at some operations, such environmental impacts are thought to be restricted to relatively small geographic areas.

World production of pumice and related material was estimated to be 18 million tons in 2019, which was essentially unchanged from that of 2018. Pumice is used more extensively as a building material outside the United States, which explained the large global production of pumice relative to that of the United States. In Europe, basic home construction uses stone and concrete as the preferred building materials. Prefabricated lightweight concrete walls, which may contain pumice as lightweight aggregate, are often produced and shipped to construction locations. Because of their cementitious properties, light weight, and strength, pumice and pumicite perform well in European-style construction.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2018	2019[e]	
United States[1]	496	510	Large in the United States. Quantitative estimates of reserves for most countries are not available.
Algeria[5]	900	900	
Cameroon[5]	300	300	
Chile[5]	840	800	
Ecuador[5]	630	600	
Ethiopia	800	800	
France[5]	280	300	
Greece[5]	1,130	1,100	
Guadeloupe	200	200	
Guatemala	570	600	
Indonesia	770	770	
Jordan	900	900	
Saudi Arabia[5]	530	550	
Spain	200	200	
Syria[5]	200	200	
Turkey[6]	7,800	7,800	
Uganda	790	800	
Other countries[5]	760	670	
World total (rounded)	18,100	18,000	

World Resources: The identified U.S. resources of pumice and pumicite are concentrated in the Western States and estimated to be more than 25 million tons. The estimated total resources (identified and undiscovered) in the Western and Great Plains States are at least 250 million tons and may total more than 1 billion tons. Large resources of pumice and pumicite have been identified on all continents.

Substitutes: The costs of transportation determine the maximum economic distance pumice and pumicite can be shipped and still remain competitive with alternative materials. Competitive materials that may be substituted for pumice and pumicite include crushed aggregates, diatomite, expanded shale and clay, and vermiculite.

[e]Estimated.

[1]Quantity sold and used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes pozzolan and (or) volcanic tuff.

[6]Data reported from a separate official Turkish source indicated a production of 3,430,000 tons in 2018.

QUARTZ CRYSTAL (INDUSTRIAL)

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Industrial cultured quartz crystal is electronic-grade quartz crystal that is manufactured, not mined. In the past, cultured quartz crystal was primarily produced using lascas[1] as raw quartz feed material. Lascas mining and processing in Arkansas ended in 1997. Anectodal evidence indicated that two companies produced cultured quartz crystal in the United States, but production statistics were not available. In addition to lascas, these companies may use cultured quartz crystal that has been rejected during the manufacturing process, owing to crystallographic imperfections, as feed material. The companies may use a mix of cultured quartz and imported lascas as feed material. In the past several years, cultured quartz crystal has been increasingly produced overseas, primarily in Asia. Electronic applications accounted for most industrial uses of quartz crystal; other uses included special optical applications.

Virtually all quartz crystal used for electronics was cultured, rather than natural, crystal. Electronic-grade quartz crystal is used to make frequency filters, frequency controls, and timers in electronic circuits employed for a wide range of products, such as communications equipment, computers, and many consumer goods, such as electronic games and television receivers.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine (lascas)	—	—	—	—	—
Cultured quartz crystal	NA	NA	NA	NA	NA
Imports for consumption:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	3,400	6,280	7,210	16,100	59,000
Exports:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	43,600	60,500	57,900	47,500	43,000
Price, dollars per kilogram:					
As-grown cultured quartz	280	280	280	280	300
Lumbered quartz[2]	160	890	300	300	500
Net import reliance[3] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: An unspecified amount of rejected cultured quartz crystal was used as feed material for the production of cultured quartz crystal.

Import Sources (2015–18): Import statistics specific to lascas are not available because they are combined with other types of quartz. Cultured quartz crystal (piezoelectric quartz, unmounted): China, 46%; Japan, 24%; Switzerland and Taiwan, 5% each; and other, 20%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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QUARTZ CRYSTAL (INDUSTRIAL)

Government Stockpile:[4] As of September 30, 2019, the National Defense Stockpile (NDS) contained 7,148 kilograms of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 kilogram to more than 10 kilograms. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal. No natural quartz crystal was sold from the NDS in 2019. Previously, the only individual crystals from the stockpile that were sold were those that weighed 10 kilograms or more and that could be used as seed material.

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Quartz crystal	7,148	—	—	—	—

Events, Trends, and Issues: Demand for cultured quartz crystal for frequency-control oscillators and frequency filters in a variety of electronic devices is expected to remain stable. However, silicon has replaced quartz crystal in two very important markets—cellular telephones and other mobile devices and automotive stability control applications. Growth of the consumer electronics market, for products such as personal computers, electronic games, and tablet computers, is likely to continue to sustain global production of cultured quartz crystal.

World Mine Production and Reserves:[5] This information is unavailable, but the global reserves for lascas are thought to be large.

World Resources: Limited resources of natural quartz crystal suitable for direct electronic or optical use are available throughout the world. World dependence on these resources will continue to decline because of the increased acceptance of cultured quartz crystal as an alternative material. Additionally, techniques using rejected cultured quartz crystal as feed material could mean a decreased dependence on lascas for growing cultured quartz.

Substitutes: Silicon is increasingly being used as a substitute for quartz crystal for frequency-control oscillators in electronic circuits. Other materials, such as aluminum orthophosphate (the very rare mineral berlinite), langasite, lithium niobate, and lithium tantalate, which have larger piezoelectric coupling constants, have been studied and used. The cost competitiveness of these materials, as opposed to cultured quartz crystal, is dependent on the type of application that the material is used for and the processing required.

[e]Estimated. NA Not available. — Zero.

[1]Lascas is a nonelectronic-grade quartz used as a feedstock for growing cultured quartz crystal and for production of fused quartz.

[2]As-grown cultured quartz that has been processed by sawing and grinding.

[3]Defined as imports - exports.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

RARE EARTHS[1]

[Data in metric tons of rare-earth-oxide (REO) equivalent content unless otherwise noted]

Domestic Production and Use: Rare earths were mined domestically in 2019. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined as a primary product at a mine in Mountain Pass, CA, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Monazite, a phosphate mineral, was produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. The estimated value of rare-earth compounds and metals imported by the United States in 2019 was $170 million, an increase from $160 million in 2018. The estimated distribution of rare earths by end use was as follows: catalysts, 75%; metallurgical applications and alloys, 5%; ceramics and glass, 5%; polishing, 5%; and other, 10%.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, bastnaesite concentrates[e]	5,900	—	—	18,000	26,000
Imports:[2]					
Compounds	9,160	11,500	11,000	10,800	14,000
Metals:					
Ferrocerium, alloys	356	268	309	301	310
Rare-earth metals, scandium, and yttrium	385	404	524	527	590
Exports:[2]					
Ores and compounds	4,980	590	1,740	16,800	26,000
Metals:					
Ferrocerium, alloys	1,220	943	982	1,210	1,400
Rare-earth metals, scandium, and yttrium	60	103	55	28	100
Consumption, apparent[3]	9,550	10,500	9,060	11,600	13,000
Price, dollars per kilogram, average:[4]					
Cerium oxide, 99.5% minimum	3	2	2	2	2
Dysprosium oxide, 99.5% minimum	279	198	187	179	240
Europium oxide, 99.99% minimum	344	74	77	53	35
Lanthanum oxide, 99.5% minimum	3	2	2	2	2
Mischmetal, 65% cerium, 35% lanthanum	7	5	6	6	6
Neodymium oxide, 99.5% minimum	48	40	50	50	45
Terbium oxide, 99.99% minimum	564	415	501	455	510
Employment, mine and mill, annual average	351	—	24	190	220
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	38	100	100	100	100
Mineral concentrates	XX	XX	XX	E	E

Recycling: Limited quantities of rare earths from batteries, permanent magnets, and fluorescent lamps are recycled.

Import Sources (2015–18): Rare-earth compounds and metals: China, 80%; Estonia, 6%; Japan and Malaysia, 3% each; and other, 8%. Compounds and metals imported from Estonia, Japan, and Malaysia were derived from mineral concentrates and chemical intermediates produced in Australia, China, and elsewhere.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Rare-earth metals, scandium, and yttrium, whether or not intermixed or interalloyed	2805.30.0000	5.0% ad val.
Cerium compounds:		
Oxides	2846.10.0010	5.5% ad val.
Other	2846.10.0050	5.5% ad val.
Other rare-earth compounds:		
Lanthanum oxides	2846.90.2005	Free.
Other oxides	2846.90.2040	Free.
Lanthanum carbonates	2846.90.8070	3.7% ad val.
Other carbonates	2846.90.8075	3.7% ad val.
Other rare-earth compounds	2846.90.8090	3.7% ad val.
Ferrocerium and other pyrophoric alloys	3606.90.3000	5.9% ad val.

Depletion Allowance: Monazite, 22% on thorium content and 14% on rare-earth content (Domestic), 14% (Foreign); bastnäsite and xenotime, 14% (Domestic and foreign).

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RARE EARTHS

Government Stockpile:[7]

Material	Inventory As of 9–30–19	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals	FY 2020 Potential Acquisitions	FY 2020 Potential Disposals
Cerium	—	—	—	900	—
Dysprosium	0.2	0.5	—	—	—
Europium	20.9	35	—	—	—
Ferrodysprosium, gross weight	0.5	—	—	—	—
Lanthanum, gross weight	—	—	—	4,100	—
Rare earths	—	416	—	—	—
Rare-earth-magnet feedstock	—	100	—	100	—
Yttrium oxide	25	10	—	—	—

Events, Trends, and Issues: Global mine production was estimated to have increased to 210,000 tons of rare-earth-oxide equivalent, an 11% increase compared with that of 2018. In the United States, domestic production of mineral concentrates, all of which were exported, increased to 26,000 tons, a 44% increase compared with that of 2018. China continued to dominate the global supply of rare earths. According to China's Ministry of Industry and Information Technology, the mine and separation production quotas for 2019 were 132,000 tons and 127,000 tons, respectively.

World Mine Production and Reserves: Reserves for Canada, Greenland, Tanzania, and South Africa were previously included with "Other countries."

	Mine production[e] 2018	Mine production[e] 2019	Reserves[8]
United States	18,000	26,000	1,400,000
Australia	21,000	21,000	[9]3,300,000
Brazil	1,100	1,000	22,000,000
Burma (Myanmar)	19,000	22,000	NA
Burundi	630	600	NA
Canada	—	—	830,000
China	[10]120,000	[10]132,000	44,000,000
Greenland	—	—	1,500,000
India	2,900	3,000	6,900,000
Madagascar	2,000	2,000	NA
Russia	2,700	2,700	12,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	1,000	1,800	NA
Vietnam	920	900	22,000,000
Other countries	60	—	310,000
World total (rounded)	190,000	210,000	120,000,000

World Resources: Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other ores. In North America, measured and indicated resources of rare earths were estimated to include 2.7 million tons in the United States and more than 15 million tons in Canada.

Substitutes: Substitutes are available for many applications but generally are less effective.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable. — Zero.

[1]Data include lanthanides and yttrium but exclude most scandium. See also Scandium and Yttrium.

[2]REO equivalent or content of various materials were estimated. Source: U.S. Census Bureau.

[3]Defined as production + imports – exports.

[4]Price range from Argus Media group – Argus Metals International.

[5]Defined as imports – exports.

[6]In 2015, domestic production of mineral concentrates was included with apparent consumption of compounds and metals. In 2018 and 2019, all domestic production of mineral concentrates was exported, and all compounds and metals consumed were assumed to be imported material.

[7]See Appendix B for definitions.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 1.9 million tons.

[10]Production quota; does not include undocumented production.

RHENIUM

(Data in kilograms of rhenium content unless otherwise noted)

Domestic Production and Use: During 2019, ores containing 8,400 kilograms of rhenium were mined at six operations (four in Arizona and one each in Montana and Utah). Rhenium compounds are included in molybdenum concentrates derived from porphyry copper deposits, and rhenium is recovered as a byproduct from roasting such molybdenum concentrates. Rhenium recovery occurred in Arizona, Utah, and Pennsylvania. Rhenium-containing products included ammonium perrhenate (APR), metal powder, and perrhenic acid. The major uses of rhenium were in superalloys used in high-temperature turbine engine components and in petroleum-reforming catalysts, representing an estimated 80% and 15%, respectively, of end uses. Bimetallic platinum-rhenium catalysts were used in petroleum reforming for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Rhenium improves the high-temperature (1,000 °C) strength properties of some nickel-base superalloys. Rhenium alloys were used in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and other applications. The value of rhenium consumed in 2019 was about $65 million as measured by the value of imports of rhenium metal and APR.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production[1]	7,900	8,440	8,200	8,220	8,400
Imports for consumption[2]	31,800	31,900	34,500	39,400	39,000
Exports	NA	NA	NA	NA	NA
Consumption, apparent[3]	39,700	40,300	42,700	47,600	47,000
Price, average value, dollars per kilogram, gross weight:[4]					
Metal pellets, 99.99% pure	2,670	2,030	1,550	1,470	1,300
Ammonium perrhenate	2,820	2,510	1,530	1,410	1,300
Employment, number	Small	Small	Small	Small	Small
Net import reliance[5] as a percentage of apparent consumption	80	79	81	83	82

Recycling: Nickel-base superalloy scrap and scrapped turbine blades and vanes continued to be recycled hydrometallurgically to produce rhenium metal for use in new superalloy melts. The scrapped parts were also processed to generate engine revert—a high-quality, lower cost superalloy meltstock—by an increasing number of companies, mainly in the United States, Canada, Estonia, France, Germany, Japan, Poland, and Russia. Rhenium-containing catalysts were also recycled.

Import Sources (2015–18): Ammonium perrhenate: Kazakhstan, 29%; Canada, 20%; Germany, 14%; China, 8%; and other, 29%. Rhenium metal powder: Chile, 83%; Germany, 7%; Belgium, 3%; Poland, 3%; and other, 4%. Total: Chile, 62%; Germany, 8%; Kazakhstan, 8%; Canada, 7%; and other, 15%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad val.
Rhenium (and other metals), waste and scrap	8112.92.0600	Free.
Rhenium, unwrought and powders	8112.92.5000	3% ad val.
Rhenium (and other metals), wrought	8112.99.9000	4% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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RHENIUM

Events, Trends, and Issues: During 2019, the United States continued to rely on imports for much of its supply of rhenium. Canada, Chile, Germany, and Kazakhstan supplied most of the imported rhenium. Rhenium imports for consumption remained essentially unchanged from those in 2018. Primary rhenium production in the United States increased slightly compared with that in 2018. Germany and the United States continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Canada, Estonia, France, Japan, Poland, and Russia. According to industry sources, approximately 20 to 25 tons of rhenium was recycled worldwide in 2019. For the eighth year in a row, rhenium metal and catalytic-grade APR prices decreased. In 2019, catalytic-grade APR prices averaged $1,300 per kilogram, an 8% decrease from the annual average price in 2018. Rhenium metal pellet prices averaged $1,300 per kilogram in 2019, a 12% decrease from the annual average price in 2018.

Consumption of catalyst-grade APR by the petroleum industry was expected to remain at high levels. Demand for rhenium in the aerospace industry, although more unpredictable, was also expected to remain at high levels. The major aerospace companies, however, were expected to continue testing superalloys that contain one-half the quantity of rhenium used in engine blades as currently designed, as well as testing rhenium-free alloys for other engine components.

World Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2018	2019[e]	
United States	8,220	8,400	400,000
Armenia	281	280	95,000
Canada	—	—	32,000
Chile[8]	27,000	27,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	1,000	1,000	190,000
Peru	—	—	45,000
Poland	9,090	9,300	NA
Russia	NA	NA	310,000
Uzbekistan	460	400	NA
World total (rounded)	48,600	49,000	2,400,000

World Resources: Most rhenium occurs with molybdenum in porphyry copper deposits. Identified U.S. resources are estimated to be about 5 million kilograms, and the identified resources of the rest of the world are approximately 6 million kilograms. Rhenium also is associated with copper minerals in sedimentary deposits in Armenia, Kazakhstan, Poland, Russia, and Uzbekistan, where ore is processed for copper recovery and the rhenium-bearing residues are recovered at copper smelters.

Substitutes: Substitutes for rhenium in platinum-rhenium catalysts are being evaluated continually. Iridium and tin have achieved commercial success in one such application. Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium's share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects. Materials that can substitute for rhenium in various end uses are as follows: cobalt and tungsten for coatings on copper x-ray targets, rhodium and rhodium-iridium for high-temperature thermocouples, tungsten and platinum-ruthenium for coatings on electrical contacts, and tungsten and tantalum for electron emitters.

[e]Estimated. NA Not available. — Zero.

[1]Based on 80% recovery of estimated rhenium contained in molybdenum disulfide concentrates. Secondary rhenium production is not included.

[2]Does not include wrought forms or waste and scrap. The rhenium content of ammonium perrhenate is 69.42%.

[3]Defined as production + imports – exports.

[4]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate. Source: Argus Media group–Argus Metals International.

[5]Defined as imports – exports.

[6]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Estimated rhenium recovered from roaster residues from Belgium, Chile, Mexico, and Peru.

RUBIDIUM

(Data in metric tons of rubidium oxide unless otherwise noted)

Domestic Production and Use: In 2019, no rubidium was mined in the United States; however, occurrences are known in Alaska, Arizona, Idaho, Maine, South Dakota, and Utah. Rubidium is also associated with some evaporate mineral occurrences in other States. Rubidium is not a major constituent of any mineral. Rubidium concentrate is produced as a byproduct of pollucite (cesium) and lepidolite (lithium) mining and is imported from other countries for processing in the United States.

Applications for rubidium and its compounds include biomedical research, electronics, specialty glass, and pyrotechnics. Specialty glasses are the leading market for rubidium; rubidium carbonate is used to reduce electrical conductivity, which improves stability and durability in fiber optic telecommunications networks. Biomedical applications include rubidium salts used in antishock agents and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride, used as an antidepressant. Rubidium atoms are used in academic research, including the development of quantum-mechanics-based computing devices, a future application with potential for relatively high consumption of rubidium. Quantum computing research uses ultracold rubidium atoms in a variety of applications. Quantum computers, which have the ability to perform more complex computational tasks than traditional computers by calculating in two quantum states simultaneously, were expected to be in prototype phase by 2025.

Rubidium's photoemissive properties make it useful for electrical-signal generators in motion-sensor devices, night-vision devices, photoelectric cells (solar panels), and photomultiplier tubes. Rubidium is used as an atomic resonance-frequency-reference oscillator for telecommunications network synchronization, playing a vital role in global positioning systems. Rubidium-rich feldspars are used in ceramic applications for spark plugs and electrical insulators because of their high dielectric constant. Rubidium hydroxide is used in fireworks to oxidize mixtures of other elements and produce violet hues. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 4 USNO rubidium fountain clocks.

Salient Statistics—United States: U.S. salient statistics, such as consumption, exports, and imports, are not available. Some concentrate was imported to the United States for further processing. Industry information during the past decade suggests a domestic consumption rate of approximately 2,000 kilograms per year. The United States was 100% import reliant for rubidium minerals.

In 2019, one company offered 1-gram ampoules of 99.75%-grade rubidium (metal basis) for $87.80, a 4% increase from $84.40 in 2018, and 100-gram ampoules of the same material for $1,592.00, a 3% increase from $1,546.00 in 2018. The price for 1-gram ampoules of 99.8% rubidium formate hydrate (metal basis) was $34.70.

In 2019, the prices for 10 grams of 99.8% (metal basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $49.80, $65.80, $56.80, $59.80, and $46.40, respectively. The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $52.10 for 50 milliliters and $85.00 for 100 milliliters, a 4% decrease and 5% increase, respectively, from those of 2018.

Recycling: None.

Import Sources (2015–18): No reliable data have been available to determine the source of rubidium ore imported by the United States since 1988. Previously, Canada was thought to be the primary supplier of rubidium ore.

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RUBIDIUM

Tariff: Item	Number	Normal Trade Relations 12–31–19
Alkali metals, other	2805.19.9000	5.5% ad val.
Chlorides, other	2827.39.9000	3.7% ad val.
Bromides, other	2827.59.5100	3.6% ad val.
Nitrates, other	2834.29.5100	3.5% ad val.
Sulfates, other	2833.29.5100	3.7% ad val.
Carbonates, other	2836.99.5000	3.7% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic rubidium occurrences will remain uneconomic unless market conditions change, such as the development of new end uses or increased consumption for existing end uses, which in turn could lead to increased prices. No known human health issues are associated with exposure to naturally occurring rubidium, and its use has minimal environmental impact.

During 2019, projects that were primarily aimed at developing lithium resources were at various stages of development, including eight subprojects at the King Col project in Australia, the Jubilee Lake lithium prospect in Canada, the Soris lithium project in Namibia, and the Winnipeg River pegmatite field in Canada. The status of these projects ranged from early feasibility studies to active exploration and drilling. No production has been reported at any sites. The projects focused on pegmatites containing pollucite and spodumene, which primarily contain lithium, tantalum, or both, but may also contain minor quantities of cesium and rubidium.

World Mine Production and Reserves: There were no official sources for rubidium production data. Production is known to take place periodically in Namibia and Zimbabwe, but production data are not available. Production of pollucite ceased at the Bernic Lake operation in Manitoba, Canada, at the end of 2015. Rubidium is thought to be mined in China, but information regarding reserves and production is unavailable. Lepidolite and pollucite, the principal rubidium-containing minerals in global rubidium reserves, can contain up to 3.5% and 1.5% rubidium oxide, respectively. Rubidium-bearing mineral resources are found in zoned pegmatites. Mineral resources exist globally, but extraction and concentration are cost prohibitive. Reserves data for Canada were added based on industry information.

	Reserves[1]
Canada	12,000
Namibia	50,000
Zimbabwe	30,000
Other countries	10,000
World total	100,000

World Resources: Significant rubidium-bearing pegmatite occurrences have been identified in the United States, Afghanistan, Australia, Canada, China, Denmark, Germany, Japan, Kazakhstan, Namibia, Peru, Russia, the United Kingdom, and Zambia. Minor quantities of rubidium are reported in brines in northern Chile and China and in evaporites in the United States (New Mexico and Utah), France, and Germany.

Substitutes: Rubidium and cesium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

SALT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Domestic production of salt was estimated to have increased slightly in 2019 to 42 million tons. The total value of salt sold or used was estimated to be about $2.3 billion. Twenty-six companies operated 63 plants in 16 States. The top producing States were, in alphabetical order, Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 92% of the salt in the United States in 2019. The estimated percentage of salt sold or used was, by type, rock salt, 41%; salt in brine, 41%; vacuum pan salt, 10%; and solar salt, 8%.

Highway deicing accounted for about 43% of total salt consumed. The chemical industry accounted for about 37% of total salt sales, with salt in brine accounting for 89% of the salt used for chemical feedstock. Chlorine and caustic soda manufacturers were the main consumers within the chemical industry. The remaining markets for salt were, in declining order of use, distributors, 9%; food processing, 4%; agricultural, 3%, general industrial, 2%; and primary water treatment, 1%. The remaining 1% was other uses combined with exports.

Salient Statistics—United States:[1]	2015	2016	2017	2018	2019[e]
Production	45,100	41,700	39,600	[e]41,000	42,000
Sold or used by producers	42,800	39,900	38,200	[e]40,000	41,000
Imports for consumption	21,600	12,100	12,600	17,900	17,000
Exports	830	729	1,120	986	730
Consumption:					
Apparent[2]	63,600	51,300	49,700	[e]57,000	57,000
Reported	52,300	47,800	45,500	[e]48,000	49,000
Price, average value of bulk, pellets and packaged salt, dollars per ton, f.o.b. mine and plant:					
Vacuum and open pan salt	188.87	197.78	211.71	[e]220.00	220.00
Solar salt	102.04	99.69	115.88	[e]120.00	120.00
Rock salt	56.32	56.75	60.41	[e]62.00	62.00
Salt in brine	10.27	8.68	9.49	[e]10.00	10.00
Employment, mine and plant, number[e]	4,200	4,000	4,100	4,100	4,100
Net import reliance[3] as a percentage of apparent consumption	33	22	23	30	29

Recycling: None.

Import Sources (2015–18): Chile, 36%; Canada, 25%; Mexico, 12%; Egypt, 6%; and other, 21%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The winter was slightly colder than average in 2018–19 for the second consecutive year. The number of winter weather events was greater than the last few years in many parts of the United States, including an increase in episodes of freeing rain and sleet, requiring more salt for highway deicing. Rock salt production and imports in 2019 remained at about the same level as that of 2018 because demand from many local and State transportation departments remained relatively high. Most local and State governments in regions that experience cold winters reportedly had depleted stockpiles and needed to replenish supplies of rock salt for the winter of 2019–20.

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SALT

For the winter of 2019–20, the National Oceanic and Atmospheric Administration predicted a neutral weather pattern without El Niño or La Niña affects: other weather patterns were expected to have a greater influence. Forecasts include warmer than average temperatures for the northeastern, northwestern, and southern areas of the United States, and the northern plains and Midwest are expected to have average temperatures. Areas from the mid-Atlantic to the northern Rocky Mountains are predicted to have a wetter than average winter, but much of New England and most of the South are forecast to have average precipitation. The early part of the season was noticeably cooler and wetter than normal, and consumers of rock salt had already begun to use stockpiles of salt and considered increasing salt purchases for the remainder of the winter season.

Demand for salt brine used in the chloralkali industry was expected to increase as demand for caustic soda increased globally, especially in Asia. Exports from Australia and especially India increased to meet the increasing demand for caustic soda in China.

World Production and Reserves:

	Mine production[e]		Reserves[4]
	2018	2019	
United States[1]	41,000	42,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	12,000	13,000	
Austria	4,900	4,900	
Brazil	7,500	7,600	
Canada	12,000	12,000	
Chile	8,000	9,000	
China	58,000	60,000	
France	5,700	5,700	
Germany	14,000	14,000	
India	29,000	30,000	
Italy	4,100	4,100	
Mexico	9,000	9,000	
Netherlands	7,000	7,000	
Pakistan	4,400	4,500	
Poland	4,400	4,500	
Russia	7,000	7,000	
Spain	4,200	4,300	
Turkey	6,500	6,600	
United Kingdom	4,100	4,100	
Other countries	43,000	44,000	
World total (rounded)	286,000	293,000	

World Resources: World continental resources of salt are vast, and the salt content in the oceans is nearly unlimited. Domestic resources of rock salt and salt from brine are primarily in Kansas, Louisiana, Michigan, New York, Ohio, and Texas. Saline lakes and solar evaporation salt facilities are in Arizona, California, Nevada, New Mexico, Oklahoma, and Utah. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

Substitutes: No economic substitutes or alternatives for salt exist in most applications. Calcium chloride and calcium magnesium acetate, hydrochloric acid, and potassium chloride can be substituted for salt in deicing, certain chemical processes, and food flavoring, but at a higher cost.

[e]Estimated.

[1]Excludes production from Puerto Rico.

[2]Defined as sold or used by producers + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SAND AND GRAVEL (CONSTRUCTION)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2019, 970 million tons of construction sand and gravel valued at $9.0 billion was produced by an estimated 3,870 companies operating 6,830 pits and 342 sales and distribution yards in 50 States. Leading producing States were Texas, California, Arizona, Minnesota, Michigan, Washington, Ohio, New York, Utah, and Colorado, in order of decreasing tonnage, which together accounted for about 55% of total output. It is estimated that about 46% of construction sand and gravel was used as concrete aggregates; 21%, for road base and coverings and road stabilization; 13%, as construction fill; 12%, as asphaltic concrete aggregates and other bituminous mixtures; 13%, as construction fill; and 4%, for other miscellaneous uses. The remaining 4% was used for concrete products, filtration, golf course maintenance, plaster and gunite sands, railroad ballast, road stabilization, roofing granules, and snow and ice control.

The estimated output of construction sand and gravel in the United States shipped for consumption in the first 9 months of 2019 was 727 million tons, an increase of 3% compared with that of the same period of 2018. Third quarter shipments for consumption increased by 5% compared with those of the same period of 2018. Additional production information by quarter for each State, geographic region, and the United States is published by the U.S. Geological Survey (USGS) in its quarterly Mineral Industry Surveys for Crushed Stone and Sand and Gravel.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production	880	887	880	937	970
Imports for consumption	4	3	7	6	5
Exports	(2)	(2)	(2)	(2)	(2)
Consumption, apparent[3]	884	891	886	943	980
Price, average value, dollars per metric ton	8.28	8.41	8.83	9.14	9.29
Employment, mine and mill, number[4]	34,800	35,300	36,500	38,600	37,800
Net import reliance[5] as a percentage of apparent consumption	(2)	(2)	1	1	1

Import Sources (2015–18): Canada, 94%; Mexico, 4%; China, 1%; and Norway, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Sand, other	2505.90.0000	Free.
Pebbles and gravel	2517.10.0015	Free.

Depletion Allowance: Common varieties, 5% (Domestic and foreign).

Government Stockpile: None.

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SAND AND GRAVEL (CONSTRUCTION)

Events, Trends, and Issues: Construction sand and gravel production was about 970 million tons in 2019, an increase of 4% compared with that of 2018. Apparent consumption also increased by 4% to 980 million tons. Demand for construction sand and gravel increased in 2019 because of continued growth in the private and public construction markets. Commercial and heavy-industrial construction activity, infrastructure funding, new single-family housing unit starts, and weather affect growth in sand and gravel production and consumption. Long-term increases in construction aggregates demand will be influenced by activity in the public and private construction sectors, as well as by construction work related to security measures being implemented around the Nation. The underlying factors that would support a rise in prices of construction sand and gravel are expected to be present in 2020, especially in and near metropolitan areas.

The construction sand and gravel industry remained concerned with environmental, health, permitting, safety, and zoning regulations. Movement of sand and gravel operations away from densely populated regions was expected to continue where regulations and local sentiment discouraged them. Resultant regional shortages of construction sand and gravel would likely result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production[e]		Reserves[6]
	2018	2019	
United States	937	970	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources: Sand and gravel resources are plentiful throughout the world. However, because of environmental regulations, geographic distribution, and quality requirements for some uses, sand and gravel extraction is uneconomic in some cases. The most important commercial sources of sand and gravel have been glacial deposits, river channels, and river flood plains. Use of offshore deposits in the United States is mostly restricted to beach erosion control and replenishment. Other countries routinely mine offshore deposits of aggregates for onshore construction projects.

Substitutes: Crushed stone, the other major construction aggregate, is often substituted for natural sand and gravel, especially in more densely populated areas of the Eastern United States. Crushed stone remains the dominant choice for construction aggregate use. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2019.

[e]Estimated. NA Not available.

[1]See also Sand and Gravel (Industrial) and Stone (Crushed).

[2]Less than ½ unit.

[3]Defined as production + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their sand and gravel production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the USGS Minerals Yearbook, Volume III, Area Reports: International.

SAND AND GRAVEL (INDUSTRIAL)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2019, industrial sand and gravel valued at about $5.7 billion was produced by about 191 companies from 308 operations in 35 States. The value of production of industrial sand and gravel in 2019 decreased by 17% compared with that of the previous year, owing primarily to reduced demand for hydraulic-fracturing sand. The likely cause was decreased activity in the oil and gas sector during the year. Leading producing States were Wisconsin, Texas, Illinois, Missouri, Minnesota, Oklahoma, Mississippi, North Carolina, Iowa, and Louisiana, in descending order of tonnage produced. Combined production from these States accounted for 85% of the domestic total. About 73% of the U.S. tonnage was used as hydraulic-fracturing sand and well-packing and cementing sand; as glassmaking sand and other whole-grain silica, 7% each; as foundry sand, 3%; as ceramics, other ground silica, and whole-grain fillers for building products, 2% each; and recreational sand, 1%. Abrasives, chemicals, fillers, filtration sand, metallurgical flux, roofing granules, silica gravel, and traction sand, combined, accounted for the remaining 3% of industrial sand and gravel end uses.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Sold or used	102,000	79,400	103,000	121,000	110,000
Imports for consumption	289	281	366	392	390
Exports	3,910	2,780	4,680	6,560	5,900
Consumption, apparent[2]	98,400	76,900	98,700	115,000	100,000
Price, average value, dollars per ton	47.30	35.40	52.00	56.40	50.40
Employment, quarry and mill, number[e]	3,500	3,500	4,000	4,000	4,000
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Some foundry sand is recycled, and recycled cullet (pieces of glass) represents a significant proportion of reused silica. About 34% of glass containers are recycled.

Import Sources (2015–18): Canada, 86%; Taiwan, 4%; Vietnam, 4%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Sand containing 95% or more silica and not more than 0.6% iron oxide	2505.10.1000	Free.

Depletion Allowance: Industrial sand or pebbles, 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of industrial sand and gravel was estimated to be 100 million tons in 2019, a 13% decrease from that of the previous year. Decreased oil and gas drilling in North America and oil well completion activity triggered a corresponding decrease in the production of hydraulic-fracturing sand in 2019 compared with that of the previous year. However, in any given year, more efficient hydraulic-fracturing techniques, which require more silica sand use per well (mostly for secondary recovery at mature wells) along with lower unit cost compared with other proppants, tends to maintain demand for hydraulic-fracturing sand. Imports of industrial sand and gravel in 2019 were about 390,000 tons—nearly the same as those of 2018. Imports of silica are generally of two types—small shipments of very high-purity silica or a few large shipments of lower grade silica shipped only under special circumstances (for example, very low freight rates). The United States remains a net exporter of industrial sand and gravel; U.S. exports of industrial sand and gravel decreased by about 10% in 2019 compared with those of 2018.

The United States was the world's leading producer and consumer of industrial sand and gravel based on estimated world production figures. It is difficult to collect definitive data on silica sand and gravel production in most nations because of the wide range of terminology and specifications found among different countries. The United States remained a major exporter of silica sand and gravel, shipping it to almost every region of the world. The high level of exports was attributed to the high quality and advanced processing techniques used in the United States for many grades of silica sand and gravel, meeting virtually every specification.

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SAND AND GRAVEL (INDUSTRIAL)

The industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2019, especially those concerning crystalline silica exposure. Beginning in 2016, the Occupational Safety and Health Administration (OSHA) finalized new regulations to further restrict exposure to crystalline silica at quarry sites and in other industries that use materials containing it. Phased implementation of the new regulations was scheduled to take effect through 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations. On August 14, 2019, OSHA requested comment and information to enable the agency to consider new developments and enhanced control methods for equipment that generates exposures to silica. Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations, and logistical issues, including ongoing development and permitting of operations producing hydraulic-fracturing sand. Natural gas and petroleum operations that use hydraulic fracturing may also undergo increased scrutiny. These factors may result in future sand and gravel operations being located farther from high-population centers.

World Mine Production and Reserves:

	Mine production[e]		Reserves[4]
	2018	2019	
United States	121,000	110,000	Large. Industrial sand and gravel deposits are widespread.
Australia	3,000	3,000	
Bulgaria	7,250	7,300	
Canada	2,500	2,500	
France	9,310	9,300	
Germany	7,500	7,500	
India	11,900	12,000	
Indonesia	5,540	5,500	
Italy	14,000	14,000	
Japan	2,520	2,500	
Korea, Republic of	4,300	4,500	
Malaysia	10,000	10,000	
Mexico	2,360	2,400	
Netherlands	54,000	54,000	
New Zealand	2,320	2,300	
Poland	5,120	5,000	
South Africa	2,400	2,400	
Spain	35,500	36,000	
Turkey	13,500	14,000	
United Kingdom	4,000	4,000	
Other countries	17,200	21,300	
World total (rounded)	335,000	330,000	

World Resources: Sand and gravel resources of the world are large. However, because of their geographic distribution, environmental restrictions, and quality requirements for some uses, extraction of these resources is sometimes uneconomic. Quartz-rich sand and sandstone, the main sources of industrial silica sand, occur throughout the world.

Substitutes: Alternative materials that can be used for glassmaking and for foundry and molding sands are chromite, olivine, staurolite, and zircon sands. Although costlier and mostly used in deeper wells, alternative materials that can be used as proppants are sintered bauxite and kaolin-based ceramic proppants.

[e]Estimated. E Net exporter.

[1]See also Sand and Gravel (Construction).

[2]Defined as production (sold or used) + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SCANDIUM[1]

(Data in metric tons of scandium oxide equivalent unless otherwise noted)

Domestic Production and Use: Domestically, scandium was neither mined nor recovered from process streams or mine tailings in 2019. Previously, scandium was produced domestically primarily from the scandium-yttrium silicate mineral thortveitite and from byproduct leach solutions from uranium operations. Limited capacity to produce ingot and distilled scandium metal existed at facilities in Ames, IA; Tolleson, AZ; and Urbana, IL. The principal source for scandium metal and scandium compounds was imports from China. The principal uses for scandium in 2019 were in aluminum-scandium alloys and solid oxide fuel cells (SOFCs). Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Price, yearend, dollars:					
Compounds, per gram:					
Acetate, 99.9% purity, 5-gram sample size[2]	43.00	44.00	44.00	44.00	45.00
Chloride, 99.9% purity, 5-gram sample size[2]	123.00	126.00	124.00	125.00	129.00
Fluoride, 99.9% purity, 1-to-5-gram sample size	[2]263.00	[3]270.00	[3]277.00	[3]206.00	[3]209.00
Iodide, 99.999% purity, 5-gram sample size[2]	187.00	149.00	183.00	165.00	157.00
Oxide, 99.99% purity, 5-kilogram lot size[4]	5.10	4.60	4.60	4.60	3.90
Metal:					
Scandium, distilled dendritic, per gram, 2-gram sample size[2]	221.00	228.00	226.00	226.00	233.00
Scandium, ingot, per gram, 5-gram sample size[2]	134.00	107.00	132.00	132.00	134.00
Scandium-aluminum alloy, per kilogram, metric-ton lot size[4]	220.00	340.00	350.00	360.00	300.00
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2015–18): Although no definitive data exist listing import sources, imported material is mostly from Europe, China, Japan, and Russia.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Rare-earth metals, unspecified, not intermixed or interalloyed	2805.30.0050	5.0% ad val.
Compounds of rare-earth metals:		
Mixtures of oxides of yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of chlorides of yttrium or scandium as the predominant metal	2846.90.2082	Free.
Mixtures of other rare-earth carbonates, including scandium	2846.90.8075	3.7% ad val.
Mixtures of other rare-earth compounds, including scandium	2846.90.8090	3.7% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global supply and consumption of scandium was estimated to be about 15 tons to 20 tons per year. Scandium was recovered from titanium, zirconium, cobalt, and nickel process streams. China, the Philippines, and Russia were the leading producers. Prices quoted for scandium oxide in the United States decreased compared with those in 2018. Owing in part to low capacity utilization, China's ex-works prices for scandium oxide were significantly less than United States quoted prices. Although global exploration and development projects continued in anticipation of increased demand, the global scandium market remained small relative to most other metals.

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SCANDIUM

In the United States, a feasibility study was completed on the polymetallic Elk Creek project in Nebraska. Probable reserves were estimated to be 36 million tons containing 65.7 parts per million (2,400 tons) of scandium. Plans for the project included downstream production of ferroniobium, titanium dioxide, and scandium oxide. The Bokan project in Alaska and the Round Top project in Texas also included scandium recovery in their process plans. In addition, Federal and State agencies were funding the development of methods to separate scandium from coal and coal byproducts.

Globally, several projects were under development while seeking permitting, project financing, and offtake agreements. Reserves at the Nyngan project in New South Wales, Australia, were estimated to be 1.4 million tons containing about 590 tons of scandium. The developer expected to begin commissioning 38.5 tons per year of scandium oxide production capacity in 2021. A definitive feasibility study on the polymetallic Owendale Project in New South Wales was completed in 2018 with the potential to produce 20 tons per year of scandium oxide from reserves of 4.0 million tons containing 570 parts per million scandium (3,500 tons of scandium oxide equivalent). Engineering and design plans for the polymetallic Sunrise Project in New South Wales, continued to advance following an offtake agreement for nickel and cobalt in 2019 and the completion of a definitive feasibility study in 2018. Proven and probable reserves for the Sunrise Project were 147 million tons containing 53 parts per million (7,800 t) scandium. In Queensland, following the completion of a bankable feasibility study on the polymetallic SCONI project in 2018, reserves were updated to 57 million tons containing 35 parts per million (2,000 tons) scandium.

In the Philippines, a plant designed to recover 7.5 tons per year of scandium oxide equivalent began commercial production at the Taganito high-pressure acid-leach nickel operation. An intermediate scandium concentrate was exported to Japan.

In Russia, feasibility studies for making scandium oxide as a byproduct of alumina refining in the Ural Mountains were ongoing. The pilot plant was reported to have produced scandium oxide with purity greater than 99%. Based on pilot test results, plans were in place for a 3-ton-per-year scandium oxide plant. In Dalur, Kurgan region, development of scandium recovery as a byproduct of uranium production continued, and production capacity included scandium oxide (570 kilograms per year) and aluminum-scandium alloy (24.5 tons per year).

In the European Union, recovery methods were being developed to produce scandium compounds and aluminum-scandium alloys from byproducts of aluminum and titanium mining and processing. Globally, several projects were underway to commercialize new aluminum-scandium alloys for casting and additive manufacturing.

World Mine Production and Reserves:[6] No scandium was recovered from mining operations in the United States. As a result of its low concentration, scandium is produced exclusively as a byproduct during processing of various ores or recovered from previously processed tailings or residues. In recent years, scandium was produced as byproduct material in China (iron ore, rare earths, titanium, and zirconium), Kazakhstan (uranium), Philippines (nickel), Russia (apatite and uranium), and Ukraine (uranium). Foreign mine production data for 2019 were not available.

World Resources: Resources of scandium are abundant. Scandium's crustal abundance is greater than that of lead. Scandium lacks affinity for the common ore-forming anions; therefore, it is widely dispersed in the lithosphere and forms solid solutions with low concentrations in more than 100 minerals. Scandium resources have been identified in Australia, Canada, China, Kazakhstan, Madagascar, Norway, the Philippines, Russia, Ukraine, and the United States.

Substitutes: Titanium and aluminum high-strength alloys, as well as carbon-fiber materials, may substitute in high-performance scandium-alloy applications. Light-emitting diodes displace mercury-vapor high-intensity lights in some industrial and residential applications. In some applications that rely on scandium's unique properties, substitution is not possible.

[e]Estimated.

[1]See also Rare Earths. Scandium is one of the 17 rare-earth elements.

[2]Prices from Alfa Aesar, a Johnson Matthey company.

[3]Prices from Sigma-Aldrich, a part of Millipore Sigma.

[4]Prices from Stanford Materials Corp.

[5]Defined as imports – exports. Quantitative data are not available.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

SELENIUM

(Data in metric tons of selenium content unless otherwise noted)

Domestic Production and Use: In 2019, primary selenium was refined from anode slimes recovered from the electrolytic refining of copper at one facility in Texas. Two other electrolytic copper refineries, operating in Arizona and Utah, did not recover selenium domestically. U.S. selenium production and consumption data were withheld to avoid disclosing company proprietary data.

Estimates for world consumption are as follows: metallurgy (including manganese production), 40%; glass manufacturing, 25%; agriculture, 10%; chemicals and pigments, 10%; electronics, 10%; and other uses, 5%.

Selenium is used in blasting caps to control delays; in catalysts to enhance selective oxidation; in copper, lead, and steel alloys to improve machinability; in the electrolytic production of manganese to increase yields; in glass manufacturing to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass; in gun bluing to improve cosmetic appearance and provide corrosion resistance; in plating solutions to improve appearance and durability; in rubber compounding chemicals to act as a vulcanizing agent; and in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells.

Selenium is an essential micronutrient and is used as a human dietary supplement, a dietary supplement for livestock, and as a fertilizer additive to enrich selenium-poor soils. Selenium is also used as an active ingredient in antidandruff shampoos.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, refinery	W	W	W	W	W
Imports for consumption:					
Selenium metal	444	411	450	445	500
Selenium dioxide	14	21	19	12	1
Exports,[1] metal	468	150	242	158	260
Consumption, apparent,[2] metal	W	W	W	W	W
Price, average, dollars per pound[3]	22.09	23.69	10.78	18.97	20.00
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption, metal	E	E	E	<25	<25

Recycling: Domestic production of secondary selenium was estimated to be very small because most scrap from older plain paper photocopiers and electronic materials was exported for recovery of the contained selenium.

Import Sources (2015–18): China, 22%; the Philippines, 17%; Mexico, 13%; Germany, 11%; and other, 37%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Selenium metal	2804.90.0000	Free.
Selenium dioxide	2811.29.2000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The supply of selenium is directly affected by the supply of the materials from which it is a byproduct—copper and, to a lesser extent, nickel—and it is directly affected by the number of facilities that recover selenium. The estimated annual average price for selenium was $20.00 per pound in 2019, about 5% more than the annual average price in 2018. Average monthly prices have remained steady since November 2018.

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SELENIUM

Electrolytic manganese production was the main metallurgical end use for selenium in China, where selenium dioxide was used in the electrolytic process to increase current efficiency and the metal deposition rate. Selenium consumption in China was thought to have increased in recent years; 49 electrolytic manganese producers were reported to have been operating and consuming selenium in 2018 (latest information available), down from 51 reported in 2017.

World Refinery Production and Reserves:

	Refinery production[5]		Reserves[6]
	2018	2019[e]	
United States	W	W	10,000
Belgium	200	200	—
Canada	61	60	6,000
China	930	930	26,000
Finland	100	100	—
Germany	300	300	—
Japan	768	770	—
Peru	45	45	13,000
Poland	76	70	3,000
Russia	150	150	20,000
Sweden	90	50	—
Turkey	50	50	—
Other countries[7]	44	40	21,000
World total (rounded)	[7]2,810	[7]2,800	99,000

World Resources: Reserves for selenium are based on identified copper deposits and average selenium content. Coal generally contains between 0.5 and 12 parts per million of selenium, or about 80 to 90 times the average for copper deposits. The recovery of selenium from coal fly ash, although technically feasible, does not appear likely to be economical in the foreseeable future.

Substitutes: Silicon is the major substitute for selenium in low- and medium-voltage rectifiers. Organic pigments have been developed as substitutes for cadmium sulfoselenide pigments. Other substitutes include cerium oxide as either a colorant or decolorant in glass; tellurium in pigments and rubber; bismuth, lead, and tellurium in free-machining alloys; and bismuth and tellurium in lead-free brasses. Sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal, but it is not as energy efficient.

The selenium-tellurium photoreceptors used in some plain paper copiers and laser printers have been replaced by organic photoreceptors in newer machines. Amorphous silicon and cadmium telluride are the two principal competitors with CIGS in thin-film photovoltaic solar cells.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]There was no exclusive Schedule B number for selenium dioxide exports.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]U.S. spot market price for selenium metal powder, minimum 99.5% purity, in 5-ton lots. Source: Platts Metals Week.

[4]Defined as imports – exports + adjustments for industry stock changes; export data incomplete for common forms of selenium, and may be exported under unexpected or misidentified forms, such as copper slimes, copper selenide, or zinc selenide.

[5]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues, but did not recover refined selenium from these materials indigenously, were excluded to avoid double counting.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production. Australia, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan are known to produce refined selenium, but output was not reported, and information was inadequate to make reliable production estimates.

SILICON

(Data in thousand metric tons of silicon content unless otherwise noted)

Domestic Production and Use: Six companies produced silicon materials at seven plants, all east of the Mississippi River. Most ferrosilicon was consumed in the ferrous foundry and steel industries, predominantly in the Eastern United States, and was sourced primarily from domestic quartzite (silica). The main consumers of silicon metal were producers of aluminum alloys and the chemical industry. The semiconductor and solar energy industries, which manufacture chips for computers and photovoltaic cells from high-purity silicon, respectively, also consumed silicon metal.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Ferrosilicon and silicon metal[1, 2]	411	384	415	430	320
Imports for consumption:					
Ferrosilicon, all grades[1]	162	155	147	140	140
Silicon metal	140	122	136	116	130
Exports:					
Ferrosilicon, all grades[1]	9	7	11	12	10
Silicon metal	37	60	71	45	40
Consumption, apparent:[3]					
Ferrosilicon, all grades[1]	W	W	W	W	W
Silicon metal[2]	W	W	W	W	W
Total	661	601	616	637	560
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% Si[4]	101	83	94	104	100
Ferrosilicon, 75% Si[5]	88	71	87	108	93
Silicon metal[2, 5]	127	91	117	134	110
Stocks, producer, yearend:					
Ferrosilicon and metal[1, 2]	33	26	26	19	20
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades[1]	>50	>50	<50	<50	<50
Silicon metal[2]	<50	<50	<50	<50	<50
Total	38	36	33	32	41

Recycling: Insignificant.

Import Sources (2015–18): Ferrosilicon: Russia, 38%; Canada, 13%; China, 13%; Brazil, 8%; and other, 28%. Silicon metal: Brazil, 28%; Canada, 18%; and other, 54%. Total: Russia, 20%; Brazil, 17%; Canada, 15%; and other, 48%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Silicon, more than 99.99% Si	2804.61.0000	Free.
Silicon, 99.00%–99.99% Si	2804.69.1000	5.3% ad val.
Silicon, other	2804.69.5000	5.5% ad val.
Ferrosilicon, 55%–80% Si:		
More than 3% Ca	7202.21.1000	1.1% ad val.
Other	7202.21.5000	1.5% ad val.
Ferrosilicon, 80%–90% Si	7202.21.7500	1.9% ad val.
Ferrosilicon, more than 90% Si	7202.21.9000	5.8% ad val.
Ferrosilicon, other:		
More than 2% Mg	7202.29.0010	Free.
Other	7202.29.0050	Free.

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SILICON

Depletion Allowance: Quartzite, 14% (Domestic and foreign); gravel, 5% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Combined domestic ferrosilicon and silicon metal production in 2019, expressed in terms of contained silicon, decreased from that of 2018. One producer idled a silicon metal production facility at the end of 2018 to consolidate operations and respond to reduced demand. Domestic production during the first 9 months of 2019 was about 19% less, on a gross-weight basis, than that during the same period in 2018. By September 2019, average U.S. ferrosilicon spot market prices had decreased slightly for 50%-grade ferrosilicon and by 14% for 75%-grade ferrosilicon compared with the annual average spot price in 2018. The average silicon metal spot market price had decreased by 18% compared with the annual average spot price in 2018. Oversupply in the market combined with decreased demand from ferrosilicon and silicon metal consumers contributed to declining prices in 2019.

Excluding the United States, ferrosilicon accounted for about 55% of world silicon production on a silicon-content basis in 2019. Global production for 2018 was revised from the previous year's publication owing to increases in the estimates for production from China. The leading countries for ferrosilicon production were, in descending order and on a contained-weight basis, China, Russia, and Norway. For silicon metal, the leading producers were China, Norway, and Brazil. China accounted for approximately 64% of total global estimated production of silicon materials in 2019.

World Production and Reserves:

	Production[e, 7]		Reserves[8]
	2018	2019	
United States	430	320	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates are not available.
Bhutan[9]	90	90	
Brazil	220	210	
Canada	57	60	
China	4,800	4,500	
France	140	140	
Iceland	83	80	
India[9]	57	60	
Malaysia[9]	140	150	
Norway	370	370	
Poland[9]	43	36	
Russia	600	600	
Spain	69	70	
Ukraine[9]	49	50	
Other countries	290	290	
World total (rounded)	7,400	7,000	

World Resources: World and domestic resources for making silicon metal and alloys are abundant and, in most producing countries, adequate to supply world requirements for many decades. The source of the silicon is silica in various natural forms, such as quartzite.

Substitutes: Aluminum, silicon carbide, and silicomanganese can be substituted for ferrosilicon in some applications. Gallium arsenide and germanium are the principal substitutes for silicon in semiconductor and infrared applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Ferrosilicon grades include the two standard grades of ferrosilicon—50% and 75% silicon—plus miscellaneous silicon alloys.

[2]Metallurgical-grade silicon metal.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]CRU Group transaction prices based on weekly averages.

[5]S&P Global Platts mean import prices based on monthly averages.

[6]Defined as imports – exports + adjustments for industry stock changes.

[7]Production quantities are the silicon content of combined totals for ferrosilicon and silicon metal, except as noted.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Silicon content of ferrosilicon only.

SILVER

(Data in metric tons[1] of silver content unless otherwise noted)

Domestic Production and Use: In 2019, U.S. mines produced approximately 980 tons of silver with an estimated value of $510 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 33 domestic base- and precious-metal operations. Alaska continued as the country's leading silver-producing State, followed by Nevada. There were 24 U.S. refiners that reported production of commercial-grade silver with an estimated total output of 2,500 tons from domestic and foreign ores and concentrates and from new and old scrap. The physical properties of silver include high ductility, electrical conductivity, malleability, and reflectivity. In 2019, the estimated domestic uses for silver were electrical and electronics, 30%; jewelry and silverware, 26%; coins and medals, 12%; photography, 3%; and other, 29%. Other applications for silver include use in antimicrobial bandages, clothing, pharmaceuticals, and plastics; batteries; bearings; brazing and soldering; catalytic converters in automobiles; electroplating; inks; mirrors; photovoltaic solar cells; water purification; and wood treatment. Mercury and silver, the main components of dental amalgam, are biocides, and their use in amalgam inhibits recurrent decay.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Mine	1,090	1,150	1,030	934	980
Refinery:					
Primary	1,530	1,530	1,420	1,420	1,400
Secondary (new and old scrap)	1,100	1,010	1,030	1,050	1,100
Imports for consumption[2]	5,930	6,160	5,040	4,840	4,700
Exports[2]	818	289	157	602	300
Consumption, apparent[3]	6,590	8,040	7,320	6,090	6,500
Price, average, dollars per troy ounce[4]	15.72	17.20	17.07	15.75	16.20
Stocks, yearend:					
Industry	869	866	490	632	630
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	5,000	5,710	7,570	9,140	9,800
Employment, mine and mill, number[6]	1,210	1,190	1,010	961	970
Net import reliance[7] as a percentage of apparent consumption	67	73	72	67	68

Recycling: In 2019, approximately 1,100 tons of silver was recovered from new and old scrap, about 17% of apparent consumption.

Import Sources (2015–18):[2] Mexico, 48%; Canada, 29%; Peru, 5%; Poland, 4%; and other, 14%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Silver ores and concentrates, silver content	2616.10.0040	0.8 ¢/kg on lead content.
Bullion, silver content	7106.91.1010	Free.
Dore, silver content	7106.91.1020	Free.

Depletion Allowance: 15% (Domestic), 14% (Foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of silver (see salient statistics above).

Events, Trends, and Issues: The estimated average silver price in 2019 was $16.20 per troy ounce, 3% higher than the average price in 2018. The price began the year at $15.46 per troy ounce, then decreased to a low of $14.37 per troy ounce on May 28. The price increased to a high of $19.40 per troy ounce on September 4 before trending downward through November.

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SILVER

In 2019, global consumption of silver was estimated to have increased slightly from that of 2018. Coin and bar consumption increased for the third year in a row. Consumption for jewelry and silverware was also estimated to have increased in 2019. Photography and other industrial uses decreased in 2019. Overall, production in the global silver market was estimated to have been greater than consumption in 2019 resulting in an excess supply of silver; however, investor purchases were expected to more than offset the surplus and support the higher silver price.[8]

World silver mine production increased slightly in 2019 to an estimated 27,000 tons, principally as a result of increased production from mines in Argentina, Australia, Mexico, and Poland. Some silver-producing mines in Chile and Peru experienced reductions in production owing to protester blockades and worker strikes. Domestic silver mine production increased by 5% in 2019 compared with that in 2018 principally from increased production at mining operations in Alaska.

World Mine Production and Reserves: Reserves for Australia, Peru, and Poland were revised based on new information from official Government sources.

	Mine production		Reserves[9]
	2018	2019[e]	
United States	934	980	25,000
Argentina	1,020	1,200	NA
Australia	1,220	1,400	[10]90,000
Bolivia	1,190	1,200	22,000
Chile	1,370	1,300	26,000
China	3,570	3,600	41,000
Mexico	6,120	6,300	37,000
Peru	4,160	3,800	120,000
Poland	1,470	1,700	100,000
Russia	2,100	2,100	45,000
Other countries	3,730	3,600	57,000
World total (rounded)	26,900	27,000	560,000

World Resources: Although silver was a principal product at several mines, silver was primarily obtained as a byproduct from lead-zinc mines, copper mines, and gold mines, in descending order of production. The polymetallic ore deposits from which silver was recovered account for more than two-thirds of U.S. and world resources of silver. Most recent silver discoveries have been associated with gold occurrences; however, copper and lead-zinc occurrences that contain byproduct silver will continue to account for a significant share of reserves and resources in the future.

Substitutes: Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for traditional photographic applications for silver. Surgical pins and plates may be made with stainless steel, tantalum, and titanium in place of silver. Stainless steel may be substituted for silver flatware. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles.

[e]Estimated. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Silver content of base metal ores and concentrates, refined bullion, and dore; excludes coinage, and waste and scrap material.

[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.

[4]Engelhard's industrial bullion quotations. Source: Platts Metals Week.

[5]Balance in U.S. Mint only; includes deep storage and working stocks.

[6]Source: U.S. Department of Labor, Mine Safety and Health Administration. Only includes mines where silver is the primary product.

[7]Defined as imports – exports + adjustments for Government and industry stock changes.

[8]DiRienzo, Michael, and Newman, Philip, 2019, Release of Metal Focus interim silver market review—Silver to remain in a small surplus in 2019, but improving investor sentiment will help drive the price higher: Silver Institute and Metal Focus, November 19, 2 p.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant reserves were 25,000 tons.

SODA ASH

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The total value of domestic natural soda ash (sodium carbonate) produced in 2019 was estimated to be about $1.8 billion[1] and U.S. production of 12 million tons was about the same as that of the previous year. The U.S. soda ash industry comprised four companies in Wyoming operating five plants and one company in California with one plant. The five producing companies have a combined annual nameplate capacity of 13.9 million tons (15.3 million short tons). Borax, salt, and sodium sulfate were produced as coproducts of sodium carbonate production in California. Chemical caustic soda, sodium bicarbonate, and sodium sulfite were manufactured as coproducts at several of the Wyoming soda ash plants. Sodium bicarbonate was produced at an operation in Colorado using soda ash feedstock shipped from the company's Wyoming facility.

Based on 2019 quarterly reports, the estimated distribution of soda ash by end use was glass, 47%; chemicals, 30%; distributors, 6%; soap and detergents, 6%; miscellaneous uses, 5%; flue gas desulfurization, 4%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production[2]	11,600	11,800	12,000	11,900	12,000
Imports for consumption	40	35	19	51	100
Exports	6,400	6,760	6,990	6,960	6,900
Consumption:					
Apparent[3]	5,200	5,030	5,040	4,980	5,200
Reported	4,990	5,120	4,910	4,850	4,800
Price:					
Average sales value (natural source):					
f.o.b. mine or plant, dollars per metric ton	155.30	149.83	146.26	148.69	150.00
f.o.b. mine or plant, dollars per short ton	140.88	135.92	132.68	134.89	136.00
Stocks, producer, yearend	285	336	293	297	300
Employment, mine and plant, number[e]	2,500	2,500	2,600	2,600	2,600
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: No soda ash was recycled by producers; however, glass container producers use cullet glass, thereby reducing soda ash consumption.

Import Sources (2015–18): Germany, 28%; Turkey, 25%; Italy, 14%; United Kingdom, 11%; and other, 22%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Disodium carbonate	2836.20.0000	1.2% ad val.

Depletion Allowance: Natural, 14% (Domestic and foreign).

Government Stockpile: None.

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SODA ASH

Events, Trends, and Issues: Relatively low production costs and lower environmental impacts provide natural soda ash producers some advantage over producers of synthetic soda ash. The production of synthetic soda ash normally consumes more energy and releases more carbon dioxide than that of natural soda ash. In recent years, U.S. producers of natural soda ash were able to expand their markets when several synthetic soda ash plants were closed or idled around the world.

Soda ash exports from Turkey increased in 2018 when a 2.5-million-ton-per-year plant opened all of its production lines after several months of operational delays. Some of the exports came to the United States starting in September 2018 and several more relatively large shipments were reported in 2019. Total production capacity in Turkey is estimated to be between 4 million and 5 million tons per year and soda ash shipments, especially for export, are expected to increase significantly during the next few years.

Three groups dominate production and have become the world's leading suppliers of soda ash—American National Soda Ash Corp., which represented three of the five domestic producers in 2019; multiple producers in China; and Solvay S.A. of Belgium. Increasing soda ash exports from Turkey may affect sales from these three groups. The United States likely will remain competitive with producers in China and Turkey for markets elsewhere in Asia. Asia and South America remain the most likely areas for increased soda ash consumption in the near future. U.S. producers expect modest growth in production and exports through 2020.

World Production and Reserves: Reserves for Ethiopia and Turkey were revised based on Government and industry reports.

	Mine production		Reserves[5, 6]
Natural:	2018	2019[e]	
United States	11,900	12,000	[7]23,000,000
Botswana	240	250	400,000
Ethiopia	8	8	400,000
Kenya	300	300	7,000
Turkey	3,400	3,500	900,000
Other countries	NA	NA	280,000
World total, natural (rounded)	16,000	16,000	25,000,000
World total, synthetic (rounded)	41,000	42,000	XX
World total (rounded)	57,000	58,000	XX

World Resources: Natural soda ash is obtained from trona and sodium carbonate-rich brines. The world's largest deposit of trona is in the Green River Basin of Wyoming. About 47 billion tons of identified soda ash resources could be recovered from the 56 billion tons of bedded trona and the 47 billion tons of interbedded or intermixed trona and halite, which are in beds more than 1.2 meters thick. Underground room-and-pillar mining, using conventional and continuous mining, is the primary method of mining Wyoming trona ore. This method has an average 45% mining recovery, whereas average recovery from solution mining is 30%. Improved solution-mining techniques, such as horizontal drilling to establish communication between well pairs, could increase this extraction rate and enable companies to develop some of the deeper trona beds. Wyoming trona resources are being depleted at the rate of about 15 million tons per year (8.3 million tons of soda ash). Searles Lake and Owens Lake in California contain an estimated 815 million tons of soda ash reserves. At least 95 natural sodium carbonate deposits have been identified in the world, only some of which have been quantified. Although soda ash can be manufactured from salt and limestone, both of which are practically inexhaustible, synthetic soda ash is costlier to produce and generates environmental wastes.

Substitutes: Caustic soda can be substituted for soda ash in certain uses, particularly in the pulp and paper, water treatment, and certain chemical sectors. Soda ash, soda liquors, or trona can be used as feedstock to manufacture chemical caustic soda, which is an alternative to electrolytic caustic soda.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable.

[1]Does not include values for soda liquors and mine waters.

[2]Natural only.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]The reported quantities are sodium carbonate only. About 1.8 tons of trona yields 1 ton of sodium carbonate.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]From trona, nahcolite, and dawsonite deposits.

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2019, 1.53 billion tons of crushed stone valued at more than $18.7 billion was produced by an estimated 1,430 companies operating 3,440 quarries and 176 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Pennsylvania, Florida, Missouri, North Carolina, Ohio, Georgia, Virginia, Illinois, and Kentucky, which combined accounted for more than one-half of the total crushed stone output. Of the total domestic crushed stone produced in 2018, about 69% was limestone and dolomite; 15%, granite; 6%, traprock; 5%, miscellaneous stone; 3%, sandstone and quartzite; and the remaining 2% was divided, in descending order of tonnage, among marble, volcanic cinder and scoria, calcareous marl, slate, and shell. It is estimated that of the 1.6 billion tons of crushed stone consumed in the United States in 2019, 72% was used as construction aggregate, mostly for road construction and maintenance; 16% for cement manufacturing; 8% for lime manufacturing; 3% for other chemical, special, and miscellaneous uses and products; and 2% for agricultural uses.

The estimated output of crushed stone in the United States shipped for consumption in the first 9 months of 2019 was 1.14 billion tons, an increase of 8% compared with that of the same period of 2018. Third quarter shipments for consumption increased by 9% compared with those of the same period of 2018. Additional production information, by quarter for each State, geographic division, and the United States, is reported in the U.S. Geological Survey quarterly Mineral Industry Surveys for Crushed Stone and Sand and Gravel.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018[e]**	**2019[e]**
Production	1,340	1,360	1,370	1,420	1,530
Recycled material	48	49	42	48	48
Imports for consumption	20	20	19	21	25
Exports	(2)	1	1	(2)	(2)
Consumption, apparent[3]	1,410	1,430	1,430	1,480	1,600
Price, average value, dollars per metric ton	10.49	11.07	11.45	11.86	12.26
Employment, quarry and mill, number[4]	67,100	68,100	68,600	68,500	67,900
Net import reliance[5] as a percentage of apparent consumption	1	1	1	1	1

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain crushed stone aggregate, were recycled on a limited but increasing basis in most States. In 2019, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2015–18): Mexico, 56%; Canada, 27%; The Bahamas, 11%; Honduras, 5%; and Jamaica, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Chalk:		
Crude	2509.00.1000	Free.
Other	2509.00.2000	Free.
Limestone, except pebbles and gravel	2517.10.0020	Free.
Crushed or broken stone	2517.10.0055	Free.
Marble granules, chippings and powder	2517.41.0000	Free.
Stone granules, chippings and powders	2517.49.0000	Free.
Limestone flux; limestone and other calcareous stone	2521.00.0000	Free.

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STONE (CRUSHED)

Depletion Allowance: (Domestic) 14% for some special uses; 5%, if used as ballast, concrete aggregate, riprap, road material, and similar purposes.

Government Stockpile: None.

Events, Trends, and Issues: Crushed stone production was about 1.53 billion tons in 2019, an increase of 8% compared with that of 2018. Apparent consumption also increased to about 1.60 billion tons. Consumption of crushed stone increased in 2019 because of continued growth in the private and public construction markets. Commercial and heavy industrial construction activity, infrastructure funding, new single-family housing unit starts, and weather, affect growth in crushed stone production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to security measures being implemented around the Nation. The underlying factors that would support a rise in prices of crushed stone are expected to be present in 2020, especially in and near metropolitan areas.

The crushed stone industry continued to be concerned with environmental, health, and safety regulations. Shortages in some urban and industrialized areas are expected to continue to increase owing to local zoning regulations and land-development alternatives. These issues are expected to continue and to cause new crushed stone quarries to locate away from large population centers.

World Mine Production and Reserves:

	Mine production[e]		Reserves[6]
	2018	2019	
United States	1,420	1,530	Adequate, except where special
Other countries[7]	NA	NA	types are needed or where
World total	NA	NA	local shortages exist.

World Resources: Stone resources are plentiful throughout the world. Supply of high-purity limestone and dolomite suitable for specialty uses is limited in many geographic areas. The largest resources of high-purity limestone and dolomite in the United States are in the central and eastern parts of the country.

Substitutes: Crushed stone substitutes for roadbuilding include sand and gravel, and iron and steel slag. Substitutes for crushed stone used as construction aggregates include construction sand and gravel, iron and steel slag, sintered or expanded clay or shale, perlite, or vermiculite. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2019.

[e]Estimated. NA Not available.

[1]See also Sand and Gravel (Construction) and Stone (Dimension).

[2]Less than ½ unit.

[3]Defined as production + recycled material + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Consistent production information is not available for other countries owing to a wide variety of ways in which countries report their crushed stone production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, Volume III, Area Reports: International.

STONE (DIMENSION)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Approximately 2.7 million tons of dimension stone, valued at $440 million, was sold or used by U.S. producers in 2019. Dimension stone was produced by 197 companies operating 250 quarries in 33 States. Leading producer States were, in descending order by tonnage, Texas, Wisconsin, Indiana, Georgia, and Vermont. These five States accounted for about 68% of the production quantity and contributed about 56% of the value of domestic production. Approximately 50%, by tonnage, of dimension stone sold or used was limestone, followed by sandstone (20%), granite (18%), miscellaneous stone (8%), and marble and slate (2% each). By value, the leading sales or uses were for limestone (45%), followed by granite (25%), sandstone (11%), miscellaneous stone (9%), slate (6%), and marble (4%). Rough stone represented 54% of the tonnage and 47% of the value of all the dimension stone sold or used by domestic producers, including exports. The leading uses and distribution of rough stone, by tonnage, were in building and construction (53%) and in irregular-shaped stone (35%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (41%), slabs and blocks for building and construction (12%), and curbing (11%).

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Sold or used by producers:[2]					
Tonnage	2,700	2,960	2,860	2,650	2,700
Value, million dollars	469	448	450	435	440
Imports for consumption, value, million dollars	2,350	2,180	2,120	2,090	1,900
Exports, value, million dollars	75	65	69	70	60
Consumption, apparent, value, million dollars[3]	2,740	2,560	2,500	2,460	2,300
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	4,000	4,000	3,900	3,900	3,900
Net import reliance[5] as a percentage of apparent consumption (based on value)	83	83	82	82	81
Granite only, sold or used by producers:					
Tonnage	585	593	510	483	480
Value, million dollars	130	130	113	108	110
Imports, value, million dollars	1,330	1,100	1,010	915	880
Exports, value, million dollars	27	21	22	19	18
Consumption, apparent, value, million dollars[3]	1,430	1,210	1,100	1,000	970
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	880	880	800	800	800
Net import reliance[5] as a percentage of apparent consumption (based on value)	91	89	90	89	89

Recycling: Small amounts of dimension stone were recycled, principally by restorers of old stone work.

Import Sources (2015–18 by value): All dimension stone: China, 25%; Brazil, 24%; Italy, 21%; Turkey, 16%; and other, 14%. Granite only: Brazil, 45%; China, 24%; India, 16%; Italy, 8%; and other, 7%.

Tariff: Dimension stone tariffs ranged from free to 6.5% ad valorem, according to type, degree of preparation, shape, and size, for countries with normal trade relations in 2019. Most crude or roughly trimmed stone was imported at 3.7% ad valorem or less.

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STONE (DIMENSION)

Depletion Allowance: 14% (Domestic and foreign); slate used or sold as sintered or burned lightweight aggregate, 7.5% (Domestic and foreign); dimension stone used for rubble and other nonbuilding purposes, 5% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The United States remained one of the world's leading markets for dimension stone. In 2019, total imports of dimension stone decreased in value by about 9% compared with the value in 2018. In 2019, steady activity in new residential construction resulted in a slight increase in domestic production of dimension stone compared with that of the previous year. Dimension stone for construction and refurbishment was used in commercial and residential markets; in 2019, the renovation market for existing homes remained steady and unchanged compared with that in the previous year. Dimension stone exports decreased to about $60 million. Apparent consumption, by value, was estimated to be $2.3 billion in 2019—a 7% decrease compared with that of 2018.

The dimension stone industry continued to be concerned with safety and health regulations and environmental restrictions in 2019, especially those concerning crystalline silica exposure. Beginning in 2016, the Occupational Safety and Health Administration (OSHA) finalized new regulations to further restrict exposure to crystalline silica at quarry sites and other industries that use materials containing it. Phased implementation of the new regulations was scheduled to take effect through 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations. On August 14, 2019, OSHA requested comment and information to enable the agency to consider new developments and enhanced control methods for equipment that generates exposures to silica.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2018	2019[e]	
United States	2,650	2,700	Adequate, except for certain
Other countries	NA	NA	special types and local
World total	NA	NA	shortages.

World Resources: Dimension stone resources of the world are sufficient. Resources can be limited on a local level or occasionally on a regional level by the lack of a particular kind of stone that is suitable for dimension purposes.

Substitutes: Substitutes for dimension stone include aluminum, brick, ceramic tile, concrete, glass, plastics, resin-agglomerated stone, and steel.

[e]Estimated. NA Not available.

[1]See also Stone (Crushed).

[2]Includes granite, limestone, and other types of dimension stone.

[3]Defined as sold or used (value) + imports (value) – exports (value).

[4]Excludes office staff.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

STRONTIUM

(Data in metric tons of strontium content unless otherwise noted)

Domestic Production and Use: Although deposits of strontium minerals occur widely throughout the United States, none have been mined in the United States since 1959. Domestic production of strontium carbonate, the principal strontium compound, ceased in 2006. Virtually all of the strontium mineral celestite consumed in the United States since 2006 is thought to have been used as an additive in drilling fluids for oil and natural gas wells. A few domestic companies produced small quantities of downstream strontium chemicals from imported strontium carbonate.

Based on import data, the estimated end-use distribution in the United States for strontium, including celestite and strontium compounds, was, in descending order, drilling fluids, 64%; ceramic ferrite magnets and pyrotechnics and signals, 12% each; and electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass, 3% each.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	24,500	4,420	11,300	16,900	11,000
Strontium compounds[2]	7,100	6,420	6,660	6,350	6,300
Exports, strontium compounds	86	91	36	32	24
Consumption, apparent:[3]					
Celestite	24,500	4,420	11,300	16,900	11,000
Strontium compounds	7,020	6,330	6,620	6,320	6,300
Total	31,500	10,700	17,900	23,200	17,000
Price, average value of celestite imports at port of exportation, dollars per ton	51	78	74	78	79
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2015–18): Celestite: Mexico, 100%. Strontium compounds: Mexico, 53%; Germany, 37%; China, 7%; and other, 3%. Total imports: Mexico, 87%; Germany, 10%; China, 2%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Celestite	2530.90.8010	Free.
Strontium compounds:		
Strontium metal	2805.19.1000	3.7% ad val.
Strontium oxide, hydroxide, peroxide	2816.40.1000	4.2% ad val.
Strontium nitrate	2834.29.2000	4.2% ad val.
Strontium carbonate	2836.92.0000	4.2% ad val.

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STRONTIUM

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Imports of celestite, the most commonly used strontium mineral, decreased by 35% following 2 years of increases. The decrease was likely the result of decreased natural gas- and oil-drilling activity. Nearly all celestite imports were from Mexico and were thought to be used as additives in drilling fluids for oil and natural gas exploration and production. For these applications, celestite is ground but undergoes no chemical processing. A small quantity of high-value celestite imports were reported; these were most likely mineral specimens. Outside the United States, celestite is the raw material from which strontium carbonate and other strontium compounds are produced.

Strontium carbonate is the most commonly traded strontium compound and is used as the raw material from which other strontium compounds are derived. Strontium carbonate is sintered with iron oxide to produce permanent ceramic ferrite magnets, and strontium nitrate contributes a brilliant red color to fireworks and signal flares. Smaller quantities of these and other strontium compounds were consumed in several other applications, including electrolytic production of zinc, glass production, master alloys, and pigments and fillers.

World Mine Production and Reserves:[4]

	Mine production		Reserves[5]
	2018[e]	2019[e]	
United States	—	—	—
Argentina	700	700	All other:
China	50,000	50,000	6,800,000
Iran	37,000	37,000	
Mexico	40,000	40,000	
Spain	90,000	90,000	
Turkey	1,000	1,000	
World total (rounded)	220,000	220,000	6,800,000

World Resources: World resources of strontium are thought to exceed 1 billion tons.

Substitutes: Barium can be substituted for strontium in ferrite ceramic magnets; however, the resulting barium composite will have reduced maximum operating temperature when compared with that of strontium composites. Substituting for strontium in pyrotechnics is hindered by difficulty in obtaining the desired brilliance and visibility imparted by strontium and its compounds. In drilling mud, barite is the preferred material, but celestite may substitute for some barite, especially when barite prices are high.

[e]Estimated. — Zero.

[1]The strontium content of celestite is 43.88%, assuming an ore grade of 92%, which was used to convert units of celestite to strontium content.

[2]Strontium compounds, with their respective strontium contents, in descending order, include metal (100.00%); oxide, hydroxide, and peroxide (70.00%); carbonate (59.35%); and nitrate (41.40%). These factors were used to convert gross weight of strontium compounds to strontium content.

[3]Defined as imports − exports.

[4]Gross weight of celestite in tons.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

SULFUR

(Data in thousand metric tons of sulfur content unless otherwise noted)

Domestic Production and Use: In 2019, recovered elemental sulfur and byproduct sulfuric acid were produced at 95 operations in 27 States. Total shipments were valued at about $440 million. Elemental sulfur production was estimated to be 8.2 million tons; Louisiana and Texas accounted for about 55% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 35 companies at 90 plants in 26 States. Byproduct sulfuric acid, representing about 7% of production of sulfur in all forms, was recovered at five nonferrous-metal smelters in four States by four companies. Domestic elemental sulfur provided 62% of domestic consumption, and byproduct acid accounted for about 6%. The remaining 32% of sulfur consumed was provided by imported sulfur and sulfuric acid. About 90% of sulfur consumed was in the form of sulfuric acid.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production:					
Recovered elemental	8,890	9,070	9,070	9,010	8,200
Other forms	646	673	575	670	620
Total (rounded)	9,540	9,740	9,640	9,680	8,800
Shipments, all forms	9,560	9,750	9,700	9,690	8,800
Imports for consumption:					
Recovered, elemental[e]	2,240	1,820	1,850	2,230	2,000
Sulfuric acid, sulfur content	1,160	1,050	954	997	980
Exports:					
Recovered, elemental	1,850	2,060	2,340	2,390	2,300
Sulfuric acid, sulfur content	58	59	80	112	70
Consumption, apparent, all forms[1]	11,000	10,500	10,000	10,400	9,400
Price, reported average value, dollars per ton of elemental sulfur, f.o.b., mine and (or) plant	87.62	37.88	46.40	70.00	50.00
Stocks, producer, yearend	138	144	124	122	110
Employment, mine and (or) plant, number	2,600	2,500	2,400	2,400	2,400
Net import reliance[2] as a percentage of apparent consumption	14	7	4	7	7

Recycling: Typically, between 2.5 million and 5 million tons of spent sulfuric acid is reclaimed from petroleum refining and chemical processes during any given year.

Import Sources (2015–18): Elemental: Canada, 77%; Russia, 10%; Kazakhstan, 5%; Mexico, 3%; and other, 5%. Sulfuric acid: Canada, 63%; Mexico, 19%; and other, 18%. Total sulfur imports: Canada, 72%; Mexico 9%; Russia, 7%; Kazakhstan, 3%; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Sulfur, crude or unrefined	2503.00.0010	Free.
Sulfur, all kinds, other	2503.00.0090	Free.
Sulfur, sublimed or precipitated	2802.00.0000	Free.
Sulfuric acid	2807.00.0000	Free.

Depletion Allowance: 22% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Total U.S. sulfur production in 2019 was estimated to have decreased by 9% from that of 2018 and shipments also decreased by 9% from those of 2018. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations decreased by 9%. A decline in refinery operating utilization and processing of more sweet crude oil likely lead to decreased production. Domestically, refinery sulfur production is expected to remain relatively constant as well as byproduct sulfuric acid, unless one or more of the remaining nonferrous-metal smelters close.

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SULFUR

Domestic phosphate rock consumption in 2019 was estimated to be slightly lower than that in 2018, which resulted in decreased consumption of sulfur to process the phosphate rock into phosphate fertilizers.

World sulfur production was about the same as it was in 2018 but is likely to steadily increase for the foreseeable future. New sulfur demand associated with phosphate fertilizer projects is expected in west Asia and Africa. A major change for 2020 will be the implementation of new international standards limiting sulfur oxide emissions from ships on January 1, 2020. The global sulfur content of marine fuels would be limited to 0.5% sulfur content from 3.5% sulfur content, likely leading to increased sulfur production in North America, Asia, and Europe.

Contract sulfur prices in Tampa, FL, began 2019 at around $140 per ton. The sulfur price continued to decrease throughout the year and reached about $46 per ton in early October, the lowest price since 2009. The price decrease was a result of a weak phosphate fertilizer market. Prices for exported sulfur were higher than domestic prices. In the past few years, sulfur prices have been variable, a result of the volatility in the demand for sulfur.

World Production and Reserves:

	Production—All forms		Reserves[3]
	2018	2019[e]	
United States	9,680	8,800	Reserves of sulfur in crude oil, natural gas, and sulfide ores are large. Because most sulfur production is a result of the processing of fossil fuels, supplies should be adequate for the foreseeable future. Because petroleum and sulfide ores can be processed long distances from where they are produced, sulfur production may not be in the country to which the reserves were attributed. For instance, sulfur from Saudi Arabian oil may be recovered at refineries in the United States.
Australia	900	900	
Brazil	500	500	
Canada	5,320	5,300	
Chile	1,500	1,500	
China[4]	17,400	17,400	
Finland	940	940	
Germany	868	870	
India	3,430	3,400	
Iran	2,200	2,200	
Italy	550	550	
Japan	3,400	3,400	
Kazakhstan	3,510	3,600	
Korea, Republic of	3,080	3,100	
Kuwait	850	900	
Netherlands	520	520	
Poland	1,230	1,230	
Qatar	2,000	2,100	
Russia	7,080	7,100	
Saudi Arabia	6,500	6,600	
United Arab Emirates	3,300	3,400	
Venezuela	700	700	
Other countries	3,930	3,900	
World total (rounded)	79,400	79,000	

World Resources: Resources of elemental sulfur in evaporite and volcanic deposits, and sulfur associated with natural gas, petroleum, tar sands, and metal sulfides, total about 5 billion tons. The sulfur in gypsum and anhydrite is almost limitless, and 600 billion tons of sulfur is contained in coal, oil shale, and shale rich in organic matter. Production from these sources would require development of low-cost methods of extraction. The domestic sulfur resource is about one-fifth of the world total.

Substitutes: Substitutes for sulfur at present or anticipated price levels are not satisfactory; some acids, in certain applications, may be substituted for sulfuric acid, but usually at a higher cost.

[e]Estimated.

[1]Defined as production + imports – exports + adjustments for industry stock changes.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]China sulfur production includes byproduct elemental sulfur recovered from natural gas and petroleum, the estimated sulfur content of byproduct sulfuric acid from metallurgy, and the sulfur content of sulfuric acid from pyrite.

TALC AND PYROPHYLLITE[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Three companies operated five talc-producing mines in three States during 2019, and domestic production of crude talc was estimated to have decreased by 3% to 630,000 tons valued at almost $24 million. Montana was the leading producer State, followed by Texas and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 570,000 tons valued at $120 million, a slight increase from those in 2018. Talc produced and sold in the United States was used in paint (23%), ceramics (including automotive catalytic converters) (20%), paper (15%), plastics (12%), rubber (4%), roofing (3%), and cosmetics (2%). The remaining 21% was for export, insecticides, refractories, and other miscellaneous uses.

One company in North Carolina mined and processed pyrophyllite in 2019. Domestic production was withheld in order to avoid disclosing company proprietary data and was estimated to have decreased from that in 2018. Pyrophyllite was sold for refractory, paint, and ceramic products.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, mine	615	578	610	[e]650	630
Sold by producers	535	528	528	[e]550	570
Imports for consumption	322	378	354	313	310
Exports	206	239	220	273	240
Consumption, apparent[2]	651	668	662	[e]590	640
Price, average, milled, dollars per metric ton[3]	186	197	214	226	230
Employment, mine and mill, talc[4]	239	223	206	208	206
Employment, mine and mill, pyrophyllite[4]	29	30	31	30	31
Net import reliance[5] as a percentage of apparent consumption	22	27	20	7	11

Recycling: Insignificant.

Import Sources (2015–18): Pakistan, 41%; Canada, 27%; China, 21%; and other, 11%. Large quantities of crude talc are thought to have been mined in Afghanistan before being milled in and exported from Pakistan.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Natural steatite and talc:		
Not crushed, not powdered	2526.10.0000	Free.
Crushed or powdered	2526.20.0000	Free.
Talc, steatite, and soapstone; cut or sawed	6815.99.2000	Free.

Depletion Allowance: Block steatite talc: 22% (Domestic), 14% (Foreign). Other talc and pyrophyllite: 14% (Domestic and foreign).

Government Stockpile: None.

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TALC AND PYROPHYLLITE

Events, Trends, and Issues: Canada, China, and Pakistan were the principal sources for United States talc imports in recent years. Imports from Pakistan increased significantly in recent years and imports from China dropped to about one-third of previous levels. In 2019, imports from China stayed near 2018 levels and imports from Pakistan increased by about 16% compared to those of the previous year. Canada and Mexico continued to be the primary destinations for United States talc exports, collectively receiving about one-half of exports. U.S. talc production decreased in 2019 from that of 2018 but was still the second-highest level of production during the past 5 years. Apparent consumption was relatively flat for 4 consecutive years through 2017 but decreased in 2018 before increasing in 2019.

Ceramic tile and sanitaryware formulations and the technology for firing ceramic tile changed over recent decades, reducing the amount of talc required for the manufacture of some ceramic products. For paint, the industry shifted its focus to production of water-based paint (a product for which talc is not well suited because it is hydrophobic) from oil-based paint, in order to reduce volatile emissions. Paper manufacturing began to decrease beginning in the 1990s, and some talc used for pitch control was replaced by chemical agents. For cosmetics, manufacturers of body dusting powders shifted some of their production from talc-based to corn-starch-based products. The paper industry has traditionally been the largest consumer of talc worldwide; however, plastics are expected to overtake paper as the predominant end use within the next several years, as papermakers in Asia make greater use of talc substitutes and as the use of talc in automobile plastics increases.

World Mine Production and Reserves: Reserves for Brazil, India, and the Republic of Korea were revised based on Government and industry sources.

	Mine production[e]		Reserves[6]
	2018	2019	
United States (crude)	650	630	140,000
Brazil (crude and beneficiated)[7]	660	650	45,000
Canada (unspecified minerals)	210	210	NA
China (unspecified minerals)	1,800	1,800	82,000
Finland	380	370	Large
France (crude)	450	450	Large
India[7]	920	950	130,000
Italy (includes steatite)	170	170	NA
Japan[7]	160	160	100,000
Korea, Republic of[7]	350	350	100,000
Other countries (includes crude)[7]	815	820	Large
World total (rounded)[7]	6,600	6,600	Large

World Resources: The United States is self-sufficient in most grades of talc and related minerals, but lower priced imports have replaced domestic minerals for some uses. Talc occurs in the United States from New England to Alabama in the Appalachian Mountains and the Piedmont region, as well as in California, Montana, Nevada, Texas, and Washington. Domestic and world identified resources are estimated to be approximately five times the quantity of reserves.

Substitutes: Substitutes for talc include bentonite, chlorite, feldspar, kaolin, and pyrophyllite in ceramics; chlorite, kaolin, and mica in paint; calcium carbonate and kaolin in paper; bentonite, kaolin, mica, and wollastonite in plastics; and kaolin and mica in rubber.

[e]Estimated. NA Not available.

[1]All statistics exclude pyrophyllite unless otherwise noted.

[2]Defined as sold by producers + imports – exports.

[3]Average ex-works unit value of milled talc sold by U.S. producers, based on data reported by companies.

[4]Includes only companies that mine talc or pyrophyllite. Excludes office workers and mills that process imported or domestically purchased material.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Includes pyrophyllite.

TANTALUM

(Data in metric tons of tantalum content unless otherwise noted)

Domestic Production and Use: Significant U.S. tantalum mine production has not been reported since 1959. Domestic tantalum resources are of low grade, some are mineralogically complex, and most are not commercially recoverable. Companies in the United States produced tantalum alloys, capacitors, carbides, compounds, and tantalum metal from imported tantalum ores and concentrates and tantalum-containing materials. Tantalum metal and alloys were recovered from foreign and domestic scrap. Domestic tantalum consumption was not reported by consumers. Major end uses for tantalum included alloys for gas turbines used in the aerospace and oil and gas industries; tantalum capacitors for automotive electronics, mobile phones, and personal computers; tantalum carbides for cutting and boring tools; and tantalum oxide (Ta_2O_5) was used in glass lenses to make lighter weight camera lenses that produce a brighter image. The value of tantalum consumed in 2019 was estimated to exceed $270 million as measured by the value of imports.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,240	1,060	1,460	1,660	1,300
Exports[1]	657	604	549	681	440
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent[2]	587	460	907	978	870
Price, tantalite, dollars per kilogram of Ta_2O_5 content[3]	193	193	193	214	162
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-containing electronic components, and from tantalum-containing cemented carbide and superalloy scrap. The amount of tantalum recycled was not available, but it may be as much as 30% of apparent consumption.

Import Sources (2015–18): Tantalum ores and concentrates: Rwanda, 39%; Brazil, 20%; Australia, 17%; Congo (Kinshasa), 10%; and other, 14%. Tantalum metal and powder: China, 39%; Germany, 19%; Kazakhstan, 14%; Thailand, 12%; and other, 16%. Tantalum waste and scrap: Mexico, 14%; Austria, 11%; Japan, 10%; Germany, 9%; and other, 56%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Tantalum ores and concentrates	2615.90.6060	Free.
Tantalum oxide[5]	2825.90.9000	3.7% ad val.
Potassium fluorotantalate[5]	2826.90.9000	3.1% ad val.
Tantalum, unwrought:		
Powders	8103.20.0030	2.5% ad val.
Alloys and metal	8103.20.0090	2.5% ad val.
Tantalum, waste and scrap	8103.30.0000	Free.
Tantalum, other	8103.90.0000	4.4% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[6]

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Tantalum carbide powder	1.71	—	1.71	—	1.71
Tantalum metal[7] (gross weight)	0.084	15.4	0.09	15.4	0.09
Tantalum alloy (gross weight)	0.0015	—	—	—	—

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TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption (measured in contained tantalum) was estimated to have decreased by 11% from that of 2018. U.S. imports for consumption decreased by 21% from those of 2018. U.S. domestic exports decreased by 35% from those of 2018. The overall decrease in tantalum trade in 2019 was attributed to decreases in the trade of tantalum ores and concentrates (43% decrease in exports; 26% decrease in imports) and tantalum scrap (60% decrease in exports; 28% decrease in imports). Congo (Kinshasa) and Rwanda accounted for 60% of estimated global tantalum production in 2019.

In 2019, the average monthly price of tantalum ore decreased to about $158 per kilogram of Ta_2O_5 content in October from about $173 per kilogram of Ta_2O_5 content in January. This average monthly price in 2019 represented a decrease of about 26% from the average monthly price in 2018. The decrease in tantalum ore prices in 2019 was largely driven by an increasing supply of low-cost byproduct tantalum concentrates from two lithium operations in Western Australia. However, in August one of the two producing companies began scaling back operations and planned to place its Bald Hill Mine on care-and-maintenance status owing to slower than expected demand growth for lithium and a sharp decline in lithium prices between 2018 and 2019. The second company, which operated the Pilgangoora project, postponed a planned yearend 2019 expansion that would have more than doubled its lithium and tantalum production capacities.

In July, a specialty metals processor in Estonia suspended its niobium and tantalum recovery operations. The company reached its limit for onsite storage of the radioactive tailings that were produced during recovery of niobium and tantalum. The Ministry of Environment of Estonia required the company to have an agreement for offsite storage or disposal of the radioactive tailings before it could resume recovery operations.

World Mine Production and Reserves: Reserves for Australia were revised based on Government and industry information.

	Mine production		Reserves[8]
	2018	2019[e]	
United States	—	—	—
Australia	23	20	[9]55,000
Brazil	250	250	34,000
Burundi	23	32	NA
China	90	100	NA
Congo (Kinshasa)	740	740	NA
Ethiopia	70	40	NA
Nigeria	200	210	NA
Russia	38	38	NA
Rwanda	421	370	NA
Other countries	40	39	NA
World total (rounded)	1,890	1,800	>90,000

World Resources: Identified world resources of tantalum, most of which are in Australia, Brazil, and Canada, are considered adequate to supply projected needs. The United States has about 55,000 tons of tantalum resources in identified deposits, most of which were considered uneconomic at 2019 prices for tantalum.

Substitutes: The following materials can be substituted for tantalum, but a performance loss or higher costs may ensue: niobium and tungsten in carbides; aluminum, ceramics, and niobium in electronic capacitors; glass, molybdenum, nickel, niobium, platinum, stainless steel, titanium, and zirconium in corrosion-resistant applications; and hafnium, iridium, molybdenum, niobium, rhenium, and tungsten in high-temperature applications.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated tantalum content of niobium and tantalum ores and concentrates, unwrought tantalum alloys and powder, tantalum waste and scrap, and other tantalum articles. Synthetic concentrates and niobium ores and concentrates were assumed to contain 32% Ta_2O_5. Tantalum ores and concentrates were assumed to contain 37% Ta_2O_5. Ta_2O_5 is 81.897% Ta.

[2]Defined as production + imports – exports + adjustments for Government stock changes.

[3]Price is annual average price reported by CRU Group. Estimate for 2019 includes data through October 2019.

[4]Defined as imports – exports + adjustments for Government stock changes.

[5]This category includes tantalum-containing material and other material.

[6]See Appendix B for definitions.

[7]Potential acquisitions are for unspecified tantalum materials; potential disposals are for tantalum scrap in the Government stockpile.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 14,000 tons.

TELLURIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2019, no tellurium was produced in the United States. One firm in Texas was thought to export copper anode slimes to Mexico for recovery of commercial-grade tellurium. Downstream companies further refined imported commercial-grade metal to produce tellurium dioxide, high-purity tellurium, and tellurium compounds for specialty applications.

Tellurium was predominantly used in the production of cadmium telluride (CdTe) for thin-film solar cells. Another important end use was for the production of bismuth telluride (BiTe), which is used in thermoelectric devices for both cooling and energy generation. Other uses were as an alloying additive in steel to improve machining characteristics, as a minor additive in copper alloys to improve machinability without reducing conductivity, in lead alloys to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. It was used in the chemical industry as a vulcanizing agent and accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production. Other uses included those in photoreceptor and thermoelectric devices, blasting caps, and as a pigment to produce various colors in glass and ceramics.

Global consumption estimates of tellurium by end use are solar, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, refinery	—	—	—	—	—
Imports for consumption	76	73	163	192	50
Exports	41	3	2	4	1
Consumption, apparent[1]	W	W	W	W	W
Price, dollars per kilogram[2]	79	36	38	80	70
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[3] as a percentage of apparent consumption	>95	>95	>95	>95	>95

Recycling: For traditional metallurgical and chemical uses, there was little or no old scrap from which to extract secondary tellurium because these uses of tellurium are highly dispersive or dissipative. A very small amount of tellurium was recovered from scrapped selenium-tellurium photoreceptors employed in older plain-paper copiers in Europe. A plant in the United States recycled tellurium from CdTe solar cells; however, the amount recycled was limited because most CdTe solar cells were relatively new and had not reached the end of their useful life.

Import Sources (2015–18): Canada, 64%; China, 25%; Germany, 7%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic tellurium production was estimated to have remained essentially unchanged from that in 2018. One domestic producer of anode slimes shipped at least a portion of its anode slimes to Mexico for treatment and refining. World production of tellurium in 2019 was estimated to be about 470 tons. In 2019, the domestic average monthly price of tellurium generally decreased in the first 10 months of the year, from around $80 per kilogram in January to $65 per kilogram in October.

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TELLURIUM

Domestic imports of tellurium were estimated to have decreased by about 74% in 2019 from those of 2018, mostly as a result of a significant decrease in imports from China and Canada. During the first 8 months of 2019, the United States imported 2 tons of tellurium from Canada and 0.3 tons of tellurium from China. During the same period of 2018, the United States imported 99 tons of tellurium from Canada and 7 tons of tellurium from China.

China was the leading producer of refined tellurium, recovering tellurium from copper anode slimes and from residues generated during the lead, nickel, precious metals, and zinc smelting processes.

The Yunnan Provincial government in China announced an auction of 170 tons of tellurium from the defunct Fanya Metal Exchange (FME) with a starting price of $43 per kilogram (306 yuan per kilogram), or a total lot bid of $7.34 million (51.95 million yuan).

A solar cell manufacturer in Germany announced in April that it would increase production rate of CdTe solar cells to 60 megawatts per year after finding a new investor in July 2018.

World Refinery Production and Reserves: The figures shown for reserves include only tellurium contained in copper reserves. These estimates assume that more than one-half of the tellurium contained in unrefined copper anodes is recoverable.

	Refinery production[e]		Reserves[4]
	2018	2019	
United States	—	—	3,500
Bulgaria	5	5	NA
Canada	25	30	800
China	280	290	6,600
Japan	58	55	—
Russia	42	40	NA
South Africa	6	5	—
Sweden	45	40	670
Other countries[5]	NA	NA	19,000
World total (rounded)	460	470	31,000

World Resources: Data on tellurium resources were not available. More than 90% of tellurium has been produced from anode slimes collected from electrolytic copper refining, and the remainder was derived from skimmings at lead refineries and from flue dusts and gases generated during the smelting of bismuth, copper, and lead-zinc ores. Potential sources of tellurium include bismuth telluride and gold telluride ores.

Substitutes: Several materials can replace tellurium in most of its uses, but usually with losses in efficiency or product characteristics. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and (or) selenium can act as vulcanization agents in place of tellurium. The selenides and sulfides of niobium and tantalum can serve as electrical-conducting solid lubricants in place of tellurides of those metals.

The selenium-tellurium photoreceptors used in some plain paper photocopiers and laser printers have been replaced by organic photoreceptors in newer devices. Amorphous silicon and copper indium gallium selenide were the two principal competitors of CdTe in thin-film photovoltaic solar cells. Bismuth selenide and organic polymers can be used to substitute for some BiTe thermal devices.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as production + imports – exports + adjustments for industry stock changes.

[2]Average annual price. Source: Argus Media group–Argus Metals International for 99.95% tellurium, free on board, U.S. warehouses.

[3]Defined as imports – exports + adjustments for industry stock changes.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]In addition to the countries listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland produced refined tellurium, but output was not reported and available information was inadequate to make reliable production and reserves estimates.

THALLIUM

(Data in kilograms unless otherwise noted)

Domestic Production and Use: The value of consumption of thallium metal and thallium compounds was estimated to be about $300,000. The primary end uses included the following: radioactive thallium-201 used for medical purposes in cardiovascular imaging; thallium as an activator (sodium iodide crystal doped with thallium) in gamma radiation detection equipment (scintillometer); thallium-barium-calcium-copper-oxide high-temperature superconductor used in filters for wireless communications; thallium in lenses, prisms, and windows for infrared detection and transmission equipment; thallium-arsenic-selenium crystal filters for light diffraction in acousto-optical measuring devices; and thallium in mercury alloys for low-temperature measurements. Other uses include: as an additive in glass to increase its refractive index and density, a catalyst for organic compound synthesis, and a component in high-density liquids for gravity separation of minerals.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	—	—	—	—	—
Waste and scrap	—	—	—	23	30
Other articles	334	193	—	41	40
Exports:					
Unwrought metal and powders	104	56	34	100	230
Waste and scrap	1,450	286	364	853	110
Other articles	1,070	973	1,560	[1]31,400	[1]79,000
Consumption, estimated[2]	334	193	—	64	70
Price, metal, dollars per kilogram[e, 3]	7,400	7,400	NA	NA	7,600
Net import reliance[4] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2015–18): Russia, 53%; Germany, 33%; China, 8%; and the United Kingdom, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Unwrought and powders	8112.51.0000	4.0% ad val.
Waste and scrap	8112.52.0000	Free.
Other	8112.59.0000	4.0% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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THALLIUM

Events, Trends, and Issues: In 2019, imports of thallium waste and scrap increased by 30% and imports of other thallium articles were essentially unchanged compared with 2018. Most imports of other thallium articles from 2015 to 2018 came into the Cleveland, OH, customs district. In 2019, imports came into the Dallas-Fort Worth, TX, customs district. Exports of unwrought thallium and powders more than doubled in 2019 compared with 2018. All exports of unwrought thallium and powders left the New Orleans, LA, customs district and 58% went to Taiwan and 42% went to Germany. All exports of thallium waste and scrap went to Mexico in 2019. In 2018 and 2019, there was a significant increase in the export quantity of other thallium articles (Schedule B number 8112.59.0000) as reported by the U.S. Census Bureau. In 2018, most of the exports of other thallium articles left from the Charleston, SC, customs district and were shipped to Colombia. In 2019, most of the exports of other thallium articles left from the customs districts of New York, NY, and Norfolk, VA. The exports from both ports were shipped to Egypt and the average unit value was extremely low. It is possible items may have been misclassified.

Demand for thallium for use in cardiovascular-imaging applications has declined owing to superior performance and availability of alternatives, such as the medical isotope technetium-99. A global shortage of technetium-99 from 2009 to 2011 had contributed to an increase in thallium consumption during that time period. Since 2011, consumption of thallium has declined significantly. Small quantities of thallium are used for research.

The leading global uses for thallium were photoelectric cells, infrared optical materials, and low melting glasses. Many producers of these products were in China, Japan, and the Republic of Korea.

Thallium metal and its compounds are highly toxic materials and are strictly controlled to prevent harm to humans and the environment. Thallium and its compounds can be absorbed into the human body by skin contact, ingestion, or inhalation of dust or fumes. Under its national primary drinking water regulations for public water supplies, the U.S. Environmental Protection Agency has set an enforceable Maximum Contaminant Level of 2 parts per billion thallium in drinking water.

World Refinery Production and Reserves:[5] Thallium is produced commercially in only a few countries as a byproduct in the roasting of copper, lead, and zinc ores and is recovered from flue dust. Because most producers withhold thallium production data, global production data are limited. In 2019, global production of thallium was estimated to be less than 8,000 kilograms. China, Kazakhstan, and Russia were thought to be leading producers of primary thallium. Since 2005, substantial thallium-rich deposits have been identified in Brazil, China, North Macedonia, and Russia.

World Resources: Although thallium is reasonably abundant in the Earth's crust, estimated at about 0.7 part per million, it exists mostly in association with potassium minerals in clays, granites, and soils, and it is not generally considered to be commercially recoverable from those materials. The major source of recoverable thallium is the trace amounts found in copper, lead, zinc, and other sulfide ores. Quantitative estimates of reserves are not available, owing to the difficulty in identifying deposits where thallium can be extracted economically. Previous estimates of reserves were based on the thallium content of zinc ores. World resources of thallium contained in zinc resources could be as much as 17 million kilograms; most are in Canada, Europe, and the United States. Global resources of coal contain an estimated 630 million kilograms of thallium.

Substitutes: Although other materials and formulations can substitute for thallium in gamma radiation detection equipment and optics used for infrared detection and transmission, thallium materials are presently superior and more cost effective for these very specialized uses. The medical isotope technetium-99 can be used in cardiovascular-imaging applications instead of thallium.

Nonpoisonous substitutes, such as tungsten compounds, are being marketed as substitutes for thallium in high-density liquids for gravity separation of minerals.

[e]Estimated. NA Not available. — Zero.

[1]Includes material that may have been misclassified.

[2]Estimated to be equal to imports.

[3]Estimated price of 99.99%-pure granules in 100 gram lots.

[4]Defined as imports – exports. Consumption and exports of unwrought thallium were from imported material or from a drawdown in unreported inventories.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

THORIUM

[Data in kilograms gross weight unless otherwise noted]

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2019, monazite may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Essentially, all thorium compounds and alloys consumed by the domestic industry were derived from imports. The number of companies that processed or fabricated various forms of thorium for commercial use was not available. Thorium's use in most products was generally limited because of concerns over its naturally occurring radioactivity. Imports of thorium compounds are sporadic owing to changes in consumption and fluctuations in consumer inventory levels. The estimated value of thorium compounds imported for consumption by the domestic industry in 2019 was about $533,000, compared with $567,000 in 2018.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, mine[1]	—	NA	NA	[e, 2]500,000	[2]1,200,000
Imports for consumption:					
Thorium ore and concentrates (monazite)	—	16,000	—	1,000	1,000
Thorium compounds (oxide, nitrate, etc.)	2,740	3,120	8,510	9,000	8,300
Exports:					
Thorium ore and concentrates (monazite)	—	NA	NA	520,000	1,200,000
Thorium compounds (oxide, nitrate, etc.)	[3]2,700	[3]6,000	[3]6,100	[3]3,000	[3]3,200
Consumption, apparent:[4]					
Thorium ore and concentrates (monazite)	—	16,000	—	([5])	1,000
Thorium compounds (oxide, nitrate, etc.)	40	([5])	2,410	6,000	5,100
Value, thorium compounds, gross weight, dollars per kilogram, India[6]	63	65	73	72	72
Net import reliance[7] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2015–18): Monazite: Canada, 100%. Thorium compounds: India, 89%; France 9%; and the United Kingdom, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Thorium ores and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad val.

Depletion Allowance: Monazite, 22% on thorium content, and 14% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile: None.

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THORIUM

Events, Trends, and Issues: Domestic demand for thorium alloys, compounds, and metals was limited. In addition to research purposes, various commercial uses of thorium included catalysts, high-temperature ceramics, magnetrons in microwave ovens, metal-halide lamps, nuclear medicine, optical coatings, tungsten filaments, and welding electrodes.

India maintained its position as the primary source of imported thorium compounds in 2019. The unit value of imports from India remained unchanged from 2018 at $72 per kilogram.

Exports of unspecified thorium compounds were 3,200 kilograms in 2019; however, 33% of the exports were reported to have a unit value of less than $50 per kilogram and may have been misclassified. Owing to potentially misclassified material and variations in the type and purity of thorium compound, the unit value of exports varied widely by month and by exporting customs district.

Globally, monazite was produced primarily for its rare-earth-element content, and only a small fraction of the byproduct thorium produced was consumed. India was the leading producer of monazite. Construction began at the Eneabba mineral sands project in Australia with production slated for 2020. Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. In international trade, China was the leading importer of monazite; Brazil, Madagascar, Thailand, and Vietnam were China's leading import sources.

Several companies and countries were active in the pursuit of commercializing thorium as a fuel material for a new generation of nuclear reactors. Thorium-based nuclear research and development programs have been or are underway in Belgium, Brazil, Canada, China, Czechia, France, Germany, India, Israel, Japan, the Netherlands, Norway, Russia, the United Kingdom, and the United States.

World Refinery Production and Reserves:[8] Production and reserves are associated with the recovery of monazite in heavy-mineral-sand deposits. Without demand for the rare earths, monazite would probably not be recovered for its thorium content under current market conditions.

World Resources: The world's leading thorium resources are found in placer, carbonatite, and vein-type deposits. Thorium is found in several minerals, including monazite, thorite, and thorianite. According to the Organisation for Economic Co-operation and Development's Nuclear Energy Agency, worldwide identified thorium resources were estimated to total 6.4 million tons of thorium. Thorium resources are found throughout the world, most notably in Australia, Brazil, India, and the United States. India has the largest resources (850,000 tons), followed by Brazil (630,000 tons), and Australia and the United States (600,000 tons each).

Substitutes: Nonradioactive substitutes have been developed for many applications of thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, yttrium, and zirconium can substitute for magnesium-thorium alloys in aerospace applications. Cerium and lanthanum can substitute for thorium in welding electrodes.

[e]Estimated. NA Not Available. — Zero.

[1]Monazite may have been produced as a separate concentrate or included as an accessory mineral in heavy-mineral concentrates.

[2]Estimates based on exports.

[3]Includes material that may have been misclassified.

[4]Defined as production + imports – exports. Shown separately for ores and concentrates and for compounds. Production is only for ores and concentrates.

[5]The apparent consumption calculation yields negative values for thorium compounds in 2016 and for thorium ores and concentrates in 2018.

[6]Based on U.S. Census Bureau customs data.

[7]Defined as imports – exports; however, a meaningful net import reliance could not be calculated owing to uncertainties in the classification of material being imported and exported.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

TIN

(Data in metric tons of tin content unless otherwise noted)

Domestic Production and Use: Tin has not been mined or smelted in the United States since 1993 and 1989, respectively. Twenty-five firms accounted for over 90% of the primary tin consumed domestically in 2019. The major uses for tin in the United States were tinplate, 21%; chemicals, 17%; solder, 14%; alloys, 10%; babbitt, brass and bronze, and tinning, 11%; and other, 27%. Based on the average Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin in 2019 was $703 million, and the estimated value of tin recovered from old scrap domestically in 2019 was $213 million.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, secondary:					
Old scrap[e]	10,100	10,300	10,300	10,300	10,000
New scrap	1,120	1,080	900	900	1,000
Imports for consumption:					
Tin, refined	33,600	32,200	34,100	36,800	35,000
Tin, alloys, gross weight	2,720	1,910	1,590	1,430	980
Tin, waste and scrap, gross weight	32,700	27,200	52,100	47,700	35,000
Exports:					
Tin, refined	807	1,150	1,560	962	1,500
Tin, alloys, gross weight	2,540	1,040	965	885	2,900
Tin, waste and scrap, gross weight	2,530	4,570	3,360	5,970	2,100
Shipments from Government stockpile, gross weight	—	—	2	13	1
Consumption, apparent, refined[1]	42,700	42,100	42,800	47,000	44,000
Price, average, cents per pound:[2]					
New York dealer	756	839	937	936	860
London Metal Exchange, cash	729	815	911	914	840
Stocks, consumer and dealer, yearend	7,090	6,370	6,390	5,570	4,900
Net import reliance[3] as a percentage of apparent consumption, refined	76	76	76	78	77

Recycling: About 11,000 tons of tin from old and new scrap was estimated to have been recycled in 2019. Of this, about 10,000 tons was recovered from old scrap at 2 detinning plants and about 75 secondary nonferrous metal-processing plants, accounting for 24% of apparent consumption.

Import Sources (2015–18): Refined tin: Indonesia, 25%; Malaysia, 24%; Peru, 20%; Bolivia, 18%; and other, 13%. Waste and scrap: Canada, 99%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Unwrought tin:		
Tin, not alloyed	8001.10.0000	Free.
Tin alloys, containing, by weight:		
5% or less lead	8001.20.0010	Free.
More than 5% but not more than 25% lead	8001.20.0050	Free.
More than 25% lead	8001.20.0090	Free.
Tin waste and scrap	8002.00.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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TIN

Government Stockpile:[4]

Material	Inventory As of 9–30–19	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals	FY 2020 Potential Acquisitions	FY 2020 Potential Disposals
Tin (gross weight)	4,025	40	—	40	—

Events, Trends, and Issues: Apparent consumption of tin in the United States was estimated to have decreased by 6% in 2019 compared with consumption in 2018. Indonesia was the leading supplier of refined tin and Canada was the leading supplier of tin waste and scrap to the United States in 2019. The estimated amount of tin recycled in 2019 decreased slightly compared with that in 2018. Estimated annual average tin prices based on the first 9 months in 2019 were 860 and 840 cents per pound for the New York dealer price and London Metal Exchange cash price, respectively—an 8% decrease for both prices from those in 2018. In 2019, the monthly average New York dealer tin price peaked in March at 992 cents per pound, then steadily decreased through August to a monthly average price of 776 cents per pound, where monthly average prices remained essentially unchanged through October.

World Mine Production and Reserves: Reserves for Australia and Burma were revised based on new information from Government sources.

	Mine production 2018	Mine production 2019[e]	Reserves[5]
United States	—	—	—
Australia	6,870	7,000	[6]420,000
Bolivia	16,900	17,000	400,000
Brazil	17,100	17,000	700,000
Burma	54,600	54,000	100,000
China	90,000	85,000	1,100,000
Congo (Kinshasa)	7,400	10,000	150,000
Indonesia	85,000	80,000	800,000
Laos[e]	1,100	1,000	NA
Malaysia	4,300	4,000	250,000
Nigeria	7,800	7,500	NA
Peru	18,600	18,500	110,000
Russia	1,400	1,400	350,000
Rwanda	2,400	3,000	NA
Vietnam	4,560	4,500	11,000
Other countries	310	1,400	350,000
World total (rounded)	318,000	310,000	4,700,000

World Resources: Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those of the rest of the world. World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

Substitutes: Aluminum, glass, paper, plastic, or tin-free steel substitute for tin content in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, alternative copper-base alloys, and plastics for bronze; plastics for bearing metals that contain tin; and compounds of lead and sodium for some tin chemicals.

[e]Estimated. NA Not available. — Zero.

[1]Defined as production (old scrap) + refined tin imports – refined tin exports + adjustments for Government and industry stock changes. Excludes imports and exports of alloys, and waste and scrap.

[2]Source: Platts Metals Week.

[3]Defined as imports – exports + adjustments for Government and industry stock changes, excluding imports and exports of waste and scrap.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant reserves were 250,000 tons.

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Titanium sponge metal was produced by two operations in Nevada and Utah. Production data were withheld to avoid disclosing company proprietary data. The facility in Salt Lake City, UT, with an estimated capacity of 500 tons per year, used the Armstrong method to produce high-purity titanium for use in electronics. The operations in Nevada, with an estimated capacity of 12,600 tons per year, used the Kroll method, the dominant process of titanium sponge production for use in aerospace, industrial, and all other applications. A third facility, in Rowley, UT, with an estimated capacity of 10,900 tons per year, was using the Kroll method until it was idled and placed on care-and-maintenance status in 2016 owing to market conditions.

In 2019, an estimated 80% of titanium metal was used in aerospace applications; the remaining 20% was used in armor, chemical processing, marine hardware, medical implants, power generation, and consumer and other applications. Assuming an average purchase price of $9.10 per kilogram, the value of sponge metal consumed was about $320 million.

In 2019, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3.0 billion. The estimated end-use distribution of TiO_2 pigment consumption was paints (including lacquers and varnishes), 59%; plastics, 20%; paper, 5%; and other, 16%. Other uses of TiO_2 included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption	20,700	16,200	24,100	23,700	27,000
Exports	1,700	724	3,130	533	1,000
Consumption, reported	31,200	34,100	37,400	35,200	35,000
Price, dollars per kilogram, yearend	9.40	9.50	9.10	9.20	9.20
Stocks, industry, yearend[e]	25,000	25,100	13,200	10,700	11,000
Employment, number[e]	300	150	150	150	150
Net import reliance[2] as a percentage of reported consumption	61	45	88	73	86
Titanium dioxide pigment:					
Production	1,220,000	1,240,000	1,260,000	1,150,000	1,100,000
Imports for consumption	221,000	247,000	239,000	269,000	240,000
Exports	649,000	651,000	634,000	529,000	400,000
Consumption, apparent[3]	792,000	840,000	870,000	893,000	900,000
Producer price index (1982=100), yearend[4]	176	175	205	205	207
Employment, number[e]	3,110	3,110	3,110	3,050	3,050
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: About 62,000 tons of titanium scrap metal was consumed in 2019—50,000 tons by the titanium industry, 10,000 tons by the steel industry, 500 tons by the superalloy industry, and the remainder in other industries.

Import Sources (2015–18): Sponge metal: Japan, 86%; Kazakhstan, 8%; Ukraine, 4%; China, 1%; and Russia, 1%. Titanium dioxide pigment: Canada, 35%; China, 25%; Germany, 9%; Mexico, 4%; and other, 27%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Titanium oxides (unfinished TiO_2 pigments)	2823.00.0000	5.5% ad val.
TiO_2 pigments, 80% or more TiO_2	3206.11.0000	6.0% ad val.
TiO_2 pigments, other	3206.19.0000	6.0% ad val.
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3.7% ad val.
Unwrought titanium metal	8108.20.0010	15.0% ad val.
Titanium waste and scrap metal	8108.30.0000	Free.
Other titanium metal articles	8108.90.3000	5.5% ad val.
Wrought titanium metal	8108.90.6000	15.0% ad val.

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TITANIUM AND TITANIUM DIOXIDE

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: Domestic consumption of titanium sponge in 2019 was essentially unchanged compared with that of 2018. Increased imports outpaced increased exports of titanium sponge leading to an increase in net import reliance to 86%. Japan and Kazakhstan were the leading import sources for titanium sponge. Domestic production of TiO_2 pigment in 2019 was estimated to be about 1.1 million tons, a decrease from that of 2018. Although heavily reliant on imports of titanium mineral concentrates, the United States was a net exporter of TiO_2 pigments.

Following a settlement reached with the U.S. Federal Trade Commission, a leading global producer of titanium minerals and pigments based in the United States acquired the second-ranked global producer of titanium pigments headquartered in Saudi Arabia. One key requirement of the approval was the divesture of two titanium pigment plants in Ashtabula, OH.

In Yanbu, Saudi Arabia, a new titanium sponge operation was being commissioned, but was delayed by technical issues. The new facility was jointly owned by companies based in Saudi Arabia and Japan and was expected to produce up to 15,600 tons per year of titanium sponge.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production		Capacity 2019[5]	
	2018	2019[e]	Sponge	Pigment
United States	W	W	13,100	1,370,000
Australia	—	—	—	260,000
Canada	—	—	—	104,000
China[e]	75,000	84,000	117,000	3,250,000
Germany	—	—	—	472,000
India	250	250	500	108,000
Japan[e]	49,000	54,000	68,800	314,000
Kazakhstan[e]	16,000	20,000	31,000	1,000
Mexico	—	—	—	300,000
Russia[e]	44,000	44,000	46,500	55,000
Saudi Arabia	—	—	15,600	210,000
Ukraine[e]	8,000	9,000	12,000	120,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	784,000
World total (rounded)	[6]192,000	[6]210,000	305,000	7,660,000

World Resources: Reserves and resources of titanium minerals are discussed in the Titanium Mineral Concentrates chapter.

Substitutes: Few materials possess titanium metal's strength-to-weight ratio and corrosion resistance. In high-strength applications, titanium competes with aluminum, composites, intermetallics, steel, and superalloys. Aluminum, nickel, specialty steels, and zirconium alloys may be substituted for titanium for applications that require corrosion resistance. Ground calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide as a white pigment.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]See also Titanium Mineral Concentrates.
[2]Defined as imports – exports.
[3]Defined as production + imports – exports.
[4]U.S. Department of Labor, Bureau of Labor Statistics.
[5]Yearend operating capacity.
[6]Excludes U.S. production.

TITANIUM MINERAL CONCENTRATES[1]

(Data in thousand metric tons of TiO_2 content unless otherwise noted)

Domestic Production and Use: At the beginning of 2019, two companies were recovering ilmenite and rutile concentrates from surface-mining operations near Nahunta, GA, and Starke, FL. In August, the owner of the operation in Florida acquired the operations in Georgia. A third (separate) company processed existing mineral sands tailings in Florida. Based on reported data through October 2019, the estimated value of titanium mineral and synthetic concentrates imported into the United States in 2019 was $840 million. Zircon was a coproduct of mining from ilmenite and rutile deposits. About 90% of titanium mineral concentrates were consumed by domestic titanium dioxide (TiO_2) pigment producers. The remaining 10% was used in welding-rod coatings and for manufacturing carbides, chemicals, and titanium metal.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production[2]	200	100	100	100	100
Imports for consumption	1,100	1,020	1,180	1,100	1,300
Exports, all forms[e]	2	5	6	32	4
Consumption, apparent[3]	1,300	1,120	1,270	1,170	1,400
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, f.o.b. Australia[4]	840	740	740	1,025	1,100
Ilmenite, bulk, minimum 54% TiO_2, f.o.b. Australia[4]	110	105	173	NA	NA
Ilmenite, import, dollars per ton	215	142	172	219	180
Slag, 80%–95% TiO_2[5]	687–742	612–682	621–700	699–738	740–900
Employment, mine and mill, number	285	156	264	270	320
Net import reliance[6] as a percentage of apparent consumption	85	91	92	91	93

Recycling: None.

Import Sources (2015–18): South Africa, 36%; Australia, 26%; Canada, 11%; Mozambique, 10%; and other, 17%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Synthetic rutile	2614.00.3000	Free.
Ilmenite and ilmenite sand	2614.00.6020	Free.
Rutile concentrate	2614.00.6040	Free.
Titanium slag	2620.99.5000	Free.

Depletion Allowance: Ilmenite and rutile; 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of titanium mineral concentrates is tied to production of TiO_2 pigments that are primarily used in paint, paper, and plastics. Domestic apparent consumption of titanium mineral concentrates in 2019 was estimated to have increased by about 16% from that of 2018. Exports in 2019 decreased substantially from those in the previous year because of a large intracompany transfer of inventory to Australia from Virginia in 2018.

In Australia, mining was restarting at the Jacinth-Ambrosia Mine in South Australia. In Greenland, a prefeasibility study was completed on the Dundas mining project on the northwestern coast of Greenland. Production capacity of up to 440,000 tons per year of ilmenite concentrate was planned to be commissioned by 2021 contingent upon approval of a mining license. China continued to be the leading producer and consumer of titanium mineral concentrates. In Saudi Arabia, a project to produce up to 500,000 tons per year of titanium slag was scheduled to be commissioned in 2020. Other projects were being developed in Australia, Mozambique, and Tanzania.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for Kenya, Madagascar, and South Africa were revised based on Government or industry reports.

	Mine production		Reserves[7]
	2018	2019[e]	
Ilmenite:			
United States[2, 8]	100	100	2,000
Australia	720	660	[9]250,000
Brazil	66	70	43,000
Canada[10]	630	690	31,000
China	2,100	2,100	230,000
India	319	320	85,000
Kenya	272	200	850
Madagascar[10]	228	300	8,600
Mozambique	575	590	14,000
Norway	236	260	37,000
Senegal	297	290	NA
South Africa[10]	765	820	35,000
Ukraine	373	380	5,900
Vietnam	105	150	1,600
Other countries	83	90	26,000
World total (ilmenite, rounded)[8]	6,870	7,000	770,000
Rutile:			
United States	([8])	([8])	([8])
Australia	141	140	[9]29,000
India	15	14	7,400
Kenya	90	74	380
Mozambique	8	8	880
Senegal	9	9	NA
Sierra Leone	114	120	490
South Africa	103	110	6,100
Ukraine	94	94	2,500
Other countries	21	29	400
World total (rutile, rounded)[8]	594	600	47,000
World total (ilmenite and rutile, rounded)	7,460	7,600	820,000

World Resources: Ilmenite accounts for about 89% of the world's consumption of titanium minerals. World resources of anatase, ilmenite, and rutile total more than 2 billion tons.

Substitutes: Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings.

[e]Estimated. NA Not available.

[1]See also Titanium and Titanium Dioxide.

[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.

[3]Defined as production + imports – exports.

[4]Source: Industrial Minerals; average of yearend price. Prices of ilmenite from Australia were discontinued at yearend 2017.

[5]Landed duty-paid value based on U.S. imports for consumption. Data series revised to reflect annual average unit value range of significant importing countries.

[6]Defined as imports – exports.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]U.S. rutile production and reserves data are included with ilmenite.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves for ilmenite and rutile were 57 million and 6.7 million tons, respectively.

[10]Mine production is primarily used to produce titaniferous slag.

TUNGSTEN

(Data in metric tons of tungsten content unless otherwise noted)

Domestic Production and Use: There has been no known domestic commercial production of tungsten concentrates since 2015. Approximately six companies in the United States used chemical processes to convert tungsten concentrates, ammonium paratungstate (APT), tungsten oxide, and (or) scrap to tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals. Nearly 60% of the tungsten used in the United States was used in cemented carbide parts for cutting and wear-resistant applications, primarily in the construction, metalworking, mining, and oil and gas drilling industries. The remaining tungsten was used to make various alloys and specialty steels; electrodes, filaments, wires, and other components for electrical, electronic, heating, lighting, and welding applications; and chemicals for various applications. The estimated value of apparent consumption in 2019 was approximately $700 million.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Mine	NA	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Concentrate	3,970	3,580	3,920	4,050	2,900
Other forms	6,270	6,300	9,780	10,400	10,900
Exports:					
Concentrate	398	183	532	284	720
Other forms	3,360	3,200	3,010	3,210	2,900
Shipments from Government stockpile:					
Concentrate	—	—	1,460	1,180	750
Other forms	—	—	—	—	—
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent, all forms[1]	W	W	W	W	W
Price, concentrate, dollars per mtu WO_3,[2] average, U.S. spot market, Platts Metals Week	302	148	245	326	270
Stocks, industry, yearend, concentrate and other forms	W	W	W	W	W
Net import reliance[3] as a percentage of apparent consumption	>25	>25	>50	>50	>50

Recycling: The estimated quantity of secondary tungsten produced and the amount consumed from secondary sources by processors and end users in 2019 were withheld to avoid disclosing company proprietary data.

Import Sources (2015–18): Tungsten contained in ores and concentrates, intermediate and primary products, wrought and unwrought tungsten, and waste and scrap: China, 31%; Bolivia, 10%; Germany, 9%; Spain, 6%; and other, 44%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Ores	2611.00.3000	Free.
Concentrates	2611.00.6000	37.5¢/kg tungsten content.
Tungsten oxides	2825.90.3000	5.5% ad val.
Ammonium tungstates	2841.80.0010	5.5% ad val.
Tungsten carbides	2849.90.3000	5.5% ad val.
Ferrotungsten	7202.80.0000	5.6% ad val.
Tungsten powders	8101.10.0000	7.0% ad val.
Tungsten waste and scrap	8101.97.0000	2.8% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[4]

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Metal powder	125	—	125	—	125
Ores and concentrates	8,370	—	1,360	—	1,360
Tungsten alloys, gross weight[5]	6	5	—	5	—

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TUNGSTEN

Events, Trends, and Issues: World tungsten supply was dominated by production in China and exports from China. China's Government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate production, and placing constraints on mining and processing. Production of tungsten concentrate outside China in 2019 was expected to be less than that of 2018, owing in part to the closure of the sole tungsten mine in the United Kingdom after the owner entered voluntary administration in late 2018. Scrap continued to be an important source of raw material for the tungsten industry worldwide.

China was the world's leading tungsten consumer. Analysts forecast global tungsten demand in 2019 to be less than that in 2018, as a result of destocking by consumers and reduced consumption owing to reported slowing global economic growth. In September, APT stocks equivalent to 3 months of production in China were sold from the Fanya Metal Exchange to a leading Chinese tungsten mining and processing company. This relieved some of the uncertainty that had been hanging over the global tungsten market since the exchange's collapse in 2015. During most of 2019, Chinese and European prices of tungsten concentrate and downstream tungsten materials trended downward; prices increased following the Fanya sale.

World Mine Production and Reserves: Reserves for the United Kingdom were revised based on a company report. Reserves for North Korea are based on a report from an independent research organization funded by the Government of the Republic of Korea.

	Mine production		Reserves[6]
	2018	2019[e]	
United States	—	—	NA
Austria	936	940	10,000
Bolivia	1,370	1,200	NA
China	65,000	70,000	1,900,000
Korea, North	1,410	1,100	29,000
Mongolia	1,940	1,900	NA
Portugal	715	700	3,100
Russia	1,500	1,500	240,000
Rwanda	920	1,100	NA
Spain	750	500	54,000
United Kingdom	900	—	44,000
Vietnam	4,800	4,800	95,000
Other countries	900	900	820,000
World total (rounded)	81,100	85,000	3,200,000

World Resources: World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits. Canada, Kazakhstan, Russia, and the United States also have significant tungsten resources.

Substitutes: Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide, niobium carbide, or titanium carbide; ceramics; ceramic-metallic composites (cermets); and tool steels. Most of these options reduce, rather than replace, the amount of tungsten used. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels, although most molybdenum steels still contain tungsten; lighting based on carbon nanotube filaments, induction technology, and light-emitting diodes for lighting based on tungsten electrodes or filaments; depleted uranium or lead for tungsten or tungsten alloys in applications requiring high-density or the ability to shield radiation; and depleted uranium alloys or hardened steel for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles. In some applications, substitution would result in increased cost or a loss in product performance.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.

[2]A metric ton unit (mtu) of tungsten trioxide (WO_3) contains 7.93 kilograms of tungsten.

[3]Defined as imports – exports + adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]Inventory includes tungsten alloys and tungsten-rhenium metal; potential acquisitions are tungsten-rhenium metal only.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

VANADIUM

(Data in metric tons of vanadium content unless otherwise noted)

Domestic Production and Use: In January 2019, byproduct vanadium production resumed in Utah and an estimated 470 tons of contained vanadium with an estimated value of $6.8 million was produced. In 2009–13, small quantities of vanadium were similarly produced as a byproduct from the mining of uraniferous sandstones on the Colorado Plateau. Secondary vanadium production continued primarily in Arkansas, Delaware, Ohio, Pennsylvania, and Texas, where processed waste materials (petroleum residues, spent catalysts, utility ash, and vanadium-bearing pig iron slag) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, vanadium metal, and vanadium pentoxide. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2019. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, mine, mill	—	—	—	—	470
Imports for consumption:					
Vanadium ores and concentrates	72	18	1	330	41
Ferrovanadium	1,980	1,590	2,810	3,130	2,500
Vanadium pentoxide, anhydride	2,870	2,460	3,400	4,600	4,000
Oxides and hydroxides, other	94	660	148	98	140
Aluminum-vanadium master alloys	143	157	288	281	240
Ash and residues	4,600	2,820	2,540	2,810	2,100
Vanadium chemicals[1]	292	407	526	470	150
Vanadium metal[2]	135	33	54	28	60
Exports:					
Vanadium ores and concentrates	166	260	37	29	47
Ferrovanadium	122	394	229	575	380
Vanadium pentoxide, anhydride	356	5	126	563	210
Oxides and hydroxides, other	100	81	148	53	480
Aluminum-vanadium master alloys	128	53	132	90	20
Ash and residues	43	123	322	289	270
Vanadium metal[2]	4	15	45	30	15
Consumption:					
Apparent[3]	9,300	7,220	8,740	10,100	8,300
Reported	4,720	4,620	4,680	5,660	4,600
Price, average, dollars per pound vanadium pentoxide[4]	4.16	3.38	7.61	16.4	11.8
Stocks, yearend[5]	136	138	125	185	190
Net import reliance[6] as a percentage of apparent consumption	100	100	100	100	94

Recycling: The quantity of vanadium recycled from spent chemical process catalysts was significant and may compose as much as 40% of total vanadium catalysts.

Import Sources (2015–18): Ferrovanadium: Austria, 48%; Canada, 22%; Russia, 14%; Republic of Korea, 11%; and other, 5%. Vanadium pentoxide: South Africa, 44%; Brazil, 29%; China, 11%; Taiwan, 6%; and other, 10%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Vanadium ores and concentrates	2615.90.6090	Free.
Vanadium bearing ash and residues	2620.40.0030	Free.
Vanadium bearing ash and residues, other	2620.99.1000	Free.
Chemical compounds:		
Vanadium pentoxide, anhydride	2825.30.0010	5.5% ad val.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad val.
Vanadium sulfates	2833.29.3000	5.5% ad val.
Vanadates	2841.90.1000	5.5% ad val.
Hydrides & nitrides, of vanadium	2850.00.2000	5.5% ad val.
Ferrovanadium	7202.92.0000	4.2% ad val.
Vanadium metal	8112.92.7000	2.0% ad val.
Vanadium and articles thereof[7]	8112.99.2000	2.0% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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VANADIUM

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of vanadium in 2019 decreased by 18% from that of 2018. Among the major uses for vanadium, production of carbon, full-alloy, and high-strength low-alloy steels accounted for 18%, 45%, and 31%, respectively, of domestic consumption. Average 2019 vanadium pentoxide prices decreased by 28% compared with 2018 prices, and ferrovanadium prices decreased by 41% to $23 per pound in 2019 compared with 2018. In January 2019, ferrovanadium prices averaged $43.10 per pound but continued to decrease for the remainder of 2019. Byproduct vanadium production in the United States resumed in early 2019 at the White Mesa mill in Utah. The company expected to continue production, subject to successful recovery and suitable prices. An iron and vanadium mine in South Africa remained closed leaving South Africa with only two major producers of vanadium. A producer in Brazil that started production in 2014 began construction on an expansion project in 2018 that would increase its production capacity by 25%. The expansion was expected to be completed by the end of the third quarter of 2019.

The implementation of the new high-strength rebar standards by the Standardization Administration of China has been enforced more gradually than originally expected. Larger mills began implementation in 2018; however, smaller mills have been slower to implement the new standards. Enforcement of the new standards was also reportedly more difficult to monitor at smaller mills. The increase of vanadium in rebar was originally expected to increase overall consumption of vanadium in China by approximately 10,000 tons per year.

World Mine Production and Reserves: Reserves for Australia and Brazil were revised based on Government reports.

	Mine production		Reserves[8]
	2018	2019[e]	(thousand metric tons)
United States	—	470	45
Australia	—	—	[9]4,000
Brazil	5,500	7,000	120
China	40,000	40,000	9,500
Russia	18,000	18,000	5,000
South Africa	7,700	8,000	3,500
World total (rounded)	71,200	73,000	22,000

World Resources: World resources of vanadium exceed 63 million tons. Vanadium occurs in deposits of phosphate rock, titaniferous magnetite, and uraniferous sandstone and siltstone, in which it constitutes less than 2% of the host rock. Significant quantities are also present in bauxite and carboniferous materials, such as coal, crude oil, oil shale, and tar sands. Because vanadium is typically recovered as a byproduct or coproduct, demonstrated world resources of the element are not fully indicative of available supplies. Although domestic resources and secondary recovery are adequate to supply a large portion of domestic needs, all of U.S. demand is currently met by foreign sources.

Substitutes: Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. Currently, no acceptable substitute for vanadium is available for use in aerospace titanium alloys.

[e]Estimated. — Zero.

[1]Includes hydrides, nitrides, sulfates, and vanadates of vanadium.

[2]Vanadium metal includes waste and scrap.

[3]Defined as production + net import reliance.

[4]Prices for 2015–2016 are U.S. annual average vanadium pentoxide prices. The 2017 annual average vanadium pentoxide price includes U.S. monthly averages for January 2017–June 2017 and China monthly average prices for July 2017–December 2017. The prices for 2018–2019 are the China annual average vanadium pentoxide prices.

[5]Includes chlorides, ferrovanadium, vanadates, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.

[6]Defined as imports – exports + adjustments for industry stock changes.

[7]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 1.1 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies with mining and processing facilities in South Carolina and Virginia produced approximately 200,000 tons of vermiculite concentrate, but actual data have been rounded to one significant digit to avoid disclosing company proprietary data. Flakes of raw vermiculite concentrate are micaceous in appearance and contain interlayer water in their structure. When the flakes are heated rapidly at a temperature above 870 °C, the water flashes into steam, and the flakes expand into accordionlike particles. This process is called exfoliation or expansion, and the resulting lightweight material is chemically inert, fire resistant, and odorless. Most of the vermiculite concentrate produced in the United States was shipped to 17 exfoliating plants in 11 States. The end uses for exfoliated vermiculite were estimated to be agriculture and horticulture, 46%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 17%; insulation, 10%; and other, 27%.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production[e, 1, 2]	100	100	100	100	200
Imports for consumption[e]	25	36	28	37	32
Exports[e]	19	21	16	14	13
Consumption, apparent, concentrate[3]	110	120	110	120	220
Consumption, reported, exfoliated	65	68	72	76	80
Price, range of value, concentrate, dollars per ton, ex-plant	140–575	140–575	140–575	140–575	140–575
Employment, number[e]	63	63	63	65	76
Net import reliance[4] as a percentage of apparent consumption[e, 2]	10	10	10	20	10

Recycling: Insignificant.

Import Sources (2015–18): South Africa, 66%; Brazil, 29%; Zimbabwe, 4%; and Kenya, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Vermiculite, perlite and chlorites, unexpanded	2530.10.0000	Free.
Exfoliated vermiculite, expanded clays, foamed slag, and similar expanded materials	6806.20.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. exports and imports of vermiculite are not collected as a separate category by the U.S. Census Bureau. However, United States imports were estimated to be about 32,000 tons in 2019, almost 14% less than those of 2018. Coarse-grade vermiculite remained in short supply; however, prices were unchanged in 2019. Most imports came from South Africa and Brazil in 2019.

Expansion at the 30,000-ton-per-year Namekara Mine in Uganda continued toward its goal of 80,000 tons per year of production. The deposit was considered to be one of the world's largest vermiculite deposits with significant portions of medium- and coarse-grade material. The Namekara deposit has enough resources for more than 50 years of production at previously announced rates.

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VERMICULITE

A company in Brazil continued to expand production capacity at its vermiculite mine in central Brazil and continued with the development of another deposit near Brasilia to bring the company's total production capacity to 200,000 tons per year. Companies in China with significant vermiculite resources also were ramping up production, although processing operations continued to be somewhat constrained by increased enforcement of environmental regulations. Specific production data were not available for China.

Exploration and development of vermiculite deposits containing medium, large, and premium (coarser) grades (mostly in China and South Africa) are likely to continue because of the higher demand for those grades. Finer grade production has exceeded consumption for several years. However, coarser grade (greater than 5-millimeter particle size) production has not been able to keep up with demand. Producers will continue to investigate ways to increase the use of the finer grades in existing products and in uses that require coarse material. Innovative applications continue to emerge, including the use of vermiculite to combat air pollution and absorb water in mines, replacing zeolites in ion-exchange columns, purifying wastewater, and containing or removing nuclear waste.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2018	2019[e]	
United States[e]	[2]100	[2]200	25,000
Brazil	50	60	6,200
Bulgaria	10	10	NA
China	NA	NA	NA
Egypt	8	10	NA
India	10	10	1,600
Russia	10	10	NA
South Africa	180	180	14,000
Uganda	20	30	NA
Zimbabwe	30	30	NA
Other countries	12	10	NA
World total (rounded)	400	500	NA

World Resources: In addition to the producing mines in South Carolina and Virginia, there are vermiculite occurrences in Colorado, Nevada, North Carolina, Texas, and Wyoming which contain estimated resources of 2 million to 3 million tons. Significant deposits have been reported in Australia, China, Russia, Uganda, and some other countries, but reserves and resource information comes from many sources and, in most cases, it is not clear whether the numbers refer to vermiculite alone or vermiculite plus other minerals and host rock and overburden.

Substitutes:
Expanded perlite is a substitute for exfoliated vermiculite in lightweight concrete and plaster. Other denser but less costly alternatives in these applications include expanded clay, shale, slag, and slate. Alternate materials for loose-fill fireproofing insulation include fiberglass, perlite, and slag wool. In agriculture, substitutes include bark and other plant materials, peat, perlite, sawdust, and synthetic soil conditioners.

[e]Estimated. NA Not available.

[1]Concentrate sold or used by producers.

[2]Data are rounded to one significant digit to avoid disclosing company proprietary data.

[3]Defined as concentrate sold or used by producers + imports – exports.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

WOLLASTONITE

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2019. U.S. production of wollastonite (sold or used by producers) was withheld to avoid disclosing company proprietary data but was estimated to have decreased from that of 2018. Economic resources of wollastonite typically form as a result of thermal metamorphism of siliceous limestone during regional deformation or chemical alteration of limestone by siliceous hydrothermal fluids along faults or contacts with magmatic intrusions. Deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah; however, New York is the only State where long-term continuous mining has taken place.

The U.S. Geological Survey does not collect consumption statistics for wollastonite, but consumption was estimated to have decreased in 2019, compared with that of 2018. Ceramics (frits, sanitaryware, and tile), friction products (primarily brake linings), metallurgical applications (flux and conditioner), paint (architectural and industrial paints), plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds), and miscellaneous uses (including adhesives, concrete, glass, and sealants) accounted for wollastonite sales in the United States.

In ceramics, wollastonite decreases shrinkage and gas evolution during firing; increases green and fired strength; maintains brightness during firing; permits fast firing; and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding, a source for calcium oxide, a slag conditioner, and protects the surface of molten metal during the continuous casting of steel. As an additive in paint, it improves the durability of the paint film, acts as a pH buffer, improves resistance to weathering, reduces gloss and pigment consumption, and acts as a flatting and suspending agent. In plastics, wollastonite improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, stable at high temperatures, and improves flexural and tensile strength.

Salient Statistics—United States: The United States was thought to be a net exporter of wollastonite in 2019. Comprehensive trade data were not available for wollastonite because it is imported and exported under a generic Harmonized Tariff Schedule of the United States code that includes multiple mineral commodities. Prices for domestically produced wollastonite were estimated to be between $300 to $320 per metric ton. Price data for globally produced wollastonite were unavailable. Products with finer grain sizes and acicular (highly elongated) particles sold for higher prices. Surface treatment, when necessary, also increased the selling price. Approximately 64 people were employed at wollastonite mines and mills in 2019 (excluding office workers).

Recycling: None.

Import Sources (2015–18): Comprehensive trade data were not available, but wollastonite was primarily imported from Canada, Finland, India, and Mexico.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

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WOLLASTONITE

Events, Trends, and Issues: Construction of new housing units through August 2019, decreased slightly compared with those during the same period in 2018, suggesting that sales of wollastonite to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, might have decreased. Most major markets, in which wollastonite is used, were estimated to have decreased, except for primary iron and steel. Production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, decreased; plastics production decreased; rubber production decreased; but primary iron and steel products increased.

Globally, ceramics, polymers (such as plastics and rubber), and paint accounted for most wollastonite sales. Lesser global uses for wollastonite included miscellaneous construction products, friction materials, metallurgical applications, and paper. Global sales of wollastonite were estimated to be in the range of 850,000 to 900,000 tons, similar to those in 2018.

The leading U.S. producer of wollastonite delayed plans to develop a mine within the Adirondack Forest Preserve of New York, and instead continued to use resources from its current mine. The Adirondack Forest Preserve land became available for development as part of a land swap transaction approved by the State of New York in 2013.

World Mine Production and Reserves: The United States is thought to rank among the top producers globally; however, many countries do not publish wollastonite production. Data for China were revised based on a new data source, which significantly increased estimated production compared with the previously published data.

	Mine production[e]		Reserves[1]
	2018	2019	
United States	W	W	World reserves of wollastonite exceed 100 million tons. Many deposits, however, have not been surveyed, precluding accurate estimates of reserves.
Canada	15,000	20,000	
China	870,000	890,000	
Finland	10,000	11,000	
India	150,000	150,000	
Mexico	84,000	93,000	
Other countries	6,000	6,000	
World total (rounded)[2]	1,100,000	1,200,000	

World Resources: Reliable estimates of wollastonite resources do not exist for most countries. Large deposits of wollastonite have been identified in China, Finland, India, Mexico, and the United States. Smaller, but significant, deposits have been identified in Canada, Chile, Kenya, Namibia, South Africa, Spain, Sudan, Tajikistan, Turkey, and Uzbekistan.

Substitutes: The acicular nature of many wollastonite products allows it to compete with other acicular materials, such as ceramic fiber, glass fiber, steel fiber, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene, in products where improvements in dimensional stability, flexural modulus, and heat deflection are sought. Wollastonite also competes with several nonfibrous minerals or rocks, such as kaolin, mica, and talc, which are added to plastics to increase flexural strength, and such minerals as barite, calcium carbonate, gypsum, and talc, which impart dimensional stability to plastics. In ceramics, wollastonite competes with carbonates, feldspar, lime, and silica as a source of calcium and silica. Its use in ceramics depends on the formulation of the ceramic body and the firing method.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

[2]Excludes U.S. production.

YTTRIUM[1]

[Data in metric tons of yttrium-oxide (Y_2O_3) equivalent content unless otherwise noted]

Domestic Production and Use: Yttrium is one of the rare-earth elements. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined in 2019 as a primary product at the Mountain Pass Mine in California, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Monazite, a rare-earth phosphate mineral, also may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Yttrium was estimated to represent about 0.12% of the rare-earth elements in the Mountain Pass bastnaesite ore.

The leading end uses of yttrium were in ceramics, metallurgy, and phosphors. In ceramic applications, yttrium compounds were used in abrasives, bearings and seals, high-temperature refractories for continuous-casting nozzles, jet-engine coatings, oxygen sensors in automobile engines, and wear-resistant and corrosion-resistant cutting tools. In metallurgical applications, yttrium was used as a grain-refining additive and as a deoxidizer. Yttrium was used in heating-element alloys, high-temperature superconductors, and superalloys. In electronics, yttrium-iron garnets were components in microwave radar to control high-frequency signals. Yttrium was an important component in yttrium-aluminum-garnet laser crystals used in dental and medical surgical procedures, digital communications, distance and temperature sensing, industrial cutting and welding, nonlinear optics, photochemistry, and photoluminescence. Yttrium was used in phosphor compounds for flat-panel displays and various lighting applications.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, mine	NA	—	—	NA	NA
Imports for consumption:					
Yttrium, alloys, compounds, and metal[e, 2]	360	340	380	450	570
Exports, compounds[e, 3]	39	2	2	14	7
Consumption, apparent[e, 4]	300	300	400	500	600
Price, dollars per kilogram, average:					
Yttrium oxide, minimum 99.999 purity[5]	8	4	3	3	3
Yttrium metal, minimum 99.9% purity[5]	48	35	35	36	34
Net import reliance[6, 7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Insignificant.

Import Sources (2015–18):[8] Yttrium compounds: China, 87%; Estonia, 5%; Republic of Korea, 2%; Japan, 2%; and other, 4%. Nearly all imports of yttrium metal and compounds are derived from mineral concentrates processed in China. Import sources do not include yttrium contained in value-added intermediates and finished products.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Rare-earth metals, unspecified, whether or not intermixed or interalloyed	2805.30.0090	5.0% ad val.
Mixtures of rare-earth oxides containing yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of rare-earth chlorides containing yttrium or scandium as the predominant metal	2846.90.2082	Free.
Yttrium-bearing materials and compounds containing by weight >19% to <85% Y_2O_3	2846.90.4000	Free.
Other rare-earth compounds, including yttrium and other compounds	2846.90.8000	3.7% ad val.

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YTTRIUM

Depletion Allowance: Monazite, thorium content, 22% (Domestic), 14% (Foreign); yttrium, rare-earth content, 14% (Domestic and foreign); and xenotime, 14% (Domestic and foreign).

Government Stockpile: [9]

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquistions	Potential Disposals	Potential Acquisitions	Potential Disposals
Yttrium oxide	25	10	—	—	—

Events, Trends, and Issues: China produced most of the world's supply of yttrium from its weathered clay ion-adsorption ore deposits in the southern Provinces—primarily Fujian, Guangdong, and Jiangxi—and from a lesser number of deposits in Guangxi and Hunan Provinces. Processing was primarily at facilities in Guangdong, Jiangsu, and Jiangxi Provinces. In 2019, yttrium was produced from similar clay deposits in Burma (Myanmar).

Globally, yttrium was mainly consumed in the form of oxide compounds for ceramics and phosphors. Lesser amounts were consumed in electronic devices, lasers, optical glass, and metallurgical applications. The average price for yttrium metal decreased by 5% compared with that of 2018. Yttrium oxide prices remained nearly unchanged since 2016. China's Ministry of Industry and Information Technology raised the rare-earth mining and separation quotas to record highs of 132,000 tons and 127,000 tons of rare-earth-oxide equivalent, respectively. The yttrium content of the production quota was not specified. In 2019, China's exports of yttrium compounds and metal were estimated to be 3,000 tons of yttrium-oxide equivalent, and the leading export destinations were, in descending order, Japan, the United States, Italy, and the Republic of Korea.

World Mine Production and Reserves:[10] World mine production of yttrium contained in rare-earth mineral concentrates was estimated to be 10,000 to 14,000 tons. Most of this production took place in China and Burma. Global reserves of yttrium oxide were estimated to be more than 500,000 tons. The leading countries for these reserves included Australia, Brazil, Canada, China, and India. Although mine production in Burma was significant, information on reserves in Burma was not available. Global reserves may be adequate to satisfy near-term demand at current rates of production; however, changes in economic conditions, environmental issues, or permitting and trade restrictions could affect the availability of many of the rare-earth elements, including yttrium.

World Resources: Large resources of yttrium in monazite and xenotime are available worldwide in placer deposits, carbonatites, uranium ores, and weathered clay deposits (ion-adsorption ore). Additional resources of yttrium occur in apatite-magnetite-bearing rocks, deposits of niobium-tantalum minerals, nonplacer monazite-bearing deposits, sedimentary phosphate deposits, and uranium ores.

Substitutes: Substitutes for yttrium are available for some applications but generally are much less effective. In most uses, especially in electronics, lasers, and phosphors, yttrium is generally not subject to direct substitution by other elements. As a stabilizer in zirconia ceramics, yttrium oxide may be substituted with calcium oxide or magnesium oxide, but the substitutes generally impart lower toughness.

[e]Estimated. NA Not available. — Zero.

[1]See also Rare Earths; trade data for yttrium are included in the data shown for rare earths.

[2]Estimated from Trade Mining LLC and IHS Markit Ltd. shipping records.

[3]Estimated from Harmonized Tariff System-based Schedule B code: 2846.90.2015.

[4]Defined as imports – exports. Rounded to one significant digit. Yttrium consumed domestically was imported or refined from imported materials.

[5]Free on board China. Source: Argus Media group-Argus Metals International, London, United Kingdom.

[6]Defined as imports – exports.

[7]In 2015, 2018, and 2019, domestic production of mineral concentrates was stockpiled or exported. Consumers of compounds and metals were reliant on imports and stockpiled inventory.

[8]Includes estimated yttrium-oxide equivalent content from the following Harmonized Tariff Schedule codes: 2846.90.2015, 2846.90.2082, 2846.90.4000, 2846.90.8050, and 2846.90.8060.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

ZEOLITES (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2019, six companies in the United States operated nine zeolite mines and produced an estimated 98,000 tons of natural zeolites, a 14% increase from that in 2018. Two mines owned by an additional company were idle during the year, but zeolites may have been sold from ore stockpiles at one of these operations. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. Minor quantities of erionite, ferrierrite, mordenite, and (or) phillipsite were also likely produced. New Mexico was estimated to be the leading natural zeolite-producing State in 2019, followed by, in descending order, California, Idaho, Texas, Oregon, and Arizona. The top three companies accounted for approximately 85% of total domestic production.

An estimated 92,000 tons of natural zeolites were sold in the United States during 2019, an increase of 14% compared with sales in 2018. Domestic uses were, in decreasing order by estimated quantity, animal feed, odor control, unclassified end uses (such as ice melt, soil amendment, synthetic turf, etc.), water purification, pet litter, wastewater treatment, fungicide or pesticide carrier, oil and grease absorbent, gas absorbent (and air filtration), fertilizer carrier, desiccant, and aquaculture. Animal feed, odor control, and water purification applications likely accounted for about 70% of the domestic sales tonnage.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production, mine	75,100	75,200	82,400	86,100	98,000
Sales, mill	73,200	71,300	81,300	80,500	92,000
Imports for consumption[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Exports[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Consumption, apparent[1]	73,200	71,300	81,300	80,500	92,000
Price, range of value, dollars per ton[2]	110–950	100–400	100–300	[e]50–300	50–300
Employment, mine and mill[e, 3]	100	115	110	110	120
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Zeolites used for desiccation, gas absorbance, wastewater cleanup, and water purification may be reused after reprocessing of the spent zeolites. Information about the quantity of recycled natural zeolites was unavailable.

Import Sources (2015–18): Comprehensive trade data were not available for natural zeolite minerals because they were imported and exported under a generic U.S. Census Bureau Harmonized Tariff Schedule code that includes multiple mineral commodities or under codes for finished products. Nearly all imports and exports consisted of synthetic zeolites.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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ZEOLITES (NATURAL)

Events, Trends, and Issues: Prior to the 1990s, annual output of natural zeolites in the United States was less than 15,000 tons. Production rose more than sixfold from 1990 through 2019 owing predominantly to increases in sales for animal feed applications, although sales for odor control and water purification also increased significantly. In contrast, sales for pet litter declined substantially during this period as a result of competition from other products.

World Mine Production and Reserves: Many countries either do not report production of natural zeolites or production is reported with a 2- to 3-year lag time. End uses for natural zeolites in countries that mine large tonnages of zeolite minerals typically include low-value, high-volume construction applications, such as dimension stone, lightweight aggregate, and pozzolanic cement. As a result, production data for some countries may not accurately indicate the quantities of natural zeolites used in the high-value applications that are reflected in the domestic data.

World reserves of natural zeolites have not been estimated. Deposits occur in many countries, but companies rarely publish reserves data. Further complicating estimates of reserves is the fact that much of the reported world production includes altered volcanic tuffs with low to moderate concentrations of zeolites that are typically used in high-volume construction applications. Some deposits should, therefore, be excluded from reserves estimates because it is the rock itself and not its zeolite content that makes the deposit valuable.

Production data for multiple countries were revised based on information from Government and industry sources.

	Mine production[e]		Reserves[5]
	2018	2019	
United States	[6]86,100	98,000	Two of the leading companies in the United States reported combined reserves of 80 million tons in 2019; total U.S. reserves likely are substantially larger. World data are unavailable, but reserves are estimated to be large.
China	320,000	320,000	
Cuba	[6]52,600	55,000	
Indonesia	130,000	130,000	
Jordan	10,000	10,000	
Korea, Republic of	[6]144,000	150,000	
New Zealand	100,000	100,000	
Russia	35,000	35,000	
Slovakia	117,000	120,000	
Turkey	65,000	65,000	
Other countries	75,000	75,000	
World total (rounded)	1,100,000	1,200,000	

World Resources: Recent estimates for domestic and global resources of natural zeolites are not available. Resources of chabazite and clinoptilolite in the United States are sufficient to satisfy foreseeable domestic demand.

Substitutes: For pet litter, zeolites compete with other mineral-based litters, such as those manufactured using bentonite, diatomite, fuller's earth, and sepiolite; organic litters made from shredded corn stalks and paper, straw, and wood shavings; and litters made using silica gel. Diatomite, perlite, pumice, vermiculite, and volcanic tuff compete with natural zeolite as lightweight aggregate. Zeolite desiccants compete against such products as magnesium perchlorate and silica gel. Zeolites compete with bentonite, gypsum, montmorillonite, peat, perlite, silica sand, and vermiculite in various soil amendment applications. Activated carbon, diatomite, or silica sand may substitute for zeolites in water-purification applications. As an oil absorbent, zeolites compete mainly with bentonite, diatomite, fuller's earth, sepiolite, and a variety of polymer and natural organic products. In animal feed, zeolites compete with bentonite, diatomite, fuller's earth, kaolin, silica, and talc as anticaking and flow-control agents.

[e]Estimated. E Net exporter.

[1]Defined as mill sales + imports – exports. Information about industry stocks was unavailable.

[2]Range of ex-works mine and mill unit values for individual natural zeolite operations, based on data reported by U.S. producers and U.S. Geological Survey estimates. Average unit values per ton for the past 5 years were $150 in 2015, $140 in 2016 and 2017, and an estimated $125 in 2018 and 2019. Prices vary with the percentage of zeolite present in the product, the chemical and physical properties of the zeolite mineral(s), particle size, surface modification and (or) activation, and end use.

[3]Excludes administration and office staff. Estimates based on data from the Mine Safety and Health Administration.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Reported figure.

ZINC

(Data in thousand metric tons of zinc content unless otherwise noted)

Domestic Production and Use: The value of zinc mined in 2019, based on zinc contained in concentrate, was about $2.1 billion. Zinc was mined in six States at 15 mines operated by five companies. Two smelter facilities, one primary and one secondary, operated by two companies, produced commercial-grade zinc metal. Of the total reported zinc consumed, most was used in galvanizing, followed by brass and bronze, zinc-based alloys, and other uses.

Salient Statistics—United States:	2015	2016	2017	2018	2019[e]
Production:					
Zinc in ore and concentrate	825	805	774	824	780
Refined zinc[1]	172	126	132	116	120
Imports for consumption:					
Zinc in ore and concentrate	(2)	(2)	7	(2)	(2)
Refined zinc	771	713	729	775	830
Exports:					
Zinc in ore and concentrate	708	597	682	806	870
Refined zinc	13	47	33	23	5
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent, refined zinc[3]	931	792	829	868	950
Price, average, cents per pound:					
North American[4]	95.5	101.4	139.3	141.0	125.0
London Metal Exchange (LME), cash	87.6	94.8	131.2	132.7	117.0
Reported producer and consumer stocks, refined zinc, yearend	87	80	112	117	120
Employment:					
Mine and mill, number[5]	2,690	2,350	2,420	2,630	2,500
Smelter, primary, number	250	246	240	250	250
Net import reliance[6] as a percentage of apparent consumption:					
Ore and concentrate	E	E	E	E	E
Refined zinc	81	84	84	87	87

Recycling: In 2019, about 25% (30,000 tons) of the refined zinc produced in the United States was recovered from secondary materials at both primary and secondary smelters. Secondary materials included galvanizing residues and crude zinc oxide recovered from electric arc furnace dust.

Import Sources (2015–18): Ore and concentrate: Peru, 98%; and other, 2%. Refined metal: Canada, 64%; Mexico, 13%; Australia, 7%; Peru, 7%; and other, 9%. Waste and scrap (gross weight): Canada, 72%; Mexico, 28%; and other, <1%. Combined total (includes gross weight of waste and scrap): Canada, 64%; Mexico, 13%; Australia, 7%; Peru, 7%; and other, 9%.

Tariff: Item	Number	Normal Trade Relations 12–31–19
Zinc ores and concentrates, Zn content	2608.00.0030	Free.
Zinc oxide; zinc peroxide	2817.00.0000	Free.
Unwrought zinc, not alloyed:		
Containing 99.99% or more zinc	7901.11.0000	1.5% ad val.
Containing less than 99.99% zinc:		
Casting-grade	7901.12.1000	3% ad val.
Other	7901.12.5000	1.5% ad val.
Zinc alloys	7901.20.0000	3% ad val.
Zinc waste and scrap	7902.00.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[7]

		FY 2019		FY 2020	
Material	Inventory As of 9–30–19	Potential Acquisitions	Potential Disposals	Potential Acquisitions	Potential Disposals
Zinc	7.25	—	7.25	—	7.25

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ZINC

Events, Trends, and Issues: Global zinc mine production in 2019 was estimated to be 13 million tons, a 4% increase from that of 2018. Notable zinc mine production increases took place in Australia, China, and South Africa. In Australia, the Woodlawn tailings project opened in May and significant increases in production took place at the Dugald River Mine, the Lady Loretta Mine, and two tailings reprocessing projects commissioned in 2018. In South Africa, production increased at the Gamsberg Mine, which was commissioned in late 2018.

According to the International Lead and Zinc Study Group,[8] global refined zinc production in 2019 was estimated to be 13.49 million tons, and metal consumption was estimated to be 13.67 million tons, resulting in a production-to-consumption deficit of about 180,000 tons of refined zinc.

Domestic zinc mine production decreased in 2019, owing partially to the closure of the Pend Oreille Mine in Washington State in July after current reserves were exhausted. The mine was reopened in December 2014 after being closed since 2009. U.S. apparent consumption of refined zinc increased to a 5-year high of 950,000 tons in 2019. The estimated annual average North American Special High Grade (SHG) zinc price decreased by 11% in 2019 from that in 2018 to $1.25 per pound.

World Mine Production and Reserves: Reserves for Australia, Canada, India, Kazakhstan, Mexico, Peru, Russia, and Sweden were revised based on Government or industry reports.

	Mine production[9]		Reserves[10]
	2018	2019[e]	
United States	824	780	11,000
Australia	1,110	1,300	[11]68,000
Bolivia	480	460	4,800
Canada	287	300	2,200
China	4,170	4,300	44,000
India	750	800	7,500
Kazakhstan	304	290	12,000
Mexico	691	690	22,000
Peru	1,470	1,400	19,000
Russia	300	300	22,000
Sweden	234	230	3,600
Other countries	1,840	1,900	34,000
World total (rounded)	12,500	13,000	250,000

World Resources: Identified zinc resources of the world are about 1.9 billion tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; aluminum alloys, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-base alloys are major competitors for zinc-base diecasting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. E Net exporter. — Zero.

[1]Includes primary and secondary refined production.

[2]Less than ½ unit.

[3]Defined as refined production + refined imports – refined exports + adjustments for Government stock changes.

[4]Platts Metals Week price for North American SHG zinc; based on the LME cash price plus premium.

[5]Includes mine and mill employment at all zinc-producing mines. Source: Mine Safety and Health Administration.

[6]Defined as imports – exports + adjustments for Government stock changes.

[7]See Appendix B for definitions.

[8]International Lead and Zinc Study Group, 2019, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 28, 7 p.

[9]Zinc content of concentrate and direct shipping ore.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant reserves were 25 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2019, two firms recovered zircon (zirconium silicate) from surface-mining operations in Florida and Georgia as a coproduct from the mining of heavy-mineral sands and the processing of titanium and zirconium mineral concentrates, and a third company processed existing mineral sands tailings in Florida. Zirconium metal and hafnium metal were produced from zirconium chemical intermediates by one producer in Oregon and one in Utah. Zirconium and hafnium are typically contained in zircon at a ratio of about 36 to 1. Zirconium chemicals were produced by the metal producer in Oregon and by at least 10 other companies. Ceramics, foundry sand, opacifiers, and refractories are the leading end uses for zircon. Other end uses of zircon include abrasives, chemicals (predominantly, zirconium basic sulfate and zirconium oxychloride octohydrate as intermediate chemicals), metal alloys, and welding rod coatings. The leading consumers of zirconium metal are the chemical process and nuclear energy industries. The leading use of hafnium metal is in superalloys.

Salient Statistics—United States:	**2015**	**2016**	**2017**	**2018**	**2019[e]**
Production, zirconium ores and concentrates (ZrO_2 content)[1]	[2]50,000	W	[2]50,000	[2]100,000	[2]100,000
Imports:					
Zirconium ores and concentrates (ZrO_2 content)	20,800	24,900	24,300	26,400	24,000
Zirconium, unwrought, powder, and waste and scrap	1,140	1,040	899	1,880	2,200
Zirconium, wrought	188	195	282	284	320
Hafnium, unwrought, powder, and waste and scrap	72	180	113	41	30
Exports:					
Zirconium ores and concentrates (ZrO_2 content)	3,200	3,280	31,500	77,500	52,000
Zirconium, unwrought, powder, and waste and scrap	515	363	627	556	730
Zirconium, wrought	1,020	788	972	1,150	950
Consumption, apparent, zirconium ores and concentrates, (ZrO_2 content)[3]	[2]70,000	W	[2]40,000	[2]50,000	[2]50,000
Prices:					
Zircon, dollars per metric ton (gross weight):					
Australia, free on board[4]	1,025	975	975	NA	NA
China, cost insurance and freight[5]	NA	NA	1,295	1,625	1,630
Imported[6]	1,061	877	916	1,290	1,500
Zirconium, unwrought, import, China, dollars per kilogram[7]	15	33	12	13	16
Hafnium, unwrought, dollars per kilogram[5]	1,250	930	900	840	830
Net import reliance[8] as a percentage of apparent consumption:					
Zirconium ores and concentrates	<25	<50	E	E	E
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and (or) from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled. Hafnium metal recycling was insignificant.

Import Sources (2015–18): Zirconium ores and concentrates: South Africa, 53%; Senegal, 28%; Australia, 15%; Russia, 2%; and other, 2%. Zirconium, unwrought, including powder: China, 78%; Germany, 14%; Japan, 5%; France, 2%; and other, 1%. Hafnium, unwrought: Germany, 45%; France, 29%; China, 15%; United Kingdom, 11%; and other, <1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–19**
Zirconium ores and concentrates	2615.10.0000	Free.
Ferrozirconium	7202.99.1000	4.2% ad val.
Zirconium, unwrought and powder	8109.20.0000	4.2% ad val.
Zirconium waste and scrap	8109.30.0000	Free.
Other zirconium articles	8109.90.0000	3.7% ad val.
Hafnium, unwrought, powder, and waste and scrap	8112.92.2000	Free.

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ZIRCONIUM AND HAFNIUM

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: The average unit value for imports of zircon concentrates increased for the third year in a row. The average unit value for exports of zircon concentrates rose slightly in 2019 compared with 2018.

In China, zircon production was estimated to have decreased significantly. It was reported that China began conducting environmental inspections in July in the Provinces of Chongqing, Fujian, Gansu, Hainan, Qinghai, and Shanghai, which resulted in mine and plant closures, including zircon mines in Hainan Province. It was uncertain how long the mines and plants would be closed.

During 2019, several large mining projects with zirconium were in development but construction had not begun on any them. In Western Australia, the Thunderbird mineral sands project received full permitting, secured a 15-year agreement with a provider of liquified natural gas, and was seeking full funding of the project. In New South Wales, Australia, the Dubbo polymetallic project also received full permitting and was seeking funding. In Siberia, construction was to begin in the second half of 2019 at the Tugan titanium-zirconium deposit but concerns regarding funding delayed the start of work.

World Mine Production and Reserves: World primary hafnium production data are not available and quantitative estimates of hafnium reserves are not available. Zirconium reserves for Kenya and South Africa were revised based on company reporting.

	Zirconium ores and concentrates, mine production (thousand metric tons, gross weight)		Zirconium reserves[9] (thousand metric tons, ZrO_2 content)
	2018	2019[e]	
United States	[2]100	[2]100	500
Australia	560	550	[10]42,000
China	140	80	500
Kenya	45	50	120
Mozambique	48	50	1,800
Senegal	64	70	NA
South Africa	350	370	6,500
Other countries	170	170	11,000
World total (rounded)	1,480	1,400	62,000

World Resources: Resources of zircon in the United States included about 14 million tons associated with titanium resources in heavy-mineral-sand deposits. Phosphate rock and sand and gravel deposits could potentially yield substantial amounts of zircon as a byproduct. World resources of hafnium are associated with those of zircon and baddeleyite. Quantitative estimates of hafnium resources are not available.

Substitutes: Chromite and olivine can be used instead of zircon for some foundry applications. Dolomite and spinel refractories can also substitute for zircon in certain high-temperature applications. Niobium (columbium), stainless steel, and tantalum provide limited substitution in nuclear applications, and titanium and synthetic materials may substitute in some chemical processing plant applications. Silver-cadmium-indium control rods are used in lieu of hafnium at numerous nuclear powerplants. Zirconium can be used interchangeably with hafnium in certain superalloys.

[e]Estimated. E Net Exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Contained ZrO_2 content calculated at 65% of gross production.

[2]Rounded to one significant digit to avoid disclosing company proprietary data.

[3]Defined as production + imports – exports.

[4]Source: Industrial Minerals, average of yearend price. Prices of zircon from Australia were discontinued at yearend 2017.

[5]Source: Argus Media group–Argus Metals International, average of yearend price.

[6]Unit value based on annual United States imports for consumption from Australia, Senegal, and South Africa.

[7]Unit value based on annual United States imports for consumption from China.

[8]Defined as imports – exports.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant reserves were 13 million tons.

APPENDIX A

Abbreviations and Units of Measure

1 carat (metric) (diamond)	= 200 milligrams
1 flask (fl)	= 76 pounds, avoirdupois
1 karat (gold)	= one twenty-fourth part
1 kilogram (kg)	= 2.2046 pounds, avoirdupois
1 long ton (lt)	= 2,240 pounds, avoirdupois
1 long ton unit (ltu)	= 1% of 1 long ton or 22.4 pounds, avoirdupois
long calcined ton (lct)	= excludes water of hydration
long dry ton (ldt)	= excludes excess free moisture
Mcf	= 1,000 cubic feet
1 metric ton (t)	= 2,204.6 pounds, avoirdupois, or 1,000 kilograms
1 metric ton (t)	= 1.1023 short ton
1 metric ton unit (mtu)	= 1% of 1 metric ton or 10 kilograms
metric dry ton (mdt)	= excludes excess free moisture
1 pound (lb)	= 453.6 grams
1 short ton (st)	= 2,000 pounds, avoirdupois
1 short ton unit (stu)	= 1% of 1 short ton or 20 pounds, avoirdupois
short dry ton (sdt)	= excludes excess free moisture
1 troy ounce (tr oz)	= 1.09714 avoirdupois ounces or 31.103 grams
1 troy pound	= 12 troy ounces

APPENDIX B

Definitions of Selected Terms Used in This Report

Terms Used for Materials in the National Defense Stockpile and Helium Stockpile

Inventory refers to the quantity of mineral materials held in the National Defense Stockpile or in the Federal Helium Reserve. Nonstockpile-grade materials may be included in the table; where significant, the quantities of these stockpiled materials are specified in the text accompanying the table.

Potential disposals indicate the total amount of a material in the National Defense Stockpile that the U.S. Department of Defense is permitted to dispose of under the Annual Materials Plan approved by Congress for the fiscal year. Congress has authorized disposal over the long term at rates designed to maximize revenue but avoid undue disruption to the usual markets and financial loss to the United States. Fiscal year (FY) 2019 is the period from October 1, 2018, through September 30, 2019. FY 2020 is the period from October 1, 2019, through September 30, 2020. Disposals are defined as any disposal or sale of National Defense Stockpile stock. For mineral commodities that have a disposal plan greater than the inventory, the actual quantity will be limited to the remaining disposal authority or inventory. Unlike sales from the National Defense Stockpile, helium sales by the Bureau of Land Management under the Helium Privatization Act of 1996 are permitted to exceed disposal plans.

Potential acquisitions indicate the maximum amount of a material that may be acquired by the U.S. Department of Defense for the National Defense Stockpile under the Annual Materials Plan approved by Congress for the fiscal year. FY 2019 is the period from October 1, 2018, through September 30, 2019. FY 2020 is the period from October 1, 2019, through September 30, 2020.

Depletion Allowance

The depletion allowance is a business tax deduction analogous to depreciation, but which applies to an ore reserve rather than equipment or production facilities. Federal tax law allows this deduction from taxable corporate income, recognizing that an ore deposit is a depletable asset that must eventually be replaced.

APPENDIX C—Reserves and Resources

Reserves data are dynamic. They may be reduced as ore is mined and (or) the feasibility of extraction diminishes, or more commonly, they may continue to increase as additional deposits (known or recently discovered) are developed, or currently exploited deposits are more thoroughly explored and (or) new technology or economic variables improve their economic feasibility. Reserves may be considered a working inventory of mining companies' supplies of an economically extractable mineral commodity. As such, the magnitude of that inventory is necessarily limited by many considerations, including cost of drilling, taxes, price of the mineral commodity being mined, and the demand for it. Reserves will be developed to the point of business needs and geologic limitations of economic ore grade and tonnage. For example, in 1970, identified and undiscovered world copper resources were estimated to contain 1.6 billion metric tons of copper, with reserves of about 280 million tons of copper. Since then, almost 560 million tons of copper have been produced worldwide, but world copper reserves in 2019 were estimated to be 870 million tons of copper, more than triple those of 1970, despite the depletion by mining of more than the original estimated reserves.

Future supplies of minerals will come from reserves and other identified resources, currently undiscovered resources in deposits that will be discovered in the future, and material that will be recycled from current in-use stocks of minerals or from minerals in waste disposal sites. Undiscovered deposits of minerals constitute an important consideration in assessing future supplies. Mineral-resource assessments have been carried out for small parcels of land being evaluated for land reclassification, for the Nation, and for the world.

Part A—Resource/Reserve Classification for Minerals[1]

INTRODUCTION

Through the years, geologists, mining engineers, and others operating in the minerals field have used various terms to describe and classify mineral resources, which as defined herein include energy materials. Some of these terms have gained wide use and acceptance, although they are not always used with precisely the same meaning.

The USGS collects information about the quantity and quality of all mineral resources. In 1976, the USGS and the U.S. Bureau of Mines developed a common classification and nomenclature, which was published as USGS Bulletin 1450–A—*"Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey."* Experience with this resource classification system showed that some changes were necessary in order to make it more workable in practice and more useful in long-term planning. Therefore, representatives of the USGS and the U.S. Bureau of Mines collaborated to revise Bulletin 1450–A. Their work was published in 1980 as USGS Circular 831—*"Principles of a Resource/Reserve Classification for Minerals."*

Long-term public and commercial planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. Thus, resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions. To best serve these planning needs, known resources should be classified from two standpoints: (1) purely geologic or physical/chemical characteristics—such as grade, quality, tonnage, thickness, and depth—of the material in place; and (2) profitability analyses based on costs of extracting and marketing the material in a given economy at a given time. The former constitutes important objective scientific information of the resource and a relatively unchanging foundation upon which the latter more valuable economic delineation can be based.

The revised classification system, designed generally for all mineral materials, is shown graphically in figures 1 and 2; its components and their usage are described in the text. The classification of mineral and energy resources is necessarily arbitrary because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy-fuel resources for the Nation or for specific areas.[1]

RESOURCE/RESERVE DEFINITIONS

A dictionary definition of resource, "something in reserve or ready if needed," has been adapted for mineral and energy resources to comprise all materials, including those only surmised to exist, that have present or anticipated future value.

Resource.—A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Original Resource.—The amount of a resource before production.

Identified Resources.—Resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified resources include economic, marginally economic, and subeconomic components. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into measured, indicated, and inferred.

[1]Based on U.S. Geological Survey Circular 831, 1980.

Demonstrated.—A term for the sum of measured plus indicated.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.—Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred.—Estimates are based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Reserve Base.—That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term “geologic reserve” has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.

Inferred Reserve Base.—The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit and for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence.

Reserves.—That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as “extractable reserves” and “recoverable reserves” are redundant and are not a part of this classification system.

Marginal Reserves.—That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technological factors.

Economic.—This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Subeconomic Resources.—The part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Undiscovered Resources.—Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, undiscovered resources may be divided into two parts, as follows:

Hypothetical Resources.—Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources.—Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Restricted Resources/Reserves.—That part of any resource/reserve category that is restricted from extraction by laws or regulations. For example, restricted reserves meet all the requirements of reserves except that they are restricted from extraction by laws or regulations.

Other Occurrences.—Materials that are too low grade or for other reasons are not considered potentially economic, in the same sense as the defined resource, may be recognized and their magnitude estimated, but they are not classified as resources. A separate category, labeled other occurrences, is included in figures 1 and 2. In figure 1, the boundary between subeconomic and other occurrences is limited by the concept of current or potential feasibility of economic production, which is required by the definition of a resource. The boundary is obviously uncertain, but limits may be specified in terms of grade, quality, thickness, depth, percent extractable, or other economic-feasibility variables.

Cumulative Production.—The amount of past cumulative production is not, by definition, a part of the resource. Nevertheless, a knowledge of what has been produced is important in order to understand current resources, in terms of both the amount of past production and the amount of residual or remaining in-place resource. A separate space for cumulative production is shown in figures 1 and 2. Residual material left in the ground during current or future extraction should be recorded in the resource category appropriate to its economic-recovery potential.

Figure 1.—Major Elements of Mineral-Resource Classification, Excluding *Reserve Base* and *Inferred Reserve Base*

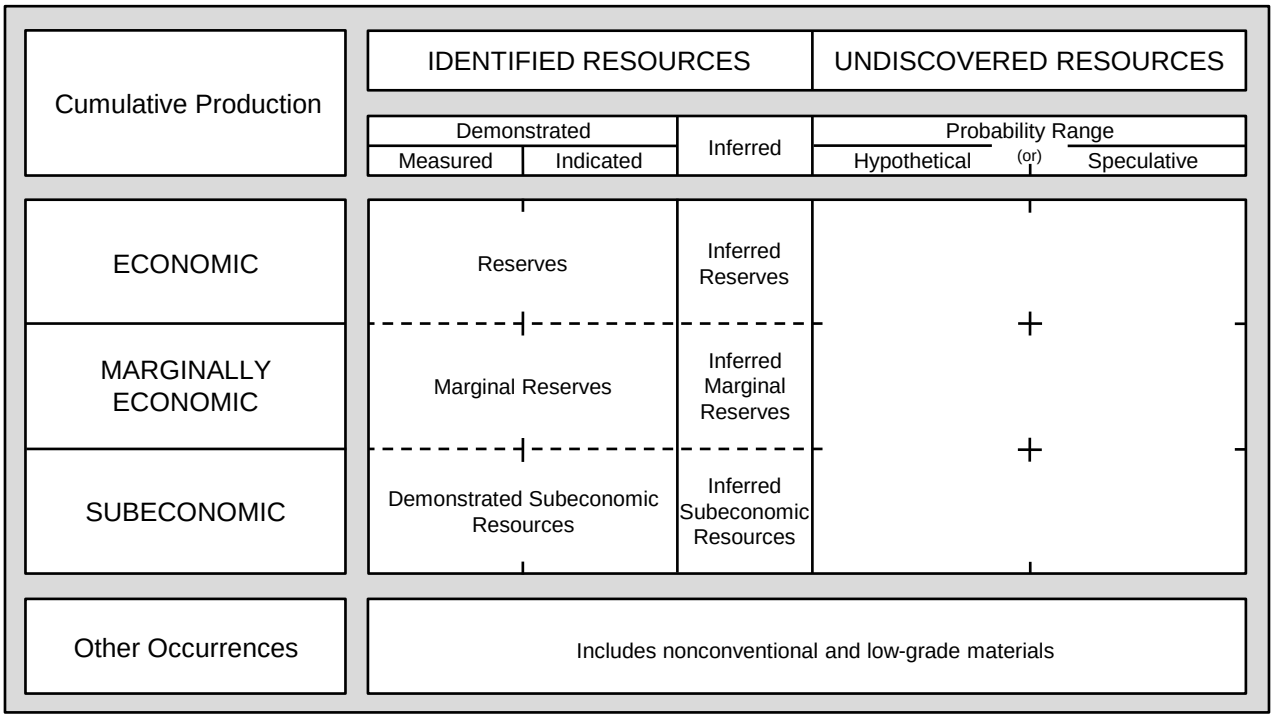
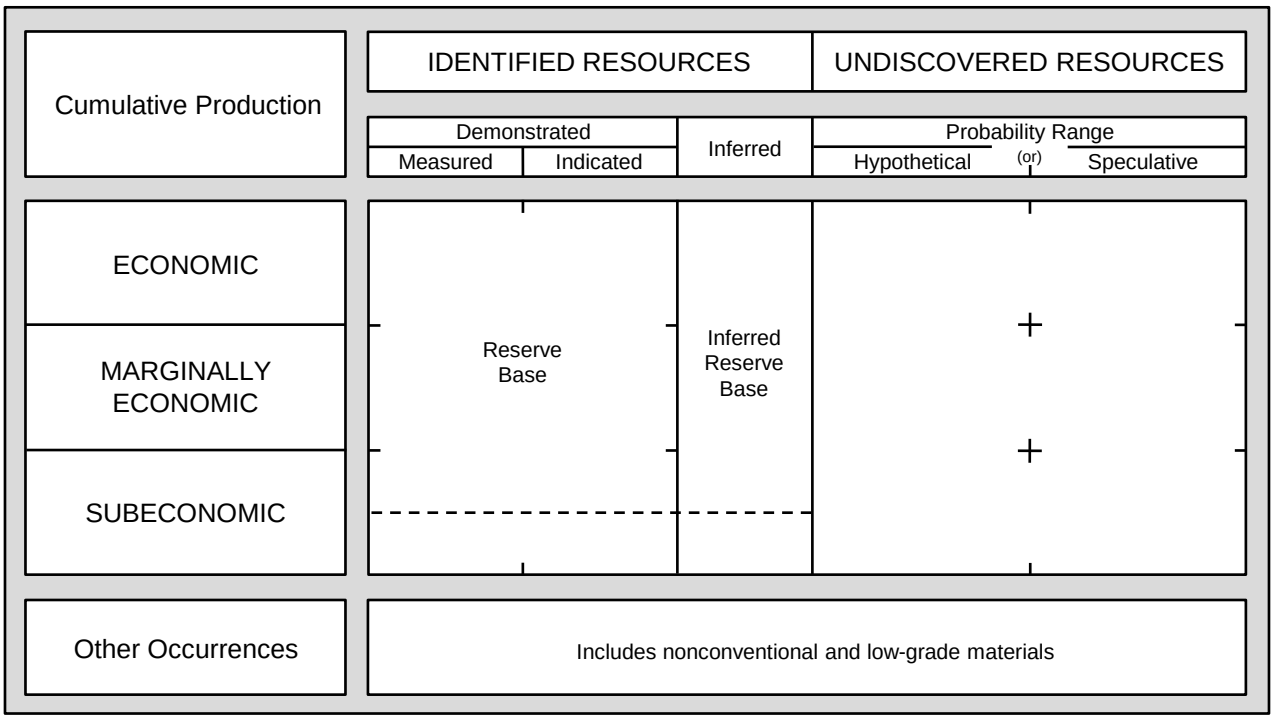


Figure 2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



Part B—Sources of Reserves Data

National information on reserves for most mineral commodities found in this report, including those for the United States, is derived from a variety of sources. The ideal source of such information would be comprehensive evaluations that apply the same criteria to deposits in different geographic areas and report the results by country. In the absence of such evaluations, national reserves estimates compiled by countries for selected mineral commodities are a primary source of national reserves information. Lacking national assessment information by governments, sources such as academic articles, company reports, presentations by company representatives, and trade journal articles, or a combination of these, serve as the basis for national information on reserves reported in the mineral commodity sections of this publication.

A national estimate may be assembled from the following: historically reported reserves information carried for years without alteration because no new information is available, historically reported reserves reduced by the amount of historical production, and company-reported reserves. International minerals availability studies conducted by the U.S. Bureau of Mines before 1996 and estimates of identified resources by an international collaborative effort (the International Strategic Minerals Inventory) are the bases for some reserves estimates. The USGS collects information about the quantity and quality of mineral resources but does not directly measure reserves, and companies or governments do not directly report reserves to the USGS. Reassessment of reserves is a continuing process, and the intensity of this process differs for mineral commodities, countries, and time period.

Some countries have specific definitions for reserves data, and reserves for each country are assessed separately, based on reported data and definitions. An attempt is made to make reserves consistent among countries for a mineral commodity and its byproducts. For example, the Australasian Joint Ore Reserves Committee (JORC) established the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code) that sets out minimum standards, recommendations, and guidelines for public reporting in Australasia of exploration results, mineral resources, and ore reserves. Companies listed on the Australian Securities Exchange and the New Zealand Stock Exchange are required to report publicly on ore reserves and mineral resources under their control, using the JORC Code.

Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources. Because of its specific use in the JORC Code, the term "reserves" is not used in the national inventory, where the highest category is "Economic Demonstrated Resources" (EDR). In essence, EDR combines the JORC Code categories proved reserves and probable reserves, plus measured resources and indicated resources. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term. Accessible Economic Demonstrated Resources represent the resources within the EDR category that are accessible for mining. Reserves for Australia in Mineral Commodity Summaries 2020 are Accessible EDR. For more information, see table 3. Australia's Identified Mineral Resources as of December 2017 can be found at https://d28rz98at9flks.cloudfront.net/124309/124309_AIMR.pdf.

In Canada, the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) provides definition standards for the classification of mineral resources and mineral reserves estimates into various categories. The category to which a resource or reserves estimate is assigned depends on the level of confidence in the geologic information available on the mineral deposit, the quality and quantity of data available on the deposit, the level of detail of the technical and economic information that has been generated about the deposit, and the interpretation of the data and information. For more information on the CIM definition standards, see https://mrmr.cim.org/en/standards/canadian-mineral-resource-and-mineral-reserve-definitions/.

In Russia, reserves for most minerals can appear in a number of sources, although no comprehensive list of reserves is published. Reserves data for a limited set of mineral commodities are available in the annual report "Gosudarstvennyi Doklad o Sostoyanii i Ispol'zovanii Mineral'no-Syryevyh Resursov Rossiyskoy Federatsii" (State report on the state and use of mineral and raw materials resources of the Russian Federation), which is published by the Ministry of Natural Resources and Environment of the Russian Federation. Reserves data for various minerals appear at times in journal articles, such as those in the journal "Mineral'nyye Resursy Rossii. Ekonomika i Upravleniye" (Mineral Resources of Russia. Economics and Management), which is published by the "OOO RG-Inform," a subsidiary of Rosgeologiya Holding. It is sometimes not clear if the reserves are being reported in ore or mineral content. It is also in many cases not clear which definition of reserves is being used, because the system inherited from the former Soviet Union has a number of ways in which the term "reserves" is defined, and these definitions qualify the percentage of reources that are included in a specific category. For example, the Soviet reserves classification system, besides the categories A, B, C1, and C2, which represent progressively detailed knowledge of a mineral deposit based on exploration data, has other subcategories cross imposed upon the system. Under the broad category reserves (zapasy), there are subcategories that include balance reserves (economic reserves or balansovyye zapasy) and outside-the-balance reserves (non-economic reserves or zabalansovye zapasy), as well as categories that include explored, industrial, and proven reserves, and the reserves totals can vary significantly, depending on the specific definition of reserves being reported.

APPENDIX D

Country Specialists Directory

Minerals information country specialists at the U.S. Geological Survey collect and analyze information on the mineral industries of more than 170 nations throughout the world. The specialists are available to answer minerals-related questions concerning individual countries.

Africa and the Middle East

Algeria	Mowafa Taib
Angola	Meralis Plaza-Toledo
Bahrain	Philip A. Szczesniak
Benin	Meralis Plaza-Toledo
Botswana	Thomas R. Yager
Burkina Faso	Alberto A. Perez
Burundi	Thomas R. Yager
Cabo Verde	Meralis Plaza-Toledo
Cameroon	Philip A. Szczesniak
Central African Republic	James J. Barry
Chad	Philip A. Szczesniak
Comoros	James J. Barry
Congo (Brazzaville)	James J. Barry
Congo (Kinshasa)	Thomas R. Yager
Côte d'Ivoire	Alberto A. Perez
Djibouti	Thomas R. Yager
Egypt	Mowafa Taib
Equatorial Guinea	Meralis Plaza-Toledo
Eritrea	Thomas R. Yager
Eswatini	James J. Barry
Ethiopia	Meralis Plaza-Toledo
Gabon	Alberto A. Perez
The Gambia	Meralis Plaza-Toledo
Ghana	Meralis Plaza-Toledo
Guinea	Alberto A. Perez
Guinea-Bissau	Meralis Plaza-Toledo
Iran	Philip A. Szczesniak
Iraq	Philip A. Szczesniak
Israel	Philip A. Szczesniak
Jordan	Mowafa Taib
Kenya	Thomas R. Yager
Kuwait	Philip A. Szczesniak
Lebanon	Mowafa Taib
Lesotho	James J. Barry
Liberia	Meralis Plaza-Toledo
Libya	Mowafa Taib
Madagascar	Thomas R. Yager
Malawi	Thomas R. Yager
Mali	Alberto A. Perez
Mauritania	Mowafa Taib
Mauritius	James J. Barry
Morocco & Western Sahara	Mowafa Taib
Mozambique	Meralis Plaza-Toledo
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Qatar	Philip A. Szczesniak
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Bhutan	Ji Won Moon
Brunei	Spencer D. Buteyn
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Cambodia	Ji Won Moon
China	Sean Xun
Fiji	Spencer D. Buteyn
India	Karine M. Renaud
Indonesia	Jaewon Chung
Japan	Keita F. DeCarlo
Korea, North	Jaewon Chung
Korea, Republic of	Jaewon Chung
Laos	Ji Won Moon
Malaysia	Spencer D. Buteyn
Mongolia	Jaewon Chung
Nauru	Spencer D. Buteyn
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New Caledonia	Spencer D. Buteyn
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Papua New Guinea	Spencer D. Buteyn
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Singapore	Spencer D. Buteyn
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Sri Lanka	Ji Won Moon
Taiwan	Jaewon Chung
Thailand	Ji Won Moon
Timor-Leste	Jaewon Chung
Vietnam	Ji Won Moon

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Belarus	Elena Safirova
Belgium	Loyd M. Trimmer III

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Estonia	Keita F. DeCarlo
Finland	Joanna Goclawska
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Spain	Loyd M. Trimmer III
Sweden	Joanna Goclawska
Switzerland	Keita F. DeCarlo
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Turkmenistan	Karine M. Renaud
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Uzbekistan	Elena Safirova

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Dominican Republic	Yadira Soto-Viruet
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French Guiana	Yolanda Fong-Sam
Guyana	Yolanda Fong-Sam
Paraguay	Yadira Soto-Viruet
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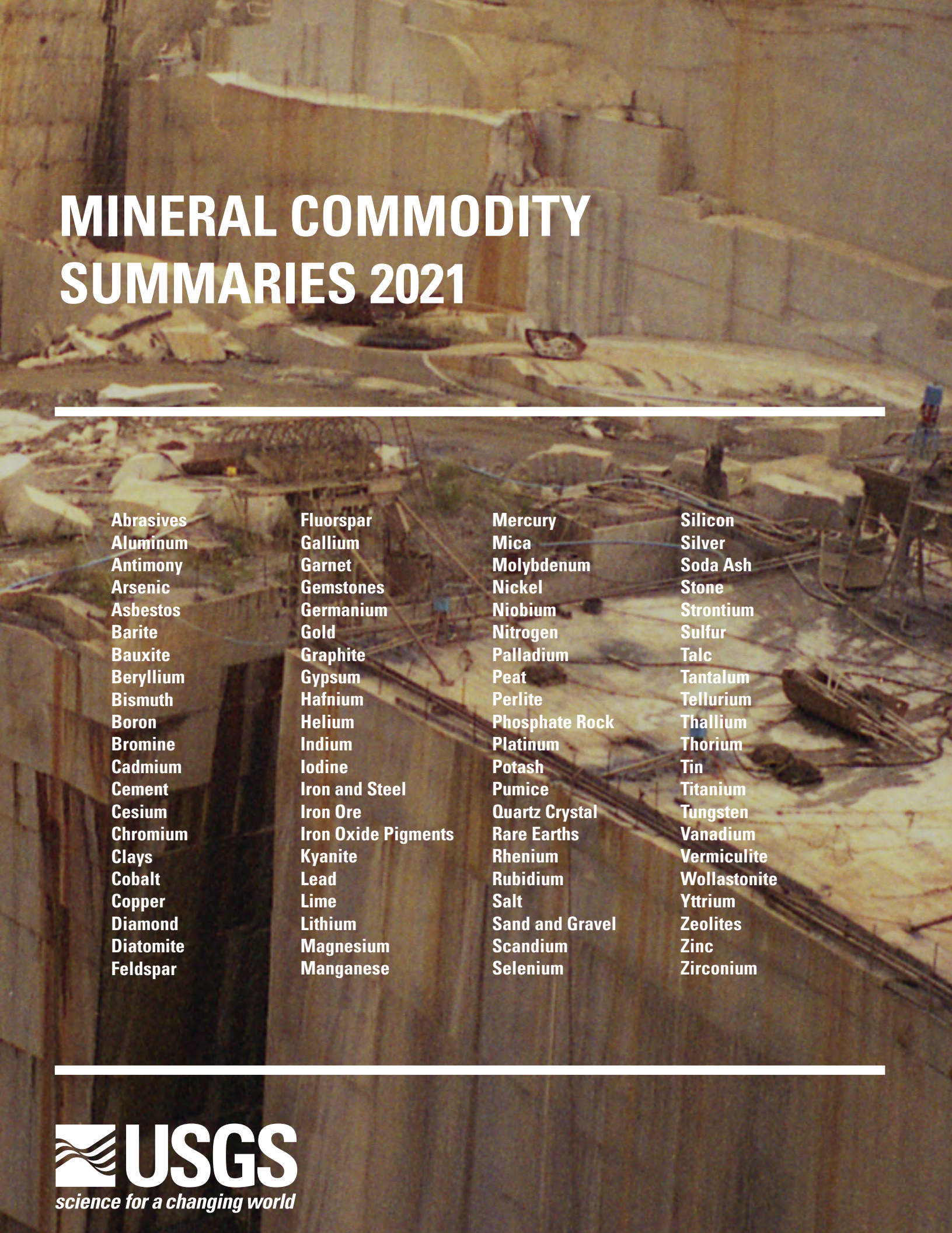

MINERAL COMMODITY SUMMARIES 2021

Abrasives
Aluminum
Antimony
Arsenic
Asbestos
Barite
Bauxite
Beryllium
Bismuth
Boron
Bromine
Cadmium
Cement
Cesium
Chromium
Clays
Cobalt
Copper
Diamond
Diatomite
Feldspar
Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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Cover: Photograph of Fletcher Granite Co.'s Chelmsford Grey Quarry in Westford, MA, taken in about 2000. This quarry has been in continual operation since 1881 and is the source of the company's Chelmsford Grey product. Over the years, granite from this quarry has been used in numerous building and civil engineering projects. According to the company, Chelmsford Grey granite was used for the Thurgood Marshall Federal Judiciary Building and the National Cathedral, both in Washington, DC. Photograph by Thomas P. Dolley, U.S. Geological Survey.

U.S. Department of the Interior
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MINERAL COMMODITY SUMMARIES 2021

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Clays
Cobalt
Copper
Diamond
Diatomite
Feldspar
Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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KEY PUBLICATIONS

Minerals Yearbook—These annual publications review the mineral industries of the United States and of more than 180 other countries. They contain statistical data on minerals and materials and include information on economic and technical trends and developments and are available at https://www.usgs.gov/centers/nmic/publications. The three volumes that make up the Minerals Yearbook are volume I, Metals and Minerals; volume II, Area Reports—Domestic; and volume III, Area Reports—International.

Mineral Commodity Summaries—Published on an annual basis, this report is the earliest Government publication to furnish estimates covering nonfuel mineral industry data and is available at https://www.usgs.gov/centers/nmic/mineral-commodity-summaries. Data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for more than 90 individual minerals and materials.

Mineral Industry Surveys—These periodic statistical and economic reports are designed to provide timely statistical data on production, shipments, stocks, and consumption of significant mineral commodities and are available at https://www.usgs.gov/centers/nmic/mineral-industry-surveys. The surveys are issued monthly, quarterly, or at other regular intervals.

Materials Flow Studies—These publications describe the flow of minerals and materials from extraction to ultimate disposition to help better understand the economy, manage the use of natural resources, and protect the environment and are available at https://www.usgs.gov/centers/nmic/materials-flow.

Recycling Reports—These studies illustrate the recycling of metal commodities and identify recycling trends and are available at https://www.usgs.gov/centers/nmic/recycling-statistics-and-information.

Historical Statistics for Mineral and Material Commodities in the United States (Data Series 140)—This report provides a compilation of statistics on production, trade, and use of approximately 90 mineral commodities since as far back as 1900 and is available at https://www.usgs.gov/centers/nmic/historical-statistics-mineral-and-material-commodities-united-states.

WHERE TO OBTAIN PUBLICATIONS

- *Mineral Commodity Summaries* and the *Minerals Yearbook* are sold by the U.S. Government Publishing Office. Orders are accepted over the internet at https://bookstore.gpo.gov, by email at ContactCenter@gpo.gov, by telephone toll free (866) 512–1800; Washington, DC, area (202) 512–1800, by fax (202) 512–2104, or through the mail (P.O. Box 979050, St. Louis, MO 63197–9000).

- All current and many past publications are available as downloadable Portable Document Format (PDF) files through https://www.usgs.gov/centers/nmic.

INTRODUCTION

Each mineral commodity chapter of the 2021 edition of the U.S. Geological Survey (USGS) Mineral Commodity Summaries (MCS) includes information on events, trends, and issues for each mineral commodity as well as discussions and tabular presentations on domestic industry structure, Government programs, tariffs, 5-year salient statistics, and world production and resources. The MCS is the earliest comprehensive source of 2020 mineral production data for the world. More than 90 individual minerals and materials are covered by 2-page synopses.

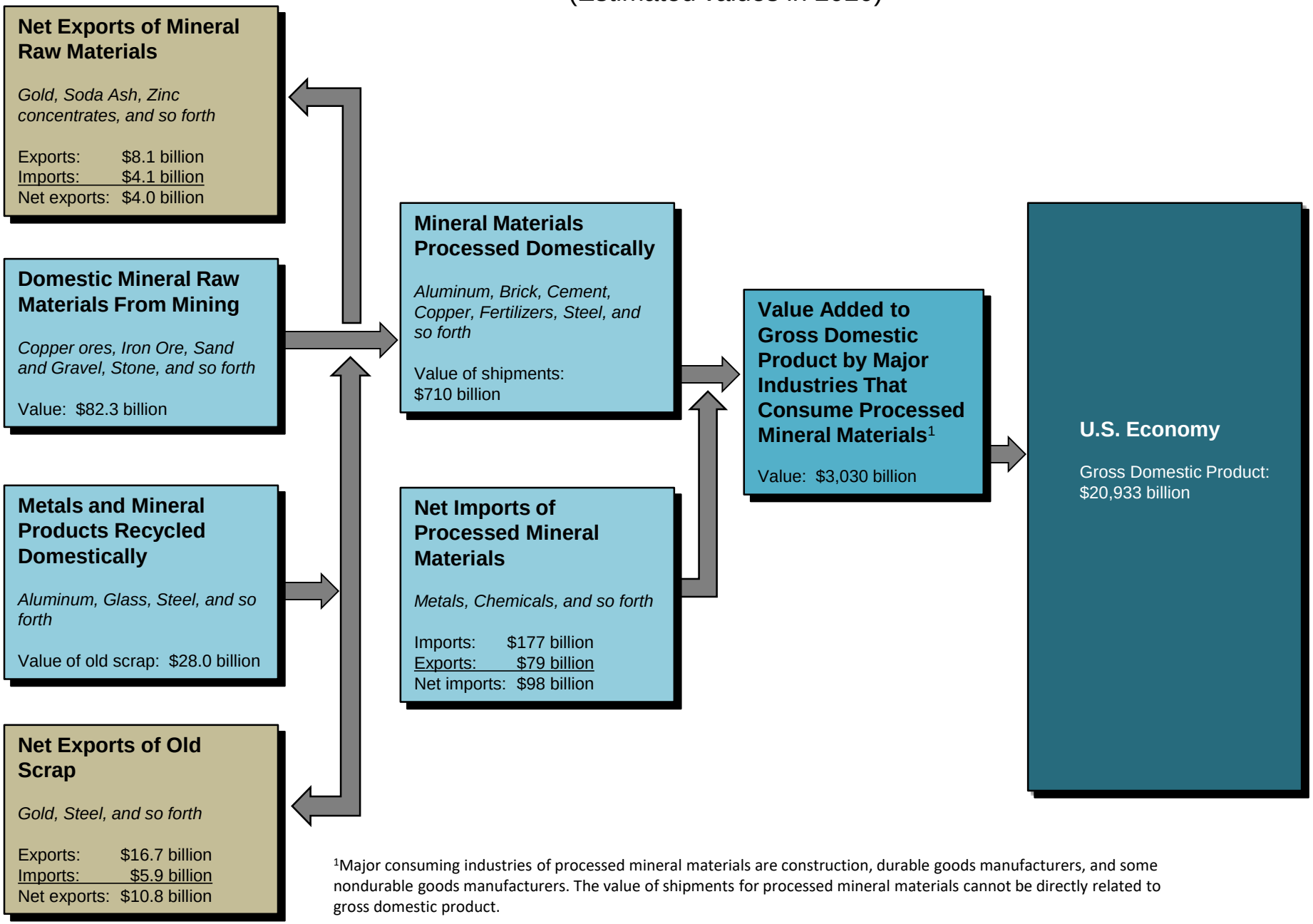
For mineral commodities for which there is a Government stockpile, detailed information concerning the stockpile status is included in the 2-page synopsis.

Abbreviations and units of measure and definitions of selected terms used in the report are in Appendix A and Appendix B, respectively. Reserves and resources information is in Appendix C, which includes “Part A—Resource and Reserve Classification for Minerals” and “Part B—Sources of Reserves Data.” A directory of USGS minerals information country specialists and their responsibilities is in Appendix D.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the MCS 2021 are welcomed.

Figure 1.—The Role of Nonfuel Minerals in the U.S. Economy

(Estimated values in 2020)



[1]Major consuming industries of processed mineral materials are construction, durable goods manufacturers, and some nondurable goods manufacturers. The value of shipments for processed mineral materials cannot be directly related to gross domestic product.

Sources: U.S. Geological Survey and the U.S. Department of Commerce.

SIGNIFICANT EVENTS, TRENDS, AND ISSUES

In 2020, the estimated total value of nonfuel mineral production in the United States was $82.3 billion, a decrease of 2% from the revised total of $83.7 billion in 2019. The estimated value of metals production increased by 3% to $27.7 billion. Increased prices for precious metals, such as gold, which reached a record-high price of $2,060 per troy ounce in August, contributed to the increased value of metal production. The total value of industrial minerals production was $54.6 billion, a 4% decrease from that of 2019. Of this total, $27.0 billion was construction aggregates production (construction sand and gravel and crushed stone). Crushed stone was the leading nonfuel mineral commodity in 2020 with a production value of $17.8 billion and accounted for 22% of the total value of U.S. nonfuel mineral production.

Decreases in consumption of nonfuel mineral commodities in commercial construction, oil and gas production, steel production, and automotive and transportation industry were attributed to the financial impacts of the global COVID-19 pandemic. For the metals sector, the aluminum, iron ore, steel, and titanium industries were particularly affected by reduced demand from manufacturing. For the industrial minerals sector, the largest decreases in production were in barite and industrial sand and gravel, commodities that are closely tied to the performance of the natural gas and oil well-drilling industry. In general, mines were not subject to COVID-19-related stay-at-home orders because they were deemed critical industries, but decreased demand from downstream industries resulted in reduced production at some operations.

In 2020, additional import duties were put in place for certain products that were derivatives of aluminum and steel articles, and the additional duties continued for most countries as a result of the U.S. Department of Commerce findings in 2018 of harm to national security under section 232 of the Trade Expansion Act of 1962 (19 U.S.C. §1862, as amended). As of December 2020, aluminum and derivative product imports from all countries except Argentina, Australia, Canada, and Mexico remained subject to a 10% ad valorem tariff, and steel and derivative product imports from all countries except Argentina, Australia, Brazil, Canada, the Republic of Korea, and Mexico remained subject to a 25% ad valorem tariff.

Under section 301(b) of the Trade Act of 1974 (19 U.S.C. §2411, as amended), in August 2020, the Office of the United States Trade Representative (USTR) published additional ad valorem duty rates on approximately $7.5 billion of imported items from specified European countries related to the Large Civil Aircraft dispute (85 FR 50866). In November, the European Union imposed additional duties on approximately $4 billion of imports from the United States. Most of the listed items were aircraft, agricultural items and spirits.

The additional 25% ad valorem duty for products imported from China (Lists 1, 2, and 3) and the 7.5% ad valorem duty for products imported from China (List 4) imposed under section 301(b) of the Trade Act of 1974, (19 U.S.C. §2411, as amended) by the USTR continued in 2020. Likewise, China imposed additional import duties for certain items originating in the United States. The United States imposed an additional tariff on approximately $309 billion of imports from China. China imposed additional tariffs on approximately $77 billion of imports from the United States.

Actions to achieve the goals and objectives of Executive Order 13817, “A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals,” issued in December 2017, continued in 2020. As outlined in a report issued by the U.S. Department of Commerce, a strategy was developed to reduce the Nation’s reliance on critical minerals; an assessment of progress toward developing critical minerals recycling and reprocessing technologies and technological alternatives to critical minerals; options for accessing and developing critical minerals through investment and trade with our allies and partners; a plan to improve the topographic, geologic, and geophysical mapping of the United States and make the resulting data and metadata electronically accessible, to the extent permitted by law and subject to appropriate limitations for purposes of privacy and security, to support private sector mineral exploration of critical minerals; and recommendations to streamline permitting and review processes related to developing leases; enhancing access to critical mineral resources; and increasing discovery, production, and domestic refining of critical minerals.

In February 2020, the U.S. Geological Survey (USGS) published a new methodology to evaluate the global supply of and U.S. demand for 52 mineral commodities for the years 2007 to 2016. It identified 23 mineral commodities, including aluminum, antimony, bismuth, cobalt, gallium, germanium, indium, niobium, platinum-group metals, rare-earth elements, tantalum, titanium, and tungsten, as posing the greatest supply risk for the U.S. manufacturing sector (Nassar and others, 2020).

On September 30, 2020, Executive Order 13953, “Addressing the Threat to the Domestic Supply Chain Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries,” was issued to address the national emergency described. Several actions by Federal agencies were ordered including tasking the Secretary of the Interior, in consultation with the Secretary of the Treasury, the Secretary of Defense, the Secretary of Commerce, and the heads of other agencies, as appropriate, to investigate the Nation’s reliance on critical minerals.

On December 7, 2020, Open-File Report 2020–1127, “Investigation of U.S. Foreign Reliance on Critical Minerals—U.S. Geological Survey Technical Input Document in Response to Executive Order No. 13953 issued September 30, 2020,” was published by the USGS. The report identified and categorized the main sources of U.S. mineral commodity imports according to

existing security of supply agreements with the United States and the U.S. Department of Commerce's list of nonmarket economies; quantified the concentration of import sources; identified net import reliance considerations, trends, and technical options salient for each mineral commodity; highlighted factors that may obscure the true net import reliance; and provided a general framework for evaluating strategies that may help reduce U.S. net import reliance.

On November 17, 2020, the U.S. Department of Defense announced contracts and agreements with rare-earth-element producers under the authorities of title III of the Defense Production Act. These agreements were put in place to support and strengthen the domestic rare earth supply chain in response to the Presidential Determinations, signed on July 22, 2019, pursuant to section 303 of the Defense Production Act of 1950, as amended (50 U.S.C. §4501 et seq.).

As shown in figure 1, minerals remained fundamental to the U.S. economy, contributing to the real gross domestic product at several levels, including mining, processing, and manufacturing finished products. The estimated value of nonfuel minerals produced at mines in the United States in 2020 was $82.3 billion. The value of net exports of mineral raw materials increased to $4.0 billion from $3.7 billion in 2019. Domestically recycled products totaled $28 billion, and iron and steel scrap contributed $9 billion to that total. Domestic raw materials and domestically recycled materials were used to produce mineral materials worth $710 billion. These mineral materials as well as imports of processed mineral materials, which increased by 83% in 2020, were, in turn, consumed by downstream industries creating an estimated value of $3.03 trillion in 2020, a 3% decrease from that in 2019.

Figure 2 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2020, imports made up more than one-half of the U.S. apparent consumption for 46 nonfuel mineral commodities, and the United States was 100% net import reliant for 17 of those. Of the 35 minerals or mineral material groups identified as "critical minerals" published in the Federal Register on May 18, 2018 (83 FR 23295), 14 of the 17 mineral commodities with 100% net import reliance were listed as critical minerals, and 14 additional critical mineral commodities had a net import reliance greater than 50% of apparent consumption.

Figure 3 shows the countries from which the majority of these mineral commodities were imported and the number of mineral commodities for which each highlighted country was a leading supplier. China, followed by Canada, supplied the largest number of nonfuel mineral commodities.

The estimated value of U.S. metal mine production in 2020 was $27.7 billion, 3% higher than the revised value of 2019 (table 1). Principal contributors to the total value of metal mine production in 2020 were gold (38%), copper (27%), iron ore (15%), and zinc (6%). The estimated value of U.S. industrial minerals production in 2020, including construction aggregates, was $54.6 billion, about 4% less than the revised value of 2019 (table 1). The value of industrial minerals production in 2020 was dominated by crushed stone, 32%; cement (masonry and portland), 20%; construction sand and gravel, 17%; and industrial sand and gravel, 6%.

In 2020, U.S. production of 12 mineral commodities was valued at more than $1 billion each. These commodities were, in decreasing order of value, crushed stone, gold, cement, construction sand and gravel, copper, iron ore, industrial sand and gravel, salt, lime, phosphate rock, zinc, and soda ash.

In 2020, 12 States each produced more than $2 billion worth of nonfuel mineral commodities. These States were, in descending order of production value, Nevada, Arizona, Texas, California, Minnesota, Florida, Alaska, Utah, Missouri, Michigan, Wyoming, and Georgia (table 3, fig. 4).

The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) is responsible for the operational oversight of the National Defense Stockpile (NDS) of strategic and critical materials. Managing the security, environmentally sound stewardship, and ensuring the readiness of all NDS stocks is the mission of DLA Strategic Materials. The NDS currently contains 48 unique commodities stored at 12 locations within the continental United States. In fiscal year 2020, approximately $9.2 million of new stocks were acquired and $56.85 million of excess materials were sold. Revenue from the Stockpile Sales Program fund the operation of the NDS and the acquisition of new stocks. As of September 30, 2020, the NDS inventory had a fair market value of $887.9 million. For reporting purposes, NDS stocks are categorized as held in reserve or available for sale. The majority of stocks are held in reserve. Additional detailed information can be found in the "Government Stockpile" sections in the mineral commodity chapters that follow. Under the authority of the Defense Production Act of 1950 (Pub. L. 81–774), the USGS advises the DLA Strategic Materials on acquisitions and disposals of NDS mineral materials.

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Figure 2.—2020 U.S. Net Import Reliance[1]

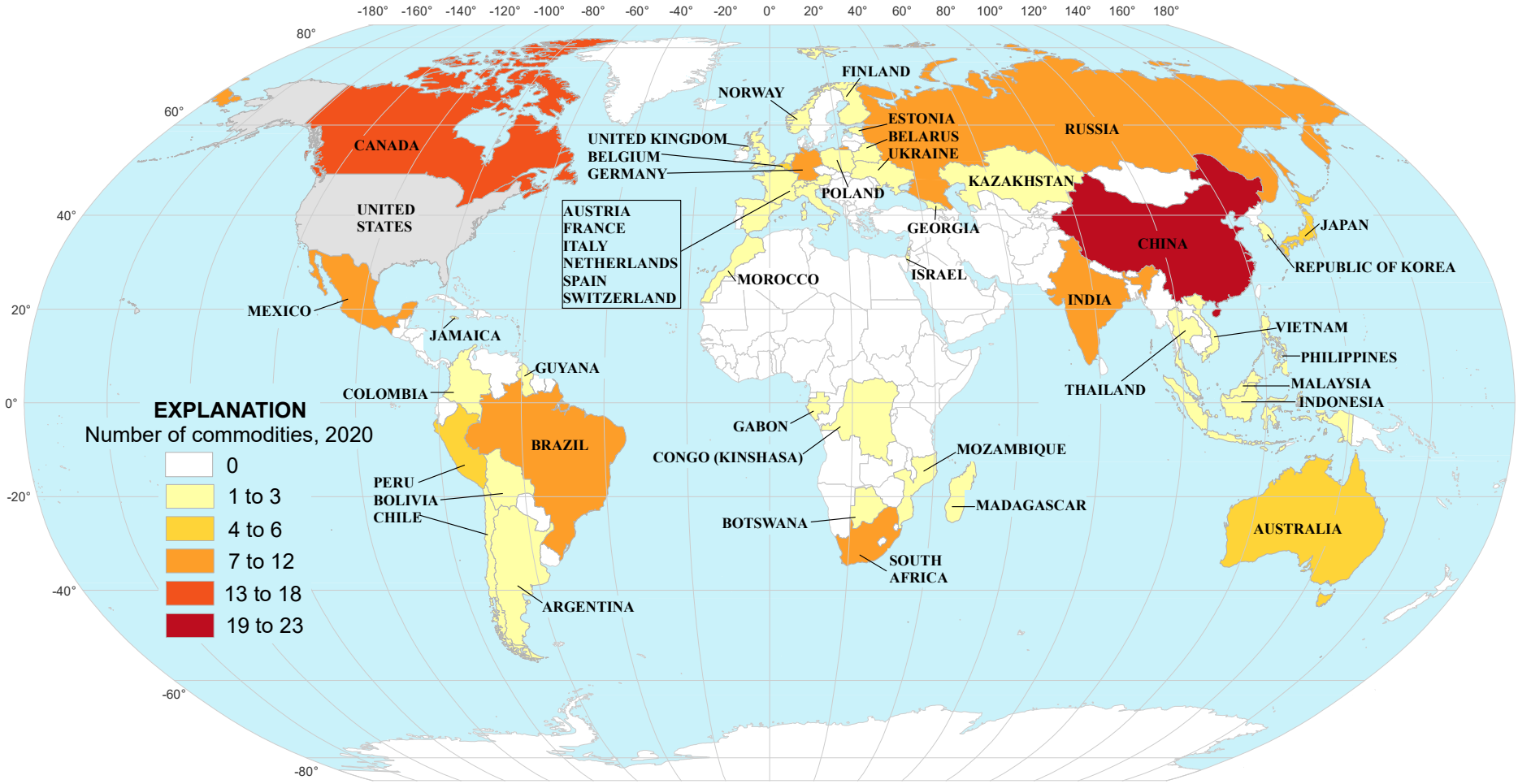
Commodity	Percent	Major import sources (2016–19)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, Vietnam, China, South Africa
GALLIUM	100	China, United Kingdom, Germany
GRAPHITE (NATURAL)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, India
NEPHELINE SYENITE	100	Canada
NIOBIUM (COLUMBIUM)	100	Brazil, Canada, Germany, Russia
RARE EARTHS,[3] compounds and metal	100	China, Estonia, Japan, Malaysia
RUBIDIUM	100	Canada
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
YTTRIUM	100	China, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
VANADIUM	96	Brazil, South Africa, Austria, Canada
TELLURIUM	>95	Canada, China, Germany, Philippines
BISMUTH	94	China, Republic of Korea, Mexico, Belgium
POTASH	90	Canada, Belarus, Russia
TITANIUM MINERAL CONCENTRATES	88	South Africa, Australia, Madagascar, Mozambique
DIAMOND (INDUSTRIAL), stones	84	South Africa, India, Botswana, Congo (Kinshasa)
ZINC, refined	83	Canada, Mexico, Peru, Spain
ANTIMONY, metal and oxide	81	China, Belgium, Thailand, India
SILVER	80	Mexico, Canada, Peru, Poland
PLATINUM	79	South Africa, Germany, Italy, Switzerland
STONE (DIMENSION)	79	China, Brazil, Italy, India
COBALT	76	Norway, Canada, Japan, Finland
PEAT	76	Canada
RHENIUM	76	Chile, Germany, Canada, Kazakhstan
ABRASIVES, crude fused aluminum oxide	>75	China, France, Canada, Russia
ABRASIVES, crude silicon carbide	>75	China, Netherlands, South Africa
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Guyana, Australia, Brazil
IRON OXIDE PIGMENTS, natural and synthetic	>75	China, Germany, Brazil
CHROMIUM	75	South Africa, Kazakhstan, Mexico, Russia
TIN, refined	75	Indonesia, Malaysia, Peru, Bolivia
MAGNESIUM COMPOUNDS	54	China, Israel, Brazil, Netherlands
GOLD	52	Mexico, Canada, Peru, Colombia
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
LITHIUM	>50	Argentina, Chile, China, Russia
TITANIUM, sponge	>50	Japan, Kazakhstan, Ukraine
TUNGSTEN	>50	China, Bolivia, Germany, Austria
NICKEL	50	Canada, Norway, Finland, Russia
CADMIUM	<50	Australia, China, Canada, Germany
MAGNESIUM METAL	<50	Canada, Israel, Mexico, Russia
SELENIUM	<50	China, Philippines, Mexico, Germany
ALUMINA	49	Brazil, Australia, Jamaica, Canada
GARNET (INDUISTRIAL)	48	South Africa, India, China, Australia
DIAMOND (INDUSTRIAL), dust, grit, and powder	47	China, Ireland, Republic of Korea, Russia
PALLADIUM	40	Russia, South Africa, Germany, United Kingdom
SILICON, metal and ferrosilicon	38	Brazil, Russia, Canada
COPPER, refined	37	Chile, Canada, Mexico
MICA (NATURAL), scrap and flake	31	Canada, China, India, Finland
PERLITE	28	Greece, China, Mexico, Turkey
SALT	27	Chile, Canada, Mexico, Egypt
BROMINE	<25	Israel, Jordan, China
ZIRCONIUM, ores and concentrates	<25	South Africa, Senegal, Australia, Russia
LEAD, refined	24	Canada, Republic of Korea, Mexico, India
VERMICULITE	20	South Africa, Brazil, Zimbabwe, Kenya

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (boron; clays; diatomite; helium; iron and steel scrap; iron ore; kyanite; molybdenum concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zinc concentrates) or less than 20% net import reliant (abrasives, metallic; aluminum; beryllium; cement; feldspar; gypsum; iron and steel; iron and steel slag; lime; nitrogen (fixed)–ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]Listed in descending order of import share.

[3]Data include lanthanides.

Figure 3.—Major Import Sources of Nonfuel Mineral Commodities for which the United States was greater than 50% Net Import Reliant in 2020



Source: U.S. Geological Survey

Table 1.—U.S. Mineral Industry Trends

	2016	2017	2018	2019	2020[e]
Total mine production (million dollars):					
Metals	23,700	26,800	28,200	26,900	27,700
Industrial minerals	47,700	52,600	56,100	56,900	54,600
Coal	22,300	26,100	27,200	25,500	18,800
Employment (thousands of workers):					
Coal mining, all employees	51	52	52	52	46
Nonfuel mineral mining, all employees	130	134	140	140	136
Chemicals and allied products, production workers	516	525	546	558	533
Stone, clay, and glass products, production workers	306	305	311	315	301
Primary metal industries, production workers	293	292	295	300	268
Average weekly earnings of workers (dollars):					
Coal mining, all employees	1,441	1,486	1,546	1,617	1,510
Chemicals and allied products, production workers	950	1,010	1,072	1,067	1,060
Stone, clay, and glass products, production workers	851	873	945	968	978
Primary metal industries, production workers	1,002	995	1,036	1,025	1,010

[e]Estimated.

Sources: U.S. Geological Survey, U.S. Department of Energy, and U.S. Department of Labor.

Table 2.—U.S. Mineral-Related Economic Trends

	2016	2017	2018	2019	2020[e]
Gross domestic product (billion dollars)	18,745	19,543	20,612	21,433	20,933
Industrial production (2012=100):					
Total index:	102	104	109	109	101
Manufacturing:	101	103	106	106	98
Nonmetallic mineral products	111	115	120	119	114
Primary metals:	93	94	98	97	82
Iron and steel	87	92	97	97	80
Aluminum	106	103	107	107	97
Nonferrous metals (except aluminum)	95	91	91	88	75
Chemicals	95	97	100	101	97
Mining:	103	110	124	133	119
Coal	70	75	74	69	52
Oil and gas extraction	129	135	156	173	165
Metals	100	98	93	93	93
Nonmetallic minerals	114	118	119	123	122
Capacity utilization (percent):					
Total industry:	75	76	79	78	72
Mining:	78	84	90	90	81
Metals	75	71	69	69	68
Nonmetallic minerals	87	88	88	90	89
Housing starts (thousands)	1,177	1,207	1,248	1,295	1,370
Light vehicle sales (thousands)	17,465	17,136	17,214	16,953	14,200
Highway construction, value, put in place (billion dollars)	94	90	91	98	100

[e]Estimated.

Sources: U.S. Department of Commerce and Federal Reserve Board.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Minerals Produced in 2020[p, 1]

State	Value (millions)	Rank[2]	Percent of U.S. total[3]	Principal nonfuel mineral commodities[4]
Alabama	$1,580	18	1.92	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Alaska	3,160	7	3.83	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	7,030	2	8.54	Cement (portland), copper, molybdenum concentrates, sand and gravel (construction), stone (crushed).
Arkansas	869	29	1.06	Bromine, cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California	4,680	4	5.68	Boron minerals, cement (portland), gold, sand and gravel (construction), stone (crushed).
Colorado	1,620	17	1.96	Cement (portland), gold, molybdenum concentrates, sand and gravel (construction), stone (crushed).
Connecticut[5]	190	43	0.23	Clay (common clay), sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[5]	23	50	0.03	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida	3,520	6	4.27	Cement (masonry and portland), phosphate rock, sand and gravel (construction), stone (crushed).
Georgia	2,020	12	2.45	Cement (portland), clay (kaolin), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Hawaii	128	45	0.16	Sand and gravel (construction), stone (crushed).
Idaho[5]	247	35	0.30	Lead, phosphate rock, sand and gravel (construction), silver, stone (crushed).
Illinois[5]	1,100	23	1.34	Cement (portland), sand and gravel (construction), sand and gravel (industrial), silica (tripoli), stone (crushed).
Indiana[5]	695	24	0.84	Cement (portland), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa[5]	727	28	0.88	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[5]	1,250	20	1.52	Cement (portland), helium (Grade-A), salt, sand and gravel (construction), stone (crushed).
Kentucky[5]	566	30	0.69	Cement (portland), clay (common clay), lime, sand and gravel (construction), stone (crushed).
Louisiana[5]	656	33	0.80	Clay (common clay), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[5]	148	44	0.18	Cement (portland), peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[5]	429	32	0.52	Cement (masonry and portland), sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[5]	267	42	0.32	Clay (common clay), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	2,630	10	3.20	Cement (portland), iron ore, salt, sand and gravel (construction), stone (crushed).
Minnesota[5]	4,090	5	4.96	Iron ore, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Mississippi[5]	286	41	0.35	Clay (bentonite and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	3,030	9	3.68	Cement (portland), lead, lime, sand and gravel (industrial), stone (crushed).
Montana	1,680	16	2.04	Copper, molybdenum concentrates, palladium, platinum, sand and gravel (construction).

See footnotes at end of table.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Minerals Produced in 2020[p, 1]—Continued

State	Value (millions)	Rank[2]	Percent of U.S. total[3]	Principal nonfuel mineral commodities[4]
Nebraska[5]	$215	38	0.26	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	9,140	1	11.10	Copper, diatomite, gold, lime, silver.
New Hampshire	110	47	0.13	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	345	40	0.42	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	864	31	1.05	Cement (portland), copper, potash, sand and gravel (construction), stone (crushed).
New York	1,690	15	2.05	Cement (portland), salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina[5]	1,150	19	1.39	Clay (common clay), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[5]	74	48	0.09	Clay (common clay), lime, sand and gravel (construction), stone (crushed).
Ohio[5]	1,340	13	1.63	Cement (portland), lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	1,040	27	1.26	Cement (portland), iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon	513	36	0.62	Cement (portland), diatomite, perlite (crude), sand and gravel (construction), stone (crushed).
Pennsylvania[5]	1,750	14	2.13	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Rhode Island[5]	48	49	0.06	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina[5]	895	25	1.09	Cement (masonry and portland), gold, sand and gravel (construction), stone (crushed).
South Dakota	449	37	0.54	Cement (portland), gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,330	22	1.61	Cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	6,090	3	7.40	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	3,150	8	3.82	Cement (portland), copper, gold, molybdenum concentrates, sand and gravel (construction).
Vermont[5]	119	46	0.14	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,370	21	1.67	Cement (portland), kyanite, lime, sand and gravel (construction), stone (crushed).
Washington	630	34	0.77	Cement (portland), diatomite, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
West Virginia[5]	164	39	0.20	Cement (masonry and portland), lime, sand and gravel (industrial), stone (crushed).
Wisconsin[5]	1,020	26	1.24	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	2,440	11	2.97	Cement (portland), clay (bentonite), helium (Grade-A), sand and gravel (construction), soda ash.
Undistributed	3,780	XX	4.61	
Total	82,300	XX	100.00	

[p]Preliminary. XX Not applicable.

[1]Table includes data available through December 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

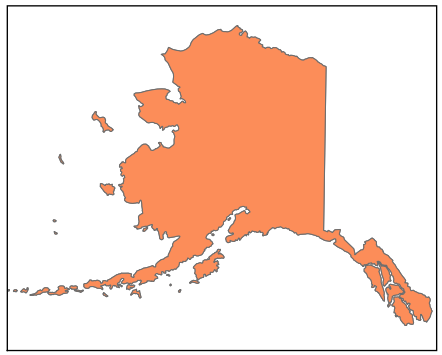
[2]Rank based on total, unadjusted State values.

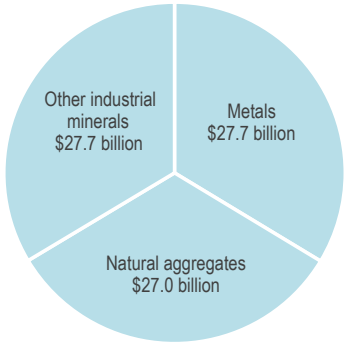
[3]Percent of U.S. total calculated to two decimal places.

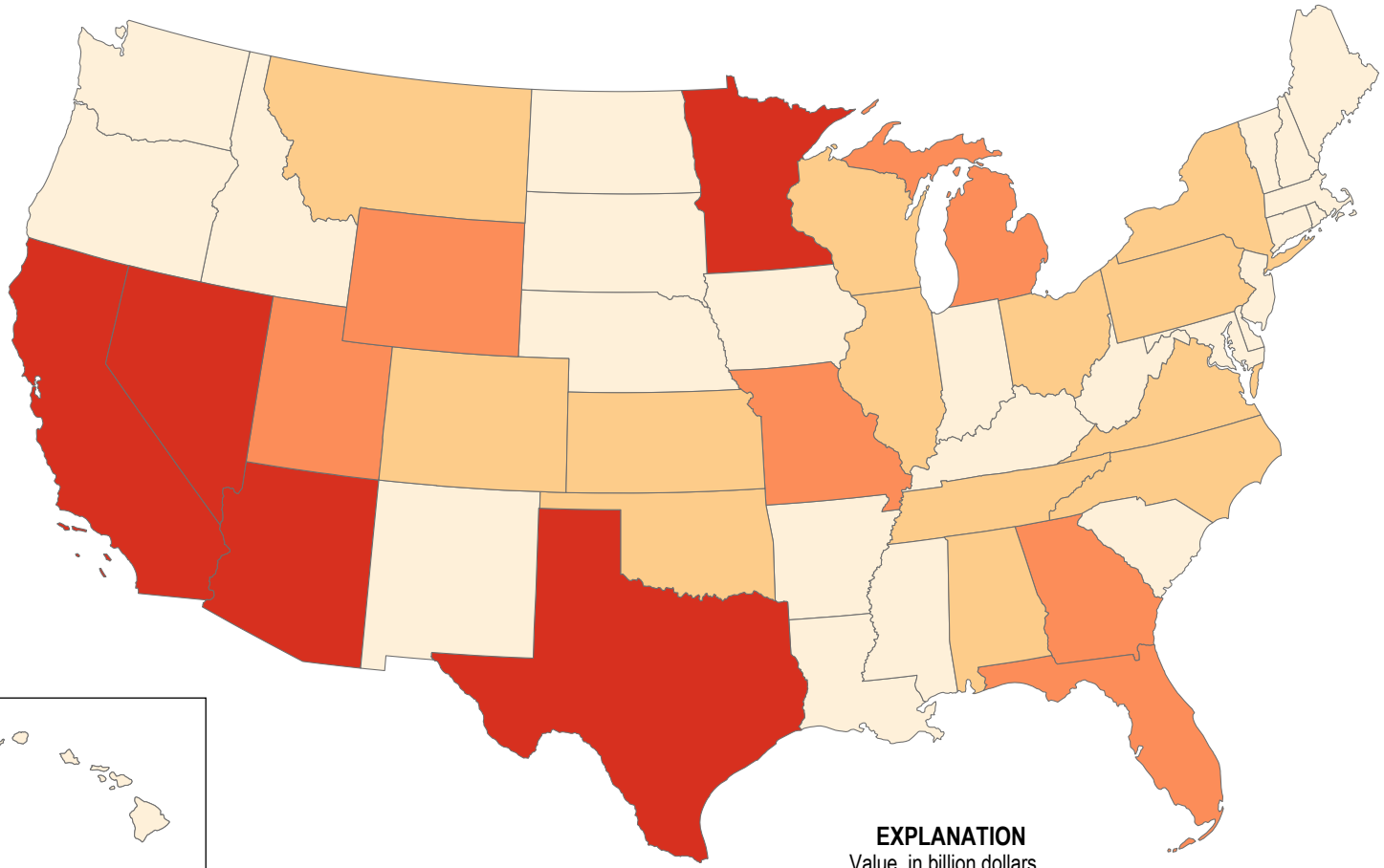
[4]Listed in alphabetical order.

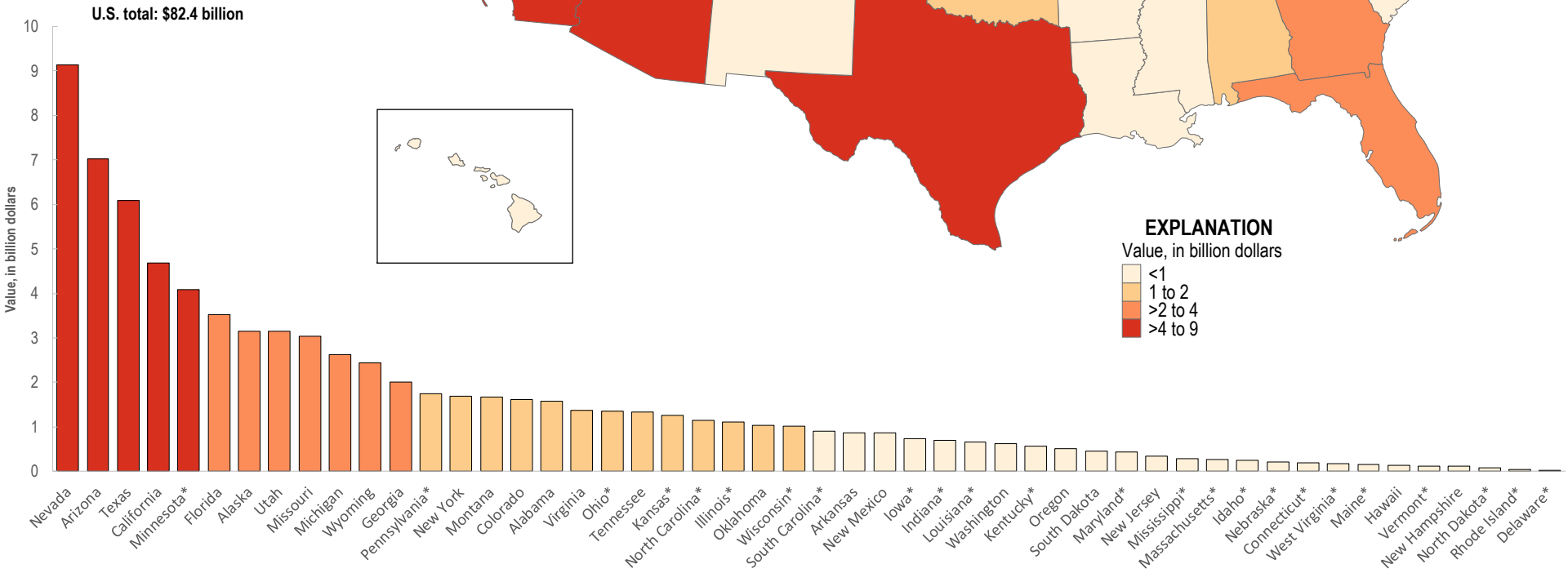
[5]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed."

Figure 4.—Value of Nonfuel Minerals Produced in 2020, by State



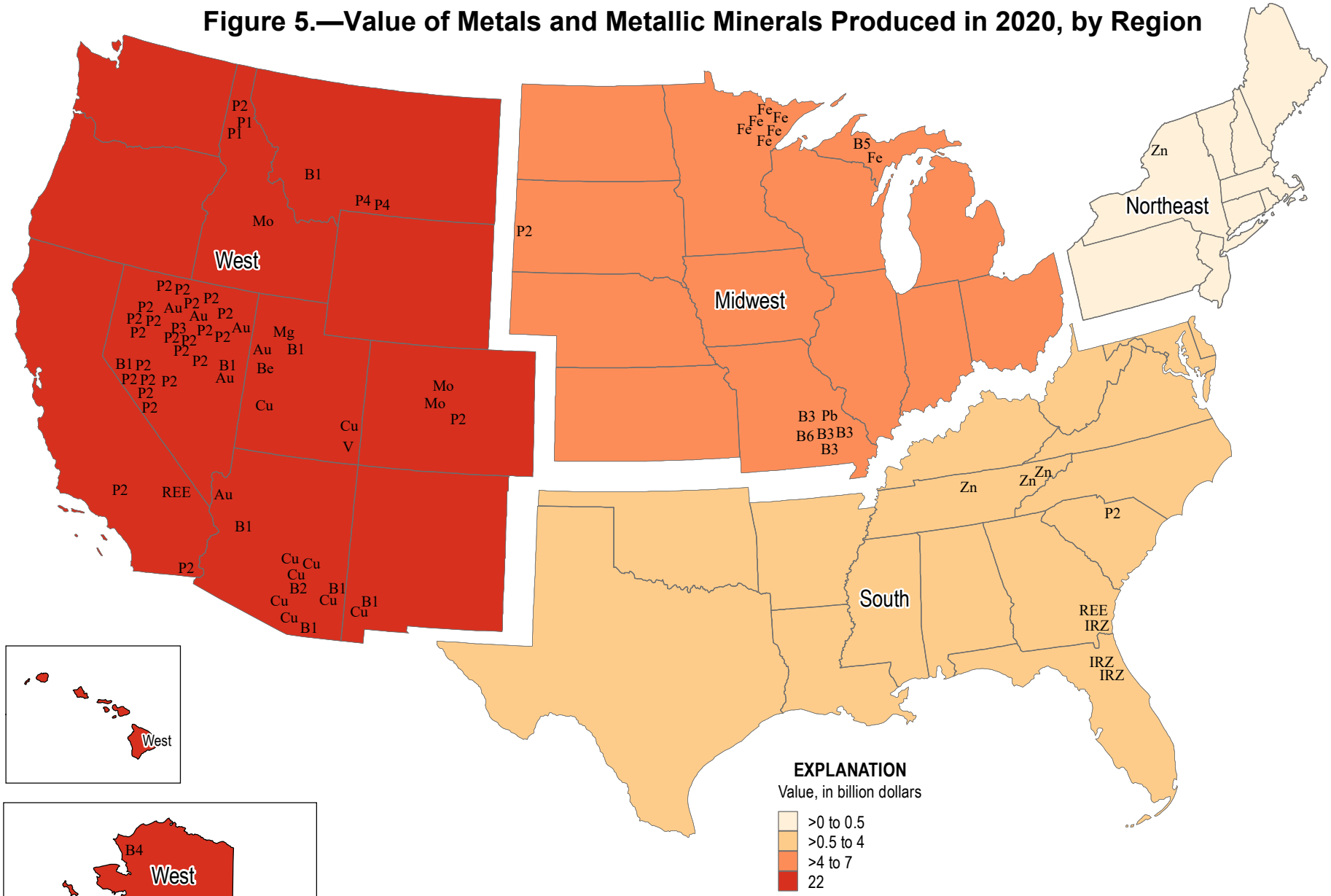






*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

Figure 5.—Value of Metals and Metallic Minerals Produced in 2020, by Region



Au	Gold	B6	Lead and zinc	Mo	Molybdenum	REE	Rare-earth elements
B1	Copper ± molybdenum ± gold and silver ± rhenium	Be	Beryllium	P1	Silver ± base metals ± gold	V	Vanadium
B2	Copper ± silver	Cu	Copper	P2	Gold and silver	Zn	Zinc
B3	Lead and zinc ± copper ± silver	Fe	Iron ore	P3	Gold and silver ± base metals		
B4	Silver and zinc ± lead and gold	IRZ	Ilmenite, rutile, and zircon	P4	Platinum and palladium ± gold and silver		
B5	Nickel, copper, cobalt, and gold	Mg	Magnesium	Pb	Lead		

Figure 6.—Value of Other Industrial Minerals Produced in 2020, by Region

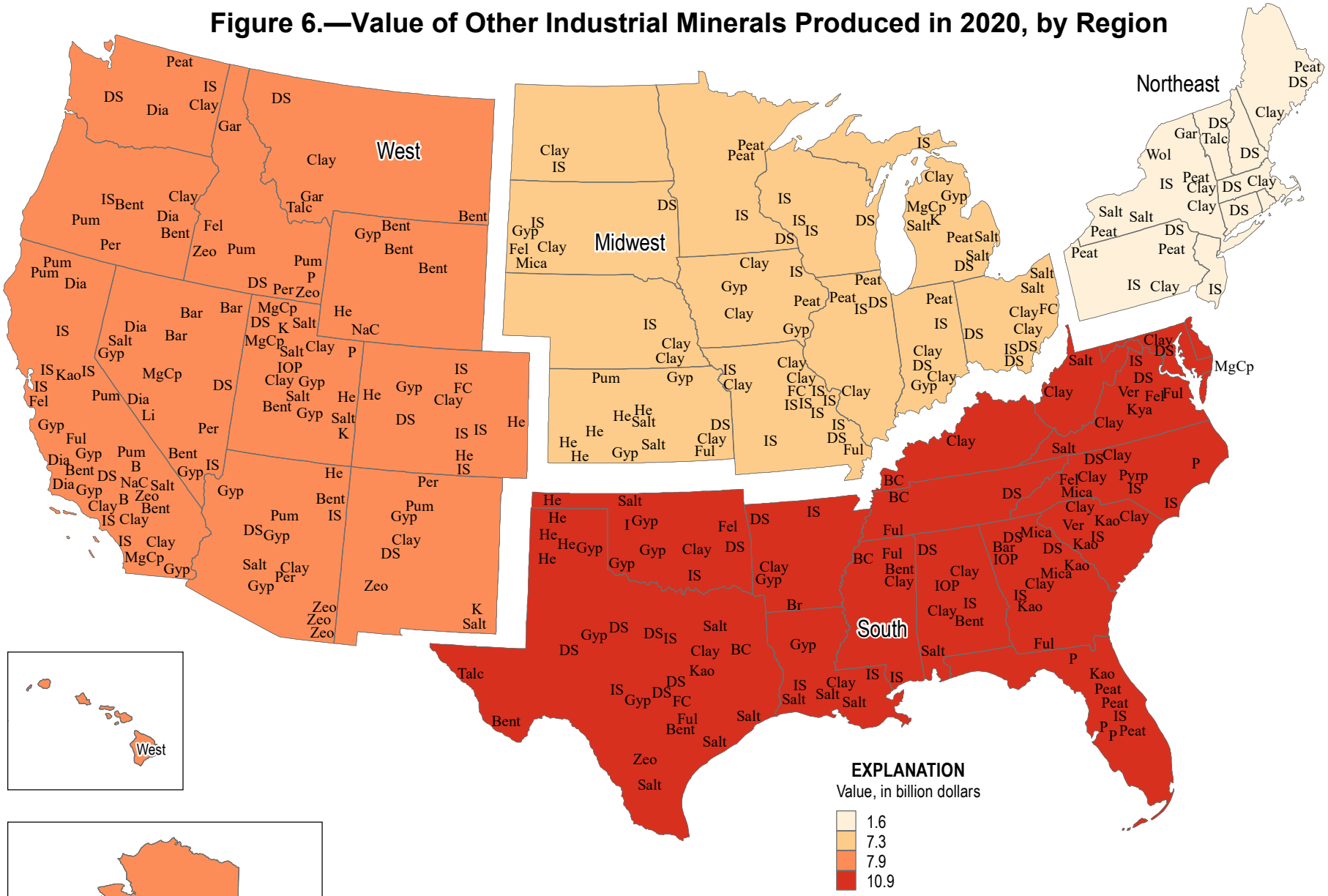


Figure 7.—Value of Crushed Stone Produced in 2020, by State

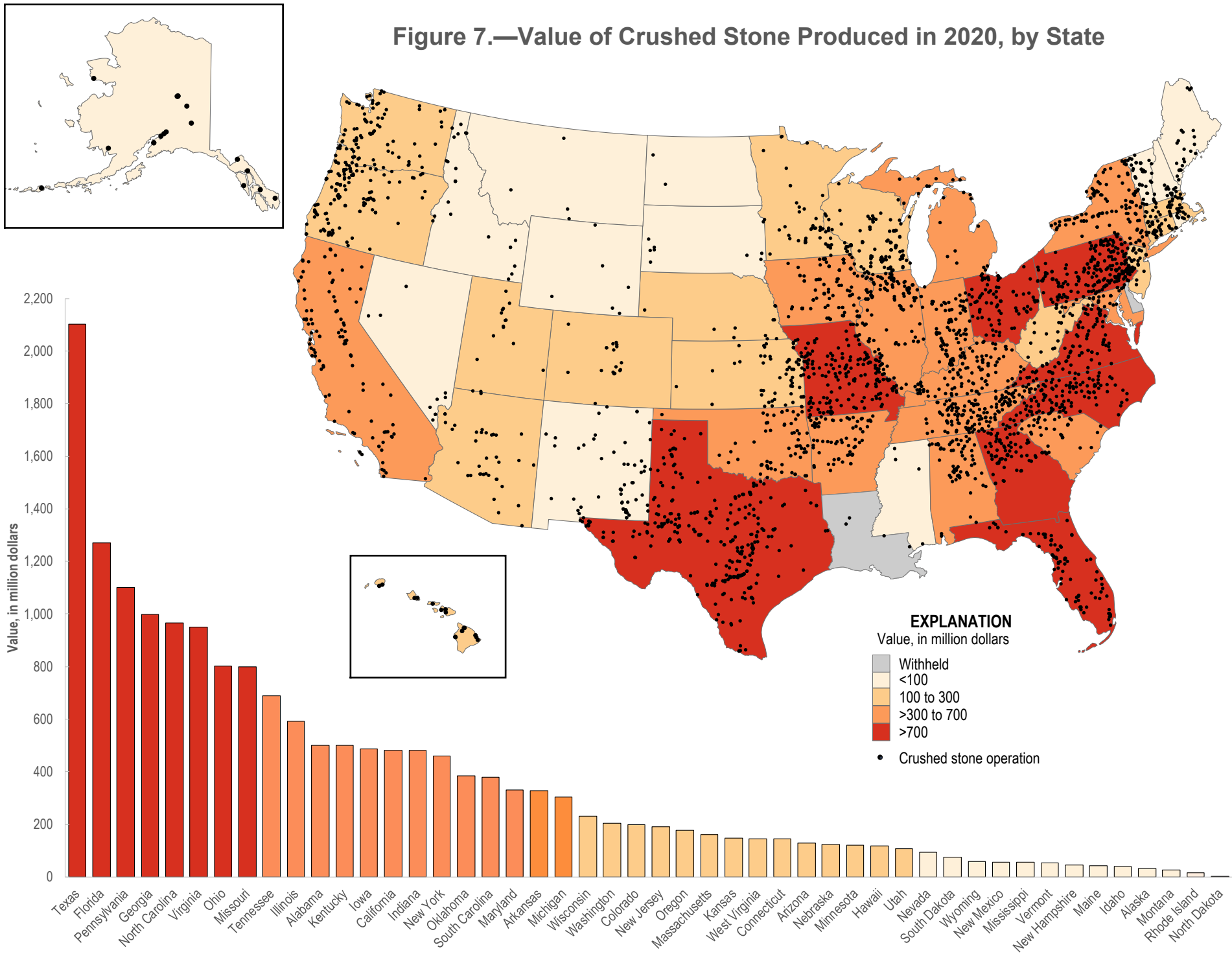
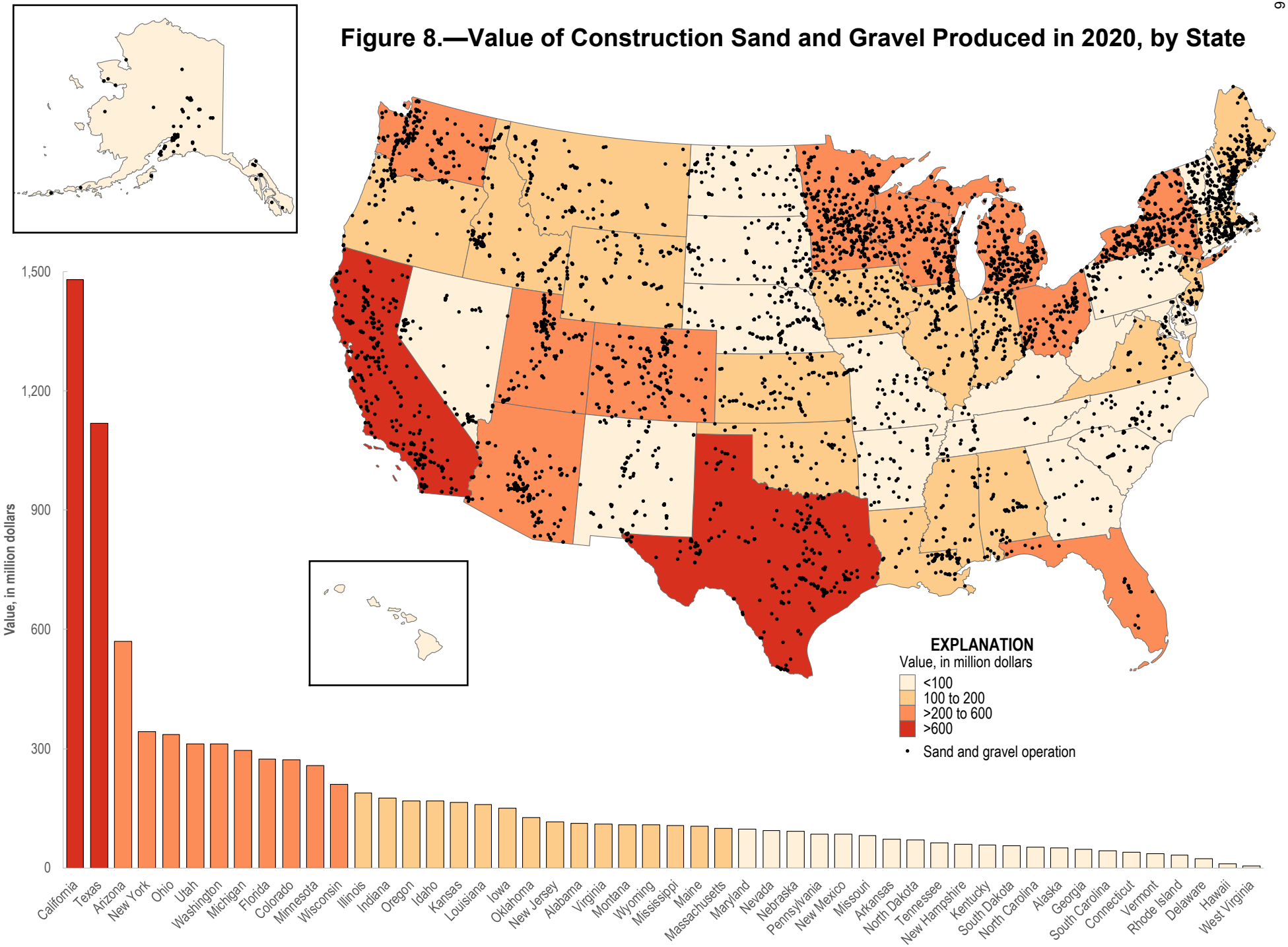


Figure 8.—Value of Construction Sand and Gravel Produced in 2020, by State



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ABRASIVES (MANUFACTURED)

(Fused aluminum oxide, silicon carbide, and metallic abrasives)
(Data in metric tons unless otherwise noted)

Domestic Production and Use: Fused aluminum oxide was produced by two companies at three plants in the United States and Canada. Production of crude fused aluminum oxide had an estimated value of $1.7 million. Silicon carbide was produced by two companies at two plants in the United States. Production of crude silicon carbide had an estimated value of about $26 million. Metallic abrasives were produced by 11 companies in eight States. Production of metallic abrasives had an estimated value of about $120 million. Bonded and coated abrasive products accounted for most abrasive uses of fused aluminum oxide and silicon carbide. Metallic abrasives are used primarily for steel shot and grit and cut wire shot, which are used for sandblasting, peening, and stonecutting applications.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	10,000	10,000
Silicon carbide[2]	35,000	35,000	35,000	35,000	35,000
Metallic abrasives	188,000	179,000	180,000	177,000	180,000
Shipments, metallic abrasives	204,000	197,000	196,000	195,000	190,000
Imports for consumption:					
Fused aluminum oxide	155,000	206,000	192,000	184,000	130,000
Silicon carbide	116,000	137,000	146,000	131,000	130,000
Metallic abrasives	54,100	29,600	29,900	27,900	25,000
Exports:					
Fused aluminum oxide	14,300	15,500	20,100	18,400	14,000
Silicon carbide	6,820	6,100	10,100	11,500	9,300
Metallic abrasives	28,600	31,000	33,600	31,200	24,000
Consumption, apparent:					
Fused aluminum oxide[3]	141,000	191,000	172,000	166,000	120,000
Silicon carbide[4]	144,000	166,000	171,000	155,000	160,000
Metallic abrasives[5]	230,000	196,000	192,000	192,000	190,000
Price, average value of imports, dollars per ton:					
Fused aluminum oxide, regular	418	489	692	716	670
Fused aluminum oxide, high-purity	1,360	1,220	1,290	1,250	1,200
Silicon carbide, crude	452	479	670	701	600
Metallic abrasives	543	1,020	1,180	1,310	1,200
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>75	>75	>75	>75	>75
Silicon carbide	>75	>75	>75	>75	>75
Metallic abrasives	11	E	E	E	1

Recycling: Up to 30% of fused aluminum oxide may be recycled, and about 5% of silicon carbide is recycled.

Import Sources (2016–19): Fused aluminum oxide, crude: China, 86%; France, 7%; Canada, 2%; and other, 5%. Fused aluminum oxide, grain: Canada, 19%; Brazil, 18%; Austria, 17%; Germany, 12%; and other, 34%. Silicon carbide, crude: China, 85%; Netherlands, 7%; South Africa, 5%; and other, 3%. Silicon carbide, grain: China, 48%; Brazil, 21%; Russia, 9%; Norway, 6%; and other, 16%. Metallic abrasives: Canada, 26%; Sweden, 19%; China, 15%; Germany, 10%; and other, 30%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Artificial corundum, crude	2818.10.1000	Free.
White, pink, ruby artificial corundum, greater than 97.5% aluminum oxide, grain	2818.10.2010	1.3% ad val.
Artificial corundum, not elsewhere specified or included, fused aluminum oxide, grain	2818.10.2090	1.3% ad val.
Silicon carbide, crude	2849.20.1000	Free.
Silicon carbide, grain	2849.20.2000	0.5% ad val.
Iron, pig iron, or steel granules	7205.10.0000	Free.

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ABRASIVES (MANUFACTURED)

Depletion Allowance: None.

Government Stockpile: None.

Events, Trends, and Issues: In 2020, China was the world's leading producer of abrasive fused aluminum oxide and abrasive silicon carbide. Imports, especially from China where operating costs were lower, continued to challenge abrasives producers in the United States and Canada. In recent years, imports of abrasives from Hong Kong have also increased. Foreign competition is expected to persist and continue to limit production in North America. The average unit value of imports had increased every year since 2016 for regular fused aluminum oxide and crude silicon carbide but decreased in 2020. The average unit values of imports of regular fused aluminum oxide and crude silicon carbide during the first 6 months of 2020 were 6% and 16% lower, respectively, than those in 2019 and 3% and 5% higher, respectively, than those in 2018.

Abrasives consumption in the United States is greatly influenced by activity in the manufacturing sectors, particularly the aerospace, automotive, furniture, housing, and steel industries. Steel grit can be reclaimed and used multiple times. The use of reclaimed metallic abrasives increased, at least in part, owing to rising surcharges on scrap and waste disposal and increasing prices for new material.

In 2020, the abrasives manufacturing industry was considered part of the critical manufacturing sector by the U.S. Department of Homeland Security. The COVID-19 pandemic "stay-at-home" orders issued in March 2020 did not affect the abrasives manufacturing industry, and these plants maintained full operations. However, imports and exports for fused aluminum oxide decreased by 29% and 24%, respectively, from those in 2019.

World Production Capacity:

	Fused aluminum oxide[e]		Silicon carbide[e]	
	2019	2020	2019	2020
United States	60,000	60,000	40,000	40,000
Argentina	—	—	5,000	5,000
Australia	50,000	50,000	—	—
Austria	60,000	60,000	—	—
Brazil	50,000	50,000	40,000	40,000
China	800,000	800,000	450,000	450,000
France	40,000	40,000	20,000	20,000
Germany	80,000	80,000	35,000	35,000
India	40,000	40,000	5,000	5,000
Japan	15,000	15,000	60,000	60,000
Mexico	—	—	45,000	45,000
Norway	—	—	80,000	80,000
Venezuela	—	—	30,000	30,000
Other countries	80,000	80,000	190,000	190,000
World total (rounded)	1,300,000	1,300,000	1,000,000	1,000,000

World Resources:[7] Although domestic resources of raw materials for the production of fused aluminum oxide are rather limited, adequate resources are available in the Western Hemisphere. Domestic resources are more than adequate for the production of silicon carbide.

Substitutes: Natural and manufactured abrasives, such as garnet, emery, or metallic abrasives, can be substituted for fused aluminum oxide and silicon carbide in various applications.

[e]Estimated. E Net exporter. — Zero.

[1]Production data for aluminum oxide are combined production data from the United States and Canada to avoid disclosing company proprietary data.

[2]Rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.

[3]Defined as imports – exports because production includes data from Canada; actual consumption is higher than that shown.

[4]Defined as production + imports – exports.

[5]Defined as shipments + imports – exports.

[6]Defined as imports – exports.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

ALUMINUM[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, three companies operated seven primary aluminum smelters in six States. Two smelters operated at full capacity and four smelters operated at reduced capacity throughout the year. One smelter operated at reduced capacity until it was idled in July. One other smelter remained on standby throughout the year. Domestic smelters were operating at about 49% of capacity of 1.79 million tons per year at yearend 2020. Production decreased by 8% after increasing in 2019. Based on published prices, the value of primary aluminum production was about $1.98 billion, 17% less than the value in 2019. The average annual U.S. market price declined by about 11% from that in 2019. Transportation applications accounted for 40% of domestic consumption; in descending order of consumption, the remainder was used in packaging, 21%; building, 14%; electrical, 8%; consumer durables, 7%; machinery, 7%; and other, 3%.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Primary	818	741	891	1,093	1,000
Secondary (from old scrap)	1,570	1,590	1,570	1,540	1,500
Secondary (from new scrap)	2,010	2,050	2,140	1,920	1,700
Imports for consumption:					
Crude and semimanufactures	5,410	6,220	5,550	5,210	3,200
Scrap	609	700	695	596	530
Exports:					
Crude and semimanufactures	1,470	1,330	1,310	1,090	880
Scrap	1,350	1,570	1,760	1,860	2,000
Consumption, apparent[2]	5,090	5,680	4,900	4,940	2,870
Supply, apparent[3]	7,100	7,730	7,040	6,860	4,570
Price, ingot, average U.S. market (spot), cents per pound	80.4	98.3	114.7	99.5	89
Stocks, yearend:					
Aluminum industry	1,400	1,470	1,570	1,600	1,400
London Metal Exchange (LME), U.S. warehouses[4]	362	254	186	120	250
Employment, number[5]	31,900	31,700	31,600	32,900	31,900
Net import reliance[6] as a percentage of apparent consumption	53	59	50	47	13

Recycling: In 2020, aluminum recovered from purchased scrap in the United States was about 3.2 million tons, of which about 53% came from new (manufacturing) scrap and 47% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 51% of apparent consumption.

Import Sources (2016–19): Canada, 50%; the United Arab Emirates, 10%; Russia 9%; China, 5%; and other, 26%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Aluminum, not alloyed:		
Unwrought (in coils)	7601.10.3000	2.6% ad val.
Unwrought (other than aluminum alloys)	7601.10.6000	Free.
Aluminum alloys, unwrought (billet)	7601.20.9045	Free.
Aluminum scrap:		
Used beverage container scrap	7602.00.0030	Free.
Industrial process scrap	7602.00.0091	Free.

Depletion Allowance: Not applicable.[1]

Government Stockpile: None.

Events, Trends, and Issues: Starting in March, many aluminum consumers shut down or reduced production in response to the COVID-19 pandemic. Several manufacturers in the aerospace and automotive industries shut down production facilities citing local government orders, agreements negotiated between the companies and the unions representing employees, or decreased demand by retail consumers. Several extruders, rolling mills, and secondary smelters decreased output or shut down in response to the COVID-19 pandemic. By July, most of the shutdowns ended as safety measures were implemented. Consumption of aluminum for containers and packaging remained steady as bars and restaurants were ordered closed by many local authorities, resulting in increased demand for beverages in aluminum cans. Rolling mills and secondary smelters that produce can sheet increased imports of

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used beverage cans to make up for decreased supply from domestic can redemption centers that were closed in most States. Primary aluminum smelters were exempted from the lockdown orders.

In March, a 252,000-ton-per-year smelter in Hawesville, KY, completed restarting one potline with 50,000 tons per year of capacity after scheduled maintenance work. The restart of another 50,000-ton-per-year potline at the Hawesville smelter was delayed because of economic conditions after maintenance work was completed. In July, a 279,000-ton-per-year smelter in Ferndale, WA, shut down four of its five potlines, citing high power prices and low aluminum prices. The rest of its capacity was shut down previously.

On January 24, the President of the United States imposed a 10% tariff on imported products made with aluminum. In March 2018, a 10% tariff was imposed on imports of aluminum but concerns had been raised that domestic manufacturers were having to pay more for aluminum and that competitors were able to import finished products without having to pay a tariff on the aluminum contained in finished products. Aluminum imports from all countries except Argentina, Australia, Canada, and Mexico remained subject to the 10% ad valorem tariff as of early December. The 10% tariffs were imposed under authority of section 232 of the Trade Expansion Act of 1962.

In March, the U.S. Department of Commerce initiated a countervailing duty investigation of imports of common alloy aluminum sheet from 18 countries. The U.S. International Trade Commission initiated an antidumping investigation on the same products from four countries. On August 10, the U.S. Department of Commerce issued its preliminary determination of the countervailing duty investigation and set preliminary subsidy rates, with a final determination expected by early 2021. The U.S. International Trade Commission was expected to issue its final determination in February 2021. In June, the U.S. Department of Commerce issued its preliminary determination of the countervailing duty investigation of foil imports from China and set preliminary subsidy rates.

World Smelter Production and Capacity: Capacity data for China and Russia were revised based on Government and company data.

	Production		Yearend capacity	
	2019	2020[e]	2019	2020[e]
United States	1,093	1,000	1,790	1,790
Australia	1,570	1,600	1,720	1,720
Bahrain	1,370	1,500	1,540	1,540
Canada	2,850	3,100	3,270	3,270
China	35,000	37,000	41,300	43,000
Iceland	845	840	890	890
India	3,640	3,600	4,060	4,060
Norway	1,400	1,400	1,430	1,430
Russia	3,640	3,600	4,020	4,020
United Arab Emirates	2,600	2,600	2,700	2,700
Other countries	9,200	9,000	12,200	12,300
World total (rounded)	63,200	65,200	74,900	76,700

World Resources:[7] Global resources of bauxite are estimated to be between 55 billion and 75 billion tons and are sufficient to meet world demand for metal well into the future.[1]

Substitutes: Composites can substitute for aluminum in aircraft fuselages and wings. Glass, paper, plastics, and steel can substitute for aluminum in packaging. Composites, magnesium, steel, and titanium can substitute for aluminum in ground transportation uses. Composites, steel, vinyl, and wood can substitute for aluminum in construction. Copper can replace aluminum in electrical and heat-exchange applications.

[e]Estimated.

[1]See also Bauxite and Alumina.

[2]Defined as domestic primary metal production + recovery from old aluminum scrap + net import reliance; excludes imported scrap.

[3]Defined as domestic primary metal production + recovery from all aluminum scrap + net import reliance; excludes imported scrap.

[4]Includes aluminum alloy. Starting with 2019, also includes off-warrant stocks of primary and alloyed aluminum; estimated for 2019.

[5]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.

[6]Defined as imports – exports + adjustments for industry stock changes; excludes imported scrap.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

ANTIMONY

(Data in metric tons of antimony content unless otherwise noted)

Domestic Production and Use: In 2020, no marketable antimony was mined in the United States. A mine in Nevada that had extracted about 800 tons of stibnite ore from 2013 through 2014 was placed on care-and-maintenance status in 2015 and had no reported production in 2020. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced in 2020, based on the average New York dealer price for antimony, was about $35 million. Recycling supplied about 18% of estimated domestic consumption, and the remainder came mostly from imports. The value of antimony consumption in 2020, based on the average New York dealer price, was about $193 million. In the United States, the leading uses of antimony were as follows: flame retardants, 42%; metal products, including antimonial lead and ammunition, 36%; and nonmetal products, including ceramics and glass and rubber products, 22%.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	664	621	331	377	260
Secondary	3,810	4,370	4,090	4,140	4,000
Imports for consumption:					
Ore and concentrates	119	61	96	121	130
Oxide	16,100	17,800	19,200	17,300	14,000
Unwrought, powder	7,110	6,810	6,320	6,670	5,500
Waste and scrap[1]	41	16	202	17	8
Exports:					
Ore and concentrates[1]	12	46	38	9	8
Oxide	1,330	1,600	1,750	1,570	1,400
Unwrought, powder	446	643	497	370	290
Waste and scrap[1]	177	11	9	14	14
Consumption, apparent[2]	25,900	27,400	27,700	26,400	22,000
Price, metal, average, dollars per pound[3]	3.35	3.98	3.88	3.90	3.98
Employment, plant, number[e]	27	27	27	27	27
Net import reliance[4] as a percentage of apparent consumption	83	82	84	83	81

Recycling: The bulk of secondary antimony is recovered at secondary lead smelters as antimonial lead, most of which was generated by, and then consumed by, the lead-acid battery industry.

Import Sources (2016–19): Ore and concentrates: Italy, 55%; China, 31%; India, 7%; Mexico, 4%; and other, 3%. Oxide: China, 69%; Belgium, 10%; Bolivia and Thailand, 6% each; and other, 9%. Unwrought metal and powder: China, 46%; India, 20%; Vietnam, 11%; the United Kingdom, 6%; and other, 17%. Total metal and oxide: China, 63%; Belgium, 7%; Thailand, 6%; India, 5%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Ore and concentrates	2617.10.0000	Free.
Antimony oxide	2825.80.0000	Free.
Antimony and articles thereof:		
Unwrought antimony; powder	8110.10.0000	Free.
Waste and scrap	8110.20.0000	Free.
Other	8110.90.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5]

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Antimony	90.16	1,100	—	1,100	—

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ANTIMONY

Events, Trends, and Issues: China continued to be the leading global antimony producer in 2020 and accounted for more than 52% of global mine production. Owing to the global COVID-19 pandemic and the consequent very tight supply of antimony raw materials, operations at China's refineries were constrained. According to China's customs data, China imported 30% less of antimony ore and concentrates from January through August 2020 than for the same period of 2019. This caused a supply shortage of antimony ingots on the market and the antimony price increased to about $4.00 per pound in 2020. In 2020, China imported 83% less unwrought antimony than in the previous year. Exports of China's unwrought antimony and antimony oxide fell by 24% and 12%, respectively.

World Mine Production and Reserves: Reserves for Canada and Kyrgyzstan were revised based on Government and industry reports.

	Mine production		Reserves[6]
	2019	2020[e]	
United States	—	—	[7]60,000
Australia	2,030	2,000	[8]140,000
Bolivia	3,000	3,000	310,000
Burma	6,000	6,000	NA
Canada	1	1	78,000
China	89,000	80,000	480,000
Ecuador	1	1	NA
Guatemala	25	25	NA
Iran	500	500	NA
Kazakhstan	300	300	NA
Kyrgyzstan	—	—	260,000
Laos	140	100	NA
Mexico	300	300	18,000
Pakistan	—	—	26,000
Russia (recoverable)	30,000	30,000	350,000
Tajikistan	28,000	28,000	50,000
Turkey	2,400	2,000	100,000
Vietnam	310	300	NA
World total (rounded)	162,000	153,000	1,900,000

World Resources:[6] U.S. resources of antimony are mainly in Alaska, Idaho, Montana, and Nevada. Principal identified world resources are in Australia, Bolivia, China, Mexico, Russia, South Africa, and Tajikistan. Additional antimony resources may occur in Mississippi Valley-type lead deposits in the Eastern United States.

Substitutes: Selected organic compounds and hydrated aluminum oxide are substitutes as flame retardants. Chromium, tin, titanium, zinc, and zirconium compounds substitute for antimony chemicals in enamels, paint, and pigments. Combinations of calcium, copper, selenium, sulfur, and tin are substitutes for alloys in lead-acid batteries.

[e]Estimated. NA Not available. — Zero.

[1]Gross weight.

[2]Defined as primary production + secondary production from old scrap + imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder + adjustments for Government stock changes.

[3]New York dealer price for 99.65% metal, cost, insurance, freight U.S. ports. Source: S&P Global Platts Metals Week.

[4]Defined as imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder + adjustments for Government stock changes.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Company-reported probable reserves for the Stibnite Gold Project in Idaho.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 64,600 tons.

ARSENIC

(Data in metric tons of arsenic content[1] unless otherwise noted)

Domestic Production and Use: Arsenic trioxide and primary arsenic metal have not been produced in the United States since 1985. The principal use for arsenic trioxide was for the production of arsenic acid used in the formulation of chromated copper arsenide (CCA) preservatives for the pressure treating of lumber used primarily in nonresidential applications. Three companies produced CCA preservatives in the United States in 2020. The grids in lead-acid storage batteries were strengthened by the addition of arsenic metal. Arsenic metal also was used as an antifriction additive for bearings, to harden lead shot, and in clip-on wheel weights. Arsenic compounds were used in herbicides and insecticides. High-purity arsenic (99.9999%) metal was used to produce gallium-arsenide (GaAs) semiconductors for solar cells, space research, and telecommunications. Arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide (InGaAs) was used for short-wave infrared technology. The value of arsenic compounds and metal imported domestically in 2020 was estimated to be about $9.3 million. Given that arsenic metal has not been produced domestically since 1985, it is likely that only a small portion of the material reported by the U.S. Census Bureau as arsenic exports was pure arsenic metal, and most of the material that has been reported under this category reflects the gross weight of alloys, compounds, residues, scrap, and waste containing arsenic. Therefore, the estimated consumption reported under salient U.S. statistics reflects only imports of arsenic products.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Imports for consumption:					
Arsenic metal	793	942	929	391	500
Compounds	5,320	5,980	5,540	7,090	10,000
Exports, all forms of arsenic (gross weight)	1,760	698	107	56	20
Consumption, estimated, all forms of arsenic[2]	6,120	6,920	6,470	7,480	10,500
Price, average value of imports (free alongside ship),[3] dollars per kilogram:					
Arsenic metal (China)	1.89	1.56	1.43	1.92	1.70
Trioxide (China)	0.46	0.45	0.44	0.46	0.42
Trioxide (Morocco)	0.68	0.68	0.75	0.78	0.83
Net import reliance[4] as a percentage of estimated consumption, all forms of arsenic	100	100	100	100	100

Recycling: Arsenic metal was contained in new scrap recycled during GaAs semiconductor manufacturing. Arsenic-containing process water was internally recycled at wood treatment plants where CCA was used. Although scrap electronic circuit boards, relays, and switches may contain arsenic, no arsenic was known to have been recovered during the recycling process to recover other contained metals. No arsenic was recovered domestically from arsenic-containing residues and dusts generated at nonferrous smelters in the United States.

Import Sources (2016–19): Arsenic metal: China, 91%; Japan, 5%; Hong Kong, 3%; and other, 1%. Arsenic trioxide: China, 55%; Morocco, 41%; Belgium, 2%; and other, 2%. All forms of arsenic: China, 58%; Morocco, 38%; Belgium, 2%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Arsenic metal	2804.80.0000	Free.
Arsenic acid	2811.19.1000	2.3% ad val.
Arsenic trioxide	2811.29.1000	Free.
Arsenic sulfide	2813.90.1000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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ARSENIC

Events, Trends, and Issues: China and Morocco continued to be the leading global producers of arsenic trioxide, accounting for about 90% of estimated world production and supplying almost all of United States imports of arsenic trioxide in 2020. China was the leading world producer of arsenic metal and, with Hong Kong, supplied about 94% of United States arsenic metal imports in 2020.

High-purity (99.9999%) arsenic metal was used to produce GaAs, indium-arsenide, and InGaAs semiconductors that were used in biomedical, communications, computer, electronics, and photovoltaic applications. In 2020, the market value of global high-purity arsenic metal was about $200 million. Almost one-half of global GaAs wafer production took place in China. See the Gallium chapter for additional details.

World Production and Reserves (gross weight):

	Production[e, 5] (arsenic trioxide)		Reserves[6]
	2019	2020	
United States	—	—	World reserves data are unavailable but are thought to be more than 20 times world production.
Belgium	1,000	1,000	
Bolivia	120	100	
China	24,000	24,000	
Iran	110	—	
Japan	45	40	
Morocco	5,500	5,500	
Russia	1,500	1,500	
World total (rounded)	32,300	32,000	

World Resources:[6] Arsenic may be obtained from copper, gold, and lead smelter flue dust, as well as from roasting arsenopyrite, the most abundant ore mineral of arsenic. Arsenic has been recovered from orpiment and realgar in China, Peru, and the Philippines and from copper-gold ores in Chile, and arsenic was associated with gold occurrences in Canada. Orpiment and realgar from gold mines in Sichuan Province, China, were stockpiled for later recovery of arsenic. Arsenic also may be recovered from enargite, a copper mineral. Arsenic trioxide was produced at the hydrometallurgical complex of Guemassa, near Marrakech, Morocco, from cobalt-arsenide ore from the Bou-Azzer Mine.

Substitutes: Substitutes for CCA in wood treatment include alkaline copper quaternary, ammoniacal copper quaternary, ammoniacal copper zinc arsenate, alkaline copper quaternary boron-based preservatives, copper azole, copper citrate, and copper naphthenate. Treated wood substitutes include concrete, plastic composite material, plasticized wood scrap, or steel. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third generation cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based integrated circuits are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. — Zero.

[1]Arsenic content of arsenic metal is 100%; arsenic content of arsenic compounds is 77.7% for arsenic acids, 60.7% for arsenic sulfides, and 75.71% for arsenic trioxide.

[2]Estimated to be the same as imports.

[3]Calculated from U.S. Census Bureau import data.

[4]Defined as imports.

[5]Includes calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide; inclusion of such materials would not duplicate reported arsenic trioxide production. Chile, Mexico, and Peru were thought to be significant producers of commercial-grade arsenic trioxide but have reported no production in recent years.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

ASBESTOS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: The last U.S. producer of asbestos ceased operations in 2002 as a result of the decline in domestic and international asbestos markets associated with health and liability issues. The United States has since been wholly dependent on imports to meet manufacturing needs. All of the asbestos fiber currently imported into and used within the United States consists of chrysotile. In 2020, domestic consumption of chrysotile was estimated to be 450 tons, and all imports originated from Brazil, based on data available through July. The chloralkali industry, which uses chrysotile to manufacture nonreactive semipermeable diaphragms that prevent chlorine generated at the anode of an electrolytic cell from reacting with sodium hydroxide generated at the cathode, has accounted for 100% of asbestos consumption since at least 2016. In addition to chrysotile, a small, but unknown, quantity of asbestos is imported annually within manufactured products, including brake blocks for use in the oil industry, rubber sheets for gaskets used to create a chemical-containment seal in the production of titanium dioxide, certain other types of preformed gaskets, and some vehicle friction products.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Imports for consumption[1]	747	332	681	172	[2]300
Exports[3]	—	—	—	—	—
Consumption, estimated[4]	770	520	500	450	450
Price, average U.S. customs value, dollars per ton	1,910	1,870	1,670	1,570	2,000
Net import reliance[5] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2016–19): Brazil, 86%; and Russia, 14%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Crocidolite	2524.10.0000	Free.
Amosite	2524.90.0010	Free.
Chrysotile:		
Crudes	2524.90.0030	Free.
Milled fibers, group 3 grades	2524.90.0040	Free.
Milled fibers, group 4 and 5 grades	2524.90.0045	Free.
Other	2524.90.0055	Free.
Other, asbestos	2524.90.0060	Free.

Depletion Allowance: 22% (domestic), 10% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of asbestos fiber in the United States has decreased during the past several decades, falling from a record high of 803,000 tons in 1973 to less than 800 tons in each year since 2016. This decline has taken place as a result of health and liability issues associated with asbestos use, leading to the displacement of asbestos from traditional domestic markets by substitutes, alternative materials, and new technology. The chloralkali industry is the only remaining domestic consumer of asbestos in mineral form. Asbestos diaphragms are used in at least 11 chloralkali plants in the United States and account for about one-third of domestic chlorine production.

The Frank R. Lautenberg Chemical Safety for the 21st Century Act, which amended the Toxic Substances Control Act of 1976 (TSCA), was signed into law in 2016. The legislation granted the U.S. Environmental Protection Agency (EPA) greater authority to evaluate the hazards posed by new chemicals as well as those already in the marketplace. In 2020, the EPA issued the final risk evaluation report for chrysotile. The agency determined that the disposal, processing, and (or) use of chrysotile in the chloralkali industry and in all chrysotile-containing manufactured products that are currently imported into the United States (oil industry brake blocks, sheet and other gaskets, and some vehicle friction products) present unreasonable risks to human health. As required by the TSCA, the EPA will propose and finalize actions to address these risks by yearend 2022. The new regulations could include limitations or prohibitions on the disposal, distribution in commerce, manufacture, processing, or use of chrysotile.[6]

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ASBESTOS

Estimated worldwide consumption of asbestos fiber decreased from approximately 2 million tons in 2010 to roughly 1 million tons per year in the past several years. Asbestos-cement products, such as corrugated roofing tiles, pipes, and wall panels, are expected to continue to be the leading global market for asbestos.

In Brazil, a comprehensive national ban on asbestos was enacted in November 2017. A judicial injunction allowed the only asbestos producer in the country to continue operating until February 2019, when production ceased. In July 2019, the government of the State of Goias passed a law that authorized the extraction of asbestos in the State for export purposes; ore processing was restarted in February 2020. The Supreme Federal Court of Brazil was expected to issue a ruling on the constitutionality of the Goias law but had not done so as of September 2020.

At the former King Mine in Mashava, Zimbabwe, asbestos production from old tailings commenced in 2019, and dewatering of the mining shafts was completed in March 2020. The company was in the process of selling real estate assets to fund the restart of mining operations and working to dewater an additional asbestos mine in Zvishvane. At full capacity, the King Mine was expected to produce 75,000 tons per year of asbestos.

World Mine Production and Reserves:

	Mine production[e]		Reserves[7]
	2019	2020	
United States	—	—	Small
Brazil	15,000	60,000	11,000,000
China	150,000	100,000	95,000,000
Kazakhstan	[8]211,000	210,000	Large
Russia	790,000	790,000	110,000,000
Zimbabwe	2,500	8,000	Large
World total (rounded)	1,170,000	1,200,000	Large

World Resources:[7] Reliable evaluations of global asbestos resources have not been published recently, and available information was insufficient to make accurate estimates for many countries. However, world resources are large and more than adequate to meet anticipated demand in the foreseeable future. Resources in the United States are composed mostly of short-fiber asbestos for which use in asbestos-based products is more limited than long-fiber asbestos.

Substitutes: Numerous materials substitute for asbestos. Substitutes include calcium silicate, carbon fiber, cellulose fiber, ceramic fiber, glass fiber, steel fiber, wollastonite, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene. Several nonfibrous minerals or rocks, such as perlite, serpentine, silica, and talc, are also considered to be possible asbestos substitutes for products in which the reinforcement properties of fibers are not required. Membrane cells and mercury cells are alternatives to asbestos diaphragms used in the chloralkali industry.

[e]Estimated. — Zero.

[1]Imports of asbestos minerals (chrysotile). Additional imports were reported by the U.S. Census Bureau in some years, but existing asbestos bans and bill of lading information from a commercial trade database suggest that some shipments were misclassified.

[2]According to the U.S. Census Bureau, imports of chrysotile totaled 138 tons through July. Final 2020 imports may differ significantly from the provided estimate because chrysotile imports typically do not follow a predictable pattern throughout the year.

[3]Exports of asbestos reported by the U.S. Census Bureau were 587 tons in 2016, 143 tons in 2017, 235 tons in 2018, 2 tons in 2019, and 0 tons through July in 2020. These shipments likely consisted of materials misclassified as asbestos, reexports, and (or) waste products because the United States no longer mines asbestos.

[4]To account for year-to-year fluctuations in asbestos imports owing to cycles of companies replenishing and drawing down stockpiles, consumption is estimated as a 5-year rolling average of imports for consumption. Information regarding the quantity of industry stocks was unavailable.

[5]Defined as imports – exports. The United States has been 100% import reliant since 2002. All consumption of asbestos was from imports and a drawdown in unreported inventories.

[6]U.S. Environmental Protection Agency, 2020, Risk evaluation for asbestos, part I—Chrysotile asbestos: Washington, DC, EPA Document # EPA-740-R1-8012, December, 352 p.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Reported.

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Numerous domestic barite mining and processing facilities were idled in 2020, and only one company in Nevada mined barite. Production data were withheld to avoid disclosing company proprietary data. An estimated 1.3 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in seven States. Typically, more than 90% of the barite sold in the United States is used as a weighting agent in fluids used in the drilling of oil and natural gas wells. The majority of Nevada crude barite was ground in Nevada and then sold to companies drilling in the Central and Western United States. Because of the higher cost of rail and truck transportation compared to ocean freight, offshore drilling operations in the Gulf of Mexico and onshore drilling operations in other regions primarily used imported barite.

Barite also is used as a filler, extender, or weighting agent in products such as paints, plastics, and rubber. Some specific applications include use in automobile brake and clutch pads, automobile paint primer for metal protection and gloss, use as a weighting agent in rubber, and in the cement jacket around underwater petroleum pipelines. In the metal-casting industry, barite is part of the mold-release compounds. Because barite significantly blocks x-ray and gamma-ray emissions, it is used as aggregate in high-density concrete for radiation shielding around x-ray units in hospitals, nuclear powerplants, and university nuclear research facilities. Ultrapure barite is used as a contrast medium in x-ray and computed tomography examinations of the gastrointestinal tract.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Sold or used, mine	232	334	366	414	W
Ground and crushed[1]	1,420	2,030	2,420	2,350	1,300
Imports for consumption[2]	1,260	2,470	2,460	2,550	1,500
Exports[3]	78	116	67	38	38
Consumption, apparent (crude and ground)[4]	1,410	2,680	2,760	2,930	W
Price, average value, ground, ex-works, dollars per ton[e]	187	179	176	179	180
Employment, mine and mill, number	400	450	520	510	350
Net import reliance[5] as a percentage of apparent consumption	84	88	87	86	>75

Recycling: None.

Import Sources (2016–19): China, 47%; India, 20%; Morocco, 14%; Mexico, 12%; and other, 7%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Ground barite	2511.10.1000	Free.
Crude barite	2511.10.5000	$1.25 per metric ton.
Barium compounds:		
Barium oxide, hydroxide, and peroxide	2816.40.2000	2% ad val.
Barium chloride	2827.39.4500	4.2% ad val.
Barium sulfate, precipitated	2833.27.0000	0.6% ad val.
Barium carbonate, precipitated	2836.60.0000	2.3% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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BARITE

Events, Trends, and Issues: Domestic consumption of barite as measured by sales of ground barite decreased by an estimated 45% in 2020. World mine production was estimated to have decreased by about 15%. Decreased demand for barite mirrored global trends in oil consumption, which was adversely affected by travel restrictions owing to the global COVID-19 pandemic and reduced demand for transport fuels.

Because of barite's role in drilling for oil and gas, drilling rig counts have historically been a good barometer of barite consumption. In 2020, the total international monthly average rig count excluding the United States peaked in February at 1,334, but began to decline in March, and by the end of October had decreased by 45%. Decreases in drilling activity were greatest in the United States, where the number of active rigs had already begun to decline in 2019. Between October 2019 and October 2020, the monthly average of active rigs decreased by 67%. The largest decrease in rig activity was in the Permian Basin, where drilling activity has been concentrated in recent years. Drilling operations there are primarily supplied by imported barite ground in Texas. Sales of barite from plants in Texas were estimated to have decreased by more than 50%. Only one company mined barite in Nevada in 2020, and domestic production was estimated to have been at its lowest level since the 1930s.

The United States is typically the world's leading barite consumer, and a key trading partner for most of the world's leading barite-producing countries. Decreased U.S. imports coupled with reduced drilling activity in almost all regions likely contributed to decreased mine production in most barite-producing countries. The most notable exception was India, where decreased exports to the United States were estimated to have been offset by increased exports to the Middle East.

World Mine Production and Reserves: In response to concerns about dwindling global reserves of 4.2-specific-gravity barite used by the oil and gas drilling industry, the American Petroleum Institute issued an alternate specification for 4.1-specific-gravity weighting agents in 2010. This has likely stimulated exploration and expansion of global barite resources. Estimated reserves data are included only if developed since the adoption of the 4.1-specific-gravity standard. Reserves data for Iran and Pakistan were revised based on company and Government information.

	Mine production		Reserves[6]
	2019	2020[e]	
United States	414	W	NA
China	2,800	2,500	36,000
India	2,000	2,000	51,000
Iran	202	200	100,000
Kazakhstan	597	600	85,000
Laos	440	330	NA
Mexico	384	280	NA
Morocco	1,100	800	NA
Pakistan	110	110	40,000
Russia	160	160	12,000
Turkey	250	130	35,000
Other countries	418	340	30,000
World total (rounded)	8,870	[7]7,500	390,000

World Resources:[6] In the United States, identified resources of barite are estimated to be 150 million tons, and undiscovered resources contribute an additional 150 million tons. The world's barite resources in all categories are about 2 billion tons, but only about 740 million tons are identified resources. However, no known quantitative assessment of either U.S. or global barite resources has been conducted since the 1980s.

Substitutes: In the drilling mud market, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. None of these substitutes, however, has had a major impact on the barite drilling mud industry.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Imported and domestic barite, crushed and ground, sold or used by domestic grinding establishments.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2511.10.1000, 2511.10.5000, and 2833.27.0000.

[3]Includes data for the following Schedule B codes: 2511.10.1000 and 2833.27.0000.

[4]Defined as sold or used by domestic mines + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production.

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise noted)

Domestic Production and Use: In 2020, the reported quantity of bauxite consumed was estimated to be 4 million tons, slightly more than that reported in 2019, with an estimated value of about $110 million. About 79% of the bauxite was refined by the Bayer process for alumina or aluminum hydroxide, and the remainder went to products such as abrasives, cement, chemicals, proppants, and refractories, and as a slag adjuster in steel mills. Two domestic Bayer-process refineries with a combined alumina production capacity of 1.7 million tons per year produced an estimated 1.3 million tons in 2020, 8% less than that in 2019. About 56% of the alumina produced went to primary aluminum smelters, and the remainder went to nonmetallurgical products, such as abrasives, ceramics, chemicals, and refractories.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	6,050	4,360	3,980	4,310	3,900
Exports[2]	40	29	17	15	17
Stocks, industry, yearend[2]	880	880	600	300	250
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	6,630	4,330	4,460	3,920	4,000
Price, average value, U.S. imports, free alongside ship (f.a.s.), dollars per ton	28	31	31	32	27
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[5]	2,360	1,430	1,570	1,410	1,300
Imports for consumption[5]	1,140	1,330	1,530	1,930	1,300
Exports[5]	1,330	481	288	200	130
Stocks, industry, yearend[5]	320	264	275	275	200
Consumption, apparent[3]	2,130	2,340	2,800	3,140	2,550
Price, average value, U.S. imports (f.a.s.), dollars per ton	362	486	592	472	370
Net import reliance[4] as a percentage of apparent consumption	E	38	44	55	49

Recycling: None.

Import Sources (2016–19): Bauxite:[2] Jamaica, 37%; Guyana, 21%; Australia, 16%; Brazil, 11%; and other, 15%. Alumina:[5] Brazil, 47%; Australia, 26%; Jamaica, 12%; Canada, 5%; and other, 10%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Bauxite, calcined (refractory grade)	2606.00.0030	Free.
Bauxite, calcined (other)	2606.00.0060	Free.
Bauxite, crude dry (metallurgical grade)	2606.00.0090	Free.
Aluminum oxide (alumina)	2818.20.0000	Free.
Aluminum hydroxide	2818.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2020, two domestic alumina refineries produced alumina from imported bauxite. A 1.2-million-ton-per-year alumina refinery in Gramercy, LA, produced alumina for aluminum smelting and specialty-grade alumina. A 500,000-ton-per-year alumina refinery in Burnside, LA, produced specialty-grade alumina until it temporarily shut down in August, citing the COVID-19 pandemic for decreased demand. The average prices free alongside ship (f.a.s.) for U.S. imports for consumption of crude-dry bauxite and metallurgical-grade alumina during the first 8 months of 2020 were $27 per ton, 16% less than that in the same period in 2019, and $370 per ton, 26% less than that in the same period of 2019, respectively.

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BAUXITE AND ALUMINA

The COVID-19 pandemic was cited for decreased alumina production in China during January and February. Shortages of bauxite and caustic soda were reported at several inland alumina refineries as shipments from ports were delayed because of limited rail and truck service, but deliveries to ports were not interrputed. Alumina prices in China and other parts of the world increased owing to supply shortages and concerns about future availablity during the first quarter of the year. Coal deliveries to some refineries also slowed. Health officials in China imposed travel and work restrictions in parts of the country most affected by the COVID-19 virus to contain it, and in other regions, higher rates of absenteeism were attribuited to concerns about the virus. In March, many of the travel restrictions were lifted and alumina production restarted. Despite the temporary shutdowns, production in China increased.

In February, a 1.7-million-ton-per-year bauxite mine in Guyana shut down, citing civil unrest that interfered with mining operations and damaged mine property. The mine was a major supplier of refractory-grade bauxite. Bauxite and alumina production increased in Brazil compared with that in 2019 after the restart of capacity that was shut down for most of 2019. In August, a 9.9-million-ton-per-year bauxite mine in Brazil temporarily shut down production, citing damage to the pipeline used to transport bauxite to an alumina refinery. Routine inspection of the pipeline dicovered that it had deteriorated more than expected and it was shut down immediately for repair. The repair work was completed and the mine restarted production in October. Production from the 6.3-million-ton-per-year alumina refinery was decreased to 35% to 40% of its capacity, a rate of 2.2 to 2.5 million tons per year, until the pipeline was repaired.

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves: Reserves for Australia, Brazil, Malaysia, and Saudi Arabia were revised based on information from Government and other sources.

	Mine production				Bauxite reserves[6]
	Alumina[5]		Bauxite		
	2019	2020[e]	2019	2020[e]	
United States	1,410	1,300	W	W	20,000
Australia	20,200	21,000	105,000	110,000	[7]5,100,000
Brazil	8,700	9,600	34,000	35,000	2,700,000
Canada	1,520	1,500	—	—	—
China	72,500	74,000	70,000	60,000	1,000,000
Guinea	368	460	67,000	82,000	7,400,000
India	6,690	6,700	23,000	22,000	660,000
Indonesia	1,000	1,000	17,000	23,000	1,200,000
Jamaica	2,170	1,700	9,020	7,700	2,000,000
Kazakhstan	1,500	1,500	5,800	5,800	160,000
Malaysia	—	—	900	500	170,000
Russia	2,760	2,800	5,570	6,100	500,000
Saudi Arabia	1,840	1,800	4,050	4,000	190,000
Vietnam	1,370	1,400	4,000	4,000	3,700,000
Other countries	10,900	12,000	12,000	11,000	4,900,000
World total (rounded)	133,000	136,000	[8]358,000	[8]371,000	30,000,000

World Resources:[6] Bauxite resources are estimated to be 55 billion to 75 billion tons, in Africa (32%), Oceania (23%), South America and the Caribbean (21%), Asia (18%), and elsewhere (6%). Domestic resources of bauxite are inadequate to meet long-term U.S. demand, but the United States and most other major aluminum-producing countries have essentially inexhaustible subeconomic resources of aluminum in materials other than bauxite.

Substitutes: Bauxite is the only raw material used in the production of alumina on a commercial scale in the United States. Although currently not economically competitive with bauxite, vast resources of clay are technically feasible sources of alumina. Other raw materials, such as alunite, anorthosite, coal wastes, and oil shales, offer additional potential alumina sources. Synthetic mullite, produced from kaolin, bauxitic kaolin, kyanite, and sillimanite, substitutes for bauxite-based refractories. Silicon carbide and alumina-zirconia can substitute for abrasives but cost more.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also Aluminum. As a general rule, 4 tons of dried bauxite is required to produce 2 tons of alumina, which, in turn, produces 1 ton of aluminum.

[2]Includes all forms of bauxite, expressed as dry equivalent weights.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]Calcined equivalent weights.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were 2.2 billion tons.

[8]Excludes U.S. production.

BERYLLIUM

(Data in metric tons of beryllium content unless otherwise noted)

Domestic Production and Use: One company in Utah mined bertrandite ore and converted it, along with imported beryl, into beryllium hydroxide. Some of the beryllium hydroxide was shipped to the company's plant in Ohio, where it was converted into metal, oxide, and downstream beryllium-copper master alloy, and some was sold. Based on the estimated unit value for beryllium in imported beryllium-copper master alloy, beryllium apparent consumption of 170 tons was valued at about $110 million. Based on sales revenues, approximately 24% of beryllium products were used in aerospace and defense applications; 23% in industrial components; 12% each in automotive electronics and telecommunications infrastructure; 11% in consumer electronics; 9% in energy applications; 1% in semiconductor applications; and 8% in other applications. Beryllium alloy strip and bulk products, the most common forms of processed beryllium, were used in all application areas. Most unalloyed beryllium metal and beryllium composite products were used in defense and scientific applications.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, mine shipments	155	150	165	160	150
Imports for consumption[1]	68	60	67	49	45
Exports[2]	34	38	30	37	30
Shipments from Government stockpile[3]	3	2	—	—	3
Consumption:					
Apparent[4]	182	179	202	167	170
Reported, ore	160	160	170	160	150
Price, annual average value, beryllium-copper master alloy,[5] dollars per kilogram of contained beryllium	510	640	590	620	620
Stocks, ore, consumer, yearend	35	30	30	35	35
Net import reliance[6] as a percentage of apparent consumption	15	16	18	4	11

Recycling: Beryllium was recovered from new scrap generated during the manufacture of beryllium products and from old scrap. Detailed data on the quantities of beryllium recycled are not available but may account for as much as 20% to 25% of total beryllium consumption. The leading U.S. beryllium producer established a comprehensive recycling program for all of its beryllium products, recovering approximately 40% of the beryllium content of the new and old beryllium alloy scrap.

Import Sources (2016–19):[1] Kazakhstan, 43%; Japan, 16%; Brazil, 12%; Latvia, 7%; and other, 22%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Beryllium ores and concentrates	2617.90.0030	Free.
Beryllium oxide and hydroxide	2825.90.1000	3.7% ad val.
Beryllium-copper master alloy	7405.00.6030	Free.
Beryllium-copper plates, sheets, and strip:		
Thickness of 5 millimeters (mm) or more	7409.90.1030	3.0% ad val.
Thickness of less than 5 mm:		
Width of 500 mm or more	7409.90.5030	1.7% ad val.
Width of less than 500 mm	7409.90.9030	3.0% ad val.
Beryllium:		
Unwrought, including powders	8112.12.0000	8.5% ad val.
Waste and scrap	8112.13.0000	Free.
Other	8112.19.0000	5.5% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7] The Defense Logistics Agency Strategic Materials had a goal of retaining 47 tons of beryllium metal in the National Defense Stockpile.

		FY 2020		**FY 2021**	
Material	**Inventory as of 9–30–20**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Beryl ore (gross weight)	1	—	—	—	—
Metal (all types)	64	—	7	—	7
Structured powder	7	—	—	—	—

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BERYLLIUM

Events, Trends, and Issues: Domestic beryllium consumption in 2020 was estimated to be about 6% lower than that of 2019. Imports of beryl concentrate have decreased substantially since 2015. During the first 6 months of 2020, the leading U.S. beryllium producer reported that net sales of its beryllium alloy strip and bulk products and beryllium metal and composite products were 24% lower than those during the first 6 months of 2019. Value-added sales of beryllium products decreased primarily in the aerospace and defense, consumer electronics, energy, and telecommunications markets. The impact of the COVID-19 pandemic was reported to have been a substantial factor in the reduction of customer demand.

Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium in air, water, and other media. Industry is required to carefully control the quantity of beryllium dust, fumes, and mists in the workplace.

World Mine Production and Reserves:

	Mine production[8, 9]		Reserves[10]
	2019	2020[e]	
United States	160	150	The United States has very little beryl that
Brazil	[e]3	3	can be economically hand sorted from
China	70	70	pegmatite deposits. The Spor Mountain
Madagascar	[e]1	1	area in Utah, an epithermal deposit,
Mozambique	[e]15	15	contains a large bertrandite resource,
Nigeria	[e]1	1	which is being mined. Proven and probable
Rwanda	[e]1	1	bertrandite reserves in Utah total about
Uganda	—	1	20,000 tons of contained beryllium. World
World total (rounded)	250	240	beryllium reserves are not available.

World Resources:[10] The world's identified resources of beryllium have been estimated to be more than 100,000 tons. About 60% of these resources are in the United States; by tonnage, the Spor Mountain area in Utah, the McCullough Butte area in Nevada, the Black Hills area in South Dakota, the Sierra Blanca area in Texas, the Seward Peninsula in Alaska, and the Gold Hill area in Utah account for most of the total.

Substitutes: Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. In some applications, certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium may be substituted for beryllium metal or beryllium composites. Copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys (copper-tin-phosphorus) may be substituted for beryllium-copper alloys, but these substitutions can result in substantially reduced performance. Aluminum nitride or boron nitride may be substituted for beryllium oxide.

[e]Estimated. — Zero.

[1]Includes estimated beryllium content of imported ores and concentrates, oxide and hydroxide, unwrought metal (including powders), beryllium articles, waste and scrap, beryllium-copper master alloy, and beryllium-copper plates, sheets, and strip.

[2]Includes estimated beryllium content of exported unwrought metal (including powders), beryllium articles, and waste and scrap.

[3]Change in total inventory level from prior yearend inventory.

[4]Defined as production + imports – exports + adjustments for Government and industry stock changes.

[5]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%. Rounded to two significant figures.

[6]Defined as imports – exports + adjustments for Government and industry stock changes.

[7]See Appendix B for definitions.

[8]In addition to the countries listed, Kazakhstan and Portugal may have produced beryl ore, but available information was inadequate to make reliable estimates of output. Other nations that produced gemstone beryl ore may also have produced some industrial beryl ore.

[9]Based on a beryllium content of 4% from bertrandite and beryl sources.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons gross weight unless otherwise noted)

Domestic Production and Use: The United States ceased production of primary refined bismuth in 1997 and is highly import dependent for its supply. Bismuth is contained in some lead ores mined domestically. However, the last domestic primary lead smelter closed at yearend 2013; since then all lead concentrates have been exported for smelting.

About three-fifths of domestic bismuth consumption was for chemicals used in cosmetic, industrial, laboratory, and pharmaceutical applications. Bismuth use in pharmaceuticals included bismuth salicylate (the active ingredient in over-the-counter stomach remedies) and other compounds used to treat burns, intestinal disorders, and stomach ulcers. Bismuth is also used in the manufacture of ceramic glazes, crystalware, and pearlescent pigments.

Bismuth has a wide variety of metallurgical applications, including use as an additive to enhance metallurgical quality in the foundry industry and as a nontoxic replacement for lead in brass, free-machining steels, and solders. The use of bismuth in brass for pipe fittings, fixtures, and water meters increased after 2014 when the definition of “lead-free” under the Safe Drinking Water Act was modified to reduce the maximum lead content of “lead-free” pipes and plumbing fixtures to 0.25% from 8%. The melting point of bismuth is relatively low at 271 degrees Celsius, and it is an important component of various fusible alloys, some of which have melting points below that of boiling water. These bismuth-containing alloys can be used in holding devices for grinding optical lenses, as a temporary filler to prevent damage to tubes in bending operations, as a triggering mechanism for fire sprinklers, and in other applications in which a low melting point is ideal. Bismuth-tellurium-oxide alloy film paste is used in the manufacture of semiconductor devices.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap	2,190	2,820	2,510	2,300	2,000
Exports, metal, alloys, and scrap	431	392	653	636	670
Consumption:					
Apparent[1]	1,780	2,530	2,080	1,650	1,400
Reported	651	694	570	548	500
Price, average,[2] dollars per pound	4.53	4.93	4.64	3.19	2.70
Stocks, yearend, consumer	513	489	346	443	500
Net import reliance[3] as a percentage of apparent consumption	96	97	96	95	94

Recycling: Bismuth-containing alloy scrap was recycled and thought to compose less than 5% of U.S. bismuth apparent consumption.

Import Sources (2016–19): China, 69%; the Republic of Korea, 10%; Mexico, 8%; Belgium, 5%; and other, 8%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–20**
Bismuth and articles thereof, including waste and scrap	8106.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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BISMUTH

Events, Trends, and Issues: Bismuth prices continued a significant downward trend that began in 2014, when the annual average domestic dealer price was $11.14 per pound. Bismuth was one of the metals held in significant quantities by the defunct Fanya Nonferrous Metals Exchange in China, which closed in 2015. In December 2019, 19,200 tons of Fanya Metal Exchange bismuth stocks were sold, which was likely the cause for the price slump at the end of that year. In 2020, it was announced that the Fanya bismuth stocks would be used internally for manufacturing, which relieved downward pricing pressures seen through the first half of 2020, resulting in a slight increase in the third quarter.

The global COVID-19 pandemic affected the global economy and trade during the first of half of 2020; in particular, China during the first quarter and the United States in the second quarter. Economies in both countries have showed some rebound in subsequent quarters. Trade data through August 2020 were mixed when compared with the same period in 2019—while bismuth exports increased, imports for consumption decreased.

World Refinery Production and Reserves: Available information was inadequate to make reliable estimates for mine production and reserves data.

	Refinery production		Reserves[4]
	2019	2020[e]	
United States	—	—	Quantitative estimates of reserves are not available.
Bolivia	15	10	
Bulgaria	50	40	
Canada	25	20	
China	16,000	14,000	
Japan	540	480	
Kazakhstan	270	240	
Korea, Republic of	930	830	
Laos	3,000	1,000	
Mexico	300	270	
World total (rounded)	21,100	17,000	

World Resources:[4] World reserves of bismuth are usually estimated based on the bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores. In China and Vietnam, bismuth production is a byproduct or coproduct of tungsten and other metal ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines where bismuth has been the primary product. The Tasna Mine has been inactive since 1996.

Substitutes: Bismuth compounds can be replaced in pharmaceutical applications by alumina, antibiotics, calcium carbonate, and magnesia. Titanium dioxide-coated mica flakes and fish-scale extracts are substitutes in pigment uses. Cadmium, indium, lead, and tin can partially replace bismuth in low-temperature solders. Resins can replace bismuth alloys for holding metal shapes during machining, and glycerine-filled glass bulbs can replace bismuth alloys in triggering devices for fire sprinklers. Free-machining alloys can contain lead, selenium, or tellurium as a replacement for bismuth. Bismuth is an environmentally friendly substitute for lead in plumbing and many other applications, including fishing weights, hunting ammunition, lubricating greases, and soldering alloys.

[e]Estimated. — Zero.

[1]Defined as secondary production + imports – exports + adjustments for industry stock changes.

[2]Price is based on 99.99%-purity metal at warehouse (Rotterdam) in minimum lots of 1 ton. Source: American Metal Market (Fastmarkets AMM).

[3]Defined as imports – exports + adjustments for industry stock changes.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

BORON

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies in southern California produced borates in 2020, and most of the boron products consumed in the United States were manufactured domestically. Estimated boron production decreased in 2020 compared with 2019 production levels. U.S. boron production and consumption data were withheld to avoid disclosing company proprietary data. The leading boron producer mined borate ores, which contain the minerals kernite, tincal, and ulexite, by open pit methods and operated associated compound plants. Kernite was used to produce boric acid, tincal was used to produce sodium borate, and ulexite was used as a primary ingredient in the manufacture of a variety of specialty glasses and ceramics. A second company produced borates from brines extracted through solution-mining techniques. Boron minerals and chemicals were principally consumed in the north-central and eastern United States. In 2020, the glass and ceramics industries remained the leading domestic users of boron products, accounting for an estimated 80% of total borates consumption. Boron also was used as a component in abrasives, cleaning products, insecticides, and insulation and in the production of semiconductors.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	173	158	133	161	180
Boric acid	46	40	51	41	50
Colemanite (calcium borates)	35	58	73	42	30
Ulexite (sodium borates)	43	24	34	38	30
Exports:					
Boric acid	238	216	251	251	250
Refined borax	581	572	610	598	640
Consumption, apparent[1]	W	W	W	W	W
Price, average value of imports, cost, insurance, and freight, dollars per ton	352	392	404	373	384
Employment, number	1,340	1,300	1,350	1,350	1330
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2016–19): All forms: Turkey, 84%; Bolivia, 8%; Chile, 3%; and other, 5%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Natural borates:		
Sodium (ulexite)	2528.00.0005	Free.
Calcium (colemanite)	2528.00.0010	Free.
Boric acids	2810.00.0000	1.5% ad val.
Borates, refined borax:		
Anhydrous	2840.11.0000	0.3% ad val.
Non-anhydrous	2840.19.0000	0.1% ad val.

Depletion Allowance: Borax, 14% (domestic and foreign).

Government Stockpile: None.

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BORON

Events, Trends, and Issues: Elemental boron is a metalloid with limited commercial applications. Although the term "boron" is commonly referenced, it does not occur in nature in an elemental state. Boron combines with oxygen and other elements to form boric acid, or inorganic salts called borates. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on their boric oxide (B_2O_3) content, varying by ore and compound and by the absence or presence of calcium and sodium. The four borate minerals—colemanite, kernite, tincal, and ulexite—account for 90% of the borate minerals used by industry worldwide. Although borates were used in more than 300 applications, more than three-quarters of world consumption was used in ceramics, detergents, fertilizers, and glass.

China, India, the Netherlands, Malaysia, and Indonesia, in decreasing order of tonnage, are the countries that imported the largest quantities of refined borates from the United States in 2020. Because China has low-grade boron reserves and demand for boron is anticipated to rise in that country, imports to China from Chile, Russia, Turkey, and the United States were expected to remain steady during the next several years.

Continued investment in new borate refineries and the continued rise in demand were expected to fuel growth in world production for the next few years. Two Australia-based mine developers confirmed that production of high-quality boron products would be possible from their projects in California and Nevada. These companies have the potential to become substantial boron producers when they are fully developed. The project in California was expected to begin production in 2021, and the project in Nevada was expected to begin production in 2023.

World Production and Reserves:

	Production—All forms		Reserves[3]
	2019	2020[e]	
United States	W	W	40,000
Argentina, crude ore	71	70	NA
Bolivia, ulexite	200	200	NA
Chile, ulexite	400	400	35,000
China, boric oxide equivalent	250	250	24,000
Germany, compounds	120	120	NA
Peru, crude borates	111	110	4,000
Russia, datolite ore	80	80	40,000
Turkey, refined borates	2,400	2,400	1,100,000
World total[4]	XX	XX	XX

World Resources:[3] Deposits of borates are associated with volcanic activity and arid climates, with the largest economically viable deposits in the Mojave Desert of the United States, the Alpide belt in southern Asia, and the Andean belt of South America. U.S. deposits consist primarily of tincal, kernite, and borates contained in brines, and to a lesser extent, ulexite and colemanite. About 70% of all deposits in Turkey are colemanite, primarily used in the production of heat-resistant glass. At current levels of consumption, world resources are adequate for the foreseeable future.

Substitutes: The substitution of other materials for boron is possible in detergents, enamels, insulation, and soaps. Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamels can use other glass-producing substances, such as phosphates. Insulation substitutes include cellulose, foams, and mineral wools. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]World totals cannot be calculated because production and reserves are not reported in a consistent manner by all countries.

BROMINE

(Data in metric tons of bromine content unless otherwise noted)

Domestic Production and Use: Bromine was recovered from underground brines by two companies in Arkansas. Bromine is one of the leading mineral commodities, in terms of value, produced in Arkansas. The two bromine companies in the United States account for a large percentage of world production capacity.

The leading global applications of bromine are for the production of brominated flame retardants and intermediates and industrial uses. Bromine compounds are also used in a variety of other applications, including drilling fluids and industrial water treatment. U.S. apparent consumption of bromine in 2020 was estimated to be less than that in 2019.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	58,400	52,700	56,200	56,300	43,000
Exports, elemental bromine and compounds[2]	28,300	32,600	21,900	29,300	35,000
Consumption, apparent[3]	W	W	W	W	W
Price, average value of imports (cost, insurance, and freight), dollars per kilogram	2.19	2.30	2.21	2.31	2.40
Employment, number[e]	1,050	1,050	1,050	1,050	1,050
Net import reliance[4] as a percentage of apparent consumption	<25	<25	<25	<25	<25

Recycling: Some bromide solutions were recycled to obtain elemental bromine and to prevent the solutions from being disposed of as hazardous waste. For example, hydrogen bromide is emitted as a byproduct in many organic reactions. This byproduct waste can be recycled with virgin bromine brines and used as a source of bromine production. Bromine contained in plastics can be incinerated as solid organic waste, and the bromine can be recovered.

Import Sources (2016–19):[5] Israel, 80%; Jordan, 11%; China, 6%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Bromine	2801.30.2000	5.5% ad val.
Hydrobromic acid	2811.19.3000	Free.
Potassium or sodium bromide	2827.51.0000	Free.
Ammonium, calcium, or zinc bromide	2827.59.2500	Free.
Potassium bromate	2829.90.0500	Free.
Sodium bromate	2829.90.2500	Free.
Ethylene dibromide	2903.31.0000	5.4% ad val.
Methyl bromide	2903.39.1520	Free.
Dibromoneopentyl glycol	2905.59.3000	Free.
Tetrabromobisphenol A	2908.19.2500	5.5% ad val.
Decabromodiphenyl and octabromodiphenyl oxide	2909.30.0700	5.5% ad val.

Depletion Allowance: Brine wells, 5% (domestic and foreign).

Government Stockpile: None.

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BROMINE

Events, Trends, and Issues: The United States maintained its position as one of the leading bromine producers in the world. China, Israel, and Jordan also are major producers of elemental bromine. In 2020, U.S. net imports of bromine and bromine compounds decreased compared with those in 2019. The average import value of bromine and bromine compounds increased by about 4% in 2020 compared with that in 2019. The leading source of imports of bromine and bromide compounds (gross weight) in 2020 was Israel. Together, the leading imported bromine products in terms of both gross weight and bromine content were bromides and bromide oxides of ammonium, calcium, or zinc and bromides of sodium or potassium (about 90%). Reported exports of methyl bromide were revised for 2017 through 2019 by the U.S. Census Bureau.

Global consumption of bromine and bromine compounds decreased in 2020. Owing to the global COVID-19 pandemic, the demand for flame retardants and clear brine fluids, leading applications for bromine and bromine compounds, decreased. This decreased demand was attributed to declining consumer spending in the automotive, electronic, and construction industries (which use brominated flame retardants in their products), as well declining demand for drilling fluids by the oil- and gas-well-drilling industries, which use clear brine fluids in oil- and gas-well drilling. Although the values of U.S.-imported bromine and bromine compounds increased in 2020 compared with those in 2019, domestic selling prices were reported to have decreased slightly.

Some bromine facilities in Shandong Province, China, restarted production in the first half of 2020 following completion of rectifications and improvements required to meet new environmental regulations initiated by the Government of China in late 2017. However, production volumes and selling prices remained low.

World Production and Reserves:

	Production		Reserves[6]
	2019	2020[e]	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	64,000	63,000	NA
India	10,000	10,000	NA
Israel	180,000	180,000	Large
Japan	20,000	20,000	NA
Jordan	150,000	150,000	Large
Ukraine	4,500	4,500	NA
World total (rounded)	[7]429,000	[7]430,000	Large

World Resources:[6] Bromine is found principally in seawater, evaporitic (salt) lakes, and underground brines associated with petroleum deposits. The Dead Sea, in the Middle East, is estimated to contain 1 billion tons of bromine. Seawater contains about 65 parts per million bromine, or an estimated 100 trillion tons. Bromine is also recovered from seawater as a coproduct during evaporation to produce salt.

Substitutes: Chlorine and iodine may be substituted for bromine in a few chemical reactions and for sanitation purposes. There are no comparable substitutes for bromine in various oil- and gas-well completion and packer applications. Because plastics have a low ignition temperature, aluminum hydroxide, magnesium hydroxide, organic chlorine compounds, and phosphorus compounds can be substituted for bromine as fire retardants in some uses.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Includes data for the Harmonized Tariff Schedule of the United States codes shown in the "Tariff" section.

[2]Includes data for the following Schedule B codes: 2801.30.2000, 2827.51.0000, 2827.59.0000, 2903.31.0000, and 2903.39.1520.

[3]Defined as production (sold or used) + imports – exports.

[4]Defined as imports – exports.

[5]Calculated using the gross weight of imports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production.

CADMIUM

(Data in metric tons of cadmium content unless otherwise noted)

Domestic Production and Use: Two companies in the United States produced refined cadmium in 2020. One company, operating in Tennessee, recovered primary refined cadmium as a byproduct of zinc leaching from roasted sulfide concentrates. The other company, operating in Ohio, recovered secondary cadmium metal from spent nickel-cadmium (NiCd) batteries. Domestic production and consumption of cadmium were withheld to avoid disclosing company proprietary data. Cadmium metal and compounds are mainly consumed for alloys, coatings, NiCd batteries, pigments, and plastic stabilizers. For the past 5 years, the United States has been a net importer of unwrought cadmium metal and cadmium metal powders and a net exporter of wrought cadmium products and cadmium pigments.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, refined[1]	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	240	274	273	385	190
Wrought cadmium and other articles (gross weight)	([2])	2	1	20	3
Cadmium waste and scrap (gross weight)	52	20	20	86	70
Exports:					
Unwrought cadmium and powders	157	223	41	32	6
Wrought cadmium and other articles (gross weight)	371	205	99	84	440
Cadmium waste and scrap (gross weight)	12	([2])	([2])	6	([2])
Consumption, reported, refined	W	W	W	W	W
Price, metal, annual average,[3] dollars per kilogram	1.34	1.75	2.89	2.67	2.30
Stocks, yearend, producer and distributor	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	<25	<25	<50	<50	<50

Recycling: Secondary cadmium is mainly recovered from spent consumer and industrial NiCd batteries. Other waste and scrap from which cadmium can be recycled includes copper-cadmium alloy scrap, some complex nonferrous alloy scrap, cadmium-containing dust from electric arc furnaces, and cadmium telluride (CdTe) solar panels.

Import Sources (2016–19):[5] Australia, 23%; China, 19%; Canada, 17%; Germany, 13%; and other, 28%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Cadmium oxide	2825.90.7500	Free.
Cadmium sulfide	2830.90.2000	3.1% ad val.
Pigments and preparations based on cadmium compounds	3206.49.6010	3.1% ad val.
Unwrought cadmium and powders	8107.20.0000	Free.
Cadmium waste and scrap	8107.30.0000	Free.
Wrought cadmium and other articles	8107.90.0000	4.4% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most of the world's primary cadmium metal was produced in Asia, and leading global producers, in descending order of production, were China and the Republic of Korea, followed by Canada and Japan with approximately equal production. A smaller amount of secondary cadmium metal was recovered from recycling NiCd batteries. In India, a major primary cadmium plant was under construction that would have a capacity of 2,600 tons per year. Although detailed data on the global consumption of primary cadmium were not available, NiCd battery production was thought to have continued to account for most global cadmium consumption. Other end uses for cadmium and cadmium compounds included alloys, anticorrosive coatings, pigments, polyvinyl chloride (PVC) stabilizers, and semiconductors for solar cells and for radiation-detecting imaging equipment. A new use for cadmium being developed in 2020 was for extremely precise cadmium-based optical lattice clocks; these would operate at room temperature, unlike those currently in use that required cryogenic cooling.

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CADMIUM

The average monthly cadmium price began 2020 averaging $2.63 per kilogram in January and trended downward to about $2.08 per kilogram in August. The decrease could be attributed to decreasing demand in India, in large part owing to the COVID-19 pandemic affecting economic activity, including a lockdown in India that extended from March 25 to May 3. As a major consumer of cadmium, India was an important driver behind cadmium prices in the spot market.

In 2020, a major United States-based CdTe thin-film solar-cell producer reached its full production rate after completing a new facility in Ohio, increasing the company's U.S. CdTe solar-cell manufacturing capacity to 1.8 gigawatts per year. A second company entered the market in 2020 with a 100-megawatt-per-year facility, also in Ohio. Innovation continued in the NiCd battery industry. A new line of compact cadmium batteries designed to compete with conventional lead-acid batteries in remote locations was introduced for manufacture in the United States. The batteries were lighter than the lead-acid batteries, had a longer expected service life of more than 20 years, and would use the existing lead-acid battery charging system, allowing a direct replacement.

World Refinery Production and Reserves:

	Refinery production		Reserves[6]
	2019	2020[e]	
United States[1]	W	W	Quantitative estimates of reserves are not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Canada	1,803	1,800	
China	8,200	8,200	
Japan	2,000	1,800	
Kazakhstan	1,500	1,500	
Korea, Republic of	4,400	3,000	
Mexico	1,395	1,300	
Netherlands	1,100	1,100	
Peru	772	700	
Russia	900	900	
Other countries	2,320	2,300	
World total (rounded)[7]	24,400	23,000	

World Resources:[6] Cadmium is generally recovered from zinc ores and concentrates. Sphalerite, the most economically significant zinc ore mineral, commonly contains minor amounts of cadmium, which shares certain similar chemical properties with zinc and often substitutes for zinc in the sphalerite crystal lattice. The cadmium mineral greenockite is frequently associated with weathered sphalerite and wurtzite.

Substitutes: Lithium-ion and nickel-metal hydride batteries can replace NiCd batteries in many applications. Except where the surface characteristics of a coating are critical (for example, fasteners for aircraft), coatings of zinc, zinc-nickel, aluminum, or tin can be substituted for cadmium in many plating applications. Cerium sulfide is used as a replacement for cadmium pigments, mostly in plastics. Barium-zinc or calcium-zinc stabilizers can replace barium-cadmium stabilizers in flexible PVC applications. Amorphous silicon and copper-indium-gallium-selenide photovoltaic cells compete with cadmium telluride in the thin-film solar-cell market. Research efforts continued to advance new thin-film technology based on perovskite material as a potential substitute.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Cadmium metal produced as a byproduct of zinc refining plus metal from recycling.

[2]Less than ½ unit.

[3]Average free market price for 99.95% purity in 10-ton lots; cost, insurance, and freight; global ports. Source: Metal Bulletin.

[4]Defined as imports of unwrought metal and metal powders – exports of unwrought metal and metal powders + adjustments for industry stock changes.

[5]Includes data for the following Harmonized Tariff Schedule of the United States code: 8107.20.0000.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, U.S. portland cement production increased slightly to an estimated 87 million tons, and masonry cement production decreased slightly to 2.3 million tons. Cement was produced at 96 plants in 34 States, and at 2 plants in Puerto Rico. Texas, Missouri, California, and Florida were, in descending order of production, the four leading cement-producing States and accounted for nearly 45% of U.S. production. Overall, the U.S. cement industry's growth continued to be constrained by closed or idle plants, underutilized capacity at others, production disruptions from plant upgrades, and relatively inexpensive imports. In 2020, shipments of cement were essentially unchanged from those of 2019 and were valued at $12.7 billion. In 2020, it was estimated that 70% to 75% of sales were to ready-mixed concrete producers, 10% to concrete product manufactures, 8% to 10% to contractors, and 5% to 12% to other customer types.

Salient Statistics—United States:[1]	2016	2017	2018	2019	2020[e]
Production:					
Portland and masonry cement[2]	84,695	86,356	86,368	[e]88,000	89,000
Clinker	75,633	76,678	77,112	79,000	79,000
Shipments to final customers, includes exports	95,397	97,935	99,419	103,000	103,000
Imports for consumption:					
Hydraulic cement	11,742	12,288	13,764	14,690	15,000
Clinker	1,496	1,209	967	1,160	1,400
Exports of hydraulic cement and clinker	1,097	1,035	919	1,002	1,000
Consumption, apparent[3]	95,150	97,160	98,500	[e]103,000	102,000
Price, average mill value, dollars per ton	111	117	121	[e]123	124
Stocks, cement, yearend	7,420	7,870	8,580	[e]7,140	7,800
Employment, mine and mill, number[e]	12,700	12,500	12,300	12,500	12,500
Net import reliance[4] as a percentage of apparent consumption	13	13	14	14	15

Recycling: Cement is not recycled, but significant quantities of concrete are recycled for use as a construction aggregate. Cement kilns can use waste fuels, recycled cement kiln dust, and recycled raw materials such as slags and fly ash. Various secondary materials can be incorporated as supplementary cementitious materials (SCMs) in blended cements and in the cement paste in concrete.

Import Sources (2016–19):[5] Canada, 33%; Turkey, 16%; Greece, 15%; China, 12%; and other, 24%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Cement clinker	2523.10.0000	Free.
White portland cement	2523.21.0000	Free.
Other portland cement	2523.29.0000	Free.
Aluminous cement	2523.30.0000	Free.
Other hydraulic cement	2523.90.0000	Free.

Depletion Allowance: Not applicable. Certain raw materials for cement production have depletion allowances.

Government Stockpile: None.

Events, Trends, and Issues: In 2020, production of cement was temporarily idled in many countries and localities in response to national lockdowns imposed to limit the spread of the global COVID-19 pandemic. The duration of the lockdowns and the return to full production following the restart of operations, varied by geographic region. Disruptions to construction activities corresponded with reduced cement demand, and some regions experienced increased fuel and freight costs. Additionally, several planned cement plant openings and expansions were delayed.

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CEMENT

Despite the economic disruptions owing to the COVID-19 pandemic, the value of total construction put in place in the United States increased by about 4% during the first 9 months of 2020 compared with that of the same period in 2019. Residential construction spending increased more than nonresidential construction spending. A cement plant in New York was idled in April because of decreased demand resulting from restrictions put in place to mitigate the spread of the virus. However, the U.S. cement industry has shown no prolonged or widespread negative effects from the pandemic. The leading cement-consuming States continued to be Texas, California, and Florida, in descending order by tonnage. Company merger-and-acquisition activity continued in 2020, with the completion of the sale of a cement company in Kentucky. In 2019, one European cement company entered into an agreement to purchase a Mexican cement company's plant in Pennsylvania and the transaction was still pending regulatory approval in 2020.

Cement plant upgrades were announced at cement plants in Alabama and Texas. Several minor upgrades were ongoing at some other domestic plants, and upgrades were also announced for a few cement terminals. However, one cement company delayed work on an upgrade to one of its plants in Indiana. Another company secured its final air permit for a new cement plant in Georgia. Numerous companies made announcements aligned with the industry's commitment to sustainability, such as new product lines, renewable energy plans, decarbonization research initiatives, and other innovations. Many plants have installed emissions-reduction equipment to comply with the 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP). It remains possible that some kilns could be shut, idled, or used in a reduced capacity to comply with NESHAP, which would constrain U.S. clinker capacity.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2019	2020	2019	2020
United States (includes Puerto Rico)	89,000	90,000	103,000	103,000
Brazil	54,000	57,000	60,000	60,000
China	2,300,000	2,200,000	1,970,000	1,970,000
Egypt	47,000	50,000	48,000	48,000
India	340,000	340,000	280,000	280,000
Indonesia	70,000	73,000	78,000	78,000
Iran	60,000	60,000	81,000	81,000
Japan	53,000	53,000	53,000	53,000
Korea, Republic of	50,000	50,000	50,000	50,000
Russia	56,000	56,000	80,000	80,000
Turkey	57,000	66,000	92,000	92,000
Vietnam	97,000	96,000	90,000	90,000
Other countries (rounded)	880,000	890,000	720,000	720,000
World total (rounded)	4,100,000	4,100,000	3,700,000	3,700,000

World Resources: Although reserves at individual plants are subject to exhaustion, limestone and other cement raw materials are geologically widespread and abundant, and overall shortages are unlikely in the future.

Substitutes: Most portland cement is used to make concrete, mortars, or stuccos, and competes in the construction sector with concrete substitutes, such as aluminum, asphalt, clay brick, fiberglass, glass, gypsum (plaster), steel, stone, and wood. Certain materials, especially fly ash and ground granulated blast furnace slag, develop good hydraulic cementitious properties by reacting with lime, such as that released by the hydration of portland cement. Where readily available (including as imports), these SCMs are increasingly being used as partial substitutes for portland cement in many concrete applications and are components of finished blended cements.

[e]Estimated.

[1]Portland plus masonry cement unless otherwise noted; excludes Puerto Rico unless otherwise noted.

[2]Includes cement made from imported clinker.

[3]Defined as production of cement (including from imported clinker) + imports (excluding clinker) – exports + adjustments for stock changes.

[4]Defined as imports (cement and clinker) – exports.

[5]Hydraulic cement and clinker; includes imports into Puerto Rico.

CESIUM

(Data in metric tons of cesium oxide unless otherwise noted)

Domestic Production and Use: In 2020, no cesium was mined domestically, and the United States was 100% import reliant for cesium minerals. Pollucite, mainly found in association with lithium-rich, lepidolite-bearing or petalite-bearing zoned granite pegmatites, is the principal cesium ore mineral. Cesium minerals are used as feedstocks to produce a variety of cesium compounds and cesium metal. The primary application for cesium, by gross weight, is in cesium formate brines used for high-pressure, high-temperature well drilling for oil and gas production and exploration. With the exception of cesium formate, cesium is used in relatively small-scale applications, using only a few grams for most applications. Owing to the lack of global availability of cesium, many applications have used mineral substitutes and the use in any particular application may no longer be viable.

Cesium metal is used in the production of cesium compounds and potentially in photoelectric cells. Cesium bromide is used in infrared detectors, optics, photoelectric cells, scintillation counters, and spectrophotometers. Cesium carbonate is used in the alkylation of organic compounds and in energy conversion devices, such as fuel cells, magneto-hydrodynamic generators, and polymer solar cells. Cesium chloride is used in analytical chemistry applications as a reagent, in high-temperature solders, as an intermediate in cesium metal production, in isopycnic centrifugation, as a radioisotope in nuclear medicine, as an insect repellent in agricultural applications, and in specialty glasses. Cesium hydroxide is used as an electrolyte in alkaline storage batteries. Cesium iodide is used in fluoroscopy equipment—Fourier-transform infrared spectrometers—as the input phosphor of x-ray image intensifier tubes, and in scintillators. Cesium nitrate is used as a colorant and oxidizer in the pyrotechnic industry, in petroleum cracking, in scintillation counters, and in x-ray phosphors. Cesium sulfates are soluble in water and are thought to be used primarily in water treatment, fuel cells, and to improve optical quality for scientific instruments.

Cesium isotopes, which are obtained as a byproduct in nuclear fission or formed from other isotopes, such as barium-131, are used in electronic, medical, metallurgical, and research applications. Cesium isotopes are used as an atomic resonance frequency standard in atomic clocks, playing a vital role in aircraft guidance systems, global positioning satellites, and internet and cellular telephone transmissions. Cesium clocks monitor the cycles of microwave radiation emitted by cesium's electrons and use these cycles as a time reference. Owing to the high accuracy of the cesium atomic clock, the international definition of 1 second is based on the cesium atom. The U.S. civilian time and frequency standard is based on a cesium fountain clock at the National Institute of Standards and Technology in Boulder, CO. The U.S. military frequency standard, the United States Naval Observatory timescale, is based on 48 weighted atomic clocks, including 25 cesium fountain clocks.

A company in Richland, WA, produced a range of cesium-131 medical products for treatment of various cancers. Cesium-137 may be used in industrial gauges, in mining and geophysical instruments, and for sterilization of food, sewage, and surgical equipment. Because of the danger posed by the radiological properties of cesium-137, efforts to find substitutes in its applications continued.

Salient Statistics—United States: Consumption, import, and export data for cesium have not been available since the late 1980s. Because cesium metal is not traded in commercial quantities, a market price is unavailable. Only a few thousand kilograms of cesium chemicals are thought to be consumed in the United States every year. The United States was 100% import reliant for its cesium needs.

In 2020, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $65.20, a 3.5% increase from $63.00 in 2019, and 99.98% (metal basis) cesium for $84.70, a 4.4% increase from $81.10 in 2019.

In 2020, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, cesium chloride, and cesium iodide were $120.00, $72.90, $104.40, $107.20, and $121.20, respectively, with increases ranging from 1.4% to 3.6% from prices in 2019. The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $77.80 for 50 milliliters and $119.00 for 100 milliliters, and the price for 25 grams of cesium formate, 98% (metal basis), was $41.40.

Recycling: Cesium formate brines are typically rented by oil and gas exploration clients. After completion of the well, the used cesium formate brine is returned and reprocessed for subsequent drilling operations. Cesium formate brines are recycled, recovering nearly 85% of the brines for recycling to be reprocessed for further use.

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CESIUM

Import Sources (2016–19): No reliable data have been available to determine the source of cesium ore imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of cesium ore.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Alkali metals, other	2805.19.9000	5.5% ad val.
Chlorides, other	2827.39.9000	3.7% ad val.
Bromides, other	2827.59.5100	3.6% ad val.
Iodides, other	2827.60.5100	4.2% ad val.
Sulfates, other	2833.29.5100	3.7% ad val.
Nitrates, other	2834.29.5100	3.5% ad val.
Carbonates, other	2836.99.5000	3.7% ad val.
Cesium-137, other	2844.40.0021	Free

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic cesium occurrences will likely remain uneconomic unless market conditions change. No known human health issues are associated with naturally occurring cesium, and its use has minimal environmental impact. Manufactured radioactive isotopes of cesium have been known to cause adverse health effects. Certain cesium compounds may be toxic if consumed. Food that has been irradiated using the radioisotope cesium-137 has been found to be safe by the U.S. Food and Drug Administration.

During 2020, no primary cesium mine production was reported globally. Mine production of cesium from all countries, excluding China, ceased within the past two decades. Production in Namibia ceased in the early 2000s, followed by the Tanco Mine in Canada shutting down and later being sold after a mine collapse in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018, and the Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019.

A company completed an updated mineral resource estimate for the Karibib project in Namibia, reporting 8.9 million metric tons of measured and indicated resources containing 0.23% rubidium and 302 parts per million cesium. Located in the Karibib Pegmatite Belt, lithium would be the primary product, with cesium, potassium, and rubidium as potential byproducts.

World Mine Production and Reserves:[1] There were no official sources for cesium production data in 2020. Cesium reserves are, therefore, estimated based on the occurrence of pollucite, a primary lithium-cesium-rubidium mineral. Most pollucite contains 5% to 32% cesium oxide. No reliable data are available to determine reserves for specific countries; however, Australia, Canada, China, Namibia, and Zimbabwe were thought to have reserves totaling less than 200,000 tons.

World Resources:[1] Cesium is associated with lithium-bearing pegmatites worldwide, and cesium resources have been identified in Australia, Canada, Namibia, the United States, and Zimbabwe. In the United States, pollucite occurs in pegmatites in Alaska, Maine, and South Dakota. Lower concentrations occur in brines in Chile and China and in geothermal systems in Germany, India, and Tibet. China was thought to have cesium-rich deposits of geyserite, lepidolite, and pollucite, with concentrations highest in Yichun, Jiangxi Province, although no resource, reserve, or production estimates were available.

Substitutes: Cesium and rubidium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications. However, rubidium is mined from similar deposits, in relatively smaller quantities, as a byproduct of cesium production in pegmatites and as a byproduct of lithium production from lepidolite (hard-rock) mining and processing, making it no more readily available than cesium.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

CHROMIUM

(Data in thousand metric tons of chromium content unless otherwise noted)

Domestic Production and Use: In 2020, the United States was expected to consume 4% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, chromium ferroalloys, chromium metal, and stainless steel. Imported chromite ore was consumed by one chemical firm to produce chromium chemicals. Stainless-steel and heat-resisting-steel producers were the leading consumers of ferrochromium. Stainless steels and superalloys require the addition of chromium via ferrochromium or chromium-containing scrap. The value of chromium material consumption was expected to be about $600 million in 2020, as measured by the value of net imports, excluding stainless steel, and was an increase from $304 million in 2019.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Mine	—	—	—	—	—
Recycling[1]	156	156	143	142	130
Imports for consumption	548	634	651	530	490
Exports	253	255	211	157	110
Shipments from Government stockpile	5	8	4	4	4
Consumption (includes recycling):					
Reported	462	523	465	489	440
Apparent[2]	455	545	587	519	510
Price, average annual value of imports, dollars per ton:					
Chromite ore (gross weight)	198	259	279	248	180
Ferrochromium (chromium content)[3]	1,750	2,547	2,549	2,094	1,800
Chromium metal (gross weight)	9,939	9,675	11,344	10,393	7,900
Stocks, consumer, yearend	9	6	5	5	5
Net import reliance[4] as a percentage of apparent consumption	66	71	76	73	75

Recycling: In 2020, recycled chromium (contained in reported stainless steel scrap receipts) accounted for 25% of apparent consumption.

Import Sources (2016–19): Chromite (mineral): South Africa, 99%; and Canada, 1%. Chromium-containing scrap:[5] Canada, 50%; Mexico, 42%; and other, 8%. Chromium (primary metal):[6] South Africa, 36%; Kazakhstan, 10%; Russia, 7%; and other, 47%. Total imports: South Africa, 39%; Kazakhstan, 8%; Mexico, 6%; Russia, 6%; and other, 41%.

Tariff:[7] Item	**Number**	**Normal Trade Relations 12–31–20**
Chromium ores and concentrates:		
Cr_2O_3 not more than 40%	2610.00.0020	Free.
Cr_2O_3 more than 40% and less than 46%	2610.00.0040	Free.
Cr_2O_3 more than or equal to 46%	2610.00.0060	Free.
Chromium oxides and hydroxides:		
Chromium trioxide	2819.10.0000	3.7% ad val.
Other	2819.90.0000	3.7% ad val.
Sodium dichromate	2841.30.0000	2.4% ad val.
Potassium dichromate	2841.50.1000	1.5% ad val.
Other chromates and dichromates	2841.50.9100	3.1% ad val.
Carbides of chromium	2849.90.2000	4.2% ad val.
Ferrochromium:		
Carbon more than 4%	7202.41.0000	1.9% ad val.
Carbon more than 3%	7202.49.1000	1.9% ad val.
Carbon more than 0.5%	7202.49.5010	3.1% ad val.
Other	7202.49.5090	3.1% ad val.
Ferrosilicon chromium	7202.50.0000	10% ad val.
Chromium metal:		
Unwrought, powder	8112.21.0000	3% ad val.
Waste and scrap	8112.22.0000	Free.
Other	8112.29.0000	3% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

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CHROMIUM

Government Stockpile:[8]

Material[9]	Inventory as of 9–30–20	FY 2020 Potential acquisitions	FY 2020 Potential disposals	FY 2021 Potential acquisitions	FY 2021 Potential disposals
Ferrochromium:					
High-carbon	33.9	—	[10]21.3	—	[10]21.8
Low-carbon	26.8	—	—	—	—
Chromium metal	3.83	—	0.181	—	0.454

Events, Trends, and Issues: Chromium is consumed in the form of ferrochromium to produce stainless steel. South Africa was the leading chromite ore producer. Increased labor costs, increased costs for electricity, an unreliable supply of electricity, temporary mine closures related to the COVID-19 pandemic, and challenges related to deep level mining could affect production in South Africa in 2020.

China was the leading chromium-consuming country. China was also the leading stainless-steel- and ferrochromium-producing country. South Africa was the second-leading country in ferrochromium production. Ferrochromium production is electrical-energy intensive, so constrained electrical power supply and rising costs for electricity in South Africa, as well as temporary closures related to the COVID-19 pandemic, could also affect ferrochromium production.

From September 2019 to September 2020, the monthly average high-carbon ferrochromium price increased by 12%. Prices of chromium metal decreased by 18% in September 2020 compared with the monthly average price in September 2019 and were below the prior low in February 2007.

World Mine Production and Reserves:

	Mine production[11] 2019	Mine production[11] 2020[e]	Reserves[12] (shipping grade)[13]
United States	—	—	620
Finland	2,415	2,400	13,000
India	4,139	4,000	100,000
Kazakhstan	6,700	6,700	230,000
South Africa	16,395	16,000	200,000
Turkey	10,000	6,300	26,000
Other countries	5,110	4,800	NA
World total (rounded)	44,800	40,000	570,000

World Resources:[12] World resources are greater than 12 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries. World chromium resources are heavily geographically concentrated (95%) in Kazakhstan and southern Africa; United States chromium resources are mostly in the Stillwater Complex in Montana.

Substitutes: Chromium has no substitute in stainless steel, the leading end use, or in superalloys, the major strategic end use. Chromium-containing scrap can substitute for ferrochromium in some metallurgical uses.

[e]Estimated. NA Not available. — Zero.

[1]Recycling production is based on reported receipts of all types of stainless-steel scrap.

[2]Defined as production (from mines and recycling) + imports – exports + adjustments for Government and industry stock changes.

[3]Excludes ferrochromium silicon.

[4]Defined as imports – exports + adjustments for Government and industry stock changes.

[5]Includes chromium metal scrap and stainless-steel scrap.

[6]Includes chromium metal, ferrochromium, and stainless steel.

[7]In addition to the tariff items listed, certain imported chromium materials (see 26 U.S.C. sec. 4661, 4662, and 4672) are subject to excise tax.

[8]See Appendix B for definitions.

[9]Units are thousand tons of material by gross weight.

[10]High-carbon and low-carbon ferrochromium, combined.

[11]Mine production units are thousand tons, gross weight, of marketable chromite ore.

[12]See Appendix C for resource and reserve definitions and information concerning data sources.

[13]Reserves units are thousand tons of shipping-grade chromite ore, which is deposit quantity and grade normalized to 45% Cr_2O_3, except for the United States where grade is normalized to 7% Cr_2O_3 and Finland where grade is normalized to 26% Cr_2O_3.

CLAYS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Production of clays (sold or used) in the United States was estimated to be 25 million tons valued at $1.6 billion in 2020, with about 125 companies operating clay and shale mines in 39 States. The leading 20 firms produced approximately 64% of the U.S. tonnage and 84% of the value for all types of clay. Principal uses for specific clays were estimated to be as follows: ball clay—55% floor and wall tile and 18% sanitaryware; bentonite—49% pet waste absorbents and 23% drilling mud; common clay—43% brick, 30% lightweight aggregate, and 23% cement; fire clay—77% heavy clay and lightweight aggregates products (for example, brick, cement, and concrete) and 23% refractory products and miscellaneous uses; fuller's earth—81% absorbents (includes oil and grease absorbents, pet waste absorbents and miscellaneous absorbents); and kaolin—49% paper coating and filling, 10% refractory products, and 8% paint.

Exports of clay and shale were estimated have decreased by 15% in 2020 after decreasing slightly in 2019. In 2020, the United States exported an estimated 760,000 tons of bentonite mainly for pet waste absorbent, drilling mud, foundry sand bond, and iron ore pelletizing applications, with Canada, Japan, and China being the leading destinations. About 1.9 million tons of kaolin were exported mainly as a paper coating and filler; a component in ceramic bodies; and fillers and extenders in paint, plastic, and rubber products, with China, Mexico, and Japan being the leading destinations. Lesser quantities of ball clay, fire clay, and fuller's earth were exported for ceramic, refractory, and absorbent uses, respectively.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production (sold or used):					
Ball clay	1,270	1,270	1,110	1,060	990
Bentonite	4,000	4,430	4,560	4,490	4,300
Common clay	13,000	13,300	12,600	12,600	12,000
Fire clay	534	575	567	603	570
Fuller's earth[1]	1,860	1,840	1,880	1,920	2,000
Kaolin	5,200	5,450	5,350	5,060	4,600
Total[1, 2]	25,900	26,900	26,100	25,700	25,000
Imports for consumption:					
Artificially activated clays and earths	26	28	23	31	29
Kaolin	389	316	330	293	190
Other	57	86	68	66	32
Total[2]	473	430	421	390	250
Exports:					
Artificially activated clays and earths	143	147	149	138	130
Ball clay	41	83	90	85	57
Bentonite	801	961	845	906	760
Clays, not elsewhere classified	256	244	244	204	180
Fire clay[3]	184	225	250	194	180
Fuller's earth	86	78	70	73	75
Kaolin	2,290	2,310	2,390	2,280	1,900
Total[2]	3,800	4,040	4,030	3,880	3,300
Consumption, apparent[4]	22,600	23,300	22,500	22,200	22,000
Price, ex-works, average, dollars per ton:					
Ball clay	39	49	55	56	53
Bentonite	99	99	98	98	98
Common clay	14	15	16	16	16
Fire clay	13	13	12	14	14
Fuller's earth[1]	89	93	88	86	82
Kaolin	159	158	160	162	160
Employment (excludes office workers), number:					
Mine (may not include contract workers)	1,120	1,220	1,110	1,110	1,060
Mill	4,440	4,370	4,310	4,310	4260
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2016–19): All clay types combined: Brazil, 72%; Mexico, 8%; China, 7%; and other, 13%.

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CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–20
Kaolin and other kaolinic clays, whether or not calcined	2507.00.0000	Free.
Bentonite	2508.10.0000	Free.
Fire clay	2508.30.0000	Free.
Common blue clay and other ball clays	2508.40.0110	Free.
Decolorizing earths and fuller's earth	2508.40.0120	Free.
Other clays	2508.40.0150	Free.
Chamotte or dinas earth	2508.70.0000	Free.
Activated clays and activated earths	3802.90.2000	2.5% ad val.
Expanded clays and other mixtures	6806.20.0000	Free.

Depletion Allowance: Ball clay, bentonite, fire clay, fuller's earth, and kaolin, 14% (domestic and foreign); clay used in the manufacture of common brick, lightweight aggregate, and sewer pipe, 7.5% (domestic and foreign); clay used in the manufacture of drain and roofing tile, flower pots, and kindred products, 5% (domestic and foreign); clay from which alumina and aluminum compounds are extracted, 22% (domestic).

Government Stockpile: None.

Events, Trends, and Issues: As in recent years, U.S. sales of clay in 2020 continued to slightly decrease. Owing to the global COVID-19 pandemic, production of all types of clays, except for fuller's earth, decreased in 2020. Housing construction decreased in the spring because of the pandemic, before rebounding during the latter part of the year. The percentage of new building construction using brick continues to decrease in favor of other materials.

World Mine Production and Reserves:[6] Global reserves are large, but country-specific data were not available.

	Mine production					
	Bentonite		Fuller's earth		Kaolin	
	2019	2020[e]	2019	2020[e]	2019	2020[e]
United States	4,490	4,300	[1]1,920	[1]2,000	5,060	4,600
Brazil (beneficiated)	610	610	—	—	1,700	1,700
China	2,000	2,000	—	—	5,000	5,000
Czechia	357	360	—	—	[7]3,450	[7]3,400
Germany	395	390	—	—	5,200	5,200
Greece	[7]1,300	[7]1,300	37	37	—	—
India	1,700	1,700	6	6	[7]4,000	[7]4,000
Iran	360	360	—	—	790	790
Mexico	250	250	110	110	140	140
Senegal	—	—	117	120	—	—
Spain	160	160	626	620	[7]450	[7]450
Turkey	1,300	1,300	20	27	1,500	1,500
Ukraine	180	180	—	—	1,840	1,800
Uzbekistan	—	—	—	—	4,500	4,500
Other countries	3,150	3,200	344	350	10,700	11,000
World total (rounded)	16,300	16,000	[1]3,180	[1]3,300	44,300	44,000

World Resources:[6] Resources of all clays are extremely large.

Substitutes: Clays compete with calcium carbonate in filler and extender applications; diatomite, organic pet litters, polymers, silica gel, and zeolites as absorbents; and various siding and roofing types in building construction.

[e]Estimated. E Net exporter. — Zero.

[1]Does not include U.S. production of attapulgite.

[2]Data may not add to totals shown because of independent rounding.

[3]Includes refractory-grade kaolin.

[4]Defined as production (sold or used) + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Includes production of crude ore.

COBALT

(Data in metric tons of cobalt content unless otherwise noted)

Domestic Production and Use: In 2020, the nickel-copper Eagle Mine in Michigan produced cobalt-bearing nickel concentrate. In Missouri, a company produced nickel-copper-cobalt concentrate from historic mine tailings. Most U.S. cobalt supply comprised imports and secondary (scrap) materials. Approximately six companies in the United States produced cobalt chemicals. About 43% of the cobalt consumed in the United States was used in superalloys, mainly in aircraft gas turbine engines; 10% in cemented carbides for cutting and wear-resistant applications; 16% in various other metallic applications; and 31% in a variety of chemical applications. The total estimated value of cobalt consumed in 2020 was $300 million.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:[e]					
Mine	690	640	480	500	600
Secondary[1]	2,750	2,750	2,750	2,750	2,100
Imports for consumption	12,800	11,900	11,900	13,900	10,000
Exports	4,160	5,690	6,950	4,070	3,500
Consumption (includes secondary):					
Reported	9,010	9,240	9,290	9,050	7,300
Apparent[2]	11,500	8,950	7,700	12,500	8,700
Price, average, dollars per pound:					
U.S. spot, cathode[3]	12.01	26.97	37.43	16.95	16.00
London Metal Exchange (LME), cash	11.57	25.28	32.94	14.88	14.00
Stocks, yearend:					
Industry[4]	969	1,020	1,060	1,090	1,000
LME, U.S. warehouse	195	160	130	102	80
Net import reliance[5] as a percentage of apparent consumption	76	69	64	78	76

Recycling: In 2020, cobalt contained in purchased scrap represented an estimated 29% of cobalt reported consumption.

Import Sources (2016–19): Cobalt contained in metal, oxide, and salts: Norway, 20%; Canada, 14%; Japan, 13%; Finland, 10%; and other, 43%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Cobalt ores and concentrates	2605.00.0000	Free.
Chemical compounds:		
Cobalt oxides and hydroxides	2822.00.0000	0.1% ad val.
Cobalt chlorides	2827.39.6000	4.2% ad val.
Cobalt sulfates	2833.29.1000	1.4% ad val.
Cobalt carbonates	2836.99.1000	4.2% ad val.
Cobalt acetates	2915.29.3000	4.2% ad val.
Unwrought cobalt, alloys	8105.20.3000	4.4% ad val.
Unwrought cobalt, other	8105.20.6000	Free.
Cobalt mattes and other intermediate products; cobalt powders	8105.20.9000	Free.
Cobalt waste and scrap	8105.30.0000	Free.
Wrought cobalt and cobalt articles	8105.90.0000	3.7% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[6] See the Lithium chapter for statistics on lithium-cobalt oxide and lithium-nickel-cobalt-aluminum oxide.

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cobalt	302	—	—	—	—
Cobalt alloys, gross weight[7]	3	—	—	50	—

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COBALT

Events, Trends, and Issues: Congo (Kinshasa) continued to be the world's leading source of mined cobalt, supplying approximately 70% of world cobalt mine production. With the exception of production in Morocco and artisanally mined cobalt in Congo (Kinshasa), most cobalt is mined as a byproduct of copper or nickel. China was the world's leading producer of refined cobalt, most of which was produced from partially refined cobalt imported from Congo (Kinshasa). China was the world's leading consumer of cobalt, with more than 80% of its consumption being used by the rechargeable battery industry.

Cobalt mine and refinery production were forecast to decrease in 2020. Estimated annual average cobalt prices declined from those of 2019. Cobalt production in Madagascar was suspended to prevent the spread of COVID-19. Increased production from recently started operations in Congo (Kinshasa) was more than offset by reduced production at other operations in response to low prices and restrictions resulting from the COVID-19 pandemic.

World Mine Production and Reserves: Reserves for multiple countries were revised based on industry reports.

	Mine production		Reserves[8]
	2019	2020[e]	
United States	500	600	53,000
Australia	5,740	5,700	[9]1,400,000
Canada	3,340	3,200	220,000
China	2,500	2,300	80,000
Congo (Kinshasa)	100,000	95,000	3,600,000
Cuba	3,800	3,600	500,000
Madagascar	3,400	700	100,000
Morocco	2,300	1,900	14,000
Papua New Guinea	2,910	2,800	51,000
Philippines	5,100	4,700	260,000
Russia	6,300	6,300	250,000
South Africa	2,100	1,800	40,000
Other countries	6,320	6,400	560,000
World total (rounded)	144,000	140,000	7,100,000

World Resources:[8] Identified cobalt resources of the United States are estimated to be about 1 million tons. Most of these resources are in Minnesota, but other important occurrences are in Alaska, California, Idaho, Michigan, Missouri, Montana, Oregon, and Pennsylvania. With the exception of resources in Idaho and Missouri, any future cobalt production from these deposits would be as a byproduct of another metal. Identified world terrestrial cobalt resources are about 25 million tons. The vast majority of these resources are in sediment-hosted stratiform copper deposits in Congo (Kinshasa) and Zambia; nickel-bearing laterite deposits in Australia and nearby island countries and Cuba; and magmatic nickel-copper sulfide deposits hosted in mafic and ultramafic rocks in Australia, Canada, Russia, and the United States. More than 120 million tons of cobalt resources have been identified in manganese nodules and crusts on the floor of the Atlantic, Indian, and Pacific Oceans.

Substitutes: Depending on the application, substitution for cobalt could result in a loss in product performance or an increase in cost. The cobalt contents of lithium-ion batteries, the leading global use for cobalt, are being reduced; potential commercially available cobalt-free substitutes use iron and phosphorus. Potential substitutes in other applications include barium or strontium ferrites, neodymium-iron-boron, or nickel-iron alloys in magnets; cerium, iron, lead, manganese, or vanadium in paints; cobalt-iron-copper or iron-copper in diamond tools; copper-iron-manganese for curing unsaturated polyester resins; iron, iron-cobalt-nickel, nickel, ceramic-metallic composites (cermets), or ceramics in cutting and wear-resistant materials; nickel-based alloys or ceramics in jet engines; nickel in petroleum catalysts; rhodium in hydroformylation catalysts; and titanium-based alloys in prosthetics.

[e]Estimated.

[1]Estimated from consumption of purchased scrap.

[2]Defined as secondary production + imports – exports + adjustments for Government and industry stock changes for refined cobalt.

[3]Source S&P Global Platts Metals Week. Cobalt cathode is refined cobalt metal produced by an electrolytic process.

[4]Stocks held by consumers and processors; excludes stocks held by trading companies and held for investment purposes.

[5]Defined as imports – exports + adjustments for Government and industry stock changes for refined cobalt.

[6]See Appendix B for definitions.

[7]Inventory is cobalt alloys; potential acquisitions are samarium-cobalt alloy; excludes potential disposals of nickel-base and aerospace alloys.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 640,000 tons.

COPPER

(Data in thousand metric tons of copper content unless otherwise noted)

Domestic Production and Use: In 2020, U.S. mine production of recoverable copper decreased by 5% to an estimated 1.2 million tons and was valued at an estimated $7.5 billion, 3% less than $7.75 billion in 2019. Arizona was the leading copper-producing State and accounted for an estimated 74% of domestic output, followed by, in descending order, Utah, New Mexico, Nevada, Montana, Michigan, and Missouri. Copper was recovered or processed at 25 mines (18 of which accounted for 99% of mine production), 3 smelters, 3 electrolytic refineries, and 14 electrowinning facilities. Refined copper and scrap were used at about 30 brass mills, 15 rod mills, and 500 foundries and miscellaneous consumers. Copper and copper alloy products were used in building construction, 43%; electrical and electronic products, 21%; transportation equipment, 19%; consumer and general products, 10%; and industrial machinery and equipment, 7%.[1]

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Mine, recoverable	1,430	1,260	1,220	1,260	1,200
Refinery:					
Primary (from ore)	1,180	1,040	1,070	985	860
Secondary (from scrap)	46	40	41	44	45
Copper recovered from old (post-consumer) scrap[2]	149	146	149	[e]150	150
Imports for consumption:					
Ore and concentrates	([3])	14	32	27	2
Refined	708	813	778	663	680
Exports:					
Ore and concentrates	331	237	253	363	390
Refined	134	94	190	125	40
Consumption:					
Reported, refined metal	1,800	1,800	1,820	1,830	1,700
Apparent, primary refined and old scrap[4]	1,880	1,860	1,830	1,810	1,600
Price, annual average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	224.9	285.4	298.7	279.6	280.0
COMEX, high-grade, first position	219.7	280.4	292.6	272.3	270.0
London Metal Exchange, high-grade	220.6	279.5	296.0	272.4	270.0
Stocks, refined, held by U.S. producers, consumers, and metal exchanges, yearend	223	265	244	111	150
Employment, mine and plant, thousands	10.1	10.5	11.7	12.0	11.0
Net import reliance[5] as a percentage of apparent consumption	30	36	33	37	37

Recycling: Old (post-consumer) scrap, converted to refined metal and alloys, provided an estimated 150,000 tons of copper. Purchased new (manufacturing) scrap, derived from fabricating operations, yielded an estimated 720,000 tons. Of the total copper recovered from scrap (including non-copper-base scrap), brass and wire-rod mills accounted for about 80%; smelters, refiners, and ingot makers, 15%; and miscellaneous chemical plants, foundries, and manufacturers, 5%. Copper recovered from scrap contributed about 38% of the U.S. copper supply.[6]

Import Sources (2016–19): Copper content of blister and anodes: Finland, 75%; Malaysia, 19%; and other, 6%. Copper content of matte, ash, and precipitates: Canada, 27%; Mexico, 21%; Spain, 11%; Belgium, 10%; and other, 31%. Copper content of ore and concentrates: Mexico, >99%; and other, <1%. Copper content of scrap: Canada, 55%; Mexico, 33%; and other, 12%. Refined copper: Chile, 59%; Canada, 24%; Mexico, 11%; and other, 6%. Refined copper accounted for 85% of all unmanufactured copper imports.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Copper ore and concentrates, copper content	2603.00.0010	1.7¢/kg on lead content.
Unrefined copper anodes	7402.00.0000	Free.
Refined copper and alloys, unwrought	7403.00.0000	1.0% ad val.
Copper wire rod	7408.11.0000	1.0% or 3.0% ad val.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

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COPPER

Events, Trends, and Issues: In 2020, U.S. mine production of copper decreased by an estimated 5%, primarily owing to reduced output from the Bingham Canyon Mine in Utah and the Chino Mine in New Mexico. At Bingham Canyon, ore grades were lower than those in 2019 because of planned pit sequencing and optimization of molybdenum production during an extended shutdown of the smelter. In April, operations at the Chino Mine were suspended after multiple workers tested positive for COVID-19; the mine was expected to restart in 2021 at about 50% of capacity. Production at the Pumpkin Hollow Mine began in December 2019, was suspended in April 2020 owing to restrictions implemented by the State of Nevada in response to the COVID-19 pandemic, and restarted in August. Output of refined copper in the United States decreased by an estimated 13% as a result of strikes, ongoing since October 2019, at a smelter in Arizona and electrolytic refinery in Texas. Refined copper production was also affected by maintenance at the smelter in Utah, which closed for several months for a complete furnace rebuild after an earthquake in March.

Global mine production of copper declined slightly to an estimated 20 million tons in 2020 from 20.4 million tons in 2019, owing primarily to COVID-19 lockdowns in April and May. These disruptions significantly affected output in Peru, the second-ranked mine producer of copper, where production through July 2020 fell by nearly 250,000 tons (23%) from that in the same period of 2019. Global refined copper production increased slightly to an estimated 25 million tons in 2020 from 24.5 million tons in 2019, when output in multiple countries was affected by temporary smelter shutdowns for maintenance and upgrades.

World Mine and Refinery Production and Reserves: Reserves for multiple countries were revised based on company and Government information.

	Mine production		Refinery production		Reserves[7]
	2019	2020[e]	2019	2020[e]	
United States	1,260	1,200	1,030	910	48,000
Australia	934	870	426	380	[8]88,000
Canada	573	570	281	290	9,000
Chile	5,790	5,700	2,270	2,400	200,000
China	1,680	1,700	9,780	9,800	26,000
Congo (Kinshasa)	1,290	1,300	1,080	1,100	19,000
Germany	—	—	632	670	2,000
Japan	—	—	1,500	1,600	—
Kazakhstan	562	580	512	540	20,000
Korea, Republic of	—	—	665	680	—
Mexico	715	690	477	470	53,000
Peru	2,460	2,200	308	330	92,000
Poland	399	400	566	550	32,000
Russia	801	850	1,050	1,060	61,000
Zambia	797	830	262	360	21,000
Other countries	3,100	3,300	3,640	3,500	200,000
World total (rounded)	20,400	20,000	24,500	25,000	870,000

World Resources:[7] A U.S. Geological Survey study of global copper deposits indicated that, as of 2015, identified resources contained 2.1 billion tons of copper, and undiscovered resources contained an estimated 3.5 billion tons.[9]

Substitutes: Aluminum substitutes for copper in automobile radiators, cooling and refrigeration tube, electrical equipment, and power cable. Titanium and steel are used in heat exchangers. Optical fiber substitutes for copper in telecommunications applications, and plastics substitute for copper in drain pipe, plumbing fixtures, and water pipe.

[e]Estimated. — Zero.

[1]Distribution reported by the Copper Development Association. Some electrical components are included in each end use.

[2]Copper converted to refined metal and alloys by brass and wire-rod mills, foundries, refineries, and other manufacturers.

[3]Less than ½ unit.

[4]Primary refined production + copper in old scrap converted to refined metal and alloys + refined imports – refined exports ± refined stock changes.

[5]Defined as refined imports – refined exports ± adjustments for refined copper stock changes.

[6]Primary refined production + copper recovered from old and new scrap + refined imports – refined exports ± refined stock changes.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]In Australia, Joint Ore Reserves Committee-compliant reserves were 22 million tons.

[9]Hammarstrom, J.M., Zientek, M.L., Parks, H.L., Dicken, C.L., and the U.S. Geological Survey Global Copper Mineral Resource Assessment Team, 2019, Assessment of undiscovered copper resources of the world, 2015 (ver.1.1, May 24, 2019): U.S. Geological Survey Scientific Investigations Report 2018–5160, 619 p., https://doi.org/10.3133/sir20185160.

DIAMOND (INDUSTRIAL)[1]

(Data in million carats unless otherwise noted)

Domestic Production and Use: In 2020, total domestic primary production of manufactured industrial diamond bort, grit, and dust and powder was estimated to be 110 million carats with a value of $44 million, a slight decrease from that in 2019. No diamond stone was produced domestically. One firm with facilities in Florida and Ohio and a second firm in Pennsylvania accounted for all of the production. At least four firms produced polycrystalline diamond from diamond powder. At least two companies recovered used industrial diamond material from used diamond drill bits, diamond tools, and other diamond-containing wastes for recycling. The major consuming sectors of industrial diamond are computer chip production; construction; drilling for minerals, natural gas, and oil; machinery manufacturing; stone cutting and polishing; and transportation (infrastructure and vehicles). Highway building, milling, and repair and stone cutting consumed most of the industrial diamond stone. About 99% of U.S. industrial diamond apparent consumption was synthetic industrial diamond because its quality can be controlled and its properties can be customized.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	42	41	184	114	110
Secondary	66	11	32	36	35
Imports for consumption	216	399	574	312	220
Exports	134	161	139	114	91
Consumption, apparent[2]	190	290	651	348	270
Price, value of imports, dollars per carat	0.23	0.16	0.12	0.14	0.18
Net import reliance[3] as a percentage of apparent consumption	43	79	67	57	47
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	83	87	—	—	—
Secondary	0.36	0.39	0.13	0.10	0.10
Imports for consumption	1.37	1.23	2.52	1.61	0.55
Exports	—	—	—	(4)	0.03
Consumption, apparent[2]	84.9	89.0	2.7	1.7	0.6
Price, value of imports, dollars per carat	13.6	12.9	2.9	3.9	7.4
Net import reliance[3] as a percentage of apparent consumption	2	1	95	94	84

Recycling: In 2020, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 35 million carats with an estimated value of $5.5 million. It was estimated that 98,000 carats of diamond stone was recycled with an estimated value of $150,000.

Import Sources (2016–19): Bort, grit, and dust and powder; natural and synthetic: China, 80%; Ireland, 7%; the Republic of Korea, 6%; Russia, 3%; and other, 4%. Stones, primarily natural: South Africa, 22%; India, 20%; Botswana, 15%; Congo (Kinshasa), 13%; and other, 30%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Industrial Miners' diamonds, carbonados	7102.21.1010	Free.
Industrial Miners' diamonds, other	7102.21.1020	Free.
Industrial diamonds, simply sawn, cleaved, or bruted	7102.21.3000	Free.
Industrial diamonds, not worked	7102.21.4000	Free.
Grit or dust and powder of natural diamonds, 80 mesh or finer	7105.10.0011	Free.
Grit or dust and powder of natural diamonds, over 80 mesh	7105.10.0015	Free.
Grit or dust and powder of synthetic diamonds, coated with metal	7105.10.0020	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, 80 mesh or finer	7105.10.0030	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, over 80 mesh	7105.10.0050	Free.

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DIAMOND (INDUSTRIAL)

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most natural industrial diamond is produced as a byproduct of mining gem-quality diamond. Global natural industrial diamond production decreased slightly during 2020. This decrease was due to mine closures and lower output as mines approach the ends of their mine life. The world's largest diamond mines have matured and are past their peak production levels, and several of the largest diamond mines are expected to close by the end of 2025. As these mines are depleted, global production is expected to continue to decline in quantity, and the global supply of crude natural diamond (including gem-quality and industrial diamond) is forecasted to steadily decrease to about 120 million carats in 2030.

Worldwide diamond exploration spending has increased over the past few years. The success rate in diamond exploration has been estimated to be less than 1%, and no major deposit has been discovered in more than 20 years.

In 2020, U.S. synthetic-industrial-diamond producers did not manufacture any diamond stone, and industrial diamond stone apparent consumption decreased. Domestic and global demand for synthetic diamond grit and powder is expected to remain greater than that for natural diamond material. In 2020, China was the leading producing country of synthetic industrial diamond, followed by the United States, Russia, Ireland, and South Africa, in descending order of quantity. These five countries produced about 99% of the world's synthetic industrial diamond. Synthetic diamond accounted for more than 99% of global industrial diamond production and consumption. Worldwide production of manufactured industrial diamond totaled more than 14.6 billion carats.

The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and is expected to remain a significant producer and exporter of synthetic industrial diamond as well. U.S. demand for industrial diamond is likely to be strong in the construction sector as the United States continues building, milling, and repairing the Nation's highway system. Industrial diamond coats the cutting edge of saws used to cut concrete in highway construction and repair work.

World Natural Industrial Diamond Mine Production and Reserves: Reserves for Australia, Botswana, and South Africa were revised based on Government and company information.

	Mine production		Reserves[5]
	2019	2020[e]	
United States	—	—	NA
Australia	13	12	[6]25
Botswana	7	5	310
Congo (Kinshasa)	11	12	150
Russia	20	19	650
South Africa	1	3	130
Zimbabwe	2	2	NA
Other countries	1	1	120
World total (rounded)	55	54	1,400

World Resources:[5] Natural diamond deposits have been discovered in more than 35 countries. Natural diamond accounts for about 1% of all industrial diamond used; synthetic diamond accounts for the remainder. At least 15 countries have the technology to produce synthetic diamond.

Substitutes: Materials that can compete with industrial diamond in some applications include manufactured abrasives, such as cubic boron nitride, fused aluminum oxide, and silicon carbide. Globally, synthetic diamond, rather than natural diamond, is used for about 99% of industrial applications.

[e]Estimated. NA Not available. — Zero.

[1]See Gemstones for information on gem-quality diamond.

[2]Defined as manufactured diamond production + secondary diamond production + imports – exports.

[3]Defined as imports – exports.

[4]Less than ½ unit.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]In Australia, Joint Ore Reserves Committee-compliant reserves were 25 million carats.

DIATOMITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, production of diatomite was estimated to be 770,000 tons with an estimated processed value of $260 million, free on board (f.o.b.) plant. Six companies produced diatomite at 12 mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Approximately 60% of diatomite is used in filtration products. The remaining 40% is used in absorbents, fillers, lightweight aggregates, and other applications. A small amount, less than 1%, is used for specialized pharmaceutical and biomedical purposes. The unit value of diatomite varied widely in 2020, from approximately $10 per ton when used as a lightweight aggregate in portland cement concrete to more than $1,000 per ton for limited specialty markets, including art supplies, cosmetics, and deoxyribonucleic acid (DNA) extraction.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production[1]	686	768	957	768	770
Imports for consumption	8	9	9	10	16
Exports	66	87	68	68	67
Consumption, apparent[2]	628	690	898	710	720
Price, average value, f.o.b. plant, dollars per ton	280	360	330	340	340
Employment, mine and plant, number[e]	350	360	370	370	370
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2016–19): Canada, 72%; Mexico, 11%; Germany, 10%; Argentina, 2%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–30–20
Siliceous fossil meals, including diatomite	2512.00.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced diatomite sold or used by producers in 2020 remained essentially the same compared with that of 2019. Apparent domestic consumption increased slightly in 2020 to an estimated 720,000 tons; exports were estimated to have decreased slightly. The United States remained the leading global producer and consumer of diatomite. Filtration (including the purification of beer, liquors, and wine and the cleansing of greases and oils) continued to be the leading end use for diatomite, also known as diatomaceous earth. An important application for diatomite is the removal of microbial contaminants, such as bacteria, protozoa, and viruses in public water systems. Other applications for diatomite include filtration of human blood plasma, pharmaceutical processing, and use as a nontoxic insecticide. Domestically, diatomite used in the production of cement was the second-ranked use. Despite disruptions caused by the global COVID-19 pandemic, the production of diatomite through the second quarter of 2020 remained consistent with that of 2019.

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DIATOMITE

In 2020, the United States accounted for an estimated 35% of total world production, followed by Denmark with 17%, Turkey with 8%, China with 7%, Peru with 5%, and Mexico with 4%. Smaller quantities of diatomite were mined in 22 additional countries.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2019	2020[e]	
United States[1]	768	770	250,000
Argentina	70	70	NA
China	150	150	110,000
Denmark[5] (processed)	370	370	NA
France	75	75	NA
Germany	52	52	NA
Japan	40	40	NA
Korea, Republic of	26	41	NA
Mexico	96	96	NA
New Zealand	40	40	NA
Peru	110	110	NA
Russia	51	51	NA
Spain	50	50	NA
Turkey	170	170	44,000
Other countries	120	170	NA
World total (rounded)	2,190	2,200	Large

World Resources:[4] Diatomite deposits form from an accumulation of amorphous hydrous silica cell walls of dead diatoms in oceanic and fresh waters. Diatomite is also known as kieselguhr (Germany), tripolite (after an occurrence near Tripoli, Libya), and moler (an impure Danish form). Because U.S. diatomite occurrences are at or near Earth's surface, recovery from most deposits is achieved through low-cost, open pit mining. Outside the United States, however, underground mining is fairly common owing to deposit location and topographic constraints. World resources of crude diatomite are adequate for the foreseeable future.

Substitutes: Many materials can be substituted for diatomite. However, the unique properties of diatomite assure its continued use in many applications. Expanded perlite and silica sand compete for filtration. Filters made from manufactured materials, notably ceramic, polymeric, or carbon membrane filters and filters made with cellulose fibers, are becoming competitive as filter media. Alternate filler materials include clay, ground limestone, ground mica, ground silica sand, perlite, talc, and vermiculite. For thermal insulation, materials such as various clays, exfoliated vermiculite, expanded perlite, mineral wool, and special brick can be used. Transportation costs will continue to determine the maximum economic distance that most forms of diatomite may be shipped and still remain competitive with alternative materials.

[e]Estimated. E Net exporter. NA Not available.

[1]Processed ore sold or used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Include sales of moler production.

FELDSPAR AND NEPHELINE SYENITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: U.S. feldspar production in 2020 had an estimated value of $45 million. Three leading companies mined and processed about 80% of production; four other companies supplied the remainder. The five leading producing States, in alphabetical order, were California, Idaho, North Carolina, Oklahoma, and Virginia. Feldspar processors reported joint product recovery of mica and silica sand. Nepheline syenite produced in the United States was not included in production figures because the material was not considered to be marketable as a flux and was mostly used in construction applications.

Feldspar is ground to about 20 mesh for glassmaking and to 200 mesh or finer for most ceramic and filler applications. It was estimated that domestically produced feldspar was transported by ship, rail, or truck to at least 30 States and to foreign destinations, including Canada and Mexico. In pottery and glass, feldspar and nepheline syenite function as a flux. The estimated 2020 end-use distribution of domestic feldspar and nepheline syenite was glass, about 65%, and ceramic tile, pottery, and other uses, 35%.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, marketable[1]	480	440	550	450	420
Imports for consumption:					
Feldspar	37	290	181	64	68
Nepheline syenite	572	1,460	1,070	508	500
Exports, feldspar	6	5	4	4	3
Consumption, apparent:[1, 2]					
Feldspar only	510	730	730	510	490
Feldspar and nepheline syenite	1,100	2,200	1,800	1,000	990
Price, average value, dollars per ton:					
Feldspar only, marketable production	69	64	97	107	110
Nepheline syenite, import value	128	61	76	156	160
Employment, mine, preparation plant, and office, number[e]	250	240	240	240	240
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	6	39	24	12	13
Nepheline syenite	100	100	100	100	100

Recycling: Feldspar and nepheline syenite are not recycled by producers; however, glass container producers use cullet (recycled container glass), thereby reducing feldspar and nepheline syenite consumption.

Import Sources (2016–19): Feldspar: Turkey, 98%; and other, 2%. Nepheline syenite: Canada, 100%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–20**
Feldspar	2529.10.0000	Free.
Nepheline syenite	2529.30.0010	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2020, domestic production and sales of feldspar decreased by almost 7%, and the average unit value of sales was about the same as that of 2019. When compared to 2019, imports of feldspar increased by about 6% and nepheline syenite imports decreased slightly in 2020. Imports of nepheline syenite reported by the U.S. Census Bureau in 2017 and 2018 were unusually high.

Domestic feldspar consumption has been gradually shifting toward glass from ceramics. A growing segment in the glass industry was solar glass, used in the production of solar panels. Glass—including beverage containers (more than one-half of the feldspar consumed by the glass industry), plate glass, and fiberglass insulation for housing and building construction—continued to be the leading end use of feldspar in the United States.

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FELDSPAR AND NEPHELINE SYENITE

In the United States, residential construction, in which feldspar is a raw material commonly used in the manufacture of plate glass, ceramic tiles and sanitaryware, and insulation, increased by 5% during the first 10 months of 2020 compared with the same period in 2019. Production and sales of feldspar are expected to increase over the next few years, owing in part to low mortgage interest rates and increased demand for single-family homes as the global COVID-19 pandemic made multifamily homes less desirable.

A company based in Canada continued development of a feldspar-quartz-kaolin project in Idaho that contained high-grade potassium feldspar. Production was expected to be about 30,000 tons per year of potassium feldspar during a 25-year mine life. For several years, the operation has produced a low-iron and trace-element feldspathic sand product from old mine tailings, which was sold to ceramic tile producers.

World Feldspar Mine Production and Reserves:[4] Reserves data for the Republic of Korea were revised based on Government information.

	Mine production		Reserves[5]
	2019	2020[e]	
United States[1]	450	420	NA
Brazil (beneficiated marketable)	300	300	150,000
China	2,000	2,000	NA
Czechia	441	460	23,000
Egypt	400	400	1,000,000
Germany	260	260	NA
India	4,000	4,000	320,000
Iran	750	1,300	630,000
Italy	4,000	4,000	NA
Korea, Republic of	620	400	180,000
Malaysia	202	200	NA
Mexico	210	210	NA
Russia	290	290	NA
Saudi Arabia	210	210	NA
Spain (includes pegmatites)	800	800	NA
Thailand	1,200	1,200	240,000
Turkey	5,500	5,000	240,000
Other countries	1,320	1,500	NA
World total (rounded)	23,000	23,000	Large

World Resources:[5] Identified and undiscovered resources of feldspar are more than adequate to meet anticipated world demand. Quantitative data on resources of feldspar existing in feldspathic sands, granites, and pegmatites generally have not been compiled. Ample geologic evidence indicates that resources are large, although not always conveniently accessible to the principal centers of consumption.

Substitutes: Imported nepheline syenite was the major alternative material for feldspar. Feldspar can be replaced in some of its end uses by clays, electric furnace slag, feldspar-silica mixtures, pyrophyllite, spodumene, or talc.

[e]Estimated. NA Not available.

[1]Rounded to two significant digits to avoid disclosing company proprietary data.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]Feldspar only.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

FLUORSPAR

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, minimal fluorspar (calcium fluoride, CaF_2) was produced in the United States. One company sold fluorspar from stockpiles produced as a byproduct of its limestone quarrying operation in Cave-in-Rock, IL, and continued development on its fluorspar mine in Kentucky. After acquiring a fluorspar mine in Utah, a second company continued a drilling program to further define the mineral resource and facilitate development of a mine plan. An estimated 29,000 tons of fluorosilicic acid (FSA), equivalent to about 47,000 tons of fluorspar grading 100%, was recovered from five phosphoric acid plants processing phosphate rock, which was primarily used in water fluoridation. The U.S. Department of Energy continued to produce aqueous hydrofluoric acid (HF) as a byproduct of the conversion of depleted uranium hexafluoride to depleted uranium oxide at plants in Paducah, KY, and Portsmouth, OH.

U.S. fluorspar consumption was satisfied primarily by imports. Domestically, production of HF in Louisiana and Texas was by far the leading use for acid-grade fluorspar. Hydrofluoric acid is the primary feedstock for the manufacture of virtually all fluorine-bearing chemicals, particularly refrigerants and fluoropolymers, and is also a key ingredient in the processing of aluminum and uranium. Fluorspar was also used in cement production, in enamels, as a flux in steelmaking, in glass manufacture, in iron and steel casting, and in welding rod coatings.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorosilicic acid from phosphate rock	44	40	33	29	29
Imports for consumption:					
Acid grade	328	331	381	317	320
Metallurgical grade	55	70	78	59	70
Total fluorspar imports	383	401	459	376	390
Hydrofluoric acid	126	123	122	124	110
Aluminum fluoride	20	21	26	37	22
Cryolite	16	10	17	21	24
Exports, fluorspar, all grades[1]	12	11	9	8	8
Consumption:					
Apparent[2]	371	390	450	368	380
Reported	W	W	W	W	W
Price, average value of imports, cost, insurance, and freight, dollars per ton:					
Acid grade	273	267	276	324	320
Metallurgical grade	233	237	258	292	160
Stocks, consumer and dealer,[3] yearend	[e]147	NA	NA	NA	NA
Employment, mine, number[e]	13	16	16	16	19
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Synthetic fluorspar may be produced from neutralization of waste in the enrichment of uranium, petroleum alkylation, and stainless-steel pickling; however, undesirable impurities constrain use. Primary aluminum producers recycle HF and fluorides from smelting operations.

Import Sources (2016–19): Mexico, 70%; Vietnam, 9%; China, 8%; South Africa, 7%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Metallurgical grade (less than 97% CaF_2)	2529.21.0000	Free.
Acid grade (97% or more CaF_2)	2529.22.0000	Free.
Natural cryolite	2530.90.1000	Free.
Hydrogen fluoride (hydrofluoric acid)	2811.11.0000	Free.
Aluminum fluoride	2826.12.0000	Free.
Synthetic cryolite	2826.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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FLUORSPAR

Events, Trends, and Issues: The global availability of fluorspar was estimated to have increased in 2020 owing to decreased consumption in some downstream applications and continued rampup of new mines in Canada and South Africa. On the consumption side, an increasing number of new projects continued to focus on developing alternatives to fluorspar in the manufacture of HF. Hydrofluoric acid was produced from FSA at four plants in China and a fifth plant was ramping up production in 2020. In June, a leading domestic fluorochemical producer and leading phosphoric acid producer announced a partnership to construct a 40,000-ton-per-year anhydrous HF plant in Aurora, NC, using FSA feedstock. The new plant, expected to begin production in 2022, would be the first plant of its kind outside of China, although similar projects were reportedly being evaluated in other countries. The agreement established a long-term HF supply agreement which would support production of fluorogases and fluoropolymers in Calvert City, KY. The capacity of existing U.S. HF plants that use fluorspar as a feedstock was 220,000 tons per year.

World Mine Production and Reserves: Reserves for Morocco were revised based on company-reported information but were only available for one producer.

	Mine production		Reserves[5, 6]
	2019	2020[e]	
United States	NA	NA	4,000
Burma	53	53	NA
Canada	80	100	NA
China	[7]4,300	[7]4,300	42,000
Germany	50	50	NA
Iran	55	55	3,400
Kazakhstan	88	77	NA
Mexico	1,230	1,200	68,000
Mongolia	718	720	22,000
Morocco	88	88	210
Pakistan	100	100	NA
South Africa	210	320	41,000
Spain	139	140	10,000
Vietnam	238	240	5,000
Other countries	107	110	120,000
World total (rounded)	7,460	7,600	320,000

World Resources:[5] Large quantities of fluorine are present in phosphate rock. Current U.S. reserves of phosphate rock are estimated to be 1 billion tons, containing about 72 million tons of 100% fluorspar equivalent assuming an average fluorine content of 3.5% in the phosphate rock. World reserves of phosphate rock are estimated to be 71 billion tons, equivalent to about 5 billion tons of 100% fluorspar equivalent.

Substitutes: FSA is used to produce aluminum fluoride (AlF_3) and HF. Because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. Aluminum smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand, and titanium dioxide have been used as substitutes for fluorspar fluxes.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Includes data for the following Schedule B codes: 2529.21.0000 and 2829.22.0000.

[2]Defined as total fluorspar imports – exports.

[3]Industry stocks for leading consumers and fluorspar distributors.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Measured as 100% calcium fluoride.

[7]As reported by China's Ministry of Natural Resources. Likely excludes production from operations that did not meet the Government's minimum mining and processing requirements. The China Non-Metallic Minerals Industry Association estimated that actual production was closer to 6 million tons.

GALLIUM

(Data in kilograms of gallium content unless otherwise noted)

Domestic Production and Use: No domestic primary (low-purity, unrefined) gallium has been recovered since 1987. Globally, primary gallium is recovered as a byproduct of processing bauxite and zinc ores. One company in Utah recovered and refined high-purity gallium from imported primary low-purity gallium metal and new scrap. Imports of gallium metal and gallium arsenide (GaAs) wafers were valued at about $1 million and $150 million, respectively. GaAs was used to manufacture integrated circuits (ICs) and optoelectronic devices, which include laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells. Gallium nitride (GaN) principally was used to manufacture optoelectronic devices. ICs accounted for 72% of domestic gallium consumption, optoelectronic devices accounted for 25%, and research and development accounted for 3%. About 80% of the gallium consumed in the United States was contained in GaAs, GaN, and gallium phosphide (GaP) wafers. Gallium metal, triethyl gallium, and trimethyl gallium, used in the epitaxial layering process to fabricate epiwafers for the production of LEDs and ICs, accounted for most of the remainder. Optoelectronic devices were used in aerospace applications, consumer goods, industrial equipment, medical equipment, and telecommunications equipment. Uses of ICs included defense applications, high-performance computers, and telecommunications equipment.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	10,500	20,200	32,000	5,740	4,600
Gallium arsenide wafers (gross weight)	1,290,000	803,000	444,000	272,000	190,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	18,100	17,900	15,000	14,900	15,000
Price, imports, dollars per kilogram:					
High-purity, refined[1]	690	477	508	570	570
Low-purity, primary[2]	125	124	185	150	170
Stocks, consumer, yearend	2,720	2,840	2,920	2,850	2,700
Net import reliance[3] as a percentage of reported consumption	100	100	100	100	100

Recycling: Old scrap, none. Substantial quantities of new scrap generated in the manufacture of GaAs-based devices were reprocessed to recover high-purity gallium at one facility in Utah.

Import Sources (2016–19): Metal: China,[4] 55%; the United Kingdom, 11%; Germany, 10%; and other, 24%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3.0% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Imports of gallium metal and GaAs wafers continued to account for all U.S. consumption of gallium. In 2020, gallium metal imports decreased by an estimated 20% from those of 2019, most likely owing to higher import tariffs on gallium from China that began in 2019. This followed a 300% increase of gallium metal imports from China in 2018 before the tariffs were introduced. In 2019, gallium metal imports from China decreased by 97% from those of 2018.

Primary low-purity (99.99%-pure) gallium prices in China increased by an estimated 32% in 2020 owing mostly to reduced production in China. The price for primary low-purity gallium in China increased to $185 per kilogram in September 2020 from approximately $140 per kilogram at yearend 2019. China's primary low-purity gallium production capacity has been approximately 600,000 kilograms per year since 2016, following an expansion from 140,000 kilograms per year in 2010. China accounted for more than 80% of worldwide low-purity gallium capacity.

The remaining primary low-purity gallium producers outside of China most likely restricted output owing to a large surplus of primary gallium that began in 2012. These producers included Japan, the Republic of Korea, and Russia. Germany and Kazakhstan ceased primary production in 2016 and 2013, respectively. Hungary and Ukraine were thought to have ceased primary production in 2015 and 2019, respectively.

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GALLIUM

High-purity refined gallium production in 2020 was estimated to be about 220,000 kilograms, a 5% increase from that of 2019. China, Japan, Slovakia, and the United States were the known principal producers of high-purity refined gallium. The United Kingdom ceased high-purity refined gallium production in 2018. Gallium was recovered from new scrap in Canada, China, Germany, Japan, Slovakia, and the United States. World primary low-purity gallium production capacity in 2020 was estimated to be 724,000 kilograms per year; high-purity refined gallium production capacity, 325,000 kilograms per year; and secondary high-purity gallium production capacity, 273,000 kilograms per year.

In 2019, the value of worldwide radio frequency (RF) GaAs device consumption decreased by 4% to $8.6 billion owing primarily to a decline in third- and fourth-generation (3G and 4G) “smartphone” shipments. In 2020, worldwide RF GaAs device consumption was expected to decrease by 4% from that of 2019 owing to the impacts of the COVID-19 pandemic and a United States–China trade dispute that resulted in higher ad valorem tariffs on imports from China. Global GaAs wafer consumption by volume was estimated to have increased by 14% in 2020, with an estimated 48%, 32%, and 20% of wafers used in LED, RF, and photonics applications, respectively. Countries within the Asia and the Pacific region dominated the GaAs wafer market.

Owing to their large power-handling capabilities, high-switching frequencies, and higher voltage capabilities, GaN-based products, which historically have been used in defense applications, are used in fifth-generation (5G) networks, cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets. The value of the GaN RF device market was estimated to be $940 million in 2020, an increase of 22% from the revised $770 million in 2019. The global high-power LED market was estimated to be $14 billion in 2020, an increase of 5.3% from that in 2019.

World Production and Reserves:

	Primary production		Reserves[5]
	2019	2020[e]	
United States	—	—	Quantitative estimates of reserves are not available.
China	338,000	290,000	
Japan	3,000	3,000	
Korea, Republic of	2,000	3,000	
Russia	8,000	4,000	
Ukraine	—	—	
World total (rounded)	351,000	300,000	

World Resources:[5] Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of processing bauxite, and the remainder is produced from zinc-processing residues. The average gallium content of bauxite is 50 parts per million. U.S. bauxite deposits consist mainly of subeconomic resources that are not generally suitable for alumina production owing to their high silica content. Some domestic zinc ores contain up to 50 parts per million gallium and could be a significant resource, although no gallium is currently recovered from domestic ores. Gallium contained in world resources of bauxite is estimated to exceed 1 million tons, and a considerable quantity could be contained in world zinc resources. However, less than 10% of the gallium in bauxite and zinc resources is potentially recoverable.

Substitutes: Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier 3G cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based ICs are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. NA Not available. — Zero.

[1]Estimated based on the average values of U.S. imports for 99.9999%- and 99.99999%-pure gallium.

[2]Estimated based on the average values of U.S. imports for 99.99%-pure gallium.

[3]Defined as imports – exports. Excludes gallium arsenide wafers.

[4]Includes Hong Kong.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: In 2020, garnet for industrial use was mined by four firms—one in Idaho, one in Montana, and two in New York. One processing facility operated in Oregon and another operated in Pennsylvania. The estimated value of crude garnet production was about $23 million, and refined material sold or used had an estimated value of $65 million. The major end uses of garnet were, in descending percentage of consumption, for abrasive blasting, water-filtration media, water-jet-assisted cutting, and other end uses, such as in abrasive powders, nonslip coatings, and sandpaper. Domestic industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, filtration plants, glass polishing, the petroleum industry, shipbuilders, textile stonewashing, and wood-furniture-finishing operations.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Crude	81,300	92,900	101,000	104,000	110,000
Refined, sold or used	46,600	84,100	166,000	147,000	150,000
Imports for consumption[e, 2]	156,000	54,200	254,000	208,000	120,000
Exports[e]	10,100	17,700	14,200	12,600	20,000
Consumption, apparent[e, 3]	227,000	129,000	341,000	300,000	210,000
Price, average import value, dollars per ton	201	305	215	214	270
Employment, mine and mill, number[e]	110	140	170	160	130
Net import reliance[4] as a percentage of apparent consumption	64	28	70	65	48

Recycling: Garnet was recycled at a plant in Oregon with a recycling capacity of 16,000 tons per year and at a plant in Pennsylvania with a recycling capacity of 25,000 tons per year. Garnet can be recycled multiple times without degradation of its quality. Most recycled garnet is from blast cleaning and water-jet-assisted cutting operations.

Import Sources (2016–19):[e] South Africa, 36%; India, 26%; China, 19%; Australia, 17%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Emery, natural corundum, natural garnet, and other natural abrasives, crude	2513.20.1000	Free.
Emery, natural corundum, natural garnet, and other natural abrasives, other than crude	2513.20.9000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2020, estimated domestic production of crude garnet concentrates increased by 6% compared with production in 2019. This increase was due to higher production levels from a mine in Montana, although all other U.S. garnet mines produced less compared with that in 2019. U.S. garnet production was estimated to be about 10% of total global garnet production. The 2020 estimated domestic sales or use of refined garnet were essentially unchanged compared with sales in 2019.

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GARNET (INDUSTRIAL)

Garnet imports in 2020 were estimated to have decreased by 42% compared with those in 2019. Most of the decrease was attributed to a lack of imports of garnet from South Africa, owing to the Pennsylvania processing facility reaching its storage capacity. In 2020, the average unit value of garnet imports was $270 per ton, an increase of 24% compared with the average unit value in 2019. In the United States, most domestically produced crude garnet concentrate was priced at about $210 per ton. U.S. exports in 2020 were estimated to have increased by 59%.

During 2020, the United States consumed about 210,000 metric tons of garnet. This was a 30% decrease from that of 2019.

The U.S. natural gas and petroleum industry is one of the leading garnet-consuming industries, using garnet for cleaning drill pipes and well casings. Natural gas and petroleum producers also use garnet as a reservoir-fracturing proppant, alone or mixed with other proppants. During 2020, the number of drill rigs operating in the United States was 804 rigs at the beginning of the year, decreasing through the year to 255 rigs at the end of September, likely indicating that less garnet was consumed in well drilling.

The garnet market is very competitive. To increase profitability and remain competitive with imported material, production may be restricted to only high-grade garnet ores or as a byproduct of other salable mineral products that occur with garnet, such as kyanite, marble, metallic ores, mica minerals, sillimanite, staurolite, or wollastonite.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2019	2020[e]	
United States	104,000	110,000	5,000,000
Australia	352,000	360,000	Moderate to large
China	310,000	310,000	Moderate to large
India	120,000	130,000	13,000,000
South Africa	179,000	140,000	NA
Other countries	60,000	60,000	6,500,000
World total (rounded)	1,120,000	1,100,000	Moderate to large

World Resources:[5] World resources of garnet are large and occur in a wide variety of rocks, particularly gneisses and schists. Garnet also occurs in contact-metamorphic deposits in crystalline limestones, pegmatites, serpentinites, and vein deposits. In addition, alluvial garnet is present in many heavy-mineral sand and gravel deposits throughout the world. Large domestic resources of garnet also are concentrated in coarsely crystalline gneiss near North Creek, NY; other significant domestic resources of garnet occur in Idaho, Maine, Montana, New Hampshire, North Carolina, and Oregon. In addition to those in the United States, major garnet deposits exist in Australia, Canada, China, India, and South Africa, where they are mined for foreign and domestic markets; deposits in Russia and Turkey also have been mined in recent years, primarily for internal markets. Additional garnet resources are in Chile, Czechia, Pakistan, Spain, Thailand, and Ukraine; small mining operations have been reported in most of these countries.

Substitutes: Other natural and manufactured abrasives can substitute to some extent for all major end uses of garnet. In many cases, however, using the substitutes would entail sacrifices in quality or cost. Fused aluminum oxide and staurolite compete with garnet as a sandblasting material. Ilmenite, magnetite, and plastics compete as filtration media. Corundum, diamond, and fused aluminum oxide compete for lens grinding and for many lapping operations. Emery is a substitute in nonskid surfaces. Fused aluminum oxide, quartz sand, and silicon carbide compete for the finishing of plastics, wood furniture, and other products.

[e]Estimated. NA Not available.

[1]Excludes gem and synthetic garnet.

[2]Source: U.S. Census Bureau and Trade Mining, LLC; adjusted by the U.S. Geological Survey.

[3]Defined as crude production + imports – exports.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

GEMSTONES[1]

(Data in million dollars unless otherwise noted)

Domestic Production and Use: The combined value of U.S. natural and synthetic gemstone output in 2020 was an estimated $99 million, a 4% decrease compared with that of 2019. Domestic gemstone production included agate, beryl, coral, diamond, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise, and many other gem materials. In descending order of production value, Arizona, Oregon, California, Nevada, Montana, Maine, Arkansas, Colorado, Utah, Idaho, Tennessee, North Carolina, and New York produced 95% of U.S. natural gemstones. Synthetic gemstones were manufactured by five companies in California, North Carolina, New York, Maryland, and Arizona, in decreasing order of production value. U.S. synthetic gemstone production decreased by 4% compared with that in 2019. Major gemstone end uses were carvings, gem and mineral collections, and jewelry.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:[2]					
Natural[3]	11.7	9.2	9.5	9.2	8.8
Laboratory-created (synthetic)	54.9	55.1	65	94	90
Imports for consumption	25,200	24,900	27,700	24,400	17,000
Exports, excluding reexports	2,940	2,440	1,850	1,050	1,500
Consumption, apparent[4]	22,300	22,500	25,900	23,500	16,000
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,120	1,120	1,120	1,120	1,120
Net import reliance[5] as a percentage of apparent consumption	99	99	99	99	99

Recycling: Gemstones are often recycled by being resold as estate jewelry, reset, or recut, but this report does not account for those stones.

Import Sources (2016–19, by value): Diamond: India, 39%; Israel, 32%; Belgium, 13%; South Africa, 4%; and other, 12%. Diamond imports accounted for an average of 90% of the total value of gem imports.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Coral and similar materials, unworked	0508.00.0000	Free.
Imitation gemstones	3926.90.4000	2.8% ad val.
Pearls, imitation, pearl beads, not strung	7018.10.1000	4.0% ad val.
Imitation gemstones, glass beads	7018.10.2000	Free.
Pearls, natural, graded and temporarily strung	7101.10.3000	Free.
Pearls, natural, other	7101.10.6000	Free.
Pearls, cultured	7101.21.0000	Free.
Diamonds, unworked or sawn	7102.31.0000	Free.
Diamonds, ½ carat or less	7102.39.0010	Free.
Diamonds, cut, more than ½ carat	7102.39.0050	Free.
Other nondiamond gemstones, unworked	7103.10.2000	Free.
Other nondiamond gemstones, uncut	7103.10.4000	10.5% ad val.
Rubies, cut	7103.91.0010	Free.
Sapphires, cut	7103.91.0020	Free.
Emeralds, cut	7103.91.0030	Free.
Other nondiamond gemstones, cut	7103.99.1000	Free.
Other nondiamond gemstones, worked	7103.99.5000	10.5% ad val.
Synthetic gemstones, cut but not set	7104.90.1000	Free.
Synthetic gemstones, other	7104.90.5000	6.4% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2020, the global COVID-19 pandemic affected the U.S. gemstone and jewelry industries. As the restrictions, lockdowns, and store closings were imposed, many jewelry stores initially saw reduced sales but later in the year successfully shifted sales to their websites. Monthly U.S. gemstone imports declined from March through August, with the largest decrease year-on-year of 96% happening in April. U.S. apparent consumption of gemstones decreased by 32%. All major U.S. gemstone trade shows were canceled from March through August.

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GEMSTONES

In 2020, U.S. imports for consumption of gem-quality diamonds were estimated to be about $15 billion, which was a 31% decrease compared with $21.7 billion in 2019. U.S. imports for consumption of natural, nondiamond gemstones were estimated to be about $2.1 billion, which was a 22% decrease compared with $2.7 billion in 2019. Despite the COVID-19 pandemic, the United States was once again the leading global market in terms of consumer demand. The United States is expected to continue to dominate global gemstone demand.

During 2020, the COVID-19 pandemic affected the global diamond industry with temporary diamond mine closings around the world and disruptions of the supply chain. Demand for diamonds plummeted during the pandemic, halting sales. Only demand for large, high-quality diamonds remained stable, and their prices increased steadily during the year. The pandemic forced mining companies to cancel or delay sales, and major diamond trade shows were canceled owing to health and travel restrictions. Rough diamond prices declined by between 15% and 27% at the few sales that took place, and the rough diamond market was not operating normally during the second quarter. In India, where about 80% of the world's diamonds are polished, cutting centers experienced major disruptions as gem workers contracted the virus. Imports of rough diamonds in India decreased from $1.5 billion in February to $1 million in April. Antwerp experienced a 20% drop in rough imports and a 46% decline in exports of polished diamonds. Worldwide, many temporary mine closures resulting from the pandemic, had yet to reopen and were at risk of becoming permanent. Many mining companies sought credit protection or were restructuring their credit. The global diamond jewelry market had an estimated value of $80 billion in 2019 and was expected to decline by 19% in 2020.

Total world diamond production during 2020 decreased by 10% from 2019 levels. This decline was attributed to pandemic mine closures and mines becoming depleted.

World Gem Diamond Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2019	2020[e]	
United States	—	—	World reserves of diamond-bearing deposits are substantial. No reserves data are available for other gemstones.
Angola	8,230	8,000	
Australia	260	200	
Botswana	16,600	13,000	
Brazil	166	100	
Canada	18,600	17,000	
Congo (Kinshasa)	2,670	3,000	
Guinea	183	150	
Lesotho	1,110	1,000	
Namibia	2,020	1,900	
Russia	25,400	24,000	
Sierra Leone	649	550	
South Africa	5,740	4,000	
Tanzania	313	300	
Zimbabwe	211	200	
Other countries	224	230	
World total (rounded)	82,400	74,000	

World Resources:[7] Most diamond ore bodies have a diamond content that ranges from less than 1 carat per ton to about 6 carats per ton of ore. The major diamond reserves are in southern Africa, Australia, Canada, and Russia.

Substitutes: Glass, plastics, and other materials are substituted for natural gemstones. Synthetic gemstones (manufactured materials that have the same chemical and physical properties as natural gemstones) are common substitutes. Simulants (materials that appear to be gems but differ in chemical and physical characteristics) also are frequently substituted for natural gemstones.

[e]Estimated. — Zero.

[1]Excludes industrial diamond and industrial garnet. See Diamond (Industrial) and Garnet (Industrial).

[2]Estimated minimum production.

[3]Includes production of freshwater shell.

[4]Defined as production (natural and synthetic) + imports – exports (excluding reexports).

[5]Defined as imports – exports (excluding reexports).

[6]Data in thousands of carats of gem diamond.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

GERMANIUM

(Data in kilograms of germanium content unless otherwise noted)

Domestic Production and Use: In 2020, zinc concentrates containing germanium were produced at mines in Alaska and Tennessee. Germanium-containing concentrates in Alaska were exported to a refinery in Canada for processing and germanium recovery. A zinc smelter in Clarksville, TN, produced and exported germanium leach concentrates recovered from processing zinc concentrates from the Middle Tennessee Mines. Germanium in the form of compounds and metal was imported into the United States for further processing by industry. A company in Utah produced germanium wafers for solar cells used in satellites from imported and recycled germanium. A refinery in Oklahoma recovered germanium from industry-generated scrap and produced germanium tetrachloride for the production of fiber optics. Although the consumption quantity was estimated to have remained level in 2020 compared with that in 2019, the estimated value of germanium consumed in 2020, based on the annual average germanium metal price, was $30 million, about 19% less than that in 2019.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, refinery:					
Primary	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Germanium metal	11,000	11,100	11,900	14,100	16,000
Germanium dioxide[1]	15,200	12,000	12,200	21,000	10,000
Exports[2]	4,780	3,670	4,880	4,600	8,000
Shipments from Government stockpile	—	—	—	—	—
Consumption, estimated[3]	30,000	30,000	30,000	30,000	30,000
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,087	1,082	1,543	1,236	1,000
Germanium dioxide	830	731	1,084	913	720
Net import reliance[5] as a percentage of estimated consumption	>50%	>50%	>50%	>50%	>50%

Recycling: Worldwide, about 30% of the total germanium consumed is produced from recycled materials. During the manufacture of most optical devices, more than 60% of the germanium metal used is routinely recycled as new scrap. Germanium scrap is also recovered from the windows in decommissioned tanks and other military vehicles. The United States has the capability to recycle new and old scrap.

Import Sources (2016–19):[6] Germanium metal: China, 58%; Belgium, 21%; Germany, 10%; Russia, 8%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad val.
Metal, unwrought	8112.92.6000	2.6% ad val.
Metal, powder	8112.92.6500	4.4% ad val.
Metal, wrought	8112.99.1000	4.4% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile:[7]

		FY 2020		**FY 2021**	
Material	**Inventory as of 9–30–20**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Germanium metal	14,004	—	—	—	—
Germanium scrap (gross weight)	3,794	—	3,000	—	3,000
Germanium wafers (each)	68,671	—	—	—	—

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GERMANIUM

Events, Trends, and Issues: The major global end uses for germanium were electronics and solar applications, fiber-optic systems, infrared optics, polymerization catalysts, and other uses (such as chemotherapy, metallurgy, and phosphors). Germanium-containing infrared optics were primarily for military use, but the commercial applications for thermal-imaging devices that use germanium lenses have increased during the past few years.

Demand for fiber-optic cable in the United States reportedly decreased during 2020 owing to decreasing demand from related industrial end use markets as a result of the COVID-19 pandemic. However, this decrease was partially offset by Federal funding to increase broadband infrastructure in rural communities and a nationwide increase in remote work. Domestic demand for fiber-optic cable was still expected to increase as wireless carriers continue to expand and upgrade their networks.

The government of Yunnan Province, a significant area of nonferrous and minor metals production in China, created a stimulus plan directing companies to purchase and stockpile nonferrous metals in response to lower demand caused by the COVID-19 pandemic. Under the plan, the government had targeted a “commercial” stockpile of about 800,000 tons of metals, including 20 tons of germanium, and set aside $141 million to subsidize the interest on any loans taken out by companies to stockpile these metals. China’s germanium exports in January through August 2020 increased by 18% compared with those in the same period of 2019. A leading Chinese producer of processed germanium products, based in Yunnan Province, reported that production of germanium wafers for satellites in January through June 2020 was more the seven times higher than wafer production in the first half of 2019 as production ramped up at its new germanium wafer production line.

World Refinery Production and Reserves:[8]

	Refinery production		Reserves[9]
	2019	2020[e]	
United States	W	W	Data on the recoverable germanium content of zinc ores are not available.
China	85,700	86,000	
Russia	5,000	5,000	
Other countries[10]	40,000	40,000	
World total (rounded)[11]	131,000	130,000	

World Resources:[9] The available resources of germanium are associated with certain zinc and lead-zinc-copper sulfide ores. Substantial U.S. reserves of recoverable germanium are contained in zinc deposits in Alaska, Tennessee, and Washington. Based on an analysis of zinc concentrates, U.S. reserves of zinc may contain as much as 2,500 tons of germanium. Because zinc concentrates are shipped globally and blended at smelters, however, the recoverable germanium in zinc reserves cannot be determined. On a global scale, as little as 3% of the germanium contained in zinc concentrates is recovered. Significant amounts of germanium are contained in ash and flue dust generated in the combustion of certain coals for power generation.

Substitutes: Silicon can be a less-expensive substitute for germanium in certain electronic applications. Some metallic compounds can be substituted in high-frequency electronics applications and in some light-emitting-diode applications. Zinc selenide and germanium glass substitute for germanium metal in infrared applications systems, but often at the expense of performance. Antimony and titanium are substitutes for use as polymerization catalysts.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Data has been adjusted to exclude low-value shipments, then multiplied by 69% to account for germanium content.

[2]Includes Schedule B numbers: 8112.92.6100, 8112.99.1000, and 2825.60.0000. Data have been adjusted to exclude low-value shipments. Oxide data have been multiplied by 69% to account for germanium content.

[3]Estimated consumption of germanium contained in metal and germanium dioxide.

[4]Average European price for minimum 99.999% purity. Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports + adjustments for Government stock changes.

[6]Import sources are based on gross weight of wrought and unwrought germanium metal and germanium metal powders.

[7]See Appendix B for definitions.

[8]Includes primary and secondary production.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Includes Belgium, Canada, Germany, Japan, and Ukraine.

[11]Excludes U.S. production.

GOLD

(Data in metric tons[1] of gold content unless otherwise noted)

Domestic Production and Use: In 2020, domestic gold mine production was estimated to be about 190 tons, 5% less than that in 2019, and the value was estimated to be about $11 billion. Gold was produced in 11 States (gold mining in Montana ceased in 2019) at more than 40 lode mines, at several large placer mines in Alaska, and numerous smaller placer mines (mostly in Alaska and in the Western States). About 7% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper ores. The top 26 operations yielded about 99% of the mined gold produced in the United States. Commercial-grade gold was produced at about 15 refineries. A few dozen companies, out of several thousand companies and artisans, dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and Providence, RI, areas, with lesser concentrations in California, Florida, and Texas. Estimated global consumption was gold-based exchange-traded funds, 34%; jewelry, 30%; physical bar, 12%; official coins and medals and imitation coins, 9%; central banks and other institutions, 7%; electrical and electronics, 6%; and other, 2%.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Mine	232	237	226	200	190
Refinery:					
Primary	242	207	205	205	200
Secondary (new and old scrap)	220	119	117	116	120
Imports for consumption[2]	374	255	213	199	610
Exports[2]	393	461	474	359	270
Consumption, reported[3]	210	159	154	151	160
Stocks, Treasury, yearend[4]	8,140	8,140	8,140	8,140	8,140
Price, dollars per troy ounce[5]	1,252	1,261	1,272	1,395	1,770
Employment, mine and mill, number[6]	11,600	11,900	12,200	12,500	12,200
Net import reliance[7] as a percentage of apparent consumption	E	E	E	E	52

Recycling: In 2020, an estimated 120 tons of new and old scrap was recycled, equivalent to about 75% of reported consumption. The domestic supply of gold from recycling increased slightly compared with that of 2019.

Import Sources (2016–19):[2] Ores and concentrates: Greece, 44%; Canada, 30%; Ireland, 26%; and other, <1%. Dore: Mexico, 42%; Peru, 16%; Colombia, 12%; Canada, 6%; and other, 24%. Bullion: Canada, 41%; Switzerland, 20%; Peru, 9%; Brazil and Mexico, 7% each; and other, 16%. Combined total: Mexico, 27%; Canada, 21%; Peru, 13%; Colombia, 8%; and other, 31%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–20**
Precious metal ore and concentrates:		
Gold content of silver ores	2616.10.0080	0.8 ¢/kg on lead content.
Gold content of other ores	2616.90.0040	1.7 ¢/kg on lead content.
Gold bullion	7108.12.1013	Free.
Gold dore	7108.12.1020	Free.
Gold scrap	7112.91.0000	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of gold (see salient statistics above), and the U.S. Department of Defense administers a Governmentwide secondary precious-metals recovery program.

Events, Trends, and Issues: The United States was not a net exporter of gold in 2020 for the first time since 2010 owing to a significant increase in imports of high-purity gold bullion. The estimated gold price in 2020 was 26% higher than the price in 2019, and 5% higher than the previous record-high annual price in 2012. The Engelhard daily price of gold in 2020 fluctuated through several cycles. Early in the year the gold price was about of $1,580 per troy ounce before decreasing in March and increasing to an alltime high of about $2,060 per troy ounce in August. During this time, several factors were reported to have caused the increase in price: gold demand increased to safe-haven buying as a result of the global COVID-19 pandemic and global investor uncertainty; the U.S. Federal Reserve Board cut interest rates; and trade negotiations halted between the United States and China. The price started a downward trend in October and November.

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GOLD

The 5% decrease in domestic mine production in 2020 was attributed to the COVID-19 pandemic. In 2020, worldwide gold mine production was estimated to be 3% less than that in 2019. Mine production remained unchanged in Argentina, China, Mali, and Sudan, and was slightly less in Australia, Canada, Ghana, and Russia compared with that of 2019.

In the first 9 months of 2020, global consumption in physical bars decreased by about 16%, in jewelry by 41%, and in industrial applications by 10%; however, gold consumption in official coins and medals and imitation coins increased by 33% compared with that of the first 9 months of 2019. Global investments in gold-based exchange-traded funds increased by almost 168%, while gold holdings in central banks decreased by about 58% during the same period.

World Mine Production and Reserves: Reserves for Canada, Papua New Guinea, Peru, Russia, and South Africa were revised based on Government and (or) industry reports.

	Mine production		Reserves[8]
	2019	2020[e]	
United States	200	190	3,000
Argentina	60	60	1,600
Australia	325	320	[9]10,000
Brazil	90	80	2,400
Canada	175	170	2,200
China	380	380	2,000
Ghana	142	140	1,000
Indonesia	139	130	2,600
Kazakhstan	107	100	1,000
Mali	61	61	800
Mexico	111	100	1,400
Papua New Guinea	74	70	1,200
Peru	128	120	2,700
Russia	305	300	7,500
South Africa	105	90	2,700
Sudan	90	90	NA
Uzbekistan	93	90	1,800
Other countries	716	750	9,200
World total (rounded)	3,300	3,200	53,000

World Resources:[8] An assessment of U.S. gold resources indicated 33,000 tons of gold in identified (15,000 tons) and undiscovered (18,000 tons) resources.[10] Nearly one-quarter of the gold in undiscovered resources was estimated to be contained in porphyry copper deposits. The gold resources in the United States, however, are only a small portion of global gold resources.

Substitutes: Base metals clad with gold alloys are widely used in electrical and electronic products, and in jewelry to economize on gold; many of these products are continually redesigned to maintain high-utility standards with lower gold content. Generally, palladium, platinum, and silver may substitute for gold.

[e]Estimated. E Net exporter. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Includes refined bullion, dore, ores, concentrates, and precipitates. Excludes waste and scrap, official monetary gold, gold in fabricated items, gold in coins, and net bullion flow (in tons) to market from foreign stocks at the New York Federal Reserve Bank.

[3]Includes gold used in the production of consumer purchased bar, coins, and jewelry. Excludes gold as an investment (except consumer purchased bar and coins). Source: World Gold Council.

[4]Includes gold in Exchange Stabilization Fund. Stocks were valued at the official price of $42.22 per troy ounce.

[5]Engelhard's average gold price quotation for the year. In 2020, the price was estimated by the U.S. Geological Survey based on data from January through November.

[6]Data from the Mine Safety and Health Administration.

[7]Defined as imports – exports.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 4,000 tons.

[10]U.S. Geological Survey National Mineral Resource Assessment Team, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

GRAPHITE (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2020, natural graphite was not produced in the United States; however, approximately 95 U.S. firms, primarily in the Great Lakes and Northeastern regions and Alabama and Tennessee, consumed 35,000 tons valued at an estimated $21 million. The major uses of natural graphite were batteries, brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2020, U.S. natural graphite imports were an estimated 41,000 tons, which were about 71% flake and high-purity, 28% amorphous, and 1% lump and chip graphite.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, mine	—	—	—	—	—
Imports for consumption	38,900	51,900	70,700	50,300	41,000
Exports	14,300	13,900	9,950	5,880	5,600
Consumption, apparent[1]	24,700	38,000	60,800	44,400	35,000
Price, imports (average dollars per ton at foreign ports):					
Flake	1,920	1,390	1,520	1,350	1,400
Lump and chip (Sri Lanka)	1,880	1,900	1,890	2,390	3,400
Amorphous	571	451	319	496	570
Net import reliance[1] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Refractory brick and linings, alumina-graphite refractories for continuous metal castings, magnesia-graphite refractory brick for basic oxygen and electric arc furnaces, and insulation brick led the way in the recycling of graphite products. The market for recycled refractory graphite material is expanding, with material being recycled into products such as brake linings and thermal insulation. Recovering high-quality flake graphite from steelmaking kish is technically feasible, but currently not practiced. The abundance of graphite in the world market inhibits increased recycling efforts. Information on the quantity and value of recycled graphite is not available.

Import Sources (2016–19): China, 33%; Mexico, 23%; Canada, 17%; India, 9%; and other, 18%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Crystalline flake (not including flake dust)	2504.10.1000	Free.
Powder	2504.10.5000	Free.
Other	2504.90.0000	Free.

Depletion Allowance: 22% (domestic lump and amorphous), 14% (domestic flake), and 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. natural graphite exports decreased each year from 2016 to 2020, with an overall 61% decline over the 5-year period. U.S. imports for consumption and apparent consumption increased each year from 2016 to 2018, when imports and consumption peaked, and declined each year during 2019 and 2020. Restrictions put in place in response to the COVID-19 pandemic caused the 2020 U.S. imports to decrease by 18%, which in turn caused a 21% decrease in U.S. apparent consumption.

In 2020, principal United States import sources of natural graphite were, in descending order of tonnage, China, Mexico, Canada, Madagascar, Mozambique, Brazil, the United Kingdom, Hong Kong, Austria, and Belgium, which combined accounted for 99% of the tonnage and 96% of the value of total United States imports. China and Mexico provided most of the amorphous graphite, and Sri Lanka provided all the lump and chip dust variety.

During 2020, China was the world's leading graphite producer, producing an estimated 62% of total world output. Approximately 40% of production in China was amorphous graphite and about 60% was flake. China produced some large flake graphite, but much of its flake graphite production is very small, in the +200-mesh range. China also processed most of the world's spherical graphite. Globally, during the first 6 months of 2020, the COVID-19 pandemic had some effect on graphite supplies, but mostly to operations outside of China. Most areas in China important for natural graphite flake production were far from the initial coronavirus occurrences. The impact was limited in these areas and the recovery was quick, which was demonstrated by China's pattern of exports. Chinese producers quickly increased production after a few months of closures in 2020. This allowed China to gain a more dominant position in the market and slow down the diversification of the supply chain.

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GRAPHITE (NATURAL)

North America produced only 2% of the world's graphite supply with production in Canada and Mexico. No production of natural graphite was reported in the United States, but two companies were developing graphite projects—one in Alabama and one in Alaska.

Large graphite deposits were being developed in Madagascar, northern Mozambique, Namibia, and south-central Tanzania. A graphite mine in Mozambique in a high-grade graphite deposit was reportedly the largest natural graphite mine globally. The mine was expected to operate for about 50 years.

A U.S. automaker continued building a large plant to manufacture lithium-ion electric vehicle batteries. The automaker reported that the plant was about 30% completed. The completed portion of the plant was operational, and it produced battery cells, battery packs, drive units, and energy storage products. At full capacity, the plant was expected to require 35,200 tons per year of spherical graphite for use as anode material for lithium-ion batteries.

New thermal technology and acid-leaching techniques have enabled the production of higher purity graphite powders that are likely to lead to development of new applications for graphite in high-technology fields. Innovative refining techniques have made the use of graphite possible in carbon-graphite composites, electronics, foils, friction materials, and specialty lubricant applications. Flexible graphite product lines are likely to be the fastest growing market. Large-scale fuel-cell applications are being developed that could consume as much graphite as all other uses combined.

World Mine Production and Reserves: Reserves for Brazil, Madagascar, Sri Lanka, and Tanzania were revised based on information reported by graphite-producing companies and the Governments of those countries.

	Mine production		Reserves[2]
	2019	2020[e]	
United States	—	—	(3)
Austria	1,000	1,000	(3)
Brazil	96,000	95,000	70,000,000
Canada	11,000	10,000	(3)
China	700,000	650,000	73,000,000
Germany	800	800	(3)
India	35,000	34,000	8,000,000
Korea, North	6,000	5,000	2,000,000
Madagascar	48,000	47,000	26,000,000
Mexico	9,000	8,000	3,100,000
Mozambique	107,000	120,000	25,000,000
Norway	16,000	15,000	600,000
Pakistan	14,000	13,000	(3)
Russia	25,100	24,000	(3)
Sri Lanka	4,000	3,500	1,500,000
Tanzania	150	150	17,000,000
Turkey	2,000	1,500	90,000,000
Ukraine	20,000	19,000	(3)
Uzbekistan	100	100	7,600,000
Vietnam	5,000	4,500	(3)
World total (rounded)	1,100,000	1,100,000	320,000,000

World Resources:[2] Domestic resources of graphite are relatively small, but the rest of the world's inferred resources exceed 800 million tons of recoverable graphite.

Substitutes: Synthetic graphite powder, scrap from discarded machined shapes, and calcined petroleum coke compete for use in iron and steel production. Synthetic graphite powder and secondary synthetic graphite from machining graphite shapes compete for use in battery applications. Finely ground coke with olivine is a potential competitor in foundry-facing applications. Molybdenum disulfide competes as a dry lubricant but is more sensitive to oxidizing conditions.

[e]Estimated. — Zero.

[1]Defined as imports – exports.

[2]See Appendix C for resource and reserve definitions and information concerning data sources.

[3]Included with "World total."

GYPSUM

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, domestic production of crude gypsum was estimated to be 22 million tons with a value of about $190 million. The leading crude gypsum-producing States were estimated to be Iowa, Kansas, Nevada, Oklahoma, and Texas. Overall, 47 companies produced or processed gypsum in the United States at 52 mines in 16 States. The majority of domestic consumption, which totaled approximately 41 million tons, was used by agriculture, cement production, and manufacturers of wallboard and plaster products. Small quantities of high-purity gypsum, used in a wide range of industrial processes, accounted for the remaining tonnage. At the beginning of 2020, the production capacity of 63 operating gypsum panel manufacturing plants in the United States was about 34.1 billion square feet[1] per year. Total wallboard sales were estimated to be 26.0 billion square feet.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Crude	19,800	20,700	21,100	21,200	22,000
Synthetic[2]	16,700	20,700	16,600	14,400	13,000
Calcined[3]	17,900	17,800	17,500	17,500	17,000
Wallboard products sold, million square feet[1]	24,400	25,000	23,700	25,200	26,000
Imports, crude, including anhydrite	4,340	4,800	5,210	6,140	5,900
Exports, crude, not ground or calcined	43	36	36	37	32
Consumption, apparent[4]	40,800	46,200	42,900	41,700	40,900
Price, average, dollars per metric ton:					
Crude, free on board (f.o.b.) mine	8	7.5	8.2	8.6	8.6
Calcined, f.o.b. plant	30	30	32	35	35
Employment, mine and calcining plant, number[e]	4,500	4,500	4,500	4,500	4,500
Net import reliance[5] as a percentage of apparent consumption	11	10	12	15	14

Recycling: Approximately 700,000 tons of gypsum scrap that was generated by wallboard manufacturing was recycled onsite. The recycling of wallboard from new construction and demolition sources also took place, although those amounts are unknown. Recycled gypsum was used primarily for agricultural purposes and feedstock for the manufacture of new wallboard. Other potential markets for recycled gypsum include athletic field marking, cement production (as a stucco additive), grease absorption, sludge drying, and water treatment.

Import Sources (2016–19): Mexico, 38%; Spain, 31%; Canada, 28%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Gypsum; anhydrite	2520.10.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. gypsum production increased by 4% compared with that of 2019. Apparent consumption decreased slightly compared with that of 2019. U.S. gypsum imports decreased by an estimated 4% compared with those of 2019. Exports, although very low compared with imports and often subject to wide fluctuations, decreased by 14%.

Demand for gypsum depends principally on construction industry activity, particularly in the United States, where the majority of gypsum consumed is used for agriculture, building plasters, the manufacture of portland cement, and wallboard products. The construction of wallboard manufacturing plants designed to use synthetic gypsum from coal flue gas desulfurization (FGD) units as feedstock has resulted in less mining of natural gypsum. The availability of inexpensive natural gas, however, has limited the additional construction of FGD units and, therefore, the use of synthetic gypsum in wallboard. Despite disruptions caused by the COVID-19 pandemic, the production of gypsum through the second quarter of 2020 was not affected.

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GYPSUM

The United States, the world's leading crude gypsum producer, produced an estimated 22 million tons. Iran was the second-leading producer with an estimated 16 million tons of crude production, followed by China with 16 million tons. Increased use of wallboard in Asia, coupled with new gypsum product plants, spurred increased production in that region. As wallboard becomes more widely used, worldwide gypsum production is expected to increase.

World Mine Production and Reserves: Reserves for Brazil, France, and Pakistan were revised based on Government and other public data.

	Mine production		Reserves[6]
	2019	2020[e]	
United States	21,200	22,000	700,000
Algeria	2,500	2,500	NA
Brazil	3,000	3,200	450,000
Canada	3,000	3,000	450,000
China	15,500	16,000	NA
France	3,000	3,000	350,000
Germany	3,300	3,200	NA
India	2,700	2,700	37,000
Iran	16,000	16,000	NA
Japan	4,300	4,700	NA
Mexico	5,400	5,400	NA
Oman	9,100	11,000	NA
Pakistan	1,670	2,200	6,000
Russia	5,500	3,800	NA
Saudi Arabia	3,300	3,300	NA
Spain	7,000	7,000	NA
Thailand	9,790	9,300	1,700
Turkey	10,000	10,000	200,000
Other countries	22,000	22,000	NA
World total (rounded)	148,000	150,000	Large

World Resources:[6] Reserves are large in major producing countries, but data for most are not available. Domestic gypsum resources are adequate but unevenly distributed. Large imports from Canada augment domestic supplies for wallboard manufacturing in the United States, particularly in the eastern and southern coastal regions. Imports from Mexico supplement domestic supplies for wallboard manufacturing along portions of the United States western seaboard. Large gypsum deposits occur in the Great Lakes region, the midcontinent region, and several Western States. Foreign resources are large and widely distributed; 78 countries were thought to produce gypsum in 2020.

Substitutes: In such applications as stucco and plaster, cement and lime may be substituted for gypsum; brick, glass, metallic or plastic panels, and wood may be substituted for wallboard. Gypsum has no practical substitute in the manufacturing of portland cement. Synthetic gypsum generated by various industrial processes, including FGD of smokestack emissions, is very important as a substitute for mined gypsum in wallboard manufacturing, cement production, and agricultural applications (in descending order by tonnage). In 2020, synthetic gypsum was estimated to account for about 40% of the total domestic gypsum supply.

[e]Estimated. NA Not available.

[1]The standard unit used in the U.S. wallboard industry is square feet; multiply square feet by 9.29×10^{-2} to convert to square meters. Source: The Gypsum Association.

[2]Synthetic gypsum used; the majority of these data were obtained from the American Coal Ash Association.

[3]From domestic crude and synthetic gypsum.

[4]Defined as domestic crude production + synthetic used + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

HELIUM

(Data in million cubic meters of contained helium gas[1] unless otherwise noted)

Domestic Production and Use: The estimated value of Grade-A helium (99.997% or greater) extracted during 2020 by private industry was about $322 million. Fourteen plants (one in Arizona, two in Colorado, five in Kansas, one in Oklahoma, four in Texas, and one in Utah) extracted helium from natural gas and produced crude helium that ranged from 50% to 99% helium. One plant in Colorado and another in Wyoming extracted helium from natural gas and produced Grade-A helium. Three plants in Kansas and one in Oklahoma accepted crude helium from other producers and the Bureau of Land Management (BLM) pipeline and purified it to Grade-A helium. In 2020, estimated domestic apparent consumption of Grade-A helium was 40 million cubic meters (1.4 billion cubic feet), and it was used for magnetic resonance imaging, lifting gas, analytical and laboratory applications, welding, engineering and scientific applications, leak detection and semiconductor manufacturing, and various other minor applications.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Helium extracted from natural gas[2]	66	63	64	68	61
Withdrawn from storage[3]	23	28	26	21	13
Grade-A helium sales	89	91	90	89	75
Imports for consumption	23	19	8	7	5
Exports	62	74	84	106	100
Consumption, apparent[4]	50	36	40	40	40
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

In fiscal year (FY) 2020, the price for crude helium to Government users was $3.10 per cubic meter ($86.00 per thousand cubic feet) and to nongovernment users was $4.29 per cubic meter ($119.00 per thousand cubic feet). The last year helium prices were posted by the Federal Government was in 2018. The estimated price for private industry's Grade-A helium was about $7.57 per cubic meter ($210 per thousand cubic feet), with some producers posting surcharges to this price.

Recycling: In the United States, helium used in large-volume applications is seldom recycled. Some low-volume or liquid boil-off recovery systems are used. In the rest of the world, helium recycling is practiced more often.

Import Sources (2016–19): Qatar, 75%; Canada, 9%; Algeria, 7%; Portugal, 5%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Helium	2804.29.0010	3.7% ad val.

Depletion Allowance: Allowances are applicable to natural gas from which helium is extracted, but no allowance is granted directly to helium.

Government Stockpile: Under the Helium Stewardship Act of 2013, the BLM manages the Federal Helium Program, which includes all operations of the Cliffside Field helium storage reservoir, in Potter County, TX, and the Government's crude helium pipeline system. Private firms that sell Grade-A helium to Federal agencies are required to purchase a like amount of (in-kind) crude helium from the BLM. The law mandated that the BLM sell at auction Federal Conservation helium stored in Bush Dome at the Cliffside Field. The last auction was completed in the summer of 2018. The remaining conservation helium is less than 83.2 million cubic meters (3 billion cubic feet). The Helium Stewardship Act requires that the BLM dispose of all helium assets including the Cliffside Field helium storage reservoir and pipeline system. The BLM will continue to make in-kind helium available to Federal customers. In fiscal year (FY) 2020, privately owned companies purchased about 5.83 million cubic meters (210 million cubic feet) of in-kind crude helium. During FY 2020, the BLM's Amarillo Field Office, Helium Operations, accepted about 0.59 million cubic meters (21 million cubic feet) of private helium for storage and redelivered nearly 1.5 million cubic meters (54 million cubic feet). As of September 30, 2020, about 62.4 million cubic meters (2.25 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

Stockpile Status—9–30–20[6]

Material	Inventory	Authorized for disposal	Disposal plan FY 2021	Disposal plan FY 2022
Helium	68.9	52.3	17.4	17.4

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HELIUM

Events, Trends, and Issues: Helium production in 2020 decreased in the United States and worldwide in response to the COVID-19 pandemic. In April, the BLM announced plans for disposal of the remaining Federal helium inventory and assets by September 2021, after which the General Services Administration would complete the disposal process. Federal in-kind users would continue to have access to helium until September 30, 2022. In Russia, a company was building a 60-million-cubic-meter-per-year helium processing plant that was expected to be completed by late 2024.

World Mine Production and Reserves:[8] Reserves for Poland and Qatar were revised based on Government and industry sources.

	Mine production		Reserves[9]
	2019	2020[e]	
United States (extracted from natural gas)	68	61	3,900
United States (from Cliffside Field)	21	13	([10])
Algeria	14	14	1,800
Australia	4	4	NA
Canada	<1	<1	NA
China	NA	NA	NA
Poland	1	1	23
Qatar	45	45	Large
Russia	5	5	1,700
World total (rounded)	160	140	NA

World Resources:[9] Section 16 of Public Law 113–40 requires the U.S. Geological Survey (USGS) to complete a national helium gas assessment. The USGS and the BLM coordinated efforts to complete this assessment. The USGS results are expected to be published in 2021. The BLM plans to publish an update to its report of the Helium Resources of the United States by midyear 2021. Until then, the following estimates are still the best available.

As of December 31, 2006, the total helium reserves and resources of the United States were estimated to be 20.6 billion cubic meters (744 billion cubic feet). This includes 4.25 billion cubic meters (153 billion cubic feet) of measured reserves, 5.33 billion cubic meters (192 billion cubic feet) of probable resources, 5.93 billion cubic meters (214 billion cubic feet) of possible resources, and 5.11 billion cubic meters (184 billion cubic feet) of speculative resources. Measured reserves include 670 million cubic meters (24.2 billion cubic feet) of helium stored in the Cliffside Field Government Reserve and 65 million cubic meters (2.3 billion cubic feet) of helium contained in Cliffside Field native gas. The Cliffside (Texas), Hugoton (Kansas, Oklahoma, and Texas), Panhandle West (Texas), Panoma (Kansas), and Riley Ridge (Wyoming) Fields are the depleting fields from which most U.S.-produced helium is extracted. These fields contained an estimated 3.9 billion cubic meters (140 billion cubic feet) of helium.

Helium resources of the world, exclusive of the United States, were estimated to be about 31.3 billion cubic meters (1.13 trillion cubic feet). The locations and volumes of the major deposits, in billion cubic meters, are Qatar, 10.1; Algeria, 8.2; Russia, 6.8; Canada, 2.0; and China, 1.1. As of December 31, 2020, the BLM had analyzed about 22,700 gas samples from 26 countries and the United States, in a program to identify world helium resources.

Substitutes: There is no substitute for helium in cryogenic applications if temperatures below –429 °F are required. Argon can be substituted for helium in welding, and hydrogen can be substituted for helium in some lighter-than-air applications in which the flammable nature of hydrogen is not objectionable. Hydrogen is also being investigated as a substitute for helium in deep-sea diving applications below 305 meters (1,000 feet).

[e]Estimated. E Net exporter. NA Not available.

[1]Measured at 101.325 kilopascals absolute (14.696 psia) and 15 °C; 27.737 cubic meters of helium = 1,000 cubic feet of helium at 70 °F and 14.7 psia.

[2]Both Grade-A and crude helium.

[3]Extracted from natural gas in prior years.

[4]Grade-A helium. Defined as Grade-A helium sales + imports – exports. However, substantial increases in exports reported in 2018, 2019, and 2020 suggest that domestic consumption declined, although no significant decline in U.S. helium consumption is thought to have taken place. For that reason, apparent consumption for 2018–2020 was estimated to have remained at about 40 million cubic meters.

[5]Defined as imports – exports.

[6]See Appendix B for definitions.

[7]Supervisory General Engineer, Helium Resources Division, Bureau of Land Management, Amarillo Field Office, Helium Operations, Amarillo, TX.

[8]Production and reserves outside of the United States are estimated.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Included in United States (extracted from natural gas) reserves.

INDIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Indium was not recovered from ores in the United States in 2020. Several companies produced indium products—including alloys, compounds, high-purity metal, and solders—from imported indium metal. Production of indium tin oxide (ITO) continued to account for most of global indium consumption. ITO thin-film coatings were primarily used for electrically conductive purposes in a variety of flat-panel displays—most commonly liquid crystal displays (LCDs). Other indium end uses included alloys and solders, compounds, electrical components and semiconductors, and research. Based on an average of recent annual import levels, estimated domestic consumption of refined indium was 100 tons in 2020. The estimated value of refined indium consumed domestically in 2020, based on the average New York dealer price, was about $40 million.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, refinery	—	—	—	—	—
Imports for consumption	160	127	125	95	100
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	160	127	125	95	100
Price, annual average, dollars per kilogram:					
New York dealer[2]	345	363	375	390	400
Duties unpaid in warehouse, Rotterdam[3]	240	225	291	185	150
Net import reliance[4] as a percentage of estimated consumption	100	100	100	100	100

Recycling: Indium is most commonly recovered from ITO scrap in Japan and the Republic of Korea. A significant quantity of scrap was recycled domestically; however, data on the quantity of secondary indium recovered from scrap were not available.

Import Sources (2016–19): China, 34%; Canada, 22%; the Republic of Korea, 15%; and other, 29%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Unwrought indium, including powders, waste, and scrap	8112.92.3000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The estimated average New York dealer price of indium was $400 per kilogram in 2020, a slight increase from that of 2019. The average monthly price was $390 per kilogram from January through April, and it increased to an average monthly price of $400 per kilogram from May through September. The 2020 estimated average duties unpaid in the warehouse, Rotterdam price of indium was $150 per kilogram, 19% less than in 2019. The average duties unpaid in the warehouse, Rotterdam price began the year at $138 per kilogram and increased throughout the year to an average of $162 per kilogram in September.

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INDIUM

On January 18, the Yunnan Provincial government sold 3,609 tons of indium that was held by the Fanya Metal Exchange that closed in 2015. The lot was offered by an auction process between January 17 and 18. The lot was purchased by the sole bidder for $416 million (2.65 billion yuan). The 3,609 tons of indium that was sold was equivalent to 4 years of global primary indium production.

The leading producer of tin in China announced the launch of a production line for high-purity indium with a capacity of 5 tons per year. The line has the capacity to produced 6N- and 7N-grade metal. The company is also ramping up its indium tin oxide production after completing small-scale operations.

World Refinery Production and Reserves:

	Refinery production		Reserves[5]
	2019	2020[e]	
United States	—	—	Quantitative estimates of reserves are not available.
Belgium	20	20	
Canada	61	50	
China	535	500	
France	40	50	
Japan	70	65	
Korea, Republic of	225	200	
Peru	12	10	
Russia	5	5	
World total (rounded)	968	900	

World Resources:[5] Indium is most commonly recovered from the zinc-sulfide ore mineral sphalerite. The indium content of zinc deposits from which it is recovered ranges from less than 1 part per million to 100 parts per million. Although the geochemical properties of indium are such that it occurs in trace amounts in other base-metal sulfides—particularly chalcopyrite and stannite—most deposits of these minerals are subeconomic for indium recovery.

Substitutes: Antimony tin oxide coatings have been developed as an alternative to ITO coatings in LCDs and have been successfully annealed to LCD glass; carbon nanotube coatings have been developed as an alternative to ITO coatings in flexible displays, solar cells, and touch screens; poly(3,4-ethylene dioxythiophene) (PEDOT) has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes; and copper or silver nanowires have been explored as a substitute for ITO in touch screens. Graphene has been developed to replace ITO electrodes in solar cells and also has been explored as a replacement for ITO in flexible touch screens. Researchers have developed a more adhesive zinc oxide nanopowder to replace ITO in LCDs. Hafnium can replace indium in nuclear reactor control rod alloys.

[e]Estimated. NA Not available. — Zero.

[1]Estimated to equal imports.

[2]Price is based on 99.99%-minimum-purity indium; delivered duty paid U.S. buyers; in minimum lots of 50 kilograms. Source: S&P Global Platts Metals Week.

[3]Price is based on 99.99%-minimum-purity indium, duties unpaid in warehouse (Rotterdam). Sources: Metal Bulletin (2016–17) and Argus Media group—Argus Metals International (2018–20).

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

IODINE

(Data in metric tons of elemental iodine unless otherwise noted)

Domestic Production and Use: Iodine was produced from brines in 2020 by three companies operating in Oklahoma. U.S. iodine production in 2020 was withheld to avoid disclosing company proprietary data. The average annual cost, insurance, and freight value of iodine imports in 2020 was estimated to be $31 per kilogram, about a 17% increase from that of 2019.

Because domestic and imported iodine was used by downstream manufacturers to produce many intermediate iodine compounds, it was difficult to establish an accurate end-use pattern. Crude iodine and inorganic iodine compounds were thought to account for more than 50% of domestic iodine consumption in 2020. Worldwide, the leading uses of iodine and its compounds were x-ray contrast media, pharmaceuticals, liquid crystal displays (LCDs), and iodophors, in descending order of quantity consumed.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production	W	W	W	W	W
Imports for consumption	4,320	4,170	4,930	4,300	4,300
Exports	1,050	1,230	1,190	1,230	1,300
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	4,610	4,500	4,620	4,000	4,000
Price, crude iodine, average value of imports (cost, insurance, and freight), dollars per kilogram	22.71	19.55	22.46	26.38	31
Employment, number[e]	60	60	60	60	60
Net import reliance[2] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled.

Import Sources (2016–19): Chile, 88%; Japan, 11%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IODINE

Events, Trends, and Issues: According to trade publications, spot prices for iodine crystal averaged about $37 per kilogram during the first 9 months of 2020. Although this was an increase from the 2019 annual average of about $30 per kilogram, prices were still considerably less than the historically high levels of $65 to $85 per kilogram in late 2012 and early 2013.

As in recent years, Chile was the world's leading producer of iodine, followed by Japan and the United States. Excluding production in the United States, Chile accounted for about two-thirds of world production in 2020. Most of the world's iodine supply comes from three areas: the Chilean desert nitrate mines, the gasfields and oilfields in Japan, and the iodine-rich brine wells in northwestern Oklahoma.

Domestic and international iodine production was not considerably affected by the global COVID-19 pandemic during the first half of 2020. However, market demand was expected to decrease in the second half of 2020 and will likely affect iodine prices in the latter half of the year.

World Mine Production and Reserves: China and Iran also produce crude iodine, but output is not officially reported.

	Mine production		Reserves[3]
	2019	2020[e]	
United States	W	W	250,000
Azerbaijan	190	200	170,000
Chile	20,200	20,000	610,000
Indonesia	40	40	100,000
Japan	9,100	9,000	4,900,000
Russia	2	2	120,000
Turkmenistan	600	600	70,000
World total (rounded)	[4]30,100	[4]30,000	6,200,000

World Resources:[3] Seawater contains 0.06 part per million iodine, and the oceans are estimated to contain approximately 90 billion tons of iodine. Seaweeds of the Laminaria family are able to extract and accumulate up to 0.45% iodine on a dry basis. Although not as economical as the production of iodine as a byproduct of gas, nitrates, and oil, the seaweed industry represented a major source of iodine prior to 1959 and remains a large resource.

Substitutes: No comparable substitutes exist for iodine in many of its principal applications, such as in animal feed, catalytic, nutritional, pharmaceutical, and photographic uses. Bromine and chlorine could be substituted for iodine in biocide, colorant, and ink, although they are usually considered less desirable than iodine. Antibiotics can be used as a substitute for iodine biocides.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Excludes U.S. production.

IRON AND STEEL[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: The U.S. iron and steel industry produced raw steel in 2020 with an estimated value of about $91 billion, an 12% decrease from $104 billion in 2019 and $103 billion in 2018. Pig iron and raw steel was produced by three companies operating integrated steel mills in 11 locations. Raw steel was produced by 51 companies at 98 minimills. Combined production capacity was about 110 million tons. Indiana accounted for an estimated 26% of total raw steel production, followed by Ohio, 12%; Michigan, 5%; and Pennsylvania, 5%, with no other State having more than 5% of total domestic raw steel production. Construction accounted for an estimated 46% of total domestic shipments by market classification, followed by transportation (predominantly automotive), 26%; machinery and equipment, 8%; energy, 6%; appliances, 5%; and other applications, 9%.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Pig iron production[2]	22.3	22.4	24.1	22.3	18.0
Raw steel production	78.5	81.6	86.6	87.8	72.0
Distribution of raw steel production, percent:					
Basic oxygen furnaces	33	32	32	30	30
Electric arc furnaces	67	68	68	70	70
Continuously cast steel	99.4	99.6	98.2	99.8	99.7
Shipments, steel mill products	78.5	82.5	86.4	87.3	71.0
Imports, steel mill products:					
Finished	23.9	26.8	23.3	19.1	14.0
Semifinished	6.1	7.8	7.3	6.2	6.1
Total	30.0	34.6	30.6	25.3	20.1
Exports, steel mill products:					
Finished	8.3	9.4	7.9	6.6	5.6
Semifinished	(3)	(3)	(3)	(3)	(3)
Total	8.4	9.6	8.0	6.7	5.7
Stocks, service centers, yearend[4]	6.6	7.0	7.3	7.4	6.0
Consumption, apparent (steel)[5]	93.0	98.4	102	100	82.0
Producer price index for steel mill products (1982=100)[6]	167.8	187.4	211.1	204.0	180.2
Employment, average, number:					
Iron and steel mills[6]	83,900	80,600	82,100	85,700	80,000
Steel product manufacturing[7]	56,300	54,300	56,700	57,800	54,000
Net import reliance[8] as a percentage of apparent consumption	16	17	15	12	12

Recycling: See Iron and Steel Scrap and Iron and Steel Slag.

Import Sources (2016–19): Canada, 18%; Brazil, 14%; Mexico, 11%; the Republic of Korea, 10%; and other, 47%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Carbon steel:		
Semifinished	7207.00.0000	Free.
Flat, hot-rolled	7208.00.0000	Free.
Flat, cold-rolled	7209.00.0000	Free.
Galvanized	7210.00.0000	Free.
Bars and rods, hot-rolled	7213.00.0000	Free.
Structural shapes	7216.00.0000	Free.
Stainless steel:		
Semifinished	7218.00.0000	Free.
Flat-rolled sheets	7219.00.0000	Free.
Bars and rods	7222.00.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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IRON AND STEEL

Events, Trends, and Issues: The World Steel Association[9] forecast global finished steel consumption to decrease by 2.4% in 2020 as a result of the impacts related to reduced consumption and demand of manufactured products, new construction, and other consumable goods owing to the global COVID-19 pandemic. On a monthly basis, global steel demand reached its lowest point in April; however, the rate of economic recovery in various countries has been variable owing to differences in containment strategies, the domestic industry structure, and economic measures to combat slowing economic growth. A rebound in steel demand later in the year following easing of restrictions was not enough to offset early losses in consumption.

In April, multiple U.S.-based blast furnaces were idled owing to the reduced steel demand resulting from the COVID-19 pandemic; however, they all reopened in the second half of 2020. In August, one iron ore and iron metallics company announced it had entered into a definitive agreement to purchase two iron ore mines, six steelmaking facilities, eight finishing facilities, and three coal and cokemaking operations from another domestic iron and steel production company, making it the largest manufacturer of flat-rolled steel in North America.

World Production:

	Pig iron		Raw steel	
	2019	2020[e]	2019	2020[e]
United States	22	18	88	72
Brazil	26	23	32	28
China	809	830	996	1,000
Germany	25	21	40	33
India	74	56	111	84
Iran	3	3	32	35
Italy	5	4	23	19
Japan	75	61	99	81
Korea, Republic of	48	43	71	65
Mexico	4	3	19	15
Russia	50	49	72	69
Taiwan	15	14	22	21
Turkey	10	10	34	33
Ukraine	20	19	21	19
Vietnam	8	9	14	15
Other countries	86	85	190	210
World total (rounded)	1,280	1,200	1,860	1,800

World Resources: Not applicable. See Iron Ore and Iron and Steel Scrap for steelmaking raw-material resources.

Substitutes: Iron is the least expensive and most widely used metal. In most applications, iron and steel compete either with less expensive nonmetallic materials or with more expensive materials that have a performance advantage. Iron and steel compete with lighter materials, such as aluminum and plastics, in the motor vehicle industry; aluminum, concrete, and wood in construction; and aluminum, glass, paper, and plastics in containers.

[e]Estimated.

[1]Production and shipments data source is the American Iron and Steel Institute; see also Iron and Steel Scrap and Iron Ore.

[2]More than 95% of iron made is transported in molten form to steelmaking furnaces located at the same site.

[3]Less than ½ unit.

[4]Steel mill products. Source: Metals Service Center Institute.

[5]Defined as steel shipments + imports of finished steel mill products – exports of steel mill products + adjustments for industry stock changes.

[6]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331100.

[7]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331200.

[8]Defined as imports of finished steel mill products – total exports + adjustments for industry stock changes.

[9]World Steel Association, 2020, Short range outlook October 2020: Brussels, Belgium, World Steel Association press release, October 15, 7 p.

IRON AND STEEL SCRAP[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: In 2020, the total value of domestic purchases of iron and steel scrap (receipts of ferrous scrap by all domestic consumers from brokers, dealers, and other outside sources) and exports was estimated to be $13 billion, approximately 20% less than the $16.3 billion in 2019 and 38% less than the $21.1 billion in 2018. U.S. apparent steel consumption, the leading end use for iron and steel scrap was estimated to have decreased by 18% to 82 million tons in 2020 from 100 million tons in 2019. Manufacturers of pig iron, raw steel, and steel castings accounted for about 93% of scrap consumption by the domestic steel industry, using scrap together with pig iron and direct-reduced iron to produce steel products for the appliance, construction, container, machinery, oil and gas, transportation, and various other consumer industries. The ferrous castings industry consumed most of the remaining scrap to produce cast iron and steel products. Relatively small quantities of steel scrap were used for producing ferroalloys, for the precipitation of copper, and by the chemical industry; these uses collectively totaled less than 1 million tons.

During 2020, raw steel production was an estimated 72 million tons, down 18% from 87.8 million tons in 2019. Net shipments of steel mill products were an estimated 71 million tons, down 19% from 87.3 million tons in 2019.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Home scrap	5.9	5.6	5.8	5.7	4.4
Purchased scrap[2]	53	55	59	57	54
Imports for consumption[3]	3.9	4.6	5.0	4.3	4.0
Exports[3]	13	15	17	18	17
Consumption:					
Reported	50	51	51	50	46
Apparent[4]	50	50	52	51	46
Price, average, delivered, No. 1 Heavy Melting composite price, dollars per ton	196	265	3	249	213
Stocks, consumer, yearend	4.3	4.5	5.1	3.9	3.2
Employment, dealers, brokers, processors, number[e]	27,000	27,000	27,000	26,000	22,000
Net import reliance[5] as a percentage of reported consumption	E	E	E	E	E

Recycling: Recycled iron and steel scrap is a vital raw material for the production of new steel and cast iron products. The steel and foundry industries in the United States have been structured to recycle scrap and, as a result, are highly dependent upon scrap. One ton of steel that is recycled conserves 1.1 tons of iron ore, 0.6 ton of coking coal, and 0.05 ton of limestone.

Overall, the scrap recycling rate in the United States has averaged between 80% and 90% during the past decade, with automobiles making up the primary source of old steel scrap. Recycling of automobiles is nearly 100% each year, with rates fluctuating slightly owing to the rate of new vehicle production and general economic trends. More than 15 million tons of steel is recycled from automobiles annually, the equivalent of approximately 12 million cars, from more than 7,000 vehicle dismantlers and 350 car shredders in North America. The recycling of steel from automobiles is estimated to save the equivalent energy necessary to power 18 million homes every year.

Recycling rates, which fluctuate annually, were estimated to be 98% for structural steel from construction, 88% for appliances, 71% for rebar and reinforcement steel, and 70% for steel packaging. The recycling rates for appliance, can, and construction steel are expected to increase in the United States and in emerging industrial countries at an even greater rate. Public interest in recycling continues, and recycling is becoming more profitable and convenient as environmental regulations for primary production increase.

Recycling of scrap plays an important role in the conservation of energy because the remelting of scrap requires much less energy than the production of iron or steel products from iron ore. Also, consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment. Recycled scrap consists of approximately 58% post-consumer (old, obsolete) scrap, 24% prompt scrap (produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

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IRON AND STEEL SCRAP

Import Sources (2016–19): Canada, 70%; Mexico, 10%; the United Kingdom, 7%; Sweden, 5%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Ferrous waste and scrap:		
Stainless steel	7204.21.0000	Free.
Turnings, shavings, chips, milling waste, sawdust, filings, trimmings, and stampings:		
No. 1 bundles	7204.41.0020	Free.
No. 2 bundles	7204.41.0040	Free.
Borings, shovelings, and turnings	7204.41.0060	Free.
Other	7204.41.0080	Free.
Other:		
No. 1 heavy melting	7204.49.0020	Free.
No. 2 heavy melting	7204.49.0040	Free.
Cut plate and structural	7204.49.0060	Free.
Shredded	7204.49.0070	Free.
Remelting scrap ingots	7204.50.0000	Free.
Powders, of pig iron, spielgeleisen, iron, or steel:		
Alloy steel	7205.21.0000	Free.
Other	7205.29.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In 2020, steel mill production capacity utilization reached its lowest monthly rate since July 2009, reaching 54.6% in May 2020, with the rate declining during the year from 81.7% in January to its lowest point in May before rebounding to 68.6% in September 2020. Composite prices published for No. 1 Heavy Melting steel scrap delivered averaged about $214 per ton during the first 8 months of 2020, a 14% decrease from $249 per ton in 2019. The average monthly prices during this time fluctuated between a high of $249.61 per ton in January and a low of $194.01 per ton in July. In the first 8 months of 2020, Turkey was the primary destination for exports of ferrous scrap, by tonnage, accounting for 26% of total exports, followed by Malaysia, Mexico, and Taiwan (10% each). The value of exported scrap decreased to an estimated $4.4 billion in 2020 from $5.3 billion in 2019.

The World Steel Association[6] forecast global finished steel consumption to decrease by 2.4% in 2020 as a result of the impacts related to reduced consumption and demand of manufactured products, new construction, and other consumable goods owing to the global COVID-19 pandemic. On a monthly basis, global steel demand reached its lowest point in April; however, the rate of economic recovery in various countries has been variable owing to differences in containment strategies, the domestic industry structure, and economic measures to combat slowing economic growth. A rebound in steel demand later in the year following easing of restrictions was not enough to offset early losses in consumption.

World Mine Production and Reserves: Not applicable. See Iron and Steel and Iron Ore.

World Resources: Not applicable. See Iron and Steel and Iron Ore.

Substitutes: An estimated 2.2 million tons of direct-reduced iron was consumed in the United States in 2020 as a substitute for iron and steel scrap, down from 2.5 million tons in 2019.

[e]Estimated. E Net exporter.

[1]See also Iron and Steel and Iron Ore.

[2]Defined as net receipts + exports – imports.

[3]Excludes used rails for rerolling and other uses, and ships, boats, and other vessels for scrapping.

[4]Defined as home scrap + purchased scrap + imports – exports + adjustments for industry stock changes.

[5]Defined as imports – exports + adjustments for industry stock changes.

[6]World Steel Association, 2020, Short range outlook October 2020: Brussels, Belgium, World Steel Association press release, October 15, 7 p.

IRON AND STEEL SLAG

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: Iron and steel (ferrous) slags are formed by the combination of slagging agents and impurities during the production of crude (or pig) iron and crude steel. The slags are tapped separately from the metals, cooled and processed, and primarily used in the construction industry. Data are unavailable on actual U.S. ferrous slag production, but domestic slag sales[1] in 2020 were estimated to be 14 million tons valued at about $380 million. Blast furnace slag was about 50% of the tonnage sold and accounted for 88% of the total value of slag, most of which was granulated. Steel slag produced from basic oxygen and electric arc furnaces accounted for the remainder of sales. Slag was processed by 28 companies servicing active iron and steel facilities or reprocessing old slag piles at about 129 processing plants (including some iron and steel plants with more than one slag-processing facility) in 33 States, including facilities that import and grind unground slag to sell as ground granulated blast furnace slag (GGBFS).

Air-cooled iron slag and steel slag are used primarily as aggregates in concrete (air-cooled iron slag only); asphaltic paving, fill, and road bases; both slag types also can be used as a feed for cement kilns. Almost all GGBFS is used as a partial substitute for portland cement in concrete mixes or in blended cements. Pelletized slag is generally used for lightweight aggregate but can be ground into material similar to GGBFS. Actual prices per ton ranged from a few cents for some steel slags at a few locations to about $120 or more for some GGBFS in 2020. Owing to low unit values, most slag types can be shipped only short distances by truck, but rail and waterborne transportation allow for greater travel distances. Because much higher unit values make it economical to ship GGBFS longer distances, much of the GGBFS consumed in the United States is imported.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production (sales)[1, 2]	15.7	16.2	16.8	[e]17	14
Imports for consumption[3]	1.8	2.1	2.2	1.8	2.0
Exports	([4])	([4])	([4])	([4])	([4])
Consumption, apparent[5]	15.7	16.2	16.8	[e]17	14
Price, average value, free on board plant, dollars per ton[6]	22.00	24.50	26.50	27.50	27.00
Employment, number[e]	1,600	1,500	1,500	1,500	1,500
Net import reliance[7] as a percentage of apparent consumption	11	13	13	10	14

Recycling: Following removal of entrained metal, slag can be returned to the blast and steel furnaces as ferrous and flux feed, but data on these returns are incomplete. Entrained metal, particularly in steel slag, is routinely recovered during slag processing for return to the furnaces and is an important revenue source for slag processors; data on metal returns are unavailable.

Import Sources (2016–19): Japan, 29%; Brazil, 18%; Canada, 14%; Italy, 12%; and other, 27%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Granulated slag	2618.00.0000	Free.
Slag, dross, scalings, and other waste from manufacture of iron and steel:		
Ferrous scale	2619.00.3000	Free.
Other	2619.00.9000	Free.

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IRON AND STEEL SLAG

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In April, several domestic blast furnaces were idled owing to the reduced steel demand resulting from the global COVID-19 pandemic. Demand increased later in the year, and all the blast furnaces idled in 2020 reopened. In recent years, U.S. blast furnaces have been closed or idled, contributing to the reduction in the domestic supply of new blast furnace slag. However, many sites have large slag stockpiles, which can allow for processing to continue for several years after the furnaces are closed or idled. The majority of U.S steel slag production is from electric arc furnaces.

During 2020, domestic GGBFS remained in limited supply because granulation cooling was available at only two active U.S. blast furnaces. It remained unclear if new granulation cooling installations at additional blast furnace sites would be economic. Another plant produced a limited supply of pelletized slag, but it was uncertain if additional pelletizing capacity would be added. Grinding of granulated blast furnace slag was only done domestically by cement companies. Supply constraints appear to have limited domestic consumption of GGBFS in recent years. Although prices have increased, sales of GGBFS have not correlated with the increases in the quantity of cement sold since 2010.

The domestic supply of fly ash, which is used as an additive in concrete production, has decreased, owing to new restrictions of mercury and carbon dioxide (CO_2) emissions at coal-fired powerplants, powerplant closures, and conversion of powerplants to natural gas. Mercury emission restrictions on cement plants, enacted in 2015, may reduce the demand for fly ash as a raw material in clinker manufacture, and air-cooled and steel slags could be used as substitute raw materials. Demand for GGBFS is likely to increase because its use in cement yields a superior product in many applications and reduces the unit CO_2 emissions in the production of the cement.

World Mine Production and Reserves: Because slag is not mined, the concept of reserves does not apply. World production data for slag were unavailable, but iron slag from blast furnaces may be estimated to be 25% to 30% of crude (pig) iron production and steel furnace slag may be estimated to be 10% to 15% of raw steel production. In 2020, world iron slag production was estimated to be between 310 million and 380 million tons, and steel slag production was estimated to be between 180 million and 270 million tons.

World Resources: Not applicable.

Substitutes: In the construction sector, ferrous slags compete with natural aggregates (crushed stone and construction sand and gravel) but are far less widely available than the natural materials. As a cementitious additive in blended cements and concrete, GGBFS mainly competes with fly ash, metakaolin, and volcanic ash pozzolans. In this respect, GGBFS reduces the amount of portland cement per ton of concrete, thus allowing more concrete to be made per ton of portland cement. Slags (especially steel slag) can be used as a partial substitute for limestone and some other natural raw materials for clinker (cement) manufacture and compete in this use with fly ash and bottom ash. Some other metallurgical slags, such as copper slag, can compete with ferrous slags in some specialty markets, such as a ferrous feed in clinker manufacture, but are generally in much more restricted supply than ferrous slags.

[e]Estimated.

[1]Processed slag sold during the year, excluding entrained metal.

[2]Data include sales of imported granulated blast furnace slag and exclude sales of pelletized slag.

[3]U.S. Census Bureau data adjusted by the U.S. Geological Survey to remove nonslag materials (such as cenospheres, fly ash, and silica fume) and slags or other residues of other metallurgical industries (especially copper slag), whose unit values are outside the range expected for granulated slag. In some years, tonnages may be underreported.

[4]Less than 0.05 million tons.

[5]Defined as total sales of slag – exports.

[6]Rounded to the nearest $0.50 per ton.

[7]Defined as imports – exports.

IRON ORE[1]

(Data in thousand metric tons, usable ore, unless otherwise noted)

Domestic Production and Use: In 2020, mines in Michigan and Minnesota shipped 98% of the usable iron ore products, which were consumed in the steel industry in the United States with an estimated value of $4.1 billion, a decrease from $4.4 billion in 2019. The remaining 2% of domestic iron ore was produced for nonsteel end uses. Seven open pit iron ore mines (each with associated concentration and pelletizing plants), and three iron metallic plants—one direct-reduced iron (DRI) plant in Louisiana and two hot-briquetted iron (HBI) plants in Indiana and Texas—operated during the year to supply steelmaking raw materials. The United States was estimated to have produced 1.5% and consumed 1.1% of the world's iron ore output.

Salient Statistics—United States:[2]	2016	2017	2018	2019	2020[e]
Production:					
Iron ore	41,800	47,900	49,500	46,900	37,000
Iron metallics	2,070	3,250	3,560	3,660	3,400
Shipments	46,600	46,900	50,400	47,000	34,000
Imports for consumption	3,010	3,720	3,810	3,980	2,900
Exports	8,710	10,600	12,700	11,400	10,000
Consumption:					
Reported	34,500	34,400	36,600	34,800	27,000
Apparent[3]	37,900	40,100	41,400	39,100	33,000
Price, average value reported by mines, dollars per ton	73.11	78.54	93.00	92.94	108.00
Stocks, mine, dock, and consuming plant, excluding byproduct ore, yearend	2,990	3,930	3,100	3,500	1,100
Employment, mine, concentrating and pelletizing plant, number	4,660	4,630	4,860	4,960	4,700
Net import reliance[4] as a percentage of apparent consumption (iron content of ore)	E	E	E	E	E

Recycling: None. See Iron and Steel Scrap.

Import Sources (2016–19): Brazil, 58%; Canada, 21%; Sweden, 7%, Chile, 4%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Iron ores and concentrates:		
Concentrates	2601.11.0030	Free.
Coarse ores	2601.11.0060	Free.
Other ores	2601.11.0090	Free.
Pellets	2601.12.0030	Free.
Briquettes	2601.12.0060	Free.
Sinter	2601.12.0090	Free.
Roasted iron pyrites	2601.20.0000	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Significant decreases in production, shipments, and trade in 2020 were due to the ongoing effects of the COVID-19 pandemic, which lowered steel production and consumption globally. Domestic iron ore production was estimated to be 37 million tons in 2020, 21% lower than 46.9 million tons in 2019, owing to the closure of multiple iron ore plants. Total raw steel production was estimated to have decreased to 69 million tons in 2020 from 87.8 million tons in 2019. The share of steel produced by basic oxygen furnaces, the process that uses iron ore, continued to decline from 37.3% in 2015 to an estimated 30% in 2020 owing to increased use of electric arc furnaces because of their energy efficiency, reduced environmental impacts, and the ready supply of scrap.

Overall, global prices trended upwards to an average value of $97.96 per ton in the first 8 months of 2020, a 4% increase from the 2019 annual average of $93.85 per ton and a 40% increase from the 2018 annual average of $69.75 per ton. Based on reported prices for iron ore fines (62% iron content) imported into China (cost and freight into Tianjin Port), the highest monthly average price during the first 8 months of 2020 was $121.07 per ton in August compared with the high of $120.24 per ton in July 2019. The lowest monthly average price during the same period in

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IRON ORE

2020 was $84.73 per ton in April compared with the low of $76.16 per ton in January 2019. The prices trended upwards owing to a reduced supply of higher grade iron ore products, spurred partially by closures of pelletizing plants in Brazil. One company in Brazil cut guidance for pellet sales in 2020 by 25 million to 30 million tons based on first-quarter projections following 302 million tons of iron ore production in 2019, a decrease from 385 million tons produced in 2018, owing to a tailings dam collapse that idled operations at the collocated mine.

In August, one company expected to begin production at a hot-briquetted iron plant under construction in Ohio in late 2020, and announced it had entered into a definitive agreement to purchase two iron ore mines, six steelmaking facilities, eight finishing facilities, and three coal and cokemaking operations from another domestic iron and steel production company. In the first half of 2020, five domestic iron ore mines were idled with only four restarting in the second half of the year. One mine continued to remain idle with no plans to restart as of October. Globally, iron ore production in 2020 was expected to decrease slightly from that of 2019. Global finished steel consumption was forecast by the World Steel Association[5] to decrease by 2.4% in 2020 and increase by 4.1% in 2021.

World Mine Production and Reserves: Reserves for Australia, Brazil, and South Africa were revised based on Government and industry sources.

	Mine production					
	Usable ore		Iron content		Reserves[6, 7]	
	2019	2020[e]	2019	2020[e]	Crude ore	Iron content
United States	46,900	37,000	29,800	24,000	3,000	1,000
Australia	919,000	900,000	569,000	560,000	[8]50,000	[8]24,000
Brazil	405,000	400,000	258,000	252,000	34,000	15,000
Canada	58,500	57,000	35,200	34,000	6,000	2,300
Chile	13,100	13,000	8,430	8,000	NA	NA
China	351,000	340,000	219,000	210,000	20,000	6,900
India	238,000	230,000	148,000	140,000	5,500	3,400
Iran	33,100	32,000	21,700	21,000	2,700	1,500
Kazakhstan	22,000	21,000	6,150	5,900	2,500	900
Peru	15,100	15,000	10,100	10,000	NA	1,500
Russia	97,500	95,000	64,300	63,000	25,000	14,000
South Africa	72,400	71,000	41,200	40,000	1,000	640
Sweden	35,700	35,000	22,100	22,000	1,300	600
Turkey	16,400	16,000	9,110	8,900	NA	NA
Ukraine	63,200	62,000	39,500	39,000	[9]6,500	[9]2,300
Other countries	67,700	75,000	39,000	43,000	18,000	9,500
World total (rounded)	2,450,000	2,400,000	1,520,000	1,500,000	180,000	84,000

World Resources:[6] U.S. resources are estimated to be 110 billion tons of iron ore containing about 27 billion tons of iron. U.S. resources are mainly low-grade taconite-type ores from the Lake Superior district that require beneficiation and agglomeration prior to commercial use. World resources are estimated to be greater than 800 billion tons of crude ore containing more than 230 billion tons of iron.

Substitutes: The only source of primary iron is iron ore, used directly as direct-shipping ore or converted to briquettes, concentrates, DRI, iron nuggets, pellets, or sinter. DRI, iron nuggets, and scrap are extensively used for steelmaking in electric arc furnaces and in iron and steel foundries. Technological advancements have been made, which allow hematite to be recovered from tailings basins and pelletized.

[e]Estimated. E Net exporter. NA Not available.

[1]Data are for iron ore used as a raw material in steelmaking unless otherwise noted. See also Iron and Steel and Iron and Steel Scrap.

[2]Except where noted, salient statistics are for all forms of iron ore used in steelmaking, and do not include iron metallics, which include DRI, hot-briquetted iron, and iron nuggets.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]World Steel Association, 2020, Short range outlook October 2020: Brussels, Belgium, World Steel Association press release, October 15, 7 p.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Million metric tons.

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 23 billion tons for crude ore and 11 billion tons for iron content.

[9]For Ukraine, reserves consist of the A and B categories of the Soviet reserves classification system.

IRON OXIDE PIGMENTS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Iron oxide pigments (IOPs) were mined domestically by two companies in Alabama and Georgia. Mine production, which was withheld to avoid disclosing company proprietary data, decreased in 2020 from that of 2019. Five companies, including the two producers of natural IOPs, processed and sold about 26,000 tons of finished natural and synthetic IOPs with an estimated value of $15 million. About 46% of natural and synthetic finished IOPs were used in concrete and other construction materials; 13% for foundry sands and other foundry uses; 6% each in animal feed and industrial coatings; 5% for paint and coatings; 3% each in plastics, and glass and ceramics; and the remaining 18% in other uses.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOPs	48,500	47,300	48,200	19,200	26,000
Imports for consumption	179,000	179,000	179,000	159,000	180,000
Exports, pigment grade	15,800	13,500	11,100	11,200	10,000
Consumption, apparent[1]	212,000	213,000	216,000	167,000	200,000
Price, average value, dollars per kilogram[2]	1.46	1.46	1.58	0.69	0.58
Employment, mine and mill, number	60	60	60	55	47
Net import reliance[3] as a percentage of:					
Apparent consumption	77	78	78	89	87
Reported consumption	>75	>75	>75	>75	>75

Recycling: None.

Import Sources (2016–19): Natural: Spain, 43%; Cyprus, 33%; France, 11%; Austria, 10%; and other, 3%. Synthetic: China, 48%; Germany, 32%; Brazil, 7%; and other, 13%. Total: China, 47%; Germany, 31%; Brazil, 7%; and other, 15%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Natural:		
Micaceous iron oxides	2530.90.2000	2.9% ad val.
Earth colors	2530.90.8015	Free.
Iron oxides and hydroxides containing 70% or more by weight Fe_2O_3:		
Synthetic:		
Black	2821.10.0010	3.7% ad val.
Red	2821.10.0020	3.7% ad val.
Yellow	2821.10.0030	3.7% ad val.
Other	2821.10.0040	3.7% ad val.
Earth colors	2821.20.0000	5.5% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IRON OXIDE PIGMENTS

Events, Trends, and Issues: In 2020, domestic mine production of crude natural IOPs decreased compared with 2019 production owing to a major producer closing down multiple facilities. Production and sales of finished natural and synthetic IOPs increased by about 35% compared with those of 2019. Production and sales of synthetic IOPs also increased in 2020, owing in part to low mortgage interest rates and increased demand for single-family homes as the global COVID-19 pandemic made multifamily homes less desirable. In the United States, residential construction, in which IOPs are commonly used to color concrete block and brick, ready-mixed concrete, and roofing tiles, increased slightly during the first 9 months of 2020 compared with that of the same period in 2019. Housing starts increased by about 5% in 2020 compared with those of 2019.

Exports of pigment-grade IOPs decreased by about 8% during the first 9 months of 2020 compared with those during the same period in 2019, mostly owing to a significant decrease in exports to Argentina, South Africa, and Spain. About 53% of pigment-grade IOPs went to Mexico, China, Thailand, Germany, Belgium, Chile, India, and Brazil, in descending order of quantity. Exports of other grades of iron oxides and hydroxides decreased by about 29% during the first 9 months of 2020 compared with those of the same period in 2019. About 92% of exports of other grades of iron oxides and hydroxides went to Germany, Colombia, Vietnam, and Canada, in descending order of quantity. Total imports of natural and synthetic IOPs increased by 13% in 2020 compared with those in 2019.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2019	2020[e]	
United States	W	W	Moderate
Austria (micaceous IOPs)	NA	NA	NA
Cyprus (umber)	3,013	3,500	Moderate
France	8,000	8,000	NA
Germany[5]	360,000	360,000	Moderate
India (ocher)	2,500,000	2,500,000	37,000,000
Italy	9,000	9,000	NA
Pakistan (ocher)	70,000	50,000	100,000
Spain (ocher and red iron oxide)	10,000	10,000	Large
World total	[6]NA	[6]NA	Large

World Resources:[4] Domestic and world resources for production of IOPs are adequate. Adequate resources are available worldwide for the manufacture of synthetic IOPs.

Substitutes: Milled IOPs are thought to be the most commonly used natural minerals for pigments. Because IOPs are color stable, low cost, and nontoxic, they can be economically used for imparting black, brown, red, and yellow coloring in large and relatively low-value applications. Other minerals may be used as colorants, but they generally cannot compete with IOPs because of their higher costs and more limited availability. Synthetic IOPs are widely used as colorants and compete with natural IOPs in many color applications. Organic colorants are used for some colorant applications, but many of the organic compounds fade over time from exposure to sunlight.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Defined as sold or used finished natural and synthetic iron oxide pigments + imports – exports.

[2]Average unit value for finished iron oxide pigments sold or used by U.S. producers.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes natural and synthetic iron oxide pigments.

[6]A significant number of other countries, including Azerbaijan, Brazil, China, Honduras, Iran, Kazakhstan, Lithuania, Paraguay, Russia, South Africa, Turkey, Ukraine, and the United Kingdom, are thought to produce iron oxide pigments, but output was not reported and no basis was available to make reliable estimates of production.

KYANITE AND RELATED MINERALS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In Virginia, one firm with integrated mining and processing operations produced an estimated 85,000 tons of kyanite worth $30 million from two hard-rock open pit mines and synthetic mullite by calcining kyanite. Two other companies, one in Alabama and another in Georgia, produced synthetic mullite from materials mined from four sites; each company sourced materials from one site in Alabama and one site in Georgia. Synthetic mullite production data are withheld to avoid disclosing company proprietary data. Commercially produced synthetic mullite is made by sintering or fusing such feedstock materials as kyanite, kaolin, bauxite, or bauxitic kaolin. Natural mullite occurrences typically are rare and not economical to mine. Of the kyanite-mullite output, 90% was estimated to have been used in refractories and 10% in other uses, including abrasive products, such as motor vehicle brake shoes and pads and grinding and cutting wheels; ceramic products, such as electrical insulating porcelains, sanitaryware, and whiteware; foundry products and precision casting molds; and other products. An estimated 60% to 70% of the refractory use was by the iron and steel industries, and the remainder was by industries that manufacture cement, chemicals, glass, nonferrous metals, and other materials. Andalusite was commercially mined from an andalusite-pyrophyllite-sericite deposit in North Carolina and processed as a blend of primarily andalusite for use by producers of refractories in making firebrick.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Kyanite, mine	[1]79,700	[1]91,300	[1]89,200	[1]91,300	85,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	2,510	7,420	8,590	6,960	1,000
Exports (kyanite)	37,100	42,300	43,000	40,100	37,000
Consumption, apparent[2]	W	W	W	W	W
Price, average, kyanite,[3] dollars per metric ton:					
Raw concentrate	270	270	NA	NA	NA
Calcined	420	420	NA	NA	NA
Employment, number:[e]					
Kyanite, mine, office, and plant	150	140	150	150	140
Synthetic mullite, office and plant	210	200	200	200	200
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2016–19):[5] South Africa, 79%; Peru, 11%; France, 6%; United Kingdom, 3%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

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KYANITE AND RELATED MINERALS

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, decreased by about 20% in the first 8 months of 2020 compared with that of the same period in 2019, indicating a similar change in consumption of kyanite-mullite refractories. Total world steel production decreased by about 4% during the first 8 months of 2020 compared with that of the same period in 2019. The decrease in world steel production during the first 8 months of 2020 was the result of economic disruptions owing to the global COVID-19 pandemic. The steel industry continued to be the largest market for refractories.

In March 2020, mines in India, Peru, and South Africa were temporarily closed in response to national lockdowns imposed to limit the spread of COVID-19. Mines gradually reopened as restrictions eased, but production recovery efforts were complicated by logistical issues as well as new health and safety guidelines implemented to help protect workers. The resulting loss of industrial output may correspond with reduced global demand in 2020.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2019	2020[e]	
United States (kyanite)	[1]91,300	85,000	Large
India (kyanite and sillimanite)	72,700	69,000	7,200,000
Peru (andalusite)	40,000	37,000	NA
South Africa (andalusite)	190,000	180,000	NA
World total (rounded)	[7]NA	[7]NA	NA

World Resources:[6] Large resources of kyanite and related minerals are known to exist in the United States. The chief resources are in deposits of micaceous schist and gneiss, mostly in the Appalachian Mountains and in Idaho. Other resources are in aluminous gneiss in southern California. These resources are not economical to mine at present. The characteristics of kyanite resources in the rest of the world are thought to be similar to those in the United States. Significant resources of andalusite are known to exist in China, France, Peru, and South Africa; kyanite resources have been identified in Brazil, India, and Russia; and sillimanite has been identified in India.

Substitutes: Two types of synthetic mullite (fused and sintered), superduty fire clays, and high-alumina materials are substitutes for kyanite in refractories. Principal raw materials for synthetic mullite are bauxite, kaolin and other clays, and silica sand.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Source: Virginia Department of Mines, Minerals and Energy.

[2]Defined as production + imports – exports.

[3]Source: Industrial Minerals (Fastmarkets IM), average yearend price.

[4]Defined as imports – exports.

[5]Includes data for the following Harmonized Tariff Schedule of the United States code: 2508.50.0000.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]In addition to the countries listed, France continued production of andalusite, and Cameroon and China produced kyanite and related minerals. Output was not reported quantitatively, and no reliable basis was available for estimation of output levels.

LEAD

(Data in thousand metric tons of lead content unless otherwise noted)

Domestic Production and Use: Six lead mines in Missouri, plus four mines in Alaska and Idaho that produced lead as a principal product or byproduct, accounted for all domestic lead mine production. One mine in Washington closed after the current reserves were exhausted in 2019. The value of the lead in concentrates mined in 2020, based on the average North American Market price for refined lead, was about $574 million. Nearly all lead mine production has been exported since the last primary refinery closed in 2013. The 12 secondary refineries in 10 States accounted for more than 95% of the secondary lead produced in 2020. It was estimated that the lead-acid battery industry accounted for about 92% of reported U.S. lead consumption during 2020. Lead-acid batteries were primarily used as starting-lighting-ignition (SLI) batteries for automobiles, as industrial-type batteries for standby power for computer and telecommunications networks, and for motive power. During the first 7 months of 2020, 73 million lead-acid automotive batteries were shipped by North American producers, essentially unchanged from those shipped in the same period of 2019.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Mine, lead in concentrates	346	310	280	274	290
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,110	1,140	1,140	1,170	1,100
Imports for consumption:					
Lead in concentrates	—	([1])	—	([1])	—
Refined metal, unwrought (gross weight)	533	658	563	501	370
Exports:					
Lead in concentrates	341	269	251	259	270
Refined metal, unwrought (gross weight)	43	24	70	25	17
Consumption, apparent[2]	1,600	1,770	1,630	1,650	1,500
Price, average, cents per pound:[3]					
North American market	94.4	114.5	110.9	99.9	89.8
London Metal Exchange (LME), cash	84.8	105.1	101.8	91.0	81.5
Employment, mine and mill (average), number[4]	1,970	1,890	1,860	1,790	1,900
Net import reliance[5] as a percentage of apparent consumption, refined metal	31	36	30	29	24

Recycling: In 2020, about 1.1 million tons of secondary lead was produced, an amount equivalent to 73% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2016–19): Refined metal: Canada, 44%; the Republic of Korea, 18%; Mexico, 18%; India, 5%; and other, 15%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Lead ores and concentrates, lead content	2607.00.0020	1.1¢/kg on lead content.
Refined lead	7801.10.0000	2.5% on the value of the lead content.
Antimonial lead	7801.91.0000	2.5% on the value of the lead content.
Alloys of lead	7801.99.9030	2.5% on the value of the lead content.
Other unwrought lead	7801.99.9050	2.5% on the value of the lead content.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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LEAD

Events, Trends, and Issues: During the first 10 months of 2020, the average LME cash price for lead was 81.5 cents per pound, 10% less than the average price in 2019. Global stocks of lead in LME-approved warehouses were 124,000 tons in October 2020, which was 88% more than those at yearend 2019.

In 2020, domestic mine production was estimated to have increased by 6% from that in the previous year. However, domestic production of secondary lead decreased by 6% from that in the previous year. U.S. apparent consumption of refined lead decreased by 9% from that in the previous year. In the first 9 months of 2020, 19.7 million spent SLI lead-acid batteries were exported, slightly less than that in the same time period in 2019.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2020 decreased by 4% to 11.7 million tons, and metal consumption decreased by 7% to 11.4 million tons. In 2020, the quarantine-related restrictions imposed as a result of the global COVID-19 pandemic affected the mining industry in several countries, especially Bolivia, Kazakhstan, Mexico, and Peru.[7] Consequently, world mine production fell by 7% in 2020 compared with the previous year.

World Mine Production and Reserves: Reserves estimates for Peru and Russia were revised based on new information from Government reports.

	Mine production		Reserves[8]
	2019	2020[e]	
United States	274	290	5,000
Australia	509	480	[9]36,000
Bolivia	88	65	1,600
China	2,000	1,900	18,000
India	200	210	2,500
Kazakhstan	56	30	2,000
Mexico	259	240	5,600
Peru	308	240	6,000
Russia	230	220	4,000
Sweden	69	70	1,100
Tajikistan	65	65	NA
Turkey	71	72	860
Other countries	591	520	5,000
World total (rounded)	4,720	4,400	88,000

World Resources:[8] Identified world lead resources total more than 2 billion tons. In recent years, significant lead resources have been identified in association with zinc and (or) silver or copper deposits in Australia, China, Ireland, Mexico, Peru, Portugal, Russia, and the United States (Alaska).

Substitutes: Substitution by plastics has reduced the use of lead in cable covering and cans. Tin has replaced lead in solder for potable water systems. The electronics industry has moved toward lead-free solders and flat-panel displays that do not require lead shielding. Steel and zinc are common substitutes for lead in wheel weights.

[e]Estimated. NA Not available. — Zero.

[1]Less than ½ unit.

[2]Defined as primary refined production + secondary refined production (old scrap) + refined imports – refined exports.

[3]Source: S&P Global Platts Metals Week.

[4]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct. Data from the Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]International Lead and Zinc Study Group, 2020, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group news release, October 16.

[7]International Lead and Zinc Study Group, 2020, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 21.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 12 million tons.

LIME[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, an estimated 16 million tons of quicklime and hydrate was produced (excluding independent commercial hydrators[2]), valued at about $2.2 billion. At yearend, 28 companies were producing lime, which included 18 companies with commercial sales and 10 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 74 primary lime plants (plants operating quicklime kilns) in 28 States and Puerto Rico. One lime plant was idle in 2020. Five of the 28 companies operated only hydrating plants in 9 States. In 2020, the five leading U.S. lime companies produced quicklime or hydrate in 22 States and accounted for about 72% of U.S. lime production. Principal producing States were, in alphabetical order, Alabama, Kentucky, Missouri, Ohio, and Texas. Major markets for lime were, in descending order of consumption, steelmaking, chemical and industrial applications (such as the manufacture of fertilizer, glass, paper and pulp, and precipitated calcium carbonate, and in sugar refining), flue gas treatment, construction, water treatment, and nonferrous mining.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production[3]	17,300	17,600	18,000	16,900	16,000
Imports for consumption	376	367	370	342	310
Exports	329	391	424	347	260
Consumption, apparent[4]	17,300	17,600	18,000	16,900	16,000
Quicklime average value, dollars per ton at plant	119.7	120.8	125.2	128.3	128
Hydrate average value, dollars per ton at plant	145.4	147.1	151.6	154.6	154
Employment, mine and plant, number	NA	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	<1	E	E	E	<1

Recycling: Large quantities of lime are regenerated by paper mills. Some municipal water-treatment plants regenerate lime from softening sludge. Quicklime is regenerated from waste hydrated lime in the carbide industry. Data for these sources were not included as production in order to avoid duplication.

Import Sources (2016–19): Canada, 92%; Mexico, 7%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Calcined dolomite	2518.20.0000	3% ad val.
Quicklime	2522.10.0000	Free.
Slaked lime	2522.20.0000	Free.
Hydraulic lime	2522.30.0000	Free.

Depletion Allowance: Limestone produced and used for lime production, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2020, domestic lime production was estimated to have decreased by 5% from that of 2019. A decline in lime production was a result of plants temporarily closing as a result of the global COVID-19 pandemic. In San Bernardino County, CA, plans were underway to a construct a new quicklime plant using crushed limestone transported to the site from a nearby quarry. In Texas, one company planned to expand lime production capacity at two separate plants by 2021. One plant was adding a new vertical kiln to meet increasing steel industry demand for high-purity dolomitic lime products. The other plant was adding a new energy-efficient lime kiln to produce high-calcium lime products to meet the increasing demand from the steel and construction industries. The total number of operating quicklime plants was 73 in 2020 along with 10 hydrating plants. Hydrated lime is a dry calcium hydroxide powder made from reacting quicklime with a controlled amount of water in a hydrator. It is used in chemical and industrial, construction, and environmental applications.

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LIME

World Lime Production and Limestone Reserves:

	Production[6]		Reserves[7]
	2019	2020[e]	
United States	16,900	16,000	Adequate for all countries listed.
Australia	1,980	2,000	
Belgium[8]	1,560	1,500	
Brazil	8,100	8,100	
Bulgaria	1,460	1,500	
Canada (shipments)	1,710	1,700	
China	310,000	300,000	
France	2,600	2,600	
Germany	7,100	7,100	
India	16,000	16,000	
Iran	3,450	3,300	
Italy[8]	3,500	3,500	
Japan (quicklime only)	7,320	7,300	
Korea, Republic of	5,200	5,200	
Malaysia	1,600	1,600	
Poland (hydrated and quicklime)	2,700	2,700	
Romania	1,960	1,900	
Russia (industrial and construction)	11,000	11,000	
Slovenia	1,190	1,100	
South Africa	1,300	1,300	
Spain	1,800	1,800	
Turkey	4,600	4,600	
Ukraine	2,250	2,200	
United Kingdom	1,500	1,500	
Other countries	15,500	15,000	
World total (rounded)	432,000	420,000	

World Resources:[7] Domestic and world resources of limestone and dolomite suitable for lime manufacture are very large.

Substitutes: Limestone is a substitute for lime in many applications, such as agriculture, fluxing, and sulfur removal. Limestone, which contains less reactive material, is slower to react and may have other disadvantages compared with lime, depending on the application; however, limestone is considerably less expensive than lime. Calcined gypsum is an alternative material in industrial plasters and mortars. Cement, cement kiln dust, fly ash, and lime kiln dust are potential substitutes for some construction uses of lime. Magnesium hydroxide is a substitute for lime in pH control, and magnesium oxide is a substitute for dolomitic lime as a flux in steelmaking.

[e]Estimated. E Net exporter. NA Not available.

[1]Data are for quicklime, hydrated lime, and refractory dead-burned dolomite. Includes Puerto Rico.

[2]To avoid double counting quicklime production, excludes independent commercial hydrators that purchase quicklime for hydration.

[3]Sold or used by producers.

[4]Defined as production + imports – exports. Includes some double counting based on nominal, undifferentiated reporting of company export sales as U.S. production.

[5]Defined as imports – exports.

[6]Only countries that produced 1 million tons of lime or more are listed separately.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Includes hydraulic lime.

LITHIUM

(Data in metric tons of lithium content unless otherwise noted)

Domestic Production and Use: The only lithium production in the United States was from a brine operation in Nevada. Two companies produced a wide range of downstream lithium compounds in the United States from domestic or imported lithium carbonate, lithium chloride, and lithium hydroxide. Domestic production data were withheld to avoid disclosing company proprietary data.

Although lithium markets vary by location, global end-use markets are estimated as follows: batteries, 71%; ceramics and glass, 14%; lubricating greases, 4%; continuous casting mold flux powders, 2%; polymer production, 2%; air treatment, 1%; and other uses, 6%. Lithium consumption for batteries has increased significantly in recent years because rechargeable lithium batteries are used extensively in the growing market for portable electronic devices and increasingly are used in electric tools, electric vehicles, and grid storage applications. Lithium minerals were used directly as ore concentrates in ceramics and glass applications.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production	W	W	W	W	W
Imports for consumption	3,140	3,330	3,420	2,620	2,900
Exports	1,520	1,960	1,660	1,680	1,400
Consumption, estimated[1]	3,000	3,000	3,000	2,000	2,000
Price, annual average, battery-grade lithium carbonate, dollars per metric ton[2]	8,650	15,000	17,000	12,700	8,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>50	>50	>50	>25	>50

Recycling: One domestic company has recycled lithium metal and lithium-ion batteries since 1992 at its facility in British Columbia, Canada. In 2015, the company began operating the first U.S. recycling facility for lithium-ion vehicle batteries in Lancaster, OH. Seven other companies located in Canada and the United States have begun recycling, or intend to begin recycling, lithium metal and lithium-ion batteries to some degree.

Import Sources (2016–19): Argentina, 55%; Chile, 36%; China, 5%; Russia, 2%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Other alkali metals	2805.19.9000	5.5% ad val.
Lithium oxide and hydroxide	2825.20.0000	3.7% ad val.
Lithium carbonate:		
U.S. pharmaceutical grade	2836.91.0010	3.7% ad val.
Other	2836.91.0050	3.7% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4]

		FY 2020		FY 2021	
Material	**Inventory as of 9–30–20**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Lithium cobalt oxide (kilograms, gross weight)	750	—	—	—	—
Lithium nickel cobalt aluminum oxide (kilograms, gross weight)	2,700	—	—	—	—
Lithium-ion precursors (kilograms, gross weight)	—	—	—	—	—

Events, Trends, and Issues: Excluding U.S. production, worldwide lithium production in 2020 decreased by 5% to 82,000 tons of lithium content from 86,000 tons of lithium content in 2019 in response to lithium production exceeding consumption and decreasing lithium prices. Global consumption of lithium in 2020 was estimated to be 56,000 tons of lithium content, about the same as that of 2019. During the first half of 2020, the economic impact of the global COVID-19 pandemic was reported to have been a substantial factor in the reduction of customer demand. The second half of 2020 saw lithium demand increase owing primarily to strong growth in the lithium-ion battery market.

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LITHIUM

Spot lithium carbonate prices in China decreased from approximately $7,100 per ton at the beginning of the year to about $6,200 per ton in November. For large fixed contracts, the annual average U.S. lithium carbonate price was $8,000 per metric ton in 2020, a 37% decrease from that of 2019. Spot lithium hydroxide prices in China decreased from approximately $7,800 per ton at the beginning of the year to about $7,000 per ton in November. Spot lithium metal (99.9% lithium) prices in China decreased from approximately $83,000 per ton at the beginning of the year to about $71,000 per ton in November.

Five mineral operations in Australia, two brine operations each in Argentina and Chile, and two brine and one mineral operation in China accounted for the majority of world lithium production. Owing to overproduction and decreased prices, several established lithium operations postponed capacity expansion plans. Junior mining operations in Australia and Canada ceased production altogether.

Lithium supply security has become a top priority for technology companies in the United States and Asia. Strategic alliances and joint ventures among technology companies and exploration companies continued to be established to ensure a reliable, diversified supply of lithium for battery suppliers and vehicle manufacturers. Brine-based lithium sources were in various stages of development in Argentina, Bolivia, Chile, China, and the United States; mineral-based lithium sources were in various stages of development in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Finland, Germany, Mali, Namibia, Peru, Portugal, Serbia, Spain, and Zimbabwe; and lithium-clay sources were in various stages of development in Mexico and the United States.

World Mine Production and Reserves: Reserves for Argentina, Australia, Canada, Chile, China, the United States, Zimbabwe, and other countries were revised based on new information from Government and industry sources.

	Mine production		Reserves[5]
	2019	2020[e]	
United States	W	W	750,000
Argentina	6,300	6,200	1,900,000
Australia	45,000	40,000	[6]4,700,000
Brazil	2,400	1,900	95,000
Canada	200	—	530,000
Chile	19,300	18,000	9,200,000
China	10,800	14,000	1,500,000
Portugal	900	900	60,000
Zimbabwe	1,200	1,200	220,000
Other countries[7]	—	—	2,100,000
World total (rounded)	[8]86,000	[8]82,000	21,000,000

World Resources:[5] Owing to continuing exploration, identified lithium resources have increased substantially worldwide and total about 86 million tons. Lithium resources in the United States—from continental brines, geothermal brines, hectorite, oilfield brines, and pegmatites—are 7.9 million tons. Lithium resources in other countries have been revised to 78 million tons. Lithium resources are Bolivia, 21 million tons; Argentina, 19.3 million tons; Chile, 9.6 million tons; Australia, 6.4 million tons; China, 5.1 million tons; Congo (Kinshasa), 3 million tons; Canada, 2.9 million tons; Germany, 2.7 million tons; Mexico, 1.7 million tons; Czechia, 1.3 million tons; Serbia, 1.2 million tons; Peru, 880,000 tons; Mali, 700,000 tons; Zimbabwe, 500,000 tons; Brazil, 470,000 tons; Spain, 300,000 tons; Portugal, 270,000 tons; Ghana, 90,000 tons; and Austria, Finland, Kazakhstan, and Namibia, 50,000 tons each.

Substitutes: Substitution for lithium compounds is possible in batteries, ceramics, greases, and manufactured glass. Examples are calcium, magnesium, mercury, and zinc as anode material in primary batteries; calcium and aluminum soaps as substitutes for stearates in greases; and sodic and potassic fluxes in ceramics and glass manufacture.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as production + imports – exports + adjustments for Government and industry stock changes. Rounded to one significant digit to avoid disclosing company proprietary data.

[2]Source: Industrial Minerals (Fastmarkets IM), lithium carbonate, large contracts, delivered continental United States.

[3]Defined as imports – exports + adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant reserves were 2.8 million tons.

[7]Other countries with reported reserves include Austria, Congo (Kinshasa), Czechia, Finland, Germany, Mali, and Mexico.

[8]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

[Data in thousand metric tons of magnesium oxide (MgO) content unless otherwise noted][2]

Domestic Production and Use: Seawater and natural brines accounted for about 70% of U.S. magnesium compound production in 2020. The value of shipments of all types of magnesium compounds was estimated to be $360 million, essentially unchanged from the revised value in 2019. Magnesium oxide and other compounds were recovered from seawater by one company in California and another company in Delaware, from well brines by one company in Michigan, and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada. One company in Washington processed olivine that was mined previously for use as foundry sand. About 67% of the magnesium compounds consumed in the United States was used in agricultural, chemical, construction, deicing, environmental, and industrial applications in the form of caustic-calcined magnesia, magnesium chloride, magnesium hydroxide, and magnesium sulfates. The remaining 33% was used for refractories in the form of dead-burned magnesia, fused magnesia, and olivine.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production (shipments)	408	438	405	376	350
Shipments (gross weight)	579	616	610	563	530
Imports for consumption	370	436	551	564	480
Exports	88	103	116	88	70
Consumption, apparent[3]	690	771	840	852	760
Employment, plant, number[e]	260	260	270	270	270
Net import reliance[4] as a percentage of apparent consumption	41	43	52	56	54

Recycling: Some magnesia-based refractories are recycled, either for reuse as refractory material or for use as construction aggregate.

Import Sources (2016–19): Caustic-calcined magnesia: China, 69%; Canada, 21%; Australia, 5%; Israel, 3%; and other, 2%. Crude magnesite: China, 84%; Singapore, 12%; and other 4%. Dead-burned and fused magnesia: China, 66%; Brazil, 10%; Turkey, 6%; Mexico, 4%; and other, 14%. Magnesium chloride: Israel, 63%; the Netherlands, 24%; China, 5%; India, 3%; and other, 5%. Magnesium hydroxide: Mexico, 53%; the Netherlands, 15%; Israel, 12%; Austria, 10%; and other, 10%. Magnesium sulfates: China, 55%; Germany, 13%; India, 11%; Canada, 8%; and other, 13%. Total imports: China, 44%; Israel, 15%; Brazil, 14%; the Netherlands, 7%; and other, 20%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Crude magnesite	2519.10.0000	Free.
Dead-burned and fused magnesia	2519.90.1000	Free.
Caustic-calcined magnesia	2519.90.2000	Free.
Kieserite	2530.20.1000	Free.
Epsom salts	2530.20.2000	Free.
Magnesium hydroxide and peroxide	2816.10.0000	3.1% ad val.
Magnesium chloride	2827.31.0000	1.5% ad val.
Magnesium sulfate (synthetic)	2833.21.0000	3.7% ad val.

Depletion Allowance: Brucite, 10% (domestic and foreign); dolomite, magnesite, and magnesium carbonate, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign); and olivine, 22% (domestic) and 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of dead-burned and fused magnesia in the United States decreased by 11% in 2020 compared with that in 2019. Global consumption of dead-burned and fused magnesia decreased by about 3% during the first 9 months of 2020 compared with that in the same period of 2019. Top domestic consumption of magnesium compounds, in descending order, were water treatment, deicing, chemical, and agriculture. The leading magnesium compounds consumed, in descending order, were magnesium oxide (caustic-calcined magnesia, dead burned magnesia, and fused magnesia), magnesium hydroxide, and magnesium chloride.

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MAGNESIUM COMPOUNDS

The global COVID-19 pandemic and efforts to mitigate the spread of the disease caused disruptions in many of the mining and manufacturing industries across the United States and around the world. Overall demand for magnesium compounds was lower in the first half of the year, rebounding to January levels by the third quarter as global lockdowns were eased.

China remains the leading producer of magnesia and magnesite. Policy changes, coupled with the impacts of the global COVID-19 pandemic, have resulted in inconsistent supplies and restricted availability of all grades of magnesia in the world market. Pandemic-related closures of mining and manufacturing activities and reduced demand from downstream industries in early 2020 caused decreased steel production, a major consumer of refractory-grade magnesia. Air pollution controls scheduled to be imposed in major steel-producing Provinces during the autumn and winter months will further reduce consumption of refractory grade magnesia. Liaoning Province, a major source of Chinese magnesite, implemented a 6-month ban on the use of explosives that began on July 1. New open pit mines were banned as well. Export prices for dead-burned and fused magnesia from China decreased by about 13% from the start of the year to the end of September, which was likely caused by a decrease in demand owing to the impact of the global pandemic.

World Magnesite Mine Production and Reserves:[5] In addition to magnesite, vast reserves exist in well and lake brines and seawater from which magnesium compounds can be recovered. Reserves for Austria, Brazil, Slovakia, and Turkey were revised based on new information from Government and industry sources.

	Mine production		Reserves[6]
	2019	2020[e]	
United States	W	W	35,000
Australia	320	310	[7]320,000
Austria	780	760	49,000
Brazil	1,500	1,500	200,000
China	19,000	18,000	1,000,000
Greece	530	500	280,000
India	150	150	82,000
Russia	1,500	1,500	2,300,000
Slovakia	475	460	370,000
Spain	570	600	35,000
Turkey	1,500	1,100	205,000
Other countries	700	680	2,700,000
World total (rounded)	[8]27,100	[8]26,000	7,600,000

World Resources:[6] Resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread. Identified world magnesite and brucite resources total 12 billion tons and several million tons, respectively. Resources of dolomite, forsterite, magnesium-bearing evaporite minerals, and magnesia-bearing brines are estimated to constitute a resource of billions of tons. Magnesium hydroxide can be recovered from seawater. Serpentine could be used as a source of magnesia but global resources, including in tailings of asbestos mines, have not been quantified but are thought to be very large.

Substitutes: Alumina, chromite, and silica substitute for magnesia in some refractory applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See also Magnesium Metal.

[2]Previously reported as magnesium content. Based on input from consumers, producers, and others involved in the industry, it was determined that reporting magnesium compound data in terms of contained magnesium oxide was more useful than reporting in terms of magnesium content. Calculations were made using the following magnesium oxide (MgO) contents: magnesite, 47.8%; magnesium chloride, 42.3%; magnesium hydroxide, 69.1%; and magnesium sulfate, 33.5%.

[3]Defined as production + imports – exports.

[4]Defined as imports – exports.

[5]Gross weight of magnesite (magnesium carbonate) in thousand tons.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were 37 million tons.

[8]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, primary magnesium was produced by one company in Utah at an electrolytic process plant that recovered magnesium from brines from the Great Salt Lake. Secondary magnesium was recovered from scrap at plants that produced magnesium ingot and castings and from aluminum alloy scrap at secondary aluminum smelters. Primary magnesium production in 2020 was estimated to have decreased from that of 2019. Information regarding U.S. primary magnesium production was withheld to avoid disclosing company proprietary data. The leading use for primary magnesium metal, which accounted for 47% of reported consumption, was in castings, principally used for the automotive industry. Aluminum-base alloys that were used for packaging, transportation, and other applications accounted for 33% of primary magnesium metal consumption; desulfurization of iron and steel, 16%; and all other uses, 4%. About 33% of the secondary magnesium was consumed for structural uses, and about 67% was used in aluminum alloys.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	101	112	109	101	90
Imports for consumption	45	42	47	59	61
Exports	19	14	12	10	12
Consumption:					
Reported, primary	69	65	51	55	50
Apparent[2]	W	W	W	W	W
Price, annual average:[3]					
U.S. spot Western, dollars per pound	2.15	2.15	2.17	2.45	2.50
European free market, dollars per metric ton	2,190	2,265	2,550	2,425	2,100
Stocks, producer, yearend	W	W	W	W	W
Employment, number[e]	420	400	400	400	400
Net import reliance[4] as a percentage of apparent consumption	<25	<25	<50	<50	<50

Recycling: In 2020, about 25,000 tons of secondary magnesium was recovered from old scrap and 65,000 tons was recovered from new scrap. Aluminum-base alloys accounted for about 55% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 45%.

Import Sources (2016–19): Canada, 23%; Israel, 20%; Mexico, 11%; Russia, 8%; and other, 38%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Unwrought metal	8104.11.0000	8.0% ad val.
Unwrought alloys	8104.19.0000	6.5% ad val.
Scrap	8104.20.0000	Free.
Powders and granules	8104.30.0000	4.4% ad val.
Wrought metal	8104.90.0000	14.8¢/kg on Mg content + 3.5% ad val.

Depletion Allowance: Dolomite, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The sole U.S. producer of primary magnesium temporarily shut down some capacity at the end of 2016 citing the shutdown of a titanium sponge plant that had been a major customer, and this capacity was not expected to restart in the foreseeable future.

Prices and demand for magnesium fluctuated during much of the year in response to the COVID-19 pandemic. The price in Europe spiked in February compared with the price at the end of January but then declined by mid-March. The price increase in Europe in February and early March was attributed to concerns that shutdowns of smelters in China would cause shortages of magnesium. During January and February, producers in China shut down some capacity citing travel and work restrictions, less demand because of the pandemic, and heavy snowfall in the northwest part of China. But as many secondary aluminum smelters and diecasters in Europe temporarily shut down production in February and March, magnesium consumption decreased. Prices in Europe decreased during April and May, on decreased demand, but increased in June. Decreased production in China during the summer months was

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MAGNESIUM METAL

cited for increased magnesium prices in Europe. In September, prices in Europe declined. In the United States, spot sales of magnesium declined dramatically in April and May, causing the price to drop. Diecasters producing parts for the automobile industry as well as secondary aluminum smelters decreased magnesium consumption in response to shutdowns of automobile assembly lines, aluminum extruders, and aluminum rolling mills. By midyear, consumption of magnesium by aluminum smelters and diecasters stabilized but prices remained at lower levels in the United States and dropped again in August.

Producers in China dominate global magnesium metal production, but several projects were under development to increase primary magnesium metal capacity elsewhere and in China. In the United States, one company obtained a location to build a pilot plant to test magnesium production from a dolomite deposit in Nevada. A company in Quebec, Canada, started construction of a secondary magnesium smelter with completion expected by midyear 2021. Then the company planned to construct a primary magnesium smelter to produce magnesium from serpentine-bearing asbestos tailings. A company in Australia was planning to start construction in 2021 on a 3,000-ton-per-year plant to recover magnesium from coal fly ash with completion expected to take 18 months.

The use of magnesium in automobile parts continued to increase as automobile manufacturers sought to decrease vehicle weight in response to consumer desires for increased fuel efficiency. Magnesium castings have substituted for aluminum, iron, and steel in some automobiles. The substitution of aluminum for steel in automobile sheet was expected to increase consumption of magnesium in aluminum alloy sheet. Although some magnesium sheet applications have been developed for automobiles, these were generally limited to expensive sports cars and luxury vehicles, automobiles where the higher price of magnesium is not a deterrent to its use.

World Primary Production and Reserves:

	Smelter production		Reserves[5]
	2019	2020[e]	
United States	W	W	Magnesium metal can be derived from seawater, natural brines, dolomite, serpentine, and other minerals. The reserves for this metal are sufficient to supply current and future requirements.
Brazil	22	20	
China	970	900	
Israel	21	20	
Kazakhstan	25	20	
Russia	67	60	
Turkey	7	11	
Ukraine	8	5	
World total (rounded)[6]	1,120	1,000	

World Resources:[5] Resources from which magnesium may be recovered range from large to virtually unlimited and are globally widespread. Resources of dolomite, serpentine, and magnesium-bearing evaporite minerals are enormous. Magnesium-bearing brines are estimated to constitute a resource in the billions of tons, and magnesium could be recovered from seawater along world coastlines.

Substitutes: Aluminum and zinc may substitute for magnesium in castings and wrought products. The relatively light weight of magnesium is an advantage over aluminum and zinc in castings and wrought products in most applications; however, its high cost is a disadvantage relative to these substitutes. For iron and steel desulfurization, calcium carbide may be used instead of magnesium. Magnesium is preferred to calcium carbide for desulfurization of iron and steel because calcium carbide produces acetylene in the presence of water.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See also Magnesium Compounds.

[2]Defined as primary production + secondary production from old scrap + imports – exports + adjustments for industry stock changes.

[3]Source: S&P Global Platts Metals Week.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Excludes U.S. production.

MANGANESE

(Data in thousand metric tons gross weight unless otherwise noted)

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by six firms with plants principally in the East and Midwest. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Manganese ferroalloys were produced at two plants. Additional quantities of ore were used for such nonmetallurgical purposes as production of dry cell batteries, in fertilizers and animal feed, and as a brick colorant.

Salient Statistics—United States:[1]	2016	2017	2018	2019	2020[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ores and concentrates	281	297	440	434	310
Ferromanganese	229	331	427	332	240
Silicomanganese[2]	264	351	412	351	240
Exports:					
Manganese ores and concentrates	1	1	3	1	1
Ferromanganese	7	9	10	5	4
Silicomanganese	2	8	4	2	2
Shipments from Government stockpile:[3]					
Manganese ore	—	—	—	—	—
Ferromanganese	44	9	10	8	21
Consumption, reported:					
Manganese ore[4]	410	378	370	[e]370	330
Ferromanganese	342	345	348	336	300
Silicomanganese[2]	139	141	139	143	130
Consumption, apparent, manganese[5]	545	714	793	[e]780	520
Price, average, 44% Mn metallurgical ore, contained Mn, cost, insurance, and freight, China, dollars per metric ton unit[6]	4.34	5.97	7.16	5.63	4.72
Stocks, producer and consumer, yearend:					
Manganese ore[4]	207	148	185	[e]190	190
Ferromanganese	21	17	27	16	16
Silicomanganese	10	11	21	11	11
Net import reliance[7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.

Import Sources (2016–19): Manganese ore: Gabon, 69%; South Africa, 17%; Mexico, 8%; Australia, 4%; and other, 2%. Ferromanganese: Australia, 21%; South Africa, 21%; Norway, 16%; the Republic of Korea, 12%; and other, 30%. Silicomanganese: Georgia, 26%; South Africa, 22%; Australia, 20%; and other, 32%. Manganese contained in principal manganese imports:[8] Gabon, 20%; South Africa, 19%; Australia, 15%; Georgia, 10%; and other, 36%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Ores and concentrates	2602.00.0040, 2602.00.0060	Free.
Manganese dioxide	2820.10.0000	4.7% ad val.
High-carbon ferromanganese	7202.11.5000	1.5% ad val.
Ferrosilicon manganese (silicomanganese)	7202.30.0000	3.9% ad val.
Metal, unwrought	8111.00.4700, 8111.00.4900	14% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

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MANGANESE

Government Stockpile:[9]

Material	Inventory as of 9–30–20	FY 2020 Potential acquisitions	FY 2020 Potential disposals	FY 2021 Potential acquisitions	FY 2021 Potential disposals
Manganese ore, metallurgical grade	292	—	292	—	292
Ferromanganese, high-carbon	163	—	45	—	45
Manganese metal, electrolytic	0.432	5	—	5	—

Events, Trends, and Issues: Steel production, the leading use of manganese, decreased across the globe in 2020 compared with production in 2019 owing to reduced demand attributed to the global COVID-19 pandemic. Global production of manganese ore was estimated to be about 6% less than that in 2019. The leading countries for manganese ore production were, in descending order on a contained-weight basis, South Africa, Australia, and Gabon. Total U.S. manganese imports were estimated to have decreased by approximately 30% in 2020 compared with those in 2019. By September 2020, average spot market prices for manganese ore from China had decreased by 16% compared with the annual average spot price in 2019.

World Mine Production and Reserves (manganese content): Reserves for Australia, Brazil, and South Africa were revised based on Government and industry sources.

	Mine production 2019	Mine production 2020[e]	Reserves[10]
United States	—	—	–
Australia	3,180	3,300	[11]230,000
Brazil	1,740	1,200	270,000
Burma	430	400	NA
China	1,330	1,300	54,000
Côte d'Ivoire	482	460	NA
Gabon	2,510	2,800	61,000
Georgia	116	150	NA
Ghana	1,550	1,400	13,000
India	801	640	34,000
Kazakhstan, concentrate	140	130	5,000
Malaysia	390	350	NA
Mexico	202	190	5,000
South Africa	5,800	5,200	520,000
Ukraine, concentrate	500	550	140,000
Vietnam	158	150	NA
Other countries	270	270	Small
World total (rounded)	19,600	18,500	1,300,000

World Resources:[10] Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs. South Africa accounts for about 40% of the world's manganese reserves, and Brazil accounts for about 20%.

Substitutes: Manganese has no satisfactory substitute in its major applications.

[e]Estimated. NA Not available. — Zero.

[1]Manganese content typically ranges from 35% to 54% for manganese ore and from 74% to 95% for ferromanganese.

[2]Imports more nearly represent amount consumed than does reported consumption.

[3]Defined as stockpile shipments – receipts, thousand tons, manganese content. If net receipts, a negative quantity is shown.

[4]Exclusive of ore consumed directly at iron and steel plants and associated yearend stocks.

[5]Defined as imports – exports + adjustments for Government and industry stock changes, thousand tons, manganese content. Based on estimates of average content for all significant components—including ore, manganese dioxide, ferromanganese, silicomanganese, and manganese metal—except imports, for which content is reported.

[6]For average metallurgical-grade ore containing 44% manganese, as reported by CRU Group.

[7]Defined as imports – exports + adjustments for Government and industry stock changes, thousand tons, manganese content.

[8]Includes imports of ferromanganese, manganese ore, silicomanganese, synthetic manganese dioxide, and unwrought manganese metal.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant reserves were 76 million tons gross weight.

MERCURY

(Data in metric tons of mercury content unless otherwise noted)

Domestic Production and Use: Mercury has not been produced as a principal mineral commodity in the United States since 1992. In 2020, mercury was recovered as a byproduct from processing gold-silver ore at several mines in Nevada; however, production data were not reported. Secondary, or recycled, mercury was recovered from batteries, compact and traditional fluorescent lamps, dental amalgam, medical devices, and thermostats, as well as mercury-contaminated soils. The U.S. Environmental Protection Agency (EPA) reported that domestic production of mercury was 33 tons in 2018 (the last year for which data were available), and about 70 tons of mercury was stored by manufactures or producers. The reported domestic consumption of mercury and mercury in compounds in products was 9 tons. The leading domestic end uses of mercury were dental amalgam (47%); relays, sensors, switches, and valves (45%); formulated products (buffers, catalysts, fixatives, and vaccination uses) (9%); bulbs, lamps, and lighting (8%); and batteries (1%). A large quantity of mercury (about 245 tons) is used in manufacturing processes such as catalysts or as a cathode in the chlorine-caustic soda (chloralkali) process. Almost all of the mercury is reused in the process. The leading manufacturing processes that use mercury are mercury-cell chloralkali plants. In 2020, only one mercury-cell chloralkali plant operated in the United States. Until December 31, 2012, domestic- and foreign-sourced mercury was refined and then exported for global use, primarily for small-scale gold mining in many parts of the world. Beginning January 1, 2013, export of elemental mercury from the United States was banned, with some exceptions, under the Mercury Export Ban Act of 2008. Effective January 1, 2020, exports of five mercury compounds were added to that ban.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption, metal (gross weight)	24	20	6	9	—
Exports, metal (gross weight)	—	—	—	—	—
Price, average value, dollars per flask 99.99%:[1]					
European Union[2]	1,402	1,041	1,100	NA	NA
Global locations[3]	1,275	1,273	2,709	2,550	NA
Net import reliance[4] as a percentage of apparent consumption	NA	NA	NA	NA	—

Recycling: In 2020, eight facilities operated by six companies in the United States accounted for the majority of secondary mercury produced and were authorized by the U.S. Department of Energy (DOE) to temporarily store mercury until the DOE's long-term facility opens. Mercury-containing automobile convenience switches, barometers, compact and traditional fluorescent bulbs, computers, dental amalgam, medical devices, and thermostats were collected by smaller companies and shipped to the refining companies for retorting to reclaim the mercury. In addition, many collection companies recovered mercury when retorting was not required. With the rapid phasing out of compact and traditional fluorescent lighting for light-emitting-diode (LED) lighting, an increased quantity of mercury was being recycled.

Import Sources (2016–19): Canada, 53%; France, 29%; China, 10%; Switzerland, 7%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Mercury	2805.40.0000	1.7% ad val.
Amalgams	2843.90.0000	3.7% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5] The Defense Logistics Agency Strategic Materials held and managed an inventory of 4,437 tons of mercury in storage at the Hawthorne Army Depot in Hawthorne, NV. On December 3, 2019, the DOE selected a site near Andrews, TX, to store up to 6,800 tons of mercury. Sales of mercury from the stockpiles remained suspended.

		FY 2020		**FY 2021**	
Material	**Inventory as of 9–30–20**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Mercury	4,437	—	—	—	—

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MERCURY

Events, Trends, and Issues: Owing to mercury toxicity and concerns for the environment and human health, overall mercury use has declined in the United States and worldwide. Mercury continues to be released to the environment from numerous sources, including mercury-containing car switches when automobiles (those produced prior to 2003) are scrapped without recovering the switches for recycling, coal-fired powerplant emissions, incineration of mercury-containing medical devices, and naturally occurring sources. Mercury is no longer used in most batteries and paints manufactured in the United States. Some button-type batteries, cleansers, fireworks, folk medicines, grandfather clocks, pesticides, and skin-lightening creams and soaps may still contain mercury. Mercury compounds were used as catalysts in the coal-based manufacture of vinyl chloride monomer in China. In some parts of the world, mercury was used in the recovery of gold in artisanal and small-scale mining operations. Conversion to nonmercury technology for chloralkali production and the ultimate closure of the world's mercury-cell chloralkali plants may release a large quantity of mercury to the global market for recycling, sale, or, owing to export bans in Europe and the United States, long-term storage.

Byproduct mercury production is expected to continue from large-scale domestic and foreign gold-silver mining and processing, as is secondary production of mercury from an ever-diminishing supply of mercury-containing products. Domestic mercury consumption will continue to decline owing to increased use of LED lighting and consequent reduced use of conventional fluorescent tubes and compact fluorescent bulbs and continued substitution of nonmercury-containing products in control, dental, and measuring applications.

World Mine Production and Reserves:

	Mine production[e]		Reserves[6]
	2019	2020	
United States	NA	NA	Quantitative estimates of reserves are not available. China, Kyrgyzstan, and Peru are thought to have the largest reserves.
Argentina	50	50	
China	3,600	3,400	
Kyrgyzstan	15	15	
Mexico (net exports)	63	60	
Norway	20	20	
Peru (exports)	40	40	
Tajikistan	100	100	
Other countries	12	20	
World total (rounded)	3,900	3,700	

World Resources:[6] China, Kyrgyzstan, Mexico, Peru, Russia, Slovenia, Spain, and Ukraine have most of the world's estimated 600,000 tons of mercury resources. Mexico reclaims mercury from Spanish colonial silver-mining waste. In Spain, once a leading producer of mercury, mining at its centuries-old Almaden Mine stopped in 2003. In the United States, mercury occurrences are in Alaska, Arkansas, California, Nevada, and Texas. The declining consumption of mercury, except for small-scale gold mining, indicates that these resources are sufficient for centuries of use.

Substitutes: Ceramic composites substitute for the dark-gray mercury-containing dental amalgam. "Galinstan," an alloy of gallium, indium, and tin, replaces the mercury used in traditional mercury thermometers, and digital thermometers have replaced traditional thermometers. At chloralkali plants around the world, mercury-cell technology is being replaced by newer diaphragm and membrane-cell technology. LEDs that contain indium substitute for mercury-containing fluorescent lamps. Lithium, nickel-cadmium, and zinc-air batteries replace mercury-zinc batteries in the United States; indium compounds substitute for mercury in alkaline batteries; and organic compounds are being used instead of mercury fungicides in latex paint.

[e]Estimated. NA Not available. — Zero.

[1]Some international data and dealer prices are reported in flasks. One metric ton (1,000 kilograms) = 29.0082 flasks, and 1 flask = 76 pounds, or 34.47 kilograms, or 0.03447 ton.

[2]Average annual price of minimum 99.99% mercury. Source: Argus Media group—Argus Metals International. Price discontinued on May 1, 2018.

[3]Average midpoint of free market 99.99% mercury in warehouse, global locations, price published by Metal Bulletin. Price discontinued on December 1, 2019.

[4]Defined as imports – exports + adjustments for Government stock changes.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data source.

MICA (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Scrap and flake mica production, excluding low-quality sericite, was estimated to be 35,000 tons valued at $4.3 million. Mica was mined in Georgia, North Carolina, and South Dakota. Scrap mica was recovered principally from mica and sericite schist and as a byproduct from feldspar, industrial sand beneficiation, and kaolin. Eight companies produced an estimated 57,000 tons of ground mica valued at about $22 million from domestic and imported scrap and flake mica. Most of the domestic production was processed into small-particle-size mica by either wet or dry grinding. Primary uses were joint compound, oil-well-drilling additives, paint, roofing, and rubber products.

A minor amount of sheet mica has been produced as incidental production from feldspar mining in North Carolina in the past several years. Data on sheet mica production were not available in 2020. The domestic consuming industry was dependent on imports to meet demand for sheet mica. Most sheet mica was fabricated into parts for electrical and electronic equipment.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Scrap and flake:					
Production:[e, 1]					
Sold and used	28,000	40,000	42,000	40,100	35,000
Ground	59,500	69,700	68,400	61,300	57,000
Imports[2]	31,500	29,700	28,100	26,700	20,000
Exports[3]	6,340	6,790	6,030	5,500	4,000
Consumption, apparent[e, 4]	53,200	62,900	64,100	61,300	51,000
Price, average, dollars per metric ton:[e]					
Scrap and flake	152	165	125	118	118
Ground:					
Dry	320	292	308	316	300
Wet	435	424	422	394	430
Employment, mine, number	NA	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	47	36	34	35	31
Sheet:					
Sold and used	W	W	W	W	W
Imports[6]	2,120	1,850	1,890	3,150	2,700
Exports[7]	689	704	686	793	550
Consumption, apparent[e, 4]	1,430	1,150	1,200	2,350	2,200
Price, average value, muscovite and phlogopite mica, dollars per kilogram:[e]					
Block	W	W	W	W	W
Splittings	1.61	1.66	1.65	1.66	1.66
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2016–19): Scrap and flake: Canada, 44%; China, 32%; India, 9%; Finland, 4%; and other, 11%. Sheet: China, 56%; Brazil, 16%; Belgium, 6%; India, 4%; and other, 18%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Split block mica	2525.10.0010	Free.
Mica splittings	2525.10.0020	Free.
Unworked, other	2525.10.0050	Free.
Mica powder	2525.20.0000	Free.
Mica waste	2525.30.0000	Free.
Plates, sheets, and strips of agglomerated or reconstituted mica	6814.10.0000	2.7% ad val.
Worked mica and articles of mica, other	6814.90.0000	2.6% ad val.

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MICA (NATURAL)

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic production of scrap and flake mica was estimated to have decreased by 13% in 2020. Apparent consumption of scrap and flake mica decreased by 17%. Apparent consumption of sheet mica was estimated to have decreased by 6% in 2020. The economic effects of the COVID-19 pandemic had a significant impact on some of industries that use mica, primarily oil-well-drilling fluid and plastics for automobiles. No environmental concerns are associated with the manufacture and use of mica products. Supplies of sheet mica for United States consumption were expected to continue to be from imports, primarily from Belgium, Brazil, China, and India.

World Mine Production and Reserves: World production of sheet mica has remained steady; however, reliable production numbers for some countries that may influence that world total were unavailable. Reserves for the Republic of Korea were revised based on official Government data.

	Scrap and flake			Sheet		
	Mine production		Reserves[8]	Mine production		Reserves[8]
	2019	2020[e]	2019	2019[e]	2020[e]	2019
United States	40,100	35,000	Large	W	NA	Very small
Canada	21,000	18,000	Large	NA	NA	NA
China	100,000	95,000	Large	NA	NA	NA
Finland	73,900	65,000	Large	NA	NA	NA
France	20,000	18,000	Large	NA	NA	NA
India	15,000	15,000	Large	1,000	1,000	110,000
Korea, Republic of	23,400	20,000	11,000,000	—	—	NA
Madagascar	50,000	30,000	Large	—	—	NA
Turkey	6,500	5,500	620,000	—	—	NA
Other countries	55,000	49,000	Large	200	200	Moderate
World total (rounded)	405,000	350,000	Large	NA	NA	NA

World Resources:[8] Resources of scrap and flake mica are available in clay deposits, granite, pegmatite, and schist, and are considered more than adequate to meet anticipated world demand in the foreseeable future. World resources of sheet mica have not been formally evaluated because of the sporadic occurrence of this material. Large deposits of mica-bearing rock are known to exist in countries such as Brazil, India, and Madagascar. Limited resources of sheet mica are available in the United States. Domestic resources are not economical because of the high cost of the hand labor required to mine and process sheet mica from pegmatites.

Substitutes: Some lightweight aggregates, such as diatomite, perlite, and vermiculite, may be substituted for ground mica when used as filler. Ground synthetic fluorophlogopite, a fluorine-rich mica, may replace natural ground mica for uses that require the thermal and electrical properties of mica. Many materials can be substituted for mica in numerous electrical, electronic, and insulation uses. Substitutes include acrylic, cellulose acetate, fiberglass, fishpaper, nylatron, nylon, phenolics, polycarbonate, polyester, styrene, polyvinyl chloride, and vulcanized fiber. Mica paper made from scrap mica can be substituted for sheet mica in electrical and insulation applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Excludes low-quality sericite used primarily for brick manufacturing.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0050, <$6.00/kg; 2525.20.0000; and 2525.30.0000.

[3]Includes data for the following Schedule B codes: 2525.10.0000, <$6.00/kg; 2525.20.0000; and 2525.30.0000.

[4]Defined as sold or used by producing companies + imports – exports.

[5]Defined as imports – exports.

[6]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0010; 2525.10.0020; 2525.10.0050, >$6.00/kg; 6814.10.0000; and 6814.90.0000.

[7]Includes data for the following Schedule B codes: 2525.10.0000, >$6.00/kg; 6814.10.0000; and 6814.90.0000.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

MOLYBDENUM

(Data in metric tons of molybdenum content unless otherwise noted)

Domestic Production and Use: U.S. mine production of molybdenum in 2020 increased by 13% to 49,000 tons compared with the previous year. Molybdenum ore was produced as a primary product at two mines—both in Colorado—whereas seven copper mines (four in Arizona and one each in Montana, Nevada, and Utah) recovered molybdenite concentrate as a byproduct. Three roasting plants converted molybdenite concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced. Metallurgical applications accounted for more than 88% of the total molybdenum consumed.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, mine	36,200	40,700	41,400	43,600	49,000
Imports for consumption	22,800	36,000	37,500	34,200	26,000
Exports	31,200	43,200	48,400	67,200	62,000
Consumption:					
Reported[1]	15,800	17,400	16,700	16,500	14,000
Apparent[2]	27,900	34,100	31,300	10,500	13,000
Price, average value, dollars per kilogram[3]	14.40	18.06	27.04	26.50	20
Stocks, consumer materials	1,910	2,010	1,940	1,980	2,100
Employment, mine and plant, number	920	940	940	950	950
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Molybdenum is recycled as a component of catalysts, ferrous scrap, and superalloy scrap. Ferrous scrap consists of revert, new, and old scrap. Revert scrap refers to remnants manufactured in the steelmaking process. New scrap is generated by steel mill customers and recycled by scrap collectors and processors. Old scrap is largely molybdenum-bearing alloys recycled after serving their useful life. The amount of molybdenum recycled as part of new and old steel and other scrap may be as much as 30% of the apparent supply of molybdenum. There are no processes for the separate recovery and refining of secondary molybdenum from its alloys. Molybdenum is not recovered separately from recycled steel and superalloys, but the molybdenum content of the recycled alloys is significant, and the molybdenum content is reused. Recycling of molybdenum-bearing scrap will continue to be dependent on the markets for the principal alloy metals in which molybdenum is contained, such as iron, nickel, and chromium.

Import Sources (2016–19): Ferromolybdenum: Chile, 54%; the Republic of Korea, 38%; Canada, 4%; and other, 4%. Molybdenum ores and concentrates: Peru, 57%; Chile, 22%; Canada, 12%; Mexico, 8%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Molybdenum ore and concentrates, roasted	2613.10.0000	12.8¢/kg + 1.8% ad val.
Molybdenum ore and concentrates, other	2613.90.0000	17.8¢/kg.
Molybdenum chemicals:		
Molybdenum oxides and hydroxides	2825.70.0000	3.2% ad val.
Molybdates of ammonium	2841.70.1000	4.3% ad val.
Molybdates, all others	2841.70.5000	3.7% ad val.
Molybdenum pigments, molybdenum orange	3206.20.0020	3.7% ad val.
Ferroalloys, ferromolybdenum	7202.70.0000	4.5% ad val.
Molybdenum metals:		
Powders	8102.10.0000	9.1¢/kg + 1.2% ad val.
Unwrought	8102.94.0000	13.9¢/kg + 1.9% ad val.
Wrought bars and rods	8102.95.3000	6.6% ad val.
Wrought plates, sheets, strips, etc.	8102.95.6000	6.6% ad val.
Wire	8102.96.0000	4.4% ad val.
Waste and scrap	8102.97.0000	Free.
Other	8102.99.0000	3.7% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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MOLYBDENUM

Events, Trends, and Issues: In 2020, the estimated average molybdic oxide price decreased by 25% compared with that of 2019, and U.S. estimated mine output of molybdenum increased by 13% from that of 2019. The increase in production was mainly the result of one byproduct mine in Utah increasing its production by more than 60%. This increase in production in Utah offset the production delays caused by the global COVID-19 pandemic at other molybdenum producers. Byproduct molybdenum production continued at the Bagdad, Morenci, Pinto Valley, and Sierrita Mines in Arizona; the Continental Pit Mine in Montana; the Robinson Mine in Nevada; and the Bingham Canyon Mine in Utah. Primary molybdenum production continued at the Climax and Henderson Mines in Colorado. The Thompson Creek Mine in Idaho continued to be on care-and-maintenance status in 2020.

Estimated U.S. imports for consumption decreased by 24% compared with those of 2019. U.S. exports decreased by 8% from those of 2019. Apparent consumption increased by 26% compared with that of 2019.

Global molybdenum production in 2020 increased slightly compared with 2019. In descending order of production, China, Chile, the United States, Peru, and Mexico provided more than 90% of total global production.

World Mine Production and Reserves: The reserves estimates for Canada, Mongolia, Peru, and Turkey were revised based on new information from company and Government reports.

	Mine production		Reserves[5]
	2019	2020[e]	(thousand metric tons)
United States	43,600	49,000	2,700
Argentina[e]	—	—	100
Armenia[e]	5,000	7,000	150
Canada	3,900	2,700	96
Chile	56,000	58,000	1,400
China[e]	130,000	120,000	8,300
Iran[e]	3,500	3,500	43
Mexico	16,600	17,000	130
Mongolia	1,800	1,800	370
Peru	30,400	30,000	2,800
Russia[e]	2,800	2,800	1,000
Turkey[e]	400	400	800
Uzbekistan[e]	200	200	60
World total (rounded)	294,000	300,000	18,000

World Resources:[5] Identified resources of molybdenum in the United States are about 5.4 million tons, and in the rest of the world, about 20 million tons. Molybdenum occurs as the principal metal sulfide in large low-grade porphyry molybdenum deposits and as an associated metal sulfide in low-grade porphyry copper deposits. Resources of molybdenum are adequate to supply world needs for the foreseeable future.

Substitutes: There is little substitution for molybdenum in its major application in steels and cast irons. In fact, because of the availability and versatility of molybdenum, industry has sought to develop new materials that benefit from its alloying properties. Potential substitutes include boron, chromium, niobium (columbium), and vanadium in alloy steels; tungsten in tool steels; graphite, tantalum, and tungsten for refractory materials in high-temperature electric furnaces; and cadmium-red, chrome-orange, and organic-orange pigments for molybdenum orange.

[e]Estimated. E Net exporter. — Zero.

[1]Reported consumption of primary molybdenum products.

[2]Defined as production + imports – exports + adjustments for concentrate, consumer, and product producer stock changes.

[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide, as reported by CRU Group.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

NICKEL

(Data in metric tons of nickel content unless otherwise noted)

Domestic Production and Use: In 2020, the underground Eagle Mine in Michigan produced approximately 16,000 tons of nickel in concentrate, which was exported to smelters in Canada and overseas. A company in Missouri recovered metals, including nickel, from mine tailings as part of the Superfund Redevelopment Initiative. Nickel in crystalline sulfate was produced as a byproduct of smelting and refining platinum-group-metal ores mined in Montana.

In the United States, the leading uses for primary nickel are stainless and alloy steels, nonferrous alloys and superalloys, electroplating, and other uses including catalysts and chemicals. Stainless and alloy steel and nickel-containing alloys typically account for more than 85% of domestic consumption.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Mine	24,100	22,100	17,600	13,500	16,000
Refinery, byproduct	W	W	W	W	W
Imports:					
Ores and concentrates	([1])	64	3	4	120
Primary	111,000	150,000	144,000	119,000	110,000
Secondary	32,300	38,100	45,100	37,700	32,000
Exports:					
Ores and concentrates	22,400	20,000	18,000	14,700	13,000
Primary	10,300	11,000	9,780	12,800	11,000
Secondary	63,700	51,500	59,400	51,100	34,000
Consumption:					
Reported, primary metal	97,800	105,000	107,000	105,000	85,000
Reported, secondary, purchased scrap	131,000	133,000	123,000	111,000	100,000
Apparent, primary metal[2]	104,000	140,000	136,000	106,000	99,000
Apparent, total[3]	235,000	273,000	259,000	217,000	200,000
Price, average annual, London Metal Exchange (LME):					
Cash, dollars per metric ton	9,594	10,403	13,114	13,903	14,000
Cash, dollars per pound	4.352	4.719	5.948	6.306	6.40
Stocks, yearend:					
Consumer	15,100	14,600	16,300	13,400	13,000
LME U.S. warehouses	5,232	3,780	2,268	1,974	2,000
Net import reliance[4] as a percentage of total apparent consumption	44	51	52	49	50

Recycling: Nickel in alloyed form was recovered from the processing of nickel-containing waste, including flue dust, grinding swarf, mill scale, and shot blast generated during the manufacturing of stainless steel; filter cakes, plating solutions, spent catalysts, spent pickle liquor, sludges, and all types of spent nickel-containing batteries. Nickel-containing alloys and stainless-steel scrap were also melted and used to produce new alloys and stainless steel. The U.S. Department of Energy's ReCell Center continued to investigate methods to more effectively recover raw materials, including nickel, from recycled batteries. In 2020, recycled nickel in all forms accounted for approximately 50% of apparent consumption.

Import Sources (2016–19): Nickel contained in ferronickel, metal, oxides, and salt: Canada, 42%; Norway, 10%; Finland, 9%; Russia, 8%; and other, 31%. Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 38%; Mexico, 27%; United Kingdom, 9%; and other, 26%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Nickel ores and concentrates, nickel content	2604.00.0040	Free.
Ferronickel	7202.60.0000	Free.
Unwrought nickel, not alloyed	7502.10.0000	Free.
Nickel waste and scrap	7503.00.0000	Free.
Nickel powders	7504.00.0010	Free.
Nickel flakes	7504.00.0050	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

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NICKEL

Government Stockpile:[5] The U.S. Department of Energy is holding nickel ingot contaminated by low-level radioactivity at Paducah, KY, and shredded nickel scrap at Oak Ridge, TN. Ongoing decommissioning activities at former nuclear defense sites were expected to generate additional nickel in scrap. See the Lithium chapter for statistics on lithium-nickel-cobalt-aluminum oxide.

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Nickel alloys, gross weight	609	—	272	—	—

Events, Trends, and Issues: Domestic reported consumption of primary nickel decreased by an estimated 20% in 2020, owing primarily to reduced demand related to the global COVID-19 pandemic. Approximately 70% of the decrease was attributed to reduced consumption of nickel alloys, primarily those used in the aviation and oil and gas sectors. Domestic production of stainless steel and related nickel consumption decreased substantially in the first half of 2020, but most of the leading domestic stainless-steel producers reported relatively robust recovery in the third quarter. Total domestic production of stainless steel in 2020 was estimated to have decreased by approximately 10%.

Globally, nickel mine production was estimated to have decreased by 5%. Although stainless-steel production in most leading producing countries and (or) localities decreased, these were mostly offset by a rapid recovery in China's production of nickel-bearing stainless-steel grades after the first quarter, and the continued rampup of nickel pig iron and stainless-steel projects in Indonesia.

World Mine Production and Reserves: Reserves for Brazil, Canada, and the United States were revised based on new information from company and (or) Government reports

	Mine production		Reserves[6]
	2019	2020[e]	
United States	13,500	16,000	100,000
Australia	159,000	170,000	[7]20,000,000
Brazil	60,600	73,000	16,000,000
Canada	181,000	150,000	2,800,000
China	120,000	120,000	2,800,000
Cuba	49,200	49,000	5,500,000
Dominican Republic	56,900	47,000	NA
Indonesia	853,000	760,000	21,000,000
New Caledonia[8]	208,000	200,000	NA
Philippines	323,000	320,000	4,800,000
Russia	279,000	280,000	6,900,000
Other countries	310,000	290,000	14,000,000
World total (rounded)	2,610,000	2,500,000	94,000,000

World Resources:[6] Identified land-based resources averaging approximately 0.5% nickel or greater contain at least 300 million tons of nickel, with about 60% in laterites and 40% in sulfide deposits. Extensive nickel resources also are found in manganese crusts and nodules on the ocean floor.

Substitutes: Low-nickel, duplex, or ultrahigh-chromium stainless steels have been substituted for austenitic grades in construction. Nickel-free specialty steels are sometimes used in place of stainless steel in the power-generating and petrochemical industries. Titanium alloys can substitute for nickel metal or nickel-base alloys in corrosive chemical environments. Lithium-ion batteries may be used instead of nickel metal hydride batteries in certain applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Less than ½ unit.

[2]Defined as primary imports – primary exports + adjustments for industry stock changes, excluding secondary consumer stocks.

[3]Defined as apparent primary metal consumption + reported secondary consumption.

[4]Defined as imports – exports + adjustments for consumer stock changes.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were 6.2 million tons.

[8]Overseas Territory of France.

NIOBIUM (COLUMBIUM)

(Data in metric tons of niobium content unless otherwise noted)

Domestic Production and Use: Significant U.S. niobium mine production has not been reported since 1959. Companies in the United States produced niobium-containing materials from imported niobium concentrates, oxides, and ferroniobium. Niobium was consumed mostly in the form of ferroniobium by the steel industry and as niobium alloys and metal by the aerospace industry. In 2020, there was a decrease in reported consumption of niobium for high-strength low-alloy steel and superalloy applications. Major end-use distribution of reported niobium consumption was as follows: steels, about 81%, and superalloys, about 19%. The estimated value of niobium consumption was $280 million, as measured by the value of imports.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, mine	—	—	—	—	—
Imports for consumption[1]	8,250	9,330	11,200	10,100	7,500
Exports[1]	1,480	1,490	955	668	520
Shipments from Government stockpile	—	—	—	—	—
Consumption:[e]					
Apparent[2]	6,730	7,780	10,100	9,370	6,900
Reported[3]	7,370	7,640	6,850	6,880	5,500
Price, unit value, ferroniobium, dollars per kilogram[4]	21	20	21	23	24
Net import reliance[2] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Niobium was recycled when niobium-bearing steels and superalloys were recycled; scrap recovery, specifically for niobium content, was negligible. The amount of niobium recycled is not available, but it may be as much as 20% of apparent consumption.

Import Sources (2016–19): Niobium and tantalum ores and concentrates: Rwanda, 36%; Australia, 25%; Brazil, 14%; Congo (Kinshasa), 7%; and other, 18%. Niobium oxide: Brazil, 54%; Russia, 19%; Thailand, 11%; Estonia, 7%; and other, 9%. Ferroniobium and niobium metal: Brazil, 68%; Canada, 25%; Germany, 5%, Russia, 1%; and other, 1%. Total imports: Brazil, 66%; Canada, 22%; Germany, 4%; Russia, 3%; and other, 5%. Of the U.S. niobium material imports (by contained weight), 76% was ferroniobium, 14% was niobium metal, 9% was niobium oxide, and 1% was niobium ores and concentrates.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Niobium oxide	2825.90.1500	3.7% ad val.
Ferroniobium:		
Less than 0.02% P or S, or less than 0.4% Si	7202.93.4000	5% ad val.
Other	7202.93.8000	5% ad val.
Niobium:		
Waste and scrap[5]	8112.92.0600	Free.
Powders and unwrought metal	8112.92.4000	4.9% ad val.
Niobium, other[5]	8112.99.9000	4% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[6]

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Ferroniobium (gross weight)	542	—	—	—	—
Niobium metal (gross weight)	10	—	—	—	—

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NIOBIUM (COLUMBIUM)

Events, Trends, and Issues: Niobium principally was imported in the form of ferroniobium. Based on data through August 2020, U.S. niobium apparent consumption (measured in contained niobium) for 2020 was estimated to be 6,900 tons, a 26% decrease from that of 2019. Brazil continued to be the world's leading niobium producer with 91% of global production, followed by Canada with 8%. Significant production decreases by major aircraft manufacturers reduced niobium consumption for superalloys. Global niobium production and consumption was thought to have decreased in 2020 owing to a decrease in steel production in most countries caused by the COVID-19 pandemic. A significant decrease in ferrovanadium prices in 2020 was also a factor in reduced ferroniobium consumption. In 2019, consumption of ferroniobium, especially in China, had increased in part because it was used as a substitute for ferrovanadium by some producers of high-strength low-alloy steel owing to the supply deficit and high price volatility of ferrovanadium. In the first 9 months of 2020, China's imports of ferrovanadium increased by 700% while ferroniobium imports decreased by 36% compared with those in the same period of 2019, suggesting that some reverse substitution was taking place. Total exports of ferroniobium to all countries from Brazil, the leading producing country, decreased by 35% during the first 9 months of 2020 compared with exports during the same period of 2019.

One domestic company developing its Elk Creek project in Nebraska announced that it had secured options to purchase all the land needed for the mine and processing facility. The company received its construction air permit from the State of Nebraska in June. The project would be the only niobium mine and primary niobium processing facility in the United States, with construction to begin after financing was obtained.

A leading niobium producer in Brazil was in the process of increasing its annual ferroniobium production capacity by 50% to 150,000 tons per year (approximately 98,000 tons per year of contained niobium). Originally expected by the end of 2020, the expansion was to be completed in 2021.

World Mine Production and Reserves:[7] The reserves data for Brazil were revised based on information reported by the Government of Brazil, and reserves data for the United States were revised based on company reports.

	Mine production		Reserves[7]
	2019	2020[e]	
United States	—	—	170,000
Brazil	88,900	71,000	16,000,000
Canada	6,800	6,200	1,600,000
Other countries	1,250	1,000	NA
World total (rounded)	97,000	78,000	>17,000,000

World Resources:[7] World resources of niobium are more than adequate to supply projected needs. Most of the world's identified resources of niobium occur as pyrochlore in carbonatite (igneous rocks that contain more than 50%-by-volume carbonate minerals) deposits and are outside the United States.

Substitutes: The following materials can be substituted for niobium, but a performance loss or higher cost may ensue: ceramic matrix composites, molybdenum, tantalum, and tungsten in high-temperature (superalloy) applications; molybdenum, tantalum, and titanium as alloying elements in stainless and high-strength steels; and molybdenum and vanadium as alloying elements in high-strength low-alloy steels.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated niobium content of ferroniobium, niobium and tantalum ores and concentrates, niobium oxide, and niobium powders and unwrought metal.

[2]Defined as imports – exports + adjustments for Government stock changes.

[3]Only includes ferroniobium and nickel niobium.

[4]Unit value is weighted average unit value of gross weight of U.S. ferroniobium trade. (Trade is imports plus exports.)

[5]This category includes niobium-containing material and other material.

[6]See Appendix B for definitions.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

NITROGEN (FIXED)—AMMONIA

(Data in thousand metric tons of contained nitrogen unless otherwise noted)

Domestic Production and Use: Ammonia was produced by 16 companies at 35 plants in 16 States in the United States during 2020; 2 additional plants were idle for the entire year. About 60% of total U.S. ammonia production capacity was in Louisiana, Oklahoma, and Texas because of their large reserves of natural gas, the dominant domestic feedstock for ammonia. In 2020, U.S. producers operated at about 85% of rated capacity. The United States was one of the world's leading producers and consumers of ammonia. Urea, ammonium nitrate, nitric acid, ammonium phosphates, and ammonium sulfate were, in descending order of importance, the major derivatives of ammonia produced in the United States.

Approximately 88% of apparent domestic ammonia consumption was for fertilizer use, including anhydrous ammonia for direct application, urea, ammonium nitrates, ammonium phosphates, and other nitrogen compounds. Ammonia also was used to produce explosives, plastics, synthetic fibers and resins, and numerous other chemical compounds.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production[1]	10,200	11,600	13,100	13,500	14,000
Imports for consumption	3,840	3,090	2,530	2,020	2,000
Exports	183	612	224	338	400
Consumption, apparent[2]	13,800	14,100	15,300	15,200	16,000
Stocks, producer, yearend	400	320	490	420	400
Price, average, free on board gulf coast,[3] dollars per short ton	267	247	281	232	220
Employment, plant, number[e]	1,300	1,500	1,600	1,600	1,600
Net import reliance[4] as a percentage of apparent consumption	27	18	14	11	10

Recycling: None.

Import Sources (2016–19): Trinidad and Tobago, 65%; Canada 30%; Venezuela, 3%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Ammonia, anhydrous	2814.10.0000	Free.
Urea	3102.10.0000	Free.
Ammonium sulfate	3102.21.0000	Free.
Ammonium nitrate	3102.30.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The Henry Hub spot natural gas price ranged between $1.34 and $2.52 per million British thermal units for most of the year, with an average of about $2.07 per million British thermal units. Natural gas prices in 2020 were lower than those in 2019—a result of mild weather that decreased demand for natural gas for heating in early 2020 and reduced manufacturing activity. The U.S. Department of Energy, Energy Information Administration, projected that Henry Hub natural gas spot prices would average higher than $3.00 per million British thermal units in 2021.

The weekly average gulf coast ammonia price was $220 per short ton at the beginning of 2020, decreased to $205 per short ton in mid-June, and then increased to $228 per short ton in early October. The average ammonia price for 2020 was estimated to be $220 per short ton. In 2020, low natural gas prices resulted in lower ammonia prices.

A long period of stable and low natural gas prices in the United States has made it economical for companies to upgrade existing ammonia plants and construct new nitrogen facilities. The additional capacity has reduced ammonia imports. Expansion in the ammonia industry took place throughout the past 5 years; however, no additional ammonia plants are expected to be commissioned before 2022.

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NITROGEN (FIXED)—AMMONIA

Global ammonia capacity is expected to increase by a total of 4% during the next 4 years. Capacity additions are expected in Africa and south Asia; however, ongoing plant closures will decrease capacity in east Asia and Latin America. Demand for ammonia is expected to increase in all regions with the largest increases expected in Africa, central Asia, and Eastern Europe.

Large corn plantings maintain the continued demand for nitrogen fertilizers. According to the U.S. Department of Agriculture, U.S. corn growers planted 37.2 million hectares of corn in the 2020 crop-year (July 1, 2019, through June 30, 2020), which was 3% greater than the area planted in crop-year 2019. Corn acreage in the 2021 crop-year is expected to increase because of anticipated higher returns for corn compared with those of other crops.

In 2020, the fertilizer industry was considered part of the critical chemical sector by the U.S. Department of Homeland Security. The COVID-19 pandemic stay-at-home orders issued in March 2020 did not affect the fertilizer industry, and U.S. ammonia plants maintained full operations.

World Ammonia Production and Reserves:

	Plant production		Reserves[5]
	2019	2020[e]	
United States	13,500	14,000	Available atmospheric nitrogen and sources of natural gas for production of ammonia are considered adequate for all listed countries.
Algeria	2,200	2,200	
Australia	1,300	1,300	
Canada	3,940	3,900	
China	38,000	38,000	
Egypt	4,200	4,500	
Germany	2,420	2,400	
India	12,200	13,000	
Indonesia	5,000	5,000	
Iran	3,500	3,500	
Netherlands	2,200	2,200	
Oman	1,700	1,700	
Pakistan	3,100	3,100	
Poland	2,200	2,200	
Qatar	3,150	3,200	
Russia	15,000	15,000	
Saudi Arabia	4,000	4,000	
Trinidad and Tobago	4,480	4,300	
Ukraine	1,500	1,500	
Uzbekistan	1,100	1,100	
Vietnam	1,100	1,100	
Other countries	16,400	17,000	
World total (rounded)	142,000	144,000	

World Resources:[5] The availability of nitrogen from the atmosphere for fixed nitrogen production is unlimited. Mineralized occurrences of sodium and potassium nitrates, such as those found in the Atacama Desert of Chile, contribute minimally to the global nitrogen supply.

Substitutes: Nitrogen is an essential plant nutrient that has no substitute. No practical substitutes for nitrogen explosives and blasting agents are known.

[e]Estimated.

[1]Source: The Fertilizer Institute; data adjusted by the U.S. Geological Survey.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]Source: Green Markets.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

PEAT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The estimated free on board (f.o.b.) mine value of sold marketable peat production in the conterminous United States was $13 million in 2020. Peat was harvested and processed by 30 companies in 12 conterminous States. Florida, Michigan, and Minnesota were the leading producing States, in order of quantity harvested. Reed-sedge peat accounted for approximately 93% of the total volume produced, followed by sphagnum moss with 3%. Domestic peat applications included earthworm culture medium, golf course construction, mixed fertilizers, mushroom culture, nurseries, packing for flowers and plants, seed inoculants, and vegetable cultivation. In the industrial sector, peat was used as an oil absorbent and as an efficient filtration medium for the removal of waterborne contaminants in mine waste streams, municipal storm drainage, and septic systems.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production	441	498	477	456	430
Sales by producers	443	515	545	556	540
Imports for consumption	1,130	1,150	1,200	1,160	1,400
Exports	30	30	37	46	50
Consumption, apparent[1]	1,590	1,520	1,670	1,480	1,800
Price, average value, f.o.b. mine, dollars per ton	31.97	27.55	25.88	24.59	24.60
Stocks, producer, yearend	125	222	196	280	250
Employment, mine and plant, number[e]	550	540	540	540	530
Net import reliance[2] as a percentage of apparent consumption	72	67	71	69	76

Recycling: None.

Import Sources (2016–19): Canada, 96%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Peat	2703.00.0000	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Peat is an important component of plant-growing media, and the demand for peat generally follows that of horticultural applications. In the United States, the short-term outlook is for production to average about 430,000 tons per year, and imported peat from Canada is expected to continue to account for more than 70% of domestic consumption. Imports for 2020 were estimated to have increased to 1.4 million tons from 1.2 million tons in 2019, and exports were estimated to have increased to about 50,000 tons from 46,000 tons in 2019. Peat stocks were estimated to have decreased in 2020 owing to a wet peat-harvesting season causing a decrease in peat production in some parts of the country. Based on estimated world production for 2020, the world's leading peat producers were, in descending order of production, Finland, Germany, Belarus, Sweden, Ireland, and Latvia.

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PEAT

In other parts of the world, concerns about climate change prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's ability to act as a carbon sink. Ireland's peat production was expected to decrease over the coming years owing to its transition to alternative fuel sources. The country was aiming to have at least 80% of its fossil fuel sector employment transitioned to the renewable energy sector by 2025. Ireland planned to stop all peat harvesting by 2028, 2 years ahead of the previously announced schedule. In 2020, Finland continued to work toward its goal of becoming carbon neutral by 2035. To achieve this, peat production will be phased out in favor for other forms of noncarbon energy. Presently, about 40% of Finland's energy consumption is supplied by peat and other fossil fuels. Several European countries, including Belarus, Ireland, and Sweden, were planning or implementing peatland restoration projects to help combat greenhouse-gas emissions and restore wildlife habitats. These initiatives were expected to decrease peat production across Europe in the future.

World Mine Production and Reserves: Reserves for countries that reported by volume only and had insufficient data for conversion to tons were combined and included with "Other countries." Reserves for Estonia and Latvia were revised based on information from company reports.

	Mine production		Reserves[3]
	2019	2020[e]	
United States	456	430	150,000
Belarus	2,670	2,600	2,600,000
Canada	1,260	1,300	720,000
Estonia	890	900	59,000
Finland	11,800	10,000	6,000,000
Germany	4,200	4,000	([4])
Ireland	1,730	2,000	([4])
Latvia	2,200	1,900	220,000
Lithuania	500	500	210,000
Poland	870	700	([4])
Russia	909	800	1,000,000
Sweden	3,000	2,500	([4])
Ukraine	685	680	([4])
Other countries[e]	730	730	1,400,000
World total (rounded)	31,900	29,000	12,000,000

World Resources:[3] Peat is a renewable resource, continuing to accumulate on 60% of global peatlands. However, the volume of global peatlands has been decreasing at a rate of 0.05% annually owing to harvesting and land development. Many countries evaluate peat resources based on volume or area because the variations in densities and thickness of peat deposits make it difficult to estimate tonnage. Volume data have been converted using the average bulk density of peat produced in each of those countries. More than 50% of the U.S. peat resources are located in undisturbed areas of Alaska.

Substitutes: Natural organic materials, such as composted yard waste and coir (coconut fiber), compete with peat in horticultural applications. Shredded paper and straw are used to hold moisture for some grass-seeding applications. The superior water-holding capacity and physiochemical properties of peat limit substitution alternatives in most applications.

[e]Estimated.

[1]Defined as production + imports – exports + adjustments for industry stock changes.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Included with "Other countries."

PERLITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, the quantity of domestic processed crude perlite sold and used was estimated to be 440,000 tons with a value of $28 million. Crude ore production was from eight mines operated by six companies in five Western States. New Mexico and Oregon continued to be the leading producing States. Processed crude perlite was expanded at 57 plants in 28 States. Domestic apparent consumption was estimated to be 610,000 tons. The applications for expanded perlite were building construction products, 53%; fillers, 16%; horticultural aggregate, 16%; filter aid, 12%; and other, 3%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Mine production, crude ore	521	570	494	526	520
Sold and used, processed crude perlite	437	479	444	416	440
Imports for consumption[1]	199	171	204	183	190
Exports[1]	16	18	16	19	22
Consumption, apparent[2]	620	632	632	580	610
Price, average value, free on board mine, dollars per ton	65	73	72	64	64
Employment, mine and mill, number	135	139	130	140	140
Net import reliance[3] as a percentage of apparent consumption	30	24	30	28	28

Recycling: Not available.

Import Sources (2016–19): Greece, 90%; China, 7%; Mexico, 2%; and Turkey, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Vermiculite, perlite and chlorites, unexpanded	2530.10.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Perlite is a siliceous volcanic glass that expands up to 20 times its original volume when rapidly heated. In horticultural uses, expanded perlite is used to provide moisture retention and aeration without compaction when added to soil. Owing primarily to cost, some commercial greenhouse growers in the United States have recently switched to a wood fiber material over perlite. Perlite, however, remained a preferred soil amendment for segments of greenhouse growers because it does not degrade or compact over lengthy growing times and is inert. Construction applications for expanded perlite are numerous because it is lightweight, fire resistant, and an excellent insulator. Novel and small markets for perlite have increased during the past 10 years; cosmetics, environmental remediation, and personal care products have become increasing markets for perlite. A major producer with operations in Arizona and New Mexico acquired another producer with a mine in Oregon during the year. Project planning progressed at a perlite deposit in Nevada that could be developed as a potential supplier of crude perlite ore for industrial and household applications.

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PERLITE

Domestic perlite mining generally takes place in remote areas, and its environmental impact is not severe. The mineral fines, overburden, and reject ore produced during ore mining and processing are used to reclaim the mined-out areas, and, therefore, little waste remains. Airborne dust is captured by baghouses, and virtually no runoff contributes to water pollution.

Despite economic disruptions owing to the global COVID-19 pandemic, the value of total construction put in place in the United States increased by about 4% during the first 8 months of 2020 compared with that of the same period in 2019, indicating a similar change in consumption of perlite. Construction products remained the largest domestic market for perlite. Increased interest in home gardening may also correspond to increased consumption of horticultural-grade perlite.

Based on estimated world production for 2020, the world's leading producers were, in descending order of production, China, Greece, Turkey, and the United States, with about 38%, 21%, 19%, and 15%, respectively, of world production. Although China was the leading producer, most of its perlite production was thought to be consumed internally. Greece and Turkey remained the leading exporters of perlite.

World Perlite Production and Reserves: Reserves for Iran were revised based on industry information.

	Production		Reserves[4]
	2019	2020[e]	
United States	[5]526	[5]520	50,000
Argentina	19	19	NA
China	1,300	1,300	NA
Greece	719	700	120,000
Hungary	71	70	49,000
Iran	72	70	73,000
Mexico	20	20	NA
New Zealand	17	17	NA
Slovakia	40	40	NA
Turkey	650	640	57,000
Other countries	29	29	NA
World total (rounded)	3,460	3,400	NA

World Resources:[4] Perlite occurrences in Arizona, Idaho, Nevada, New Mexico, and Oregon are thought to contain large resources. Significant deposits have been reported in China, Greece, Hungary, and Turkey, and a few other countries. Insufficient information is available to make reliable estimates of resources in many perlite-producing countries.

Substitutes: In construction applications, diatomite, expanded clay and shale, pumice, and slag can be substituted for perlite. For horticultural uses, vermiculite, coco coir, wood pulp, and pumice are alternative soil additives and are sometimes used in conjunction with perlite.

[e]Estimated. NA Not available.

[1]Exports and imports were estimated by the U.S. Geological Survey from U.S. Census Bureau combined data for vermiculite, perlite, and chlorites, unexpanded.

[2]Defined as sold or used processed perlite + imports – exports.

[3]Defined as imports − exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Mine production of crude ore.

PHOSPHATE ROCK

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, phosphate rock ore was mined by five firms at 10 mines in four States and processed into an estimated 24 million tons of marketable product, valued at $1.7 billion, free on board (f.o.b.) mine. Florida and North Carolina accounted for more than 75% of total domestic output; the remainder was produced in Idaho and Utah. Marketable product refers to beneficiated phosphate rock with phosphorus pentoxide (P_2O_5) content suitable for phosphoric acid or elemental phosphorus production. More than 95% of the phosphate rock mined in the United States was used to manufacture wet-process phosphoric acid and superphosphoric acid, which were used as intermediate feedstocks in the manufacture of granular and liquid ammonium phosphate fertilizers and animal feed supplements. Approximately 50% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium phosphate (DAP) and monoammonium phosphate (MAP) fertilizer, and merchant-grade phosphoric acid. The balance of the phosphate rock mined was for the manufacture of elemental phosphorus, which was used to produce phosphorus compounds for industrial applications, primarily glyphosate herbicide.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, marketable	27,100	27,900	25,800	23,300	24,000
Sold or used by producers	26,700	26,300	23,300	23,400	24,000
Imports for consumption	1,590	2,470	2,770	2,140	2,300
Consumption, apparent[1]	28,200	28,800	26,000	25,500	26,000
Price, average value, f.o.b. mine,[2] dollars per ton	76.90	73.67	70.77	67.98	70.00
Stocks, producer, yearend	7,450	8,440	10,600	9,940	9,500
Employment, mine and beneficiation plant, number[e]	2,000	2,000	2,000	2,000	2,000
Net import reliance[3] as a percentage of apparent consumption	4	5	2	11	10

Recycling: None.

Import Sources (2016–19): Peru, 85%; Morocco, 15%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Natural calcium phosphates:		
Unground	2510.10.0000	Free.
Ground	2510.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The COVID-19 pandemic did not have a major effect on the domestic phosphate rock market in 2020. The fertilizer industry and related agricultural businesses were considered essential industries in the United States and most other countries. U.S. consumption and production of phosphate rock were estimated to have increased slightly in 2020, owing to a slight increase in phosphoric acid and combined DAP and MAP production.

The U.S. Department of the Interior, Bureau of Land Management, and the U.S. Department of Agriculture, Forest Service, approved an expansion to the largest phosphate rock mine in Idaho. The expansion will allow the operating company to continue mining at the site for about 10 years, after which it will shift mining to a new mine that is under development in the same area.

A new phosphate rock mine began operation near Spanish Forks, UT, in July 2020. The operating company will market its phosphate rock for direct application to soil for organic farming. Production initially was to be about 5,000 tons per year, eventually increasing to 48,000 tons per year after 5 years. The mine site was developed in the early 1980s by another company, but the project was cancelled after 2 years.

According to industry analysts, the rated capacity of global phosphate rock mines was projected to increase to 261 million tons in 2024 from 238 million tons in 2020, including production of marketable phosphate rock in China of between 80 million and 85 million tons per year, compared with official production statistics of 90 million to 95 million tons per year that included some crude ore production. Most of the increases in production capacity were planned for Africa and the Middle East, where major expansion projects were in progress in Algeria, Egypt, Guinea Bissau, Morocco, Senegal, and Togo.

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PHOSPHATE ROCK

World consumption of P_2O_5 contained in fertilizer and industrial uses was projected to increase to 49 million tons in 2024 from 47 million tons in 2020. Asia and South America are projected to be the leading regions of growth. U.S. consumption of contained P_2O_5 has remained steady at about 4 million tons per year over the past decade.

World Mine Production and Reserves: Reserves for Australia, Brazil, Israel, and Jordan were revised based on company or Government reports. Reserves for Egypt were revised based on information from an independent research organization.

	Mine production		Reserves[4]
	2019	2020[e]	
United States	23,300	24,000	1,000,000
Algeria	1,300	1,300	2,200,000
Australia	2,700	2,700	[5]1,100,000
Brazil	4,700	5,500	1,600,000
China[6]	95,000	90,000	3,200,000
Egypt	5,000	5,000	2,800,000
Finland	995	1,000	1,000,000
India	1,480	1,500	46,000
Israel	2,810	2,800	57,000
Jordan	9,220	9,200	800,000
Kazakhstan	1,500	1,500	260,000
Mexico	558	600	30,000
Morocco and Western Sahara	35,500	37,000	50,000,000
Peru	4,000	4,000	210,000
Russia	13,100	13,000	600,000
Saudi Arabia	6,500	6,500	1,400,000
Senegal	3,420	3,500	50,000
South Africa	2,100	2,100	1,400,000
Syria	2,000	360	1,800,000
Togo	800	800	30,000
Tunisia	4,110	4,000	100,000
Uzbekistan	900	900	100,000
Vietnam	4,650	4,700	30,000
Other countries	1,140	1,100	840,000
World total (rounded)	227,000	223,000	71,000,000

World Resources:[4] Some world reserves were reported only in terms of ore tonnage and grade. Phosphate rock resources occur principally as sedimentary marine phosphorites. The largest sedimentary deposits are found in northern Africa, China, the Middle East, and the United States. Significant igneous occurrences are found in Brazil, Canada, Finland, Russia, and South Africa. Large phosphate resources have been identified on the continental shelves and on seamounts in the Atlantic Ocean and the Pacific Ocean. World resources of phosphate rock are more than 300 billion tons. There are no imminent shortages of phosphate rock.

Substitutes: There are no substitutes for phosphorus in agriculture.

[e]Estimated.

[1]Defined as phosphate rock sold or used by producers + imports. U.S. producers stopped exporting phosphate rock in 2003.

[2]Marketable phosphate rock, weighted value, all grades.

[3]Defined as imports + adjustments for industry stock changes.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]For Australia, Joint Ore Reserves Committee-compliant reserves were 113 million tons.

[6]Production data for large mines only, as reported by the National Bureau of Statistics of China.

PLATINUM-GROUP METALS

(Palladium, platinum, iridium, osmium, rhodium, and ruthenium)
(Data in kilograms of platinum-group-metal content unless otherwise noted)

Domestic Production and Use: One company in Montana produced approximately 18,000 kilograms of platinum-group metals (PGMs) with an estimated value of about $1.1 billion. Small quantities of primary PGMs also were recovered as byproducts of copper-nickel mining in Michigan; however, this material was sold to foreign companies for refining. The leading domestic use for PGMs was in catalytic converters to decrease harmful emissions from automobiles. PGMs are also used in catalysts for bulk-chemical production and petroleum refining; dental and medical devices; electronic applications, such as in computer hard disks, hybridized integrated circuits, and multilayer ceramic capacitors; glass manufacturing; investment; jewelry; and laboratory equipment.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Mine production:[1]					
Palladium	13,100	14,000	14,300	14,300	14,000
Platinum	3,890	4,000	4,160	4,150	4,000
Imports for consumption:[2]					
Palladium	80,400	86,000	92,900	84,300	78,000
Platinum	42,300	53,200	58,500	42,300	60,000
PGM waste and scrap	154,000	354,000	40,700	54,300	130,000
Iridium	1,300	1,420	1,020	875	1,300
Osmium	27	856	25	([3])	—
Rhodium	10,700	11,600	14,500	15,000	20,000
Ruthenium	8,410	14,600	17,900	11,200	11,000
Exports:[4]					
Palladium	17,500	52,300	52,900	55,500	36,000
Platinum	14,000	16,700	18,900	17,400	18,000
PGM waste and scrap	48,100	37,200	31,700	20,800	29,000
Rhodium	794	844	2,010	1,210	1,300
Other PGMs	736	939	2,500	1,330	1,400
Consumption, apparent:[5, 6]					
Palladium	118,000	89,700	96,200	96,100	110,000
Platinum	43,200	51,600	53,700	37,100	53,000
Price, dollars per troy ounce:[7]					
Palladium	617.39	874.30	1,036.43	1,544.31	2,100.00
Platinum	989.52	951.23	882.66	866.94	850.00
Iridium	586.90	908.35	1,293.27	1,485.80	1,600.00
Rhodium	696.84	1,112.59	2,225.30	3,918.78	9,200.00
Ruthenium	42.00	76.86	244.41	262.59	260.00
Employment, mine, number[1]	1,432	1,513	1,628	1,789	1,600
Net import reliance[6, 8] as a percentage of apparent consumption:					
Palladium	53	38	42	30	40
Platinum	66	71	74	67	79

Recycling: About 102,000 kilograms of palladium and platinum was recovered globally from new and old scrap in 2020, including about 57,000 kilograms recovered from automobile catalytic converters in the United States.

Import Sources (2016–19): Palladium: Russia, 38%; South Africa, 33%; Germany, 8%; United Kingdom, 5%; and other, 16%. Platinum: South Africa, 43%; Germany, 21%; Italy, 7%; Switzerland, 6%; and other, 23%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free. See footnotes for specific Harmonized Tariff Schedule of the United States codes.

Depletion Allowance: 22% (domestic), 14% (foreign).

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PLATINUM-GROUP METALS

Government Stockpile:[9]

Material	Inventory as of 9–30–20	FY 2020 Potential acquisitions	FY 2020 Potential disposals	FY 2021 Potential acquisitions	FY 2021 Potential disposals
Iridium	15	—	15	—	15
Platinum	261	—	261	—	261

Events, Trends, and Issues: Progress continued at a domestic mine expansion project; full production from the project was expected by late 2021. Production of PGMs in South Africa, the world's leading supplier of mined material, decreased by 11% compared with that of 2019 owing to temporary lockdowns related to the COVID-19 pandemic as well as increased labor costs, increased costs for electricity, an unreliable supply of electricity, and challenges related to deep-level mining.

The estimated annual average prices of iridium, palladium, rhodium, and ruthenium increased by 5%, 38%, 136%, and slightly, respectively, compared with those of 2019. The estimated average annual price of platinum decreased slightly compared with that of 2019, continuing a 5-year trend of declining prices. The price of palladium remained higher than that of platinum in 2020, with palladium prices exceeding a previous high of $1,977.00 in December 2019.

World Mine Production and Reserves:

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2019	2020[e]	2019	2020[e]	
United States	14,300	14,000	4,150	4,000	900,000
Canada	20,000	20,000	7,800	7,800	310,000
Russia	98,000	91,000	24,000	21,000	3,900,000
South Africa	80,700	70,000	133,000	120,000	63,000,000
Zimbabwe	11,400	12,000	13,500	14,000	1,200,000
Other countries	2,420	2,600	3,730	3,800	NA
World total (rounded)	227,000	210,000	186,000	170,000	69,000,000

World Resources:[10] World resources of PGMs are estimated to total more than 100 million kilograms. The largest reserves are in the Bushveld Complex in South Africa.

Substitutes: Palladium has been substituted for platinum in most gasoline-engine catalytic converters because of the historically lower price for palladium relative to that of platinum. About 25% of palladium can routinely be substituted for platinum in diesel catalytic converters; the proportion can be as much as 50% in some applications. For some industrial end uses, one PGM can substitute for another, but with losses in efficiency.

[e]Estimated. NA Not available. — Zero.

[1]Estimated from published sources.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 7110.11.0010, 7110.11.0020, 7110.11.0050, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0010, 7110.41.0020, 7110.41.0030, 7110.49.0010, 7112.92.0000, and 7118.90.0020.

[3]Less than ½ unit.

[4]Includes data for the following Schedule B codes: 7110.11.0000, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0000, 7110.49.0000, and 7112.92.0000.

[5]Defined as primary production + secondary production + imports – exports.

[6]Excludes imports and (or) exports of waste and scrap.

[7]Engelhard Corp. unfabricated metal.

[8]Defined as imports – exports.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

POTASH

(Data in thousand metric tons of K_2O equivalent unless otherwise noted)

Domestic Production and Use: In 2020, the estimated sales value of marketable potash, free on board (f.o.b.) mine, was $430 million, which was 10% higher than that in 2019. Potash denotes a variety of mined and manufactured salts that contain the element potassium in water-soluble form. In agriculture, the term potash refers to potassic fertilizers, which are potassium chloride (KCl), potassium sulfate or sulfate of potash (SOP), and potassium magnesium sulfate (SOPM) or langbeinite. Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride for fertilizer use. The majority of U.S. production was from southeastern New Mexico, where two companies operated two underground mines and one deep-well solution mine. Sylvinite and langbeinite ores in New Mexico were beneficiated by flotation, dissolution-recrystallization, heavy-media separation, solar evaporation, and (or) combinations of these processes, and accounted for about 50% of total U.S. producer sales. In Utah, two companies operated three facilities. One company extracted underground sylvinite ore by deep-well solution mining. Solar evaporation crystallized the sylvinite ore from the brine solution, and a flotation process separated the MOP from byproduct sodium chloride. The firm also processed subsurface brines by solar evaporation and flotation to produce MOP at its other facility. Another company processed brine from the Great Salt Lake by solar evaporation to produce SOP and other byproducts.

The fertilizer industry used about 85% of U.S. potash sales, and the remainder was used for chemical and industrial applications. About 65% of the potash produced was SOPM and SOP, which are required to fertilize certain chloride-sensitive crops. The remaining 35% of production was MOP and was used for agricultural and chemical applications.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, marketable[1]	510	480	520	510	470
Sales by producers, marketable[1]	600	490	520	480	520
Imports for consumption	4,550	5,870	5,710	4,940	5,100
Exports	96	128	105	145	140
Consumption, apparent[1, 2]	5,100	6,200	6,100	5,300	5,500
Price, average, all products, f.o.b. mine,[3] dollars per ton of K_2O	680	770	750	820	830
Price, average, muriate, f.o.b. mine, dollars per ton of K_2O	350	410	440	480	500
Employment, mine and mill, number	1,150	900	900	900	900
Net import reliance[4] as a percentage of apparent consumption	88	92	92	90	90

Recycling: None.

Import Sources (2016–19): Canada, 83%; Belarus and Russia, 6% each; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Potassium nitrate	2834.21.0000	Free.
Potassium chloride	3104.20.0000	Free.
Potassium sulfate	3104.30.0000	Free.
Potassic fertilizers, other	3104.90.0100	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The COVID-19 pandemic had a minimal effect on the domestic potash market. Potash is an essential plant nutrient and fertilizers were designated as essential products in most countries. Financial assistance was provided to farmers and agribusinesses in the United States and other countries. Domestic potash consumption was estimated to have increased by about 4% from that of 2019, owing to fertilizer application rates recovering after unfavorable weather conditions in 2019 affected the spring planting season. Industrial potash use was lower, primarily for oil- and gas-well-drilling additives because those industries were affected severely by the economic downturn caused by the COVID-19 pandemic. Domestic potash production was lower because of higher than average inventories carried over from 2019 and lower production in the first half because of lower evaporation rates at some solar evaporation facilities.

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POTASH

The company that was developing the Sevier Playa SOP project, which is about 225 kilometers southwest of Salt Lake City, UT, was unable to secure financing because of economic conditions caused by the COVID-19 pandemic. The project, which had planned to begin construction in 2020, was expected to be put on hold. Production was scheduled to begin in 2022 at 30,000 tons per year of SOP with rampup to full capacity of 372,000 tons per year of SOP in 2025.

World potash production increased, owing to increased output in Canada and Russia. World potash consumption was estimated to have been about the same as in 2019 at about 41 million tons of K_2O. Asia and South America were the leading consuming regions. World consumption of potash was projected to increase slightly in 2021, with Asia and South America as the leading regions for growth.

World potash capacity was projected to increase to 69 million tons in 2024 from 64 million tons in 2020. Most of the increase would be MOP from new mines and expansion projects in Belarus, Canada, and Russia. Other projects that were ongoing included new SOP mines in Australia, China, and Eritrea and new MOP mines in Brazil, Ethiopia, and Spain. The startup for some of the other projects was likely to be delayed to beyond 2025 because of unfavorable economic conditions.

World Mine Production and Reserves: Reserves for Brazil and Canada were revised with information reported by the producing companies. Reserves for Laos were revised with official Government data.

	Mine production		Reserves[5]	
	2019	2020[e]	Recoverable ore	K_2O equivalent
United States[1]	510	470	970,000	220,000
Belarus	7,350	7,300	3,300,000	750,000
Brazil	247	250	10,000	2,300
Canada	12,300	14,000	4,500,000	1,100,000
Chile	840	900	NA	100,000
China	5,000	5,000	NA	350,000
Germany	3,000	3,000	NA	150,000
Israel	2,040	2,000	NA	[6]Large
Jordan	1,520	1,500	NA	[6]Large
Laos	400	400	500,000	75,000
Russia	7,340	7,600	NA	600,000
Spain	500	470	NA	68,000
Other countries	310	300	1,500,000	300,000
World total (rounded)	41,300	43,000	NA	>3,700,000

World Resources:[5] Estimated domestic potash resources total about 7 billion tons. Most of these lie at depths between 1,800 and 3,100 meters in a 3,110-square-kilometer area of Montana and North Dakota as an extension of the Williston Basin deposits in Manitoba and Saskatchewan, Canada. The Paradox Basin in Utah contains resources of about 2 billion tons, mostly at depths of more than 1,200 meters. The Holbrook Basin of Arizona contains resources of about 0.7 to 2.5 billion tons. A large potash resource lies about 2,100 meters under central Michigan and contains more than 75 million tons. Estimated world resources total about 250 billion tons.

Substitutes: No substitutes exist for potassium as an essential plant nutrient and as an essential nutritional requirement for animals and humans. Manure and glauconite (greensand) are low-potassium-content materials that can be profitably transported only short distances to crop fields.

[e]Estimated. NA Not available.

[1]Data are rounded to no more than two significant digits to avoid disclosing company proprietary data.

[2]Defined as sales + imports – exports.

[3]Includes MOP, SOP, and SOPM. Does not include other chemical compounds that contain potassium.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Israel and Jordan recover potash from the Dead Sea, which contains nearly 2 billion tons of potassium chloride.

PUMICE AND PUMICITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 480,000 tons with an estimated processed value of about $13 million, free on board (f.o.b.) plant. That represented decreases of 15% in quantity and 18% in value from the 2019 reported production of 565,000 tons valued at $15.9 million. Pumice and pumicite were mined in California, Idaho, Kansas, New Mexico, and Oregon. The porous, lightweight properties of pumice are well suited for its main uses. Mined pumice was used in the production of abrasives, concrete admixtures and aggregates, lightweight building blocks, horticultural purposes, and other uses, including absorbent, filtration, laundry stone washing, and road use.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, mine[1]	374	383	496	565	480
Imports for consumption	170	166	159	136	48
Exports[e]	10	12	11	11	7
Consumption, apparent[2]	534	537	644	690	520
Price, average value, f.o.b. mine or mill, dollars per ton	38	39	32	28	28
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	30	29	23	18	8

Recycling: Little to no known recycling.

Import Sources (2016–19): Greece, 93%; Iceland, 5%; and Mexico, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Pumice, crude or in irregular pieces, including crushed	2513.10.0010	Free.
Pumice, other	2513.10.0080	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced pumice and pumicite sold or used in 2020 was estimated to be 15% less than that in 2019. Owing to disruptions likely caused by the COVID-19 pandemic during the first 6 months of 2020, mine production decreased by approximately 15% compared with the same period of 2019. Imports and exports were estimated to have decreased substantially compared with those of 2019. Since 2015, apparent consumption of pumice and the quantity of pumice that was sold or used followed an upward trend until 2020. Almost all imported pumice originated from Greece in 2020 and primarily supplied markets in the eastern and gulf coast regions of the United States. Although the domestic mill price for pumice was approximately $28 per ton, the average imported value of pumice was approximately $98 per ton.

Pumice and pumicite are plentiful in the Western United States, but legal challenges and public land designations could limit access to known deposits. Pumice and pumicite production is sensitive to mining and transportation costs. Although unlikely in the short term, an increase in fuel prices would likely lead to increases in production costs, making imports and competing materials attractive substitutes for domestic products.

All known domestic pumice and pumicite mining in 2020 was accomplished through open pit methods, generally in remote areas, away from major population centers. Although the generation and disposal of reject fines in mining and milling may result in local dust issues at some operations, such environmental impacts are thought to be restricted to relatively small geographic areas.

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PUMICE AND PUMICITE

World production of pumice and related material was estimated to be 21 million tons in 2020, which was 7% more than that of 2019. Turkey, followed by Ethiopia, was the leading global producer of pumice and pumicite. Pumice is used more extensively as a building material outside the United States, which explained the large global production of pumice relative to that of the United States. In Europe, basic home construction uses stone and concrete as the preferred building materials. Prefabricated lightweight concrete walls, which may contain pumice as lightweight aggregate, are often produced and shipped to construction locations. Because of their cementitious properties, light weight, and strength, pumice and pumicite perform well in European-style construction.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2019	2020[e]	
United States[1]	565	480	Large in the United States.
Algeria[5]	900	900	Quantitative estimates of reserves for
Cameroon[5]	300	1,000	most countries are not available.
Chile[5]	800	800	
Ecuador[5]	800	600	
Ethiopia	2,400	2,400	
France[5]	280	300	
Greece[5]	1,020	1,000	
Guadeloupe	200	200	
Guatemala	570	600	
Indonesia	200	770	
Jordan	900	900	
New Zealand	220	220	
Saudi Arabia[5]	560	550	
Spain	200	200	
Syria[5]	200	200	
Tanzania	263	260	
Turkey	7,800	7,800	
Uganda	880	1,000	
Other countries[5]	640	640	
World total (rounded)	19,700	21,000	

World Resources:[4] The identified U.S. resources of pumice and pumicite, estimated to be more than 25 million tons, are concentrated in the Western States. The estimated total resources (identified and undiscovered) in the Western and Great Plains States are at least 250 million tons and may total more than 1 billion tons. Large resources of pumice and pumicite have been identified on all continents.

Substitutes: The costs of transportation determine the maximum economic distance pumice and pumicite can be shipped and still remain competitive with alternative materials. Competitive materials that may be substituted for pumice and pumicite include crushed aggregates, diatomite, expanded shale and clay, and vermiculite.

[e]Estimated.

[1]Quantity sold and used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes pozzolan and (or) volcanic tuff.

QUARTZ CRYSTAL (INDUSTRIAL)

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Industrial cultured quartz crystal is electronic-grade quartz crystal that is manufactured, not mined. In the past, cultured quartz crystal was primarily produced using lascas[1] as raw quartz feed material. Lascas mining and processing in Arkansas ended in 1997. In 2020, production of cultured quartz crystal was reported and evidence indicated that two companies produced cultured quartz crystal in the United States. However, production data was withheld in order to avoid disclosing company proprietary data. In addition to lascas, these companies may use cultured quartz crystal that has been rejected during the manufacturing process, owing to crystallographic imperfections, as feed material. The companies may use a mix of cultured quartz and imported lascas as feed material. In the past several years, cultured quartz crystal has been increasingly produced overseas, primarily in Asia. Electronic applications accounted for most industrial uses of quartz crystal; other uses included special optical applications.

Virtually all quartz crystal used for electronics was cultured, rather than natural, crystal. Electronic-grade quartz crystal is used to make frequency filters, frequency controls, and timers in electronic circuits employed for a wide range of products, such as communications equipment, computers, and many consumer goods, such as electronic games and television receivers.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Mine (lascas)	—	—	—	—	—
Cultured quartz crystal	W	W	W	W	W
Imports for consumption:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	6,280	6,760	16,100	54,600	95,000
Exports:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	60,500	55,300	43,400	40,900	42,000
Price, dollars per kilogram:					
As-grown cultured quartz	280	280	300	200	200
Lumbered quartz[2]	890	300	500	500	500
Net import reliance[3] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: An unspecified amount of rejected cultured quartz crystal was used as feed material for the production of cultured quartz crystal.

Import Sources (2016–19): Import statistics specific to lascas are not available because they are combined with other types of quartz. Cultured quartz crystal (piezoelectric quartz, unmounted): China, 76%; Japan, 11%; Switzerland and Russia, 2% each; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

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QUARTZ CRYSTAL (INDUSTRIAL)

Government Stockpile:[5] As of September 30, 2020, the National Defense Stockpile (NDS) contained 7,148 kilograms of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 kilograms to more than 10 kilograms. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal. No natural quartz crystal was sold from the NDS in 2020. Previously, the only individual crystals from the stockpile that were sold were those that weighed 10 kilograms or more and that could be used as seed material.

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Quartz crystal	7,148	—	—	—	—

Events, Trends, and Issues: Rising imports of piezoelectric quartz in the past several years are likely the result of increased demand for vibration sensors such as accelerometers, which are utilized in aerospace and automotive applications. Demand for cultured quartz crystal for frequency-control oscillators and frequency filters in a variety of electronic devices is expected to remain stable. Growth of the consumer electronics market, for products such as personal computers, electronic games, and tablet computers, is likely to continue to sustain global production of cultured quartz crystal.

World Mine Production and Reserves:[6] This information is unavailable, but the global reserves for lascas are thought to be large.

World Resources:[6] Limited resources of natural quartz crystal suitable for direct electronic or optical use are available throughout the world. World dependence on these resources will continue to decline because of the increased acceptance of cultured quartz crystal as an alternative material. Additionally, techniques using rejected cultured quartz crystal as feed material could mean a decreased dependence on lascas for growing cultured quartz.

Substitutes: Silicon is increasingly being used as a substitute for quartz crystal for frequency-control oscillators in electronic circuits. Other materials, such as aluminum orthophosphate (the very rare mineral berlinite), langasite, lithium niobate, and lithium tantalate, which have larger piezoelectric coupling constants, have been studied and used. The cost competitiveness of these materials, as opposed to cultured quartz crystal, is dependent on the type of application that the material is used for and the processing required.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Lascas is a nonelectronic-grade quartz used as a feedstock for growing cultured quartz crystal and for production of fused quartz.

[2]As-grown cultured quartz that has been processed by sawing and grinding.

[3]Defined as imports – exports.

[4]Deceased.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

RARE EARTHS[1]

[Data in metric tons of rare-earth-oxide (REO) equivalent content unless otherwise noted]

Domestic Production and Use: Rare earths were mined domestically in 2020. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined as a primary product at a mine in Mountain Pass, CA. Monazite, a phosphate mineral, was produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. The estimated value of rare-earth compounds and metals imported by the United States in 2020 was $110 million, a significant decrease from $160 million in 2019. The estimated distribution of rare earths by end use was as follows: catalysts, 75%; ceramics and glass, 6%; polishing, 5%; metallurgical applications and alloys, 4%; and other, 10%.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, bastnaesite and monazite concentrates[e]	—	—	14,000	28,000	38,000
Imports:[e, 2]					
Compounds	11,800	11,000	10,800	12,300	6,700
Metals:					
Ferrocerium, alloys	268	309	298	332	260
Rare-earth metals, scandium, and yttrium	404	524	526	627	380
Exports:[e, 2]					
Ores and compounds	590	1,740	17,900	28,200	38,000
Metals:					
Ferrocerium, alloys	943	982	1,250	1,290	630
Rare-earth metals, scandium, and yttrium	103	55	28	83	27
Consumption, apparent[3]	10,500	9,060	6,520	11,700	7,800
Price, average, dollars per kilogram:[4]					
Cerium oxide, 99.5% minimum	2	2	2	2	2
Dysprosium oxide, 99.5% minimum	198	187	179	239	258
Europium oxide, 99.99% minimum	74	77	53	35	31
Lanthanum oxide, 99.5% minimum	2	2	2	2	2
Mischmetal, 65% cerium, 35% lanthanum	5	6	6	6	5
Neodymium oxide, 99.5% minimum	40	50	50	45	47
Terbium oxide, 99.99% minimum	415	501	455	507	628
Employment, mine and mill, annual average, number	—	24	190	202	180
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	100	100	100	100	100
Mineral concentrates	XX	XX	E	E	E

Recycling: Limited quantities of rare earths are recovered from batteries, permanent magnets, and fluorescent lamps.

Import Sources (2016–19): Rare-earth compounds and metals: China, 80%; Estonia, 5%; Japan and Malaysia, 4% each; and other, 7%. Compounds and metals imported from Estonia, Japan, and Malaysia were derived from mineral concentrates and chemical intermediates produced in Australia, China, and elsewhere.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Rare-earth metals	2805.30.0000	5.0% ad val.
Cerium compounds	2846.10.0000	5.5% ad val.
Other rare-earth compounds:		
Oxides or chlorides	2846.90.2000	Free.
Carbonates	2846.90.8000	3.7% ad val.
Ferrocerium and other pyrophoric alloys	3606.90.3000	5.9% ad val.

Depletion Allowance: Monazite, 22% on thorium content and 14% on rare-earth content (domestic), 14% (foreign); bastnäsite and xenotime, 14% (domestic and foreign).

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RARE EARTHS

Government Stockpile:[7] In the addition to the materials listed below, the FY 2021 potential acquisitions include neodymium, 600 tons; praseodymium, 70 tons; and samarium-cobalt alloy, 50 tons.

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cerium	—	900	—	500	—
Dysprosium	0.2	—	—	20	—
Europium	20.9	—	—	—	—
Ferrodysprosium	0.5	—	—	—	—
Lanthanum	—	4,100	—	1,300	—
Rare-earth-magnet feedstock	—	100	—	100	—
Yttrium	25	—	—	600	—

Events, Trends, and Issues: Global mine production was estimated to have increased to 240,000 tons of rare-earth-oxide equivalent. According to China's Ministry of Industry and Information Technology, the mine production quota for 2020 was 140,000 tons with 120,850 tons allocated to light rare earths and 19,150 tons allocated to ion-adsorption clays.

World Mine Production and Reserves: Reserves for Brazil and the United States were revised based on information from Government and industry reports.

	Mine production		Reserves[8]
	2019	2020[e]	
United States	28,000	38,000	1,500,000
Australia	20,000	17,000	[9]4,100,000
Brazil	710	1,000	21,000,000
Burma	25,000	30,000	NA
Burundi	200	500	NA
Canada	—	—	830,000
China	[10]132,000	[10]140,000	44,000,000
Greenland	—	—	1,500,000
India	2,900	3,000	6,900,000
Madagascar	4,000	8,000	NA
Russia	2,700	2,700	12,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	1,900	2,000	NA
Vietnam	1,300	1,000	22,000,000
Other countries	66	100	310,000
World total (rounded)	220,000	240,000	120,000,000

World Resources:[8] Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other mineral commodities. In North America, measured and indicated resources of rare earths were estimated to include 2.7 million tons in the United States and more than 15 million tons in Canada.

Substitutes: Substitutes are available for many applications but generally are less effective.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable. — Zero.

[1]Data include lanthanides and yttrium but exclude most scandium. See also Scandium and Yttrium.

[2]REO equivalent or content of various materials were estimated. Source: U.S. Census Bureau.

[3]Defined as production + imports – exports.

[4]Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports.

[6]In 2018–2020, all domestic production of mineral concentrates was exported, and all compounds and metals consumed were assumed to be imported material.

[7]Gross weight. See Appendix B for definitions.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 2.8 million tons.

[10]Production quota; does not include undocumented production.

RHENIUM

(Data in kilograms of rhenium content unless otherwise noted)

Domestic Production and Use: During 2020, rhenium-containing products including ammonium perrhenate (APR), metal powder, and perrhenic acid were produced as byproducts from roasting molybdenum concentrates from porphyry copper-molybdenum deposits in Arizona and Montana. U.S. primary production was approximately 7,800 kilograms in 2020, a 6% decrease from the previous year. The United States continued to be a leading producer of secondary rhenium, recovering rhenium from nickel base superalloy scrap, spent oil-refining catalysts, and foundry revert. The major uses of rhenium were in superalloys used in high-temperature turbine engine components and in petroleum-reforming catalysts, representing an estimated 80% and 15%, respectively, of end uses. Bimetallic platinum-rhenium catalysts were used in petroleum reforming for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Rhenium improves the high-temperature (>1,000 °C) strength properties of some nickel-base superalloys. Rhenium alloys were used in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and other applications. The value of rhenium consumed in 2020 was about $35 million as measured by the value of imports of rhenium metal and APR.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production[1]	8,440	8,200	8,220	8,360	7,800
Imports for consumption[2]	31,900	34,500	39,400	44,300	24,000
Exports	NA	NA	NA	NA	NA
Consumption, apparent[3]	40,300	42,700	47,600	52,600	32,000
Price, average value, gross weight, dollars per kilogram:[4]					
Metal pellets, 99.99% pure	2,030	1,550	1,470	1,300	1,000
Ammonium perrhenate	2,510	1,530	1,410	1,300	1,100
Employment, number	Small	Small	Small	Small	Small
Net import reliance[5] as a percentage of apparent consumption	79	81	83	84	76

Recycling: Nickel-base superalloy scrap and scrapped turbine blades and vanes continued to be recycled hydrometallurgically to produce rhenium metal for use in new superalloy melts. The scrapped parts were also processed to generate engine revert—a high-quality, lower cost superalloy meltstock—by an increasing number of companies, mainly in the United States, Canada, Estonia, France, Germany, Japan, Poland, and Russia. Rhenium-containing catalysts were also recycled.

Import Sources (2016–19): Ammonium perrhenate: Kazakhstan, 23%; Germany, 18%; Canada, 16%; Poland, 14%; and other, 29%. Rhenium metal powder: Chile, 82%; Germany, 7%; Canada, 5%; Poland, 3%; and other, 3%. Total imports: Chile, 60%; Germany, 10%; Canada, 8%; Kazakhstan, 7%; and other, 15%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad val.
Rhenium (and other metals), waste and scrap	8112.92.0600	Free.
Rhenium, unwrought and powders	8112.92.5000	3% ad val.
Rhenium (and other metals), wrought	8112.99.9000	4% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2020, rhenium production in the United States decreased by 6% compared with that in 2019. A rhenium recovery facility in Utah was closed in 2019; however, the company announced the possibility of reopening the facility in the near future. During 2020, the United States continued to rely on imports for much of its supply of rhenium. Canada, Chile, Germany, and Kazakhstan supplied most of the imported rhenium. Imports of APR decreased by 16% in 2020 compared with the previous year. Imports of rhenium metal decreased by 57% in 2020 compared with the previous year. This large decrease in rhenium metal imports was attributed in part to lower consumption by the aerospace industry owing to travel lockdown measures in response to the COVID-19 pandemic and reduced production of airplanes. Additionally, mine production of rhenium-containing feedstocks was lower in 2020.

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RHENIUM

The United States and Germany continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Canada, Estonia, France, Japan, Poland, and Russia. According to industry sources, approximately 20 to 25 tons of rhenium was recycled worldwide in 2020. For the ninth year in a row, rhenium metal and catalytic-grade APR prices decreased. In 2020, catalytic-grade APR prices averaged $1,100 per kilogram, a 12% decrease from the annual average price in 2019. Rhenium metal pellet prices averaged $1,000 per kilogram in 2020, a 20% decrease from the annual average price in 2019.

There were no primary rhenium projects in 2020 that were expected to significantly contribute to rhenium availability in the near future. Continued low prices of rhenium as well as the global COVID-19 pandemic caused many rhenium recyclers as well as primary-rhenium production facilities to stop recycling or producing rhenium to focus on a more profitable market. The major aerospace companies were expected to continue testing superalloys that contain one-half the quantity of rhenium used in engine blades as currently designed, as well as testing rhenium-free alloys for other engine components.

World Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2019	2020[e]	
United States	8,360	7,800	400,000
Armenia	280	280	95,000
Canada	—	—	32,000
Chile[8]	30,000	30,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	500	1,000	190,000
Korea, Republic of	2,800	2,700	NA
Peru	—	—	45,000
Poland	8,340	8,300	NA
Russia	NA	NA	310,000
Uzbekistan	460	460	NA
World total (rounded)	53,200	53,000	2,400,000

World Resources:[7] Most rhenium occurs with molybdenum in porphyry copper deposits. Identified U.S. resources are estimated to be about 7 million kilograms. Rhenium also is associated with copper minerals in sedimentary deposits in Armenia, Kazakhstan, Poland, Russia, and Uzbekistan, where ore is processed for copper recovery and the rhenium-bearing residues are recovered at copper smelters.

Substitutes: Substitutes for rhenium in platinum-rhenium catalysts are being evaluated continually. Iridium and tin have achieved commercial success in one such application. Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium's share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects. Materials that can substitute for rhenium in various end uses are as follows: cobalt and tungsten for coatings on copper x-ray targets, rhodium and rhodium-iridium for high-temperature thermocouples, tungsten and platinum-ruthenium for coatings on electrical contacts, and tungsten and tantalum for electron emitters.

[e]Estimated. NA Not available. — Zero.

[1]Based on 80% recovery of estimated rhenium contained in molybdenum disulfide concentrates. Secondary rhenium production is not included.

[2]Does not include wrought forms or waste and scrap. The rhenium content of ammonium perrhenate is 69.42%.

[3]Defined as production + imports – exports.

[4]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate. Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports.

[6]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Estimated rhenium recovered from roaster residues from Belgium, Chile, Mexico, and Peru.

RUBIDIUM

(Data in metric tons of rubidium oxide unless otherwise noted)

Domestic Production and Use: In 2020, no rubidium was mined in the United States; however, occurrences of rubidium-bearing minerals are known in Alaska, Arizona, Idaho, Maine, South Dakota, and Utah. Rubidium is also associated with some evaporate mineral occurrences in other States. Rubidium is not a major constituent of any mineral. Rubidium concentrate is produced as a byproduct of pollucite (cesium) and lepidolite (lithium) mining and is imported from other countries for processing in the United States.

Applications for rubidium and its compounds include biomedical research, electronics, specialty glass, and pyrotechnics. Specialty glasses are the leading market for rubidium; rubidium carbonate is used to reduce electrical conductivity, which improves stability and durability in fiber optic telecommunications networks. Biomedical applications include rubidium salts used in antishock agents and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride, used as an antidepressant. Rubidium atoms are used in academic research, including the development of quantum-mechanics-based computing devices, a future application with potential for relatively high consumption of rubidium. Quantum computing research uses ultracold rubidium atoms in a variety of applications. Quantum computers, which have the ability to perform more complex computational tasks than traditional computers by calculating in two quantum states simultaneously, were expected to be in prototype phase within 10 years.

Rubidium's photoemissive properties make it useful for electrical-signal generators in motion-sensor devices, night-vision devices, photoelectric cells (solar panels), and photomultiplier tubes. Rubidium is used as an atomic resonance-frequency-reference oscillator for telecommunications network synchronization, playing a vital role in global positioning systems. Rubidium-rich feldspars are used in ceramic applications for spark plugs and electrical insulators because of their high dielectric constant. Rubidium hydroxide is used in fireworks to oxidize mixtures of other elements and produce violet hues. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 4 USNO rubidium fountain clocks.

Salient Statistics—United States: Consumption, export, and import data are not available. Some concentrate was imported to the United States for further processing. Industry information during the past decade suggests a domestic consumption rate of approximately 2,000 kilograms per year. The United States was 100% import reliant for rubidium minerals.

In 2020, one company offered 1-gram ampoules of 99.75%-grade rubidium (metal basis) for $89.00, a slight increase from $87.80 in 2019, and 100-gram ampoules of the same material for $1,608.00, a slight increase from $1,592.00 in 2019. The price for 1-gram ampoules of 99.8% rubidium formate hydrate (metal basis) was $34.70, unchanged from 2019.

In 2020, the prices for 10 grams of 99.8% (metal basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $50.60, $67.00, $56.80, $61.30, and $47.20, respectively. The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $49.50 for 50 milliliters and $80.80 for 100 milliliters, a 5% decrease, each, from those of 2019.

Recycling: None.

Import Sources (2016–19): No reliable data have been available to determine the source of rubidium ore imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of rubidium ore.

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RUBIDIUM

Tariff: Item	Number	Normal Trade Relations 12–31–20
Alkali metals, other	2805.19.9000	5.5% ad val.
Chlorides, other	2827.39.9000	3.7% ad val.
Bromides, other	2827.59.5100	3.6% ad val.
Iodides, other	2827.60.5100	4.2% ad val.
Sulfates, other	2833.29.5100	3.7% ad val.
Nitrates, other	2834.29.5100	3.5% ad val.
Carbonates, other	2836.99.5000	3.7% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic rubidium occurrences will remain uneconomic unless market conditions change, such as the development of new end uses or increased consumption for existing end uses, which in turn could lead to increased prices. No known human health issues are associated with exposure to naturally occurring rubidium, and its use has minimal environmental impact.

During 2020, no rubidium production was reported globally. Production of rubidium from all countries, excluding China, ceased within the past two decades. Production in Namibia ceased in the early 2000s, followed by the Tanco Mine in Canada shutting down and later being sold after a mine collapse in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018, and the Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019. Recent reports indicate that with current processing rates, the world's stockpiles of rubidium ore, excluding those in China, will be depleted by 2022.

The primary processing plant of rubidium compounds globally, located in Germany, has reportedly operated far below capacity for the past few years. A company completed an updated mineral resource estimate for the Karibib project in Namibia, reporting 8.9 million metric tons of measured and indicated resources containing 0.23% rubidium and 302 parts per million cesium. Located in the Karibib Pegmatite Belt, lithium would be the primary product, with cesium, potassium, and rubidium as potential byproducts.

World Mine Production and Reserves:[1] There were no official sources for rubidium production data in 2020. Lepidolite and pollucite, the principal rubidium-containing minerals in global rubidium reserves, can contain up to 3.5% and 1.5% rubidium oxide, respectively. Rubidium-bearing mineral resources are found in zoned pegmatites. Mineral resources exist globally, but extraction and concentration are mostly cost prohibitive. No reliable data are available to determine reserves for specific countries; however, Australia, Canada, China, Namibia, and Zimbabwe were thought to have reserves totaling less than 200,000 tons.

World Resources:[1] Significant rubidium-bearing pegmatite occurrences have been identified in Afghanistan, Australia, Canada, China, Denmark, Germany, Japan, Kazakhstan, Namibia, Peru, Russia, the United Kingdom, the United States, and Zambia. Minor quantities of rubidium are reported in brines in northern Chile and China and in evaporites in the United States (New Mexico and Utah), France, and Germany.

Substitutes: Rubidium and cesium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

SALT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Domestic production of salt was estimated to have decreased by 7% in 2020 to 39 million tons. The total value of salt sold or used was estimated to be about $2.4 billion. Twenty-six companies operated 63 plants in 16 States. The top producing States were, in alphabetical order, Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 95% of the salt in the United States in 2020. The estimated percentage of salt sold or used was, by type, rock salt, 43%; salt in brine, 40%; vacuum pan salt, 10%; and solar salt, 7%.

Highway deicing accounted for about 43% of total salt consumed. The chemical industry accounted for about 38% of total salt sales, with salt in brine accounting for 90% of the salt used for chemical feedstock. Chlorine and caustic soda manufacturers were the main consumers within the chemical industry. The remaining markets for salt were distributors, 9%; food processing, 4%; agricultural, 2%; and general industrial and primary water treatment, 1% each. The remaining 2% was other uses combined with exports.

Salient Statistics—United States:[1]	2016	2017	2018	2019	2020[e]
Production	41,700	39,600	[e]42,000	[e]42,000	39,000
Sold or used by producers	39,900	38,200	[e]41,000	[e]41,000	38,000
Imports for consumption	12,100	12,600	17,900	18,600	16,000
Exports	729	1,120	986	1,020	1,200
Consumption:					
Apparent[2]	51,300	49,700	[e]58,000	[e]58,000	53,000
Reported	47,800	45,500	[e]48,000	[e]49,000	43,000
Price, average value of bulk, pellets and packaged salt, f.o.b. mine and plant, dollars per ton:					
Vacuum and open pan salt	197.78	211.71	[e]220.00	[e]215.00	215.00
Solar salt	99.69	115.88	[e]120.00	[e]120.00	120.00
Rock salt	56.75	60.41	[e]58.00	[e]58.00	57.00
Salt in brine	8.68	9.49	[e]9.00	[e]9.00	9.00
Employment, mine and plant, number[e]	4,000	4,100	4,100	4,100	4,000
Net import reliance[3] as a percentage of apparent consumption	22	23	29	30	27

Recycling: None.

Import Sources (2016–19): Chile, 33%; Canada, 24%; Mexico, 13%; Egypt, 9%; and other, 21%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global COVID-19 pandemic affected production and consumption of salt throughout the world in 2020. The most significant impact was felt in the chloroalkali industry because international trade declined, but the entire salt sector was negatively affected to varying degrees. The chloralkali industry was also disrupted by severe weather events, mainly hurricanes, in the primary production areas of Louisiana and Texas.

The 2019–20 winter was slightly milder than average after several years of average or below average winter temperatures and more winter weather events than usual. The number of winter weather events including freezing rain, sleet, and snow is a better predictor of demand for rock salt than total snow fall. Several low snowfall or icing events will usually require more salt for highway deicing than a single large snowfall event. Rock salt production and imports in 2020 decreased compared with those of 2019 because demand from many local and State transportation departments decreased. Most local and State governments in regions that experienced a less intense winter season reportedly had remaining stockpiles and therefore less need to replenish supplies of rock salt for the winter of 2020–21.

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SALT

For the winter of 2020–21, the National Oceanic and Atmospheric Administration predicted a moderate to strong La Niña weather pattern. A strong La Niña historically favors an average to warmer temperature pattern, but a moderate La Niña favors a colder winter. Based on several factors, the forecasts slightly favored a wetter than normal winter. A warmer and drier pattern was predicted for the southern areas of the United States, but the northwestern and northern plains were more likely to have below average temperatures and elevated precipitation. Areas from the mid-Atlantic to New England were thought to have a better than average chance for warmer temperatures and average precipitation. These forecasts would indicate that demand for rock salt could increase in the Midwest and decrease in the northeastern United States from Maine through Virginia.

Demand for salt brine used in the chloralkali industry was expected to rebound in 2021 as demand for caustic soda increases globally, especially in Asia. Exports from Australia and especially India increased to meet the increasing demand for caustic soda in China, but tensions between China and both countries could affect trade.

World Production and Reserves:

	Mine production[e]		Reserves[4]
	2019	2020	
United States[1]	42,000	39,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	13,000	12,000	
Belarus	3,300	3,000	
Brazil	7,400	7,200	
Canada	11,000	10,000	
Chile	10,000	10,000	
China	59,000	60,000	
Djibouti	3,800	3,500	
France	5,600	5,500	
Germany	14,300	14,000	
India	29,000	28,000	
Iran	3,000	3,000	
Italy	4,200	4,000	
Mexico	9,000	9,000	
Netherlands	5,910	5,000	
Pakistan	3,700	3,000	
Poland	4,480	4,000	
Russia	6,700	6,000	
Spain	4,200	4,000	
Turkey	6,500	6,400	
United Kingdom	4,100	4,000	
Other countries	33,000	30,000	
World total (rounded)	283,000	270,000	

World Resources:[4] World continental resources of salt are vast, and the salt content in the oceans is nearly unlimited. Domestic resources of rock salt and salt from brine are primarily in Kansas, Louisiana, Michigan, New York, Ohio, and Texas. Saline lakes and solar evaporation salt facilities are in Arizona, California, Nevada, New Mexico, Oklahoma, and Utah. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

Substitutes: No economic substitutes or alternatives for salt exist in most applications. Calcium chloride and calcium magnesium acetate, hydrochloric acid, and potassium chloride can be substituted for salt in deicing, certain chemical processes, and food flavoring, but at a higher cost.

[e]Estimated.

[1]Excludes production from Puerto Rico.

[2]Defined as sold or used by producers + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SAND AND GRAVEL (CONSTRUCTION)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2020, 960 million tons of construction sand and gravel valued at $9.2 billion was produced by an estimated 3,870 companies operating 6,800 pits and 340 sales and distribution yards in 50 States. Leading producing States were, in order of decreasing tonnage, California, Texas, Arizona, Minnesota, Michigan, Utah, Ohio, Washington, Colorado, and New York, which together accounted for about 53% of total output. It is estimated that about 46% of construction sand and gravel was used as portland cement concrete aggregates, 21% for road base and coverings and road stabilization, 13% for construction fill, 12% for asphaltic concrete aggregate and for other bituminous mixtures, and 4% for other miscellaneous uses. The remaining 4% was used for concrete products, filtration, golf course maintenance, plaster and gunite sands, railroad ballast, road stabilization, roofing granules, and snow and ice control.

The estimated output of construction sand and gravel in the United States shipped for consumption in the first 9 months of 2020 was 719 million tons, a slight decrease compared with that of the same period of 2019. Third quarter shipments for consumption decreased by 4% compared with those of the same period of 2019. Additional production information by quarter for each State, geographic region, and the United States is published by the U.S. Geological Survey in its quarterly Mineral Industry Surveys for crushed stone and sand and gravel.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production	887	880	937	962	960
Imports for consumption	3	7	6	5	5
Exports	(2)	(2)	(2)	(2)	(2)
Consumption, apparent[3]	891	886	943	967	965
Price, average value, dollars per metric ton	8.41	8.83	9.14	9.32	9.59
Employment, mine and mill, number[4]	35,300	36,500	38,600	39,600	36,300
Net import reliance[5] as a percentage of apparent consumption	(2)	1	1	1	1

Import Sources (2016–19): Canada, 95%; Mexico, 3%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Sand, other	2505.90.0000	Free.
Pebbles and gravel	2517.10.0015	Free.

Depletion Allowance: Common varieties, 5% (domestic and foreign).

Government Stockpile: None.

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SAND AND GRAVEL (CONSTRUCTION)

Events, Trends, and Issues: Construction sand and gravel production was about 960 million tons in 2020, a slight decrease compared with that of 2019. Apparent consumption also decreased slightly to 965 million tons. Demand for construction sand and gravel decreased in 2020 because of measures instituted to mitigate the spread of the global COVID-19 pandemic that caused disruptions in the mining and construction industries. Usually commercial and heavy-industrial construction activity, infrastructure funding, new single-family housing unit starts, and weather affect growth in sand and gravel production and consumption. Long-term increases in construction aggregates demand will be influenced by activity in the public and private construction sectors, as well as by construction work related to security measures being implemented around the Nation. The underlying factors that would support a rise in prices of construction sand and gravel are expected to be present in 2021, especially in and near metropolitan areas.

The construction sand and gravel industry remained concerned with environmental, health, permitting, safety, and zoning regulations. Movement of sand and gravel operations away from densely populated regions was expected to continue where regulations and local sentiment discouraged them. Resultant regional shortages of construction sand and gravel would result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2019	2020[e]	
United States	962	960	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources:[6] Sand and gravel resources are plentiful throughout the world. However, because of environmental regulations, geographic distribution, and quality requirements for some uses, sand and gravel extraction is uneconomical in some cases. The most important commercial sources of sand and gravel have been glacial deposits, river channels, and river flood plains. Use of offshore deposits in the United States is mostly restricted to beach erosion control and replenishment. Other countries routinely mine offshore deposits of aggregates for onshore construction projects.

Substitutes: Crushed stone, the other major construction aggregate, is often substituted for natural sand and gravel, especially in more densely populated areas of the Eastern United States. Crushed stone remains the dominant choice for construction aggregate use. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2020.

[e]Estimated. NA Not available.

[1]See also Sand and Gravel (Industrial) and Stone (Crushed).

[2]Less than ½ unit.

[3]Defined as production + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their sand and gravel production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

SAND AND GRAVEL (INDUSTRIAL)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, industrial sand and gravel valued at about $3.2 billion was produced by about 180 companies from about 280 operations in 34 States. The value of production of industrial sand and gravel in 2020 decreased by 40% compared with that of the previous year, owing primarily to reduced demand for hydraulic-fracturing sand and metallurgical uses. Demand declined as a result of restrictions put in place in response to the global COVID-19 pandemic coupled with ongoing weak demand from the oil and gas sector. Leading producing States were Texas, Wisconsin, Illinois, Missouri, Minnesota, Oklahoma, Mississippi, North Carolina, Louisiana, and Iowa, in descending order of tonnage produced. Combined production from these States accounted for about 81% of total domestic sales and use. About 58% of the U.S. tonnage was used as hydraulic-fracturing sand and well-packing and cementing sand; as glassmaking sand and as other whole-grain silica, 12% each; as foundry sand, 4%; as ceramics, whole-grain fillers for building products, and recreational sand, 3% each; and as other ground silica, 2%. Abrasives, chemicals, fillers, filtration sand, metallurgical flux, roofing granules, silica gravel, and traction sand, combined, accounted for the remaining 3% of industrial sand and gravel end uses.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Sold or used	79,400	103,000	123,000	114,000	71,000
Imports for consumption	281	366	392	389	380
Exports	2,780	4,680	6,550	5,620	3,700
Consumption, apparent[2]	76,900	98,700	117,000	109,000	68,000
Price, average value, dollars per ton	35.40	52.00	56.40	47.30	45.00
Employment, quarry and mill, number[e]	3,500	4,000	4,000	3,500	2,000
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Some foundry sand is recycled, and recycled cullet (pieces of glass) represents a significant proportion of reused silica. About 34% of glass containers are recycled.

Import Sources (2016–19): Canada, 85%; Taiwan and Vietnam, 3% each; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Sand containing 95% or more silica and not more than 0.6% iron oxide	2505.10.1000	Free.

Depletion Allowance: Industrial sand or pebbles, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of industrial sand and gravel was estimated to be 68 million tons in 2020, a 38% decrease from that of the previous year. The primary causes of the decline were decreased natural gas and petroleum well drilling in North America and oil well completion activity. These decreases were exacerbated by COVID-19 pandemic restrictions, which resulted in a significant decline in consumption of petroleum products, which in turn prompted a decrease in demand for hydraulic-fracturing sand in 2020 compared with that of the previous year. Imports of industrial sand and gravel in 2020 were about 380,000 tons—slightly less than those of 2019. Imports of silica are generally of two types—small shipments of very high-purity silica or a few large shipments of lower grade silica shipped only under special circumstances (for example, very low freight rates). The United States remained a net exporter of industrial sand and gravel, although U.S. exports of industrial sand and gravel decreased by 34% in 2020 compared with those of 2019, also a result of the global pandemic.

The United States was the world's leading producer and consumer of industrial sand and gravel based on estimated world production figures. It is difficult to collect definitive data on industrial sand and gravel (sometimes also referred to as silica sand and gravel) production in most nations because of the wide range of terminology and specifications used by different countries. The United States remained a major exporter of industrial sand and gravel, shipping it to almost every region of the world. High global demand for U.S. industrial sand and gravel can be attributed to the high quality and advanced processing techniques used in the United States for many grades of industrial sand and gravel, meeting specifications for virtually any use.

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SAND AND GRAVEL (INDUSTRIAL)

The duration and outcome of the COVID-19 pandemic remains uncertain, but it is likely that the performance of the industrial sand and gravel industry will continue to be negatively affected, although natural gas and petroleum well drilling activity began to recover in the latter part of the year, indicating that demand for hydraulic-fracturing sand may increase also. The effects of the pandemic were felt throughout the industry with employment declining in the industry and several companies filing for Chapter 11 bankruptcy protection during the year.

Additionally, the industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2020, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration (OSHA) finalized regulations to further restrict exposure to crystalline silica at quarry sites and in other industries that use materials containing it. Phased implementation of the new regulations was scheduled to take effect through 2021, affecting various industries that use materials containing silica. Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations, and logistical issues, including ongoing development and permitting of operations producing hydraulic-fracturing sand. Natural gas and petroleum operations that use hydraulic fracturing may also undergo increased scrutiny. These factors may result in future sand and gravel operations being located farther from high-population centers.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2019	2020[e]	
United States	114,000	71,000	Large. Industrial sand and gravel deposits are widespread.
Australia	3,000	2,900	
Bulgaria	7,650	7,300	
Canada	2,800	2,700	
France	9,310	8,800	
Germany	7,500	7,100	
India	11,900	11,000	
Indonesia	5,540	2,600	
Italy	14,000	13,000	
Japan	2,270	2,200	
Korea, Republic of	4,250	1,300	
Malaysia	10,000	9,500	
Mexico	2,360	2,300	
Netherlands	54,000	51,000	
New Zealand	1,620	1,500	
Poland	5,110	4,800	
South Africa	2,300	1,900	
Spain	35,500	34,000	
Turkey	9,100	8,600	
United Kingdom	4,000	3,800	
Other countries	18,900	18,000	
World total (rounded)	325,000	265,000	

World Resources:[5] Sand and gravel resources of the world are large. However, because of their geographic distribution, environmental restrictions, and quality requirements for some uses, extraction of these resources is sometimes uneconomic. Quartz-rich sand and sandstone, the main sources of industrial silica sand, occur throughout the world.

Substitutes: Alternative materials that can be used for glassmaking and for foundry and molding sands are chromite, olivine, staurolite, and zircon sands. Although costlier and mostly used in deeper wells, alternative materials that can be used as proppants are sintered bauxite and kaolin-based ceramic proppants.

[e]Estimated. E Net exporter.

[1]See also Sand and Gravel (Construction).

[2]Defined as production (sold or used) + imports – exports.

[3]Defined as imports – exports.

[4]Deceased.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

SCANDIUM[1]

(Data in metric tons of scandium oxide equivalent unless otherwise noted)

Domestic Production and Use: Domestically, scandium was neither mined nor recovered from process streams or mine tailings in 2020. Previously, scandium was produced domestically primarily from the scandium-yttrium silicate mineral thortveitite and from byproduct leach solutions from uranium operations. Limited capacity to produce ingot and distilled scandium metal existed at facilities in Ames, IA; Tolleson, AZ; and Urbana, IL. The principal uses for scandium in 2020 were in aluminum-scandium alloys and solid oxide fuel cells (SOFCs). Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Price, yearend:					
Compounds, dollars per gram:					
Acetate, 99.9% purity, 5-gram lot size[2]	44	44	44	45	45
Chloride, 99.9% purity, 5-gram lot size[2]	126	124	125	129	133
Fluoride, 99.9% purity, 1- to 5-gram lot size[3]	270	277	206	209	214
Iodide, 99.999% purity, 5-gram lot size[2]	149	183	165	157	161
Oxide, 99.99% purity, 5-kilogram lot size[4]	4.6	4.6	4.6	3.9	3.8
Metal:					
Scandium, distilled dendritic, 2-gram lot size,[2] dollars per gram	228	226	226	233	233
Scandium, ingot, 5-gram lot size,[2] dollars per gram	107	132	132	134	134
Scandium-aluminum alloy, 1-kilogram lot size,[4] dollars per kilogram	340	350	360	300	340
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2016–19): Although no definitive data exist listing import sources, imported material is mostly from Europe, China, Japan, and Russia.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Rare-earth metals, unspecified, not intermixed or interalloyed	2805.30.0050	5.0% ad val.
Compounds of rare-earth metals:		
Mixtures of oxides of yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of chlorides of yttrium or scandium as the predominant metal	2846.90.2082	Free.
Mixtures of other rare-earth carbonates, including scandium	2846.90.8075	3.7% ad val.
Mixtures of other rare-earth compounds, including scandium	2846.90.8090	3.7% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global supply and consumption of scandium oxide was estimated to be about 15 to 25 tons per year. Scandium was recovered from titanium, zirconium, cobalt, and nickel process streams. China, the Philippines, and Russia were the leading producers. Prices quoted for scandium oxide in the United States decreased slightly compared with those in 2019. Owing in part to low capacity utilization, China's ex-works prices for scandium oxide were significantly less than United States quoted prices. Although global exploration and development projects continued, the COVID-19 pandemic slowed the development of new projects.

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SCANDIUM

In the United States, environmental and construction permits were approved by the State of Nebraska on the polymetallic Elk Creek project; however, construction was pending additional financing. Probable reserves were estimated to be 36 million tons containing 65.7 parts per million (2,400 tons) scandium. Plans for the project included downstream production of ferroniobium, titanium dioxide, and scandium oxide. The Bokan project in Alaska and the Round Top project in Texas also included scandium recovery in their process plans. In addition, research continued on the development of methods to separate scandium from coal and coal byproducts.

A global mining and polymetallic metal producer announced that it had developed a method to recover scandium from byproduct streams at its titanium slag operations in Sorel-Tracy, Quebec, Canada. The same company was piloting production of aluminum-scandium alloys. In Australia, several polymetallic projects were under development and seeking permitting, financing, and offtake agreements. Projects included the Owendale and Sunrise projects in New South Wales and the SCONI project in Queensland. In the Philippines, a commercial plant designed to recover scandium at the Taganito high-pressure acid-leach nickel operation entered its second year of operation. In the first half of 2020, production of scandium oxalate was reported to be about 5.7 tons. In Russia, feasibility studies for making scandium oxide as a byproduct of alumina refining in the Ural Mountains were ongoing. The pilot plant was reported to have produced scandium oxide with purity greater than 99%. Based on pilot-plant test results, plans were in place for a 3-ton-per-year scandium oxide plant. In Dalur, Kurgan region, development of scandium recovery as a byproduct of uranium production continued, and production capacity included scandium oxide (570 kilograms per year) and aluminum-scandium alloy (24.5 tons per year). In the European Union, recovery methods were being developed to produce scandium compounds and aluminum-scandium alloys from byproducts of aluminum and titanium mining and processing. In Turkey, a pilot plant produced scandium from byproducts of a nickel and cobalt operation in Gordes; however, the plant produced less than one kilogram of ammonium-scandium-hexafluoride. Globally, several projects were underway to commercialize new aluminum-scandium alloys for casting and additive manufacturing.

World Mine Production and Reserves:[6] No scandium was recovered from mining operations in the United States. As a result of its low concentration, scandium is produced exclusively as a byproduct during processing of various ores or recovered from previously processed tailings or residues. Historically scandium was produced as byproduct material in China (iron ore, rare earths, titanium, and zirconium), Kazakhstan (uranium), the Philippines (nickel), Russia (apatite and uranium), and Ukraine (uranium). Foreign mine production data for 2020 were not available.

World Resources:[6] Resources of scandium are abundant. Scandium's crustal abundance is greater than that of lead. Scandium lacks affinity for the common ore-forming anions; therefore, it is widely dispersed in the lithosphere and forms solid solutions with low concentrations in more than 100 minerals. Scandium resources have been identified in Australia, Canada, China, Finland, Guinea, Kazakhstan, Madagascar, Norway, South Africa, the Philippines, Russia, Ukraine, and the United States.

Substitutes: Titanium and aluminum high-strength alloys as well as carbon-fiber materials may substitute in high-performance scandium-alloy applications. Under certain conditions, light-emitting diodes may displace mercury-vapor high-intensity lamps that contain scandium iodide. In some applications that rely on scandium's unique properties, substitution is not possible.

[e]Estimated.

[1]See also Rare Earths. Scandium is one of the 17 rare-earth elements.

[2]Source: Alfa Aesar, a Johnson Matthey company.

[3]Source: Sigma-Aldrich, a part of Millipore Sigma.

[4]Source: Stanford Materials Corp.

[5]Defined as imports – exports. Quantitative data are not available.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

SELENIUM

(Data in metric tons of selenium content unless otherwise noted)

Domestic Production and Use: In 2020, primary selenium was refined from anode slimes recovered from the electrolytic refining of copper at one facility in Texas. Two other electrolytic copper refineries, operating in Arizona and Utah, did not recover selenium domestically, but did produce selenium-bearing anode slimes. U.S. selenium production and consumption data were withheld to avoid disclosing company proprietary data.

Estimates for end uses in global consumption were, in descending order, metallurgy (including manganese production), glass manufacturing, agriculture, chemicals and pigments, electronics, and other uses.

Selenium is used in blasting caps to control delays; in catalysts to enhance selective oxidation; in copper, lead, and steel alloys to improve machinability; in the electrolytic production of manganese to increase yields; in glass manufacturing to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass; in gun bluing to improve cosmetic appearance and provide corrosion resistance; in plating solutions to improve appearance and durability; in rubber compounding chemicals to act as a vulcanizing agent; and in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells.

Selenium is an essential micronutrient and is used as a human dietary supplement, a dietary supplement for livestock, and as a fertilizer additive to enrich selenium-poor soils. Selenium is also used as an active ingredient in antidandruff shampoos.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, refinery	W	W	W	W	W
Imports for consumption:					
Selenium metal	411	450	445	496	340
Selenium dioxide	21	19	12	5	13
Exports,[1] metal	150	242	158	361	160
Consumption, apparent,[2] metal	W	W	W	W	W
Price, average,[3] dollars per pound	23.69	10.78	18.97	20.00	20.00
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption, metal	E	E	<25	<25	<50

Recycling: Domestic production of secondary selenium was estimated to be very small because most scrap from older plain paper photocopiers and electronic materials was exported for recovery of the contained selenium.

Import Sources (2016–19): Selenium metal: China, 20%; the Philippines, 19%; Mexico, 14%; Germany, 13%; and other, 34%. Selenium dioxide: China, 27%; the Republic of Korea, 25%; Germany, 22%; Canada, 13%; and other, 13%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Selenium metal	2804.90.0000	Free.
Selenium dioxide	2811.29.2000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The supply of selenium is directly affected by the supply of the materials from which it is a byproduct—copper and, to a lesser extent, nickel—and it is directly affected by the number of facilities that recover selenium. The estimated annual average price for selenium was $20.00 per pound in 2020, unchanged from that in 2019. Average monthly prices have remained steady since November 2018.

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SELENIUM

Electrolytic manganese production was the main metallurgical end use for selenium in China, where selenium dioxide was used in the electrolytic process to increase current efficiency and the metal deposition rate. Selenium consumption in China was thought to have increased in recent years, owing to higher manganese metal production. In January, Chinese production of selenium dioxide was temporarily halted owing to the COVID-19 pandemic, but production resumed in late February. Later in the year, Chinese importers of selenium had decreased their intakes owing to adequate stocks from previous purchases, reduced demand from the manganese, glassmaking, and ceramics sectors, and sufficient feedstock from domestic copper producers who sold crude selenium to selenium powder and selenium dioxide producers.

World Refinery Production and Reserves:

	Refinery production[5]		Reserves[6]
	2019	2020[e]	
United States	W	W	10,000
Belgium	200	200	—
Canada	57	60	6,000
China	1,100	1,100	26,000
Finland	115	100	—
Germany	300	300	—
Japan	740	750	—
Peru	40	40	13,000
Poland	64	65	3,000
Russia	150	150	20,000
Sweden	19	20	—
Turkey	50	50	—
Other countries[7]	45	45	22,000
World total (rounded)	[7]2,880	[7]2,900	100,000

World Resources:[6] Reserves for selenium are based on identified copper deposits and average selenium content. Coal generally contains between 0.5 and 12 parts per million selenium, or about 80 to 90 times the average for copper deposits. The recovery of selenium from coal fly ash, although technically feasible, does not appear likely to be economical in the foreseeable future.

Substitutes: Silicon is the major substitute for selenium in low- and medium-voltage rectifiers. Organic pigments have been developed as substitutes for cadmium sulfoselenide pigments. Other substitutes include cerium oxide as either a colorant or decolorant in glass; tellurium in pigments and rubber; bismuth, lead, and tellurium in free-machining alloys; and bismuth and tellurium in lead-free brasses. Sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal, but it is not as energy efficient.

The selenium-tellurium photoreceptors used in some plain paper copiers and laser printers have been replaced by organic photoreceptors in newer machines. Amorphous silicon and cadmium telluride are the two principal competitors with CIGS in thin-film photovoltaic solar cells.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]There was no exclusive Schedule B number for selenium dioxide exports.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]U.S. spot market price for selenium metal powder, minimum 99.5% purity, in 5-ton lots. Source: S&P Global Platts Metals Week.

[4]Defined as imports – exports + adjustments for industry stock changes; export data are incomplete for common forms of selenium, which may be exported under unexpected or misidentified forms, such as copper slimes, copper selenide, or zinc selenide.

[5]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues but did not recover refined selenium from these materials indigenously were excluded to avoid double counting.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production. Australia, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan are known to produce refined selenium, but output was not reported, and information was inadequate to make reliable production estimates.

SILICON

(Data in thousand metric tons of silicon content unless otherwise noted)

Domestic Production and Use: Six companies produced silicon materials in 2020, all east of the Mississippi River. Most ferrosilicon was consumed in the ferrous foundry and steel industries, predominantly in the Eastern United States, and was sourced primarily from domestic quartzite (silica). The main consumers of silicon metal were producers of aluminum alloys and the chemical industry, in particular for the manufacture of silicones. The semiconductor and solar energy industries, which manufacture chips for computers and photovoltaic cells from high-purity silicon, respectively, also consumed silicon metal.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, ferrosilicon[1] and silicon metal[2]	384	415	430	310	290
Imports for consumption:					
Ferrosilicon, all grades	155	147	140	127	120
Silicon metal	122	136	116	124	95
Exports:					
Ferrosilicon, all grades	7	11	12	8	4
Silicon metal	60	71	45	40	31
Consumption, apparent,[3] ferrosilicon[1] and silicon metal[2]	601	616	637	517	470
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% Si[4]	83	94	104	102	104
Ferrosilicon, 75% Si[5]	71	87	108	89	88
Silicon metal[2, 5]	91	117	134	106	96
Stocks, producer, ferrosilicon[1] and silicon metal,[2] yearend	26	26	19	15	16
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades	>50	<50	<50	<50	<50
Silicon metal[2]	<50	<50	<50	<50	<50
Total	36	33	32	40	38

Recycling: Insignificant.

Import Sources (2016–19): Ferrosilicon: Russia, 37%; Canada, 14%; Brazil, 11%; and other, 38%. Silicon metal: Brazil, 30%; Canada, 20%; Norway, 12%; and other, 38%. Total: Brazil, 20%; Russia, 20%; Canada, 16%; and other, 44%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Silicon, more than 99.99% Si	2804.61.0000	Free.
Silicon, 99.00%–99.99% Si	2804.69.1000	5.3% ad val.
Silicon, other	2804.69.5000	5.5% ad val.
Ferrosilicon, 55%–80% Si:		
More than 3% Ca	7202.21.1000	1.1% ad val.
Other	7202.21.5000	1.5% ad val.
Ferrosilicon, 80%–90% Si	7202.21.7500	1.9% ad val.
Ferrosilicon, more than 90% Si	7202.21.9000	5.8% ad val.
Ferrosilicon, other:		
More than 2% Mg	7202.29.0010	Free.
Other	7202.29.0050	Free.

Depletion Allowance: Quartzite, 14% (domestic and foreign); gravel, 5% (domestic and foreign).

Government Stockpile: None.

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SILICON

Events, Trends, and Issues: Combined domestic ferrosilicon and silicon metal production in 2020, expressed in terms of contained silicon, decreased from that of 2019. One producer shut down its ferrosilicon production facility on July 1 owing to decreased demand and lower prices—in part because of the global COVID-19 pandemic, as well as competition from lower priced imported ferrosilicon. Domestic production during the first 8 months of 2020 was about 11% less, on a contained-weight basis, than that during the same period in 2019. By August 2020, average U.S. ferrosilicon spot market prices had increased slightly for 50%-grade ferrosilicon and decreased slightly for 75%-grade ferrosilicon compared with those in 2019; the average silicon metal spot market price had decreased by 10% compared with the annual average spot price in 2019.

Excluding the United States, ferrosilicon accounted for about 64% of world silicon production on a silicon-content basis in 2020. The leading countries for ferrosilicon production were, in descending order and on a contained-weight basis, China, Russia, and Norway. For silicon metal, the leading producers were China, Brazil, Norway, and France. China accounted for approximately 68% of total global estimated production of silicon materials in 2020. Global production of silicon materials, on a contained weight basis, was estimated to be about 5% less than that in 2019.

Steel production, the leading use of ferrosilicon, decreased across the globe in 2020 compared with production in 2019 owing to reduced demand attributed to the global COVID-19 pandemic.

World Production and Reserves:

	Production[7]		Reserves[8]
	2019	2020[e]	
United States	310	290	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates are not available.
Bhutan[9]	90	85	
Brazil	340	340	
Canada	57	57	
China	5,700	5,400	
France	130	130	
Iceland	88	87	
India[9]	60	55	
Malaysia[9]	150	130	
Norway	375	330	
Russia	610	540	
South Africa	96	96	
Spain	66	66	
Ukraine[9]	63	60	
Other countries	278	290	
World total (rounded)	8,410	8,000	

World Resources:[8] World and domestic resources for making silicon metal and alloys are abundant and, in most producing countries, adequate to supply world requirements for many decades. The source of the silicon is silica in various natural forms, such as quartzite.

Substitutes: Aluminum, silicon carbide, and silicomanganese can be substituted for ferrosilicon in some applications. Gallium arsenide and germanium are the principal substitutes for silicon in semiconductor and infrared applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Ferrosilicon grades include the two standard grades of ferrosilicon—50% and 75% silicon—plus miscellaneous silicon alloys.

[2]Metallurgical-grade silicon metal.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Source: CRU Group, transaction prices based on weekly averages.

[5]Source: S&P Global Platts Metals Week, mean import prices based on monthly averages.

[6]Defined as imports – exports + adjustments for industry stock changes.

[7]Production quantities are the silicon content of combined totals for ferrosilicon and silicon metal, except as noted.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Silicon content of ferrosilicon only.

SILVER

(Data in metric tons[1] of silver content unless otherwise noted)

Domestic Production and Use: In 2020, U.S. mines produced approximately 1,000 tons of silver with an estimated value of $670 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 33 domestic base- and precious-metal operations. Alaska continued as the country's leading silver-producing State, followed by Nevada. There were 24 U.S. refiners that reported production of commercial-grade silver with an estimated total output of 2,000 tons from domestic and foreign ores and concentrates and from new and old scrap. The physical properties of silver include high ductility, electrical conductivity, malleability, and reflectivity. In 2020, the estimated domestic uses for silver were electrical and electronics, 28%; jewelry and silverware, 26%; coins and medals, 19%; photography, 3%; and other, 24%. Other applications for silver include use in antimicrobial bandages, clothing, pharmaceuticals, and plastics; batteries; bearings; brazing and soldering; catalytic converters in automobiles; electroplating; inks; mirrors; photovoltaic solar cells; water purification; and wood treatment. Mercury and silver, the main components of dental amalgam, are biocides, and their use in amalgam inhibits recurrent decay.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Mine	1,150	1,030	934	977	1,000
Refinery:					
Primary	1,530	1,420	1,420	1,420	1,400
Secondary (new and old scrap)	866	490	632	643	640
Imports for consumption[2]	6,160	5,040	4,830	4,760	6,500
Exports[2]	289	157	603	220	130
Consumption, apparent[3]	7,890	6,420	5,790	6,160	8,000
Price, bullion, average, dollars per troy ounce[4]	17.20	17.07	15.75	17.17	20.00
Stocks, yearend:					
Industry	63	45	51	52	50
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	5,710	7,570	9,150	9,860	12,000
Employment, mine and mill, number[6]	1,050	805	823	869	1,100
Net import reliance[7] as a percentage of apparent consumption	74	76	73	74	80

Recycling: In 2020, approximately 640 tons of silver was recovered from new and old scrap, about 8% of apparent consumption.

Import Sources (2016–19):[2] Mexico, 50%; Canada, 27%; Peru, 4%; Poland, 4%; and other, 15%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Silver ores and concentrates, silver content	2616.10.0040	0.8 ¢/kg on lead content.
Bullion, silver content	7106.91.1010	Free.
Dore, silver content	7106.91.1020	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of silver (see salient statistics above).

Events, Trends, and Issues: The estimated average silver price in 2020 was $20.00 per troy ounce, 16% higher than the average price in 2019. The price began the year at $17.98 per troy ounce, then decreased to a low of $12.13 per troy ounce on March 18. The price of silver increased to a high of $28.99 per troy ounce, in August, because the COVID-19 pandemic caused an increase in investor demand as well as in industrial demand. The price was the highest since March 2013; however, it trended downward through November.

In 2020, global consumption of silver was estimated to have decreased slightly from that of 2019. Coin and bar consumption increased for the fourth year in a row. Consumption for industrial uses was estimated to have decreased in the first half of 2020 owing to lockdown restrictions in response to the COVID-19 pandemic, supply chain disruptions, lowered inventory replenishment, and reduced labor forces within factories. Jewelry and silverware consumption of silver was estimated to have decreased by 23% and 34%, respectively. In 2020, there was increased physical investment in silver, reaching an estimated 7,370 tons (236.8 million troy ounces) compared with 5,820 tons (187 million troy ounces) in 2019. Global holdings reached a reported 28,800 tons (925 million troy ounces) compared with 30,890 tons (993 million troy ounces) in 2019.[8]

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SILVER

World silver mine production decreased by 6% in 2020 to an estimated 25,000 tons, principally as a result of decreased production from mines in China, Mexico, and Peru, primarily owing to shutdowns in the first half of the year in response to the COVID-19 pandemic. Domestic silver mine production increased slightly in 2020 compared with that in 2019 principally from increased production at mining operations in Alaska. The COVID-19 pandemic did affect silver production in the United States; however, the ending of the strike at the Lucky Friday Mine in January offset the production losses.

World Mine Production and Reserves: Reserves for Australia, Peru, Poland, and the United States were revised based on information from Government and industry sources.

	Mine production		Reserves[9]
	2019	2020[e]	
United States	977	1,000	26,000
Argentina	1,080	1,000	NA
Australia	1,330	1,300	[10]88,000
Bolivia	1,160	1,100	22,000
Chile	1,350	1,300	26,000
China	3,440	3,200	41,000
Mexico	5,920	5,600	37,000
Peru	3,860	3,400	91,000
Poland	1,470	1,300	70,000
Russia	2,000	1,800	45,000
Other countries	3,920	3,500	57,000
World total (rounded)	26,500	25,000	500,000

World Resources:[9] Although silver was a principal product at several mines, silver was primarily obtained as a byproduct from lead-zinc mines, copper mines, and gold mines, in descending order of production. The polymetallic ore deposits from which silver was recovered account for more than two-thirds of U.S. and world resources of silver. Most recent silver discoveries have been associated with gold occurrences; however, copper and lead-zinc occurrences that contain byproduct silver will continue to account for a significant share of reserves and resources in the future.

Substitutes: Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for traditional photographic applications for silver. Surgical pins and plates may be made with stainless steel, tantalum, and titanium in place of silver. Stainless steel may be substituted for silver flatware. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles.

[e]Estimated. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Silver content of base metal ores and concentrates, refined bullion, and dore; excludes coinage, and waste and scrap material.

[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.

[4]Engelhard's industrial bullion quotations. Source: S&P Global Platts Metals Week.

[5]Source: U.S. Mint. Balance in U.S. Mint only; includes deep storage and working stocks.

[6]Source: U.S. Department of Labor, Mine Safety and Health Administration (MSHA). Only includes mines where silver is the primary product. In 2020, MSHA changed the Mine Employment values in their publicly available database.

[7]Defined as imports – exports + adjustments for Government and industry stock changes.

[8]DiRienzo, Michael, and Newman, Philip, 2020, Key components of silver market affected by pandemic in 2020—Global demand and mine supply impacted, while physical silver investment expected to surge to a 5-year high: Silver Institute and Metal Focus, November 19, 2 p.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant reserves were 25,000 tons.

SODA ASH

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The total value of domestic natural soda ash (sodium carbonate) produced in 2020 was estimated to be about $1.5 billion,[1] and the quantity produced was 9.7 million tons, about 17% less than that of the previous year. The U.S. soda ash industry comprised four companies in Wyoming operating five plants and one company in California operating one plant. The five producing companies have a combined annual nameplate capacity of 13.9 million tons (15.3 million short tons). Borax, salt, and sodium sulfate were produced as coproducts of sodium carbonate production in California. Chemical caustic soda, sodium bicarbonate, and sodium sulfite were manufactured as coproducts at several of the Wyoming soda ash plants. Sodium bicarbonate was produced at an operation in Colorado using soda ash feedstock shipped from the company's Wyoming facility.

Based on 2020 quarterly reports, the estimated distribution of soda ash by end use was glass, 48%; chemicals, 28%; miscellaneous uses, 8%; soap and detergents, 6%; distributors, 5%; flue gas desulfurization, 3%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production[2]	11,800	12,000	11,900	11,700	9,700
Imports for consumption	35	19	51	115	90
Exports	6,760	6,990	6,960	7,020	5,700
Consumption:					
Apparent[3]	5,030	5,040	4,980	4,830	4,100
Reported	5,120	4,910	4,850	4,720	4,400
Price, average sales value (natural source), free on board (f.o.b.) mine or plant:					
Dollars per metric ton	149.83	146.26	148.69	153.24	154
Dollars per short ton	135.92	132.68	134.89	139.02	140
Stocks, producer, yearend	336	293	297	289	320
Employment, mine and plant, number[e]	2,500	2,600	2,600	2,600	2,500
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: No soda ash was recycled by producers; however, glass container producers use cullet glass, thereby reducing soda ash consumption.

Import Sources (2016–19): Turkey, 62%; Germany, 9%; Italy, 7%; Bulgaria, 5%; and other, 17%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–20**
Disodium carbonate	2836.20.0000	1.2% ad val.

Depletion Allowance: Natural, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Primarily owing to the global COVID-19 pandemic, U.S. soda ash consumption, exports, imports, production, and sales significantly decreased in 2020 from those of 2019. More than one-half of U.S. production of soda ash was exported, and exports were estimated to have decreased by 19% compared with those in 2019. Domestic consumption reported by producers decreased by about 7% in 2020 compared with that of 2019, and apparent consumption in 2020 decreased by about 15% compared with that of 2019.

Relatively low production costs and lower environmental impacts provide natural soda ash producers some advantage over producers of synthetic soda ash. The production of synthetic soda ash normally consumes more energy and releases more carbon dioxide than that of natural soda ash. In recent years, U.S. producers of natural soda ash were able to expand their markets when several synthetic soda ash plants were closed or idled in other parts of the world.

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SODA ASH

After increasing capacity during the past 3 years, total production capacity in Turkey is estimated to be between 4 million and 5 million tons per year, and soda ash shipments, especially for export, are expected to increase during the next few years. Total United States imports, mostly from Turkey, have recently been about 100,000 tons per year, which is more than double the average amount of annual imports during the past decade.

Three groups dominate production and have become the world's leading suppliers of soda ash—American National Soda Ash Corp., which represented three of the five domestic producers in 2020; multiple producers in China; and Solvay S.A. of Belgium. Increasing soda ash exports from Turkey may affect sales from these three groups. The United States likely will remain competitive with producers in China and Turkey for markets elsewhere in Asia. Asia and South America remain the most likely areas for increased soda ash consumption in the near future.

World Production and Reserves: Reserves for Turkey were revised based on Government and industry reports.

	Mine production		Reserves[5, 6]
	2019	2020[e]	
Natural:			
United States	11,700	9,700	[7]23,000,000
Botswana	290	250	400,000
Ethiopia	18	20	400,000
Kenya	330	300	7,000
Turkey	3,500	3,400	1,650,000
Other countries	NA	NA	280,000
World total, natural (rounded)	15,800	14,000	26,000,000
World total, synthetic (rounded)	41,000	38,000	XX
World total (rounded)	56,800	52,000	XX

World Resources:[6] Natural soda ash is obtained from trona and sodium carbonate-rich brines. The world's largest deposit of trona is in the Green River Basin of Wyoming. About 47 billion tons of identified soda ash resources could be recovered from the 56 billion tons of bedded trona and the 47 billion tons of interbedded or intermixed trona and halite, which are in beds more than 1.2 meters thick. Underground room-and-pillar mining, using conventional and continuous mining, is the primary method of mining Wyoming trona ore. This method has an average 45% mining recovery, whereas average recovery from solution mining is 30%. Improved solution-mining techniques, such as horizontal drilling to establish communication between well pairs, could increase this extraction rate and enable companies to develop some of the deeper trona beds. Wyoming trona resources are being depleted at the rate of about 15 million tons per year (8.3 million tons of soda ash). Searles Lake and Owens Lake in California contain an estimated 815 million tons of soda ash reserves. At least 95 natural sodium carbonate deposits have been identified in the world, the resources of only some of which have been quantified. Although soda ash can be manufactured from salt and limestone, both of which are practically inexhaustible, synthetic soda ash is costlier to produce and generates environmental wastes.

Substitutes: Caustic soda can be substituted for soda ash in certain uses, particularly in the pulp and paper, water treatment, and certain chemical sectors. Soda ash, soda liquors, or trona can be used as feedstock to manufacture chemical caustic soda, which is an alternative to electrolytic caustic soda.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable.

[1]Does not include values for soda liquors and mine waters.

[2]Natural only.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]The reported quantities are sodium carbonate only. About 1.8 tons of trona yield 1 ton of sodium carbonate.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]From trona, nahcolite, and dawsonite deposits.

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2020, 1.46 billion tons of crushed stone valued at more than $17.8 billion was produced by an estimated 1,410 companies operating 3,440 quarries and 180 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Missouri, Florida, Pennsylvania, Ohio, Georgia, Virginia, Illinois, North Carolina, and Kentucky, which combined accounted for more than one-half of the total crushed stone output. Of the total domestic crushed stone produced in 2020, about 70% was limestone and dolomite; 15%, granite; 6%, traprock; 5%, miscellaneous stone; 3%, sandstone and quartzite; and the remaining 1% was divided, in descending order of tonnage, among marble, volcanic cinder and scoria, calcareous marl, slate, and shell. It is estimated that of the 1.5 billion tons of crushed stone consumed in the United States in 2020, 72% was used as construction aggregate, mostly for road construction and maintenance; 16% for cement manufacturing; 8% for lime manufacturing; 2% for agricultural uses; and the remainder for other chemical, special, and miscellaneous uses and products.

The estimated output of crushed stone in the United States shipped for consumption in the first 9 months of 2020 was 1.10 billion tons, a decrease of 3% compared with that of the same period of 2019. Third quarter shipments for consumption decreased by 6% compared with those of the same period of 2019. Additional production information, by quarter for each State, geographic division, and the United States, is reported in the U.S. Geological Survey quarterly Mineral Industry Surveys for Crushed Stone and Sand and Gravel.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production	1,360	1,370	1,390	1,490	1,460
Recycled material	49	43	38	38	38
Imports for consumption	20	19	21	24	21
Exports	1	1	(2)	(2)	(2)
Consumption, apparent[3]	1,430	1,430	1,450	1,550	1,520
Price, average value, dollars per metric ton	11.06	11.36	11.64	11.96	12.19
Employment, quarry and mill, number[4]	68,100	68,600	68,500	69,000	67,000
Net import reliance[5] as a percentage of apparent consumption	1	1	1	2	1

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain crushed stone aggregate, were recycled on a limited but increasing basis in most States. In 2020, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2016–19): Mexico, 56%; Canada, 27%; The Bahamas, 11%; Honduras, 5%; and Jamaica, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–20**
Chalk:		
Crude	2509.00.1000	Free.
Other	2509.00.2000	Free.
Limestone, except pebbles and gravel	2517.10.0020	Free.
Crushed or broken stone	2517.10.0055	Free.
Marble granules, chippings and powder	2517.41.0000	Free.
Stone granules, chippings and powders	2517.49.0000	Free.
Limestone flux; limestone and other calcareous stone	2521.00.0000	Free.

Depletion Allowance: (domestic) 14% for some special uses; 5%, if used as ballast, concrete aggregate, riprap, road material, and similar purposes.

Government Stockpile: None.

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STONE (CRUSHED)

Events, Trends, and Issues: Crushed stone production was about 1.46 billion tons in 2020, a slight decrease compared with 1.49 billion tons in 2019. Apparent consumption also decreased slightly to about 1.52 billion tons. Consumption of crushed stone decreased in 2020 because of measures instituted to mitigate the spread of the global COVID-19 pandemic that caused disruptions in the mining and construction industries. Usually commercial and heavy industrial construction activity, infrastructure funding, new single-family housing unit starts, and weather, affect growth in crushed stone production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to security measures being implemented around the Nation. The underlying factors that would support a rise in prices of crushed stone are expected to be present in 2021, especially in and near metropolitan areas.

The crushed stone industry continued to be concerned with environmental, health, and safety regulations. Shortages in some urban and industrialized areas are expected to continue to increase owing to local zoning regulations and land-development alternatives. These issues are expected to continue and to cause new crushed stone quarries to be located away from large population centers.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2019	2020[e]	
United States	1,490	1,460	Adequate, except where special types are needed or where local shortages exist.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources:[6] Stone resources are plentiful throughout the world. Supply of high-purity limestone and dolomite suitable for specialty uses is limited in many geographic areas. The largest resources of high-purity limestone and dolomite in the United States are in the central and eastern parts of the country.

Substitutes: Crushed stone substitutes for roadbuilding include sand and gravel, and iron and steel slag. Substitutes for crushed stone used as construction aggregates include construction sand and gravel, iron and steel slag, sintered or expanded clay or shale, perlite, or vermiculite. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2020.

[e]Estimated. NA Not available.

[1]See also Sand and Gravel (Construction) and Stone (Dimension).

[2]Less than ½ unit.

[3]Defined as production + recycled material + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Consistent production information is not available for other countries owing to the wide variety of ways in which countries report their crushed stone production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

STONE (DIMENSION)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Approximately 2.6 million tons of dimension stone, valued at $400 million, was sold or used by U.S. producers in 2020. Dimension stone was produced by around 200 companies operating 250 quarries in 34 States. Leading producing States were, in descending order by tonnage, Texas, Wisconsin, Indiana, Vermont, and New York. These five States accounted for about 71% of the production quantity and contributed about 61% of the value of domestic production. Approximately 50%, by tonnage, of dimension stone sold or used was limestone, followed by sandstone (19%), granite (17%), dolomite (4%), miscellaneous stone (3%), and the remaining 7% was divided, in descending order of tonnage, among slate, marble, quartzite, and traprock. By value, the leading sales or uses were for limestone (46%), followed by granite (25%), sandstone (11%), slate (5%), marble (4%), dolomite (4%), and the remaining 5% was divided, in descending order of total value, among quartzite, traprock, and miscellaneous stone. Rough stone represented 54% of the tonnage and 47% of the value of all the dimension stone sold or used by domestic producers, including exports. The leading uses and distribution of rough stone, by tonnage, were in building and construction (53%) and in irregular-shaped stone (35%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (41%), slabs and blocks for building and construction (12%), and curbing (11%).

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Sold or used by producers:[2]					
Quantity	2,960	2,880	2,660	2,520	2,600
Value, million dollars	448	453	437	415	400
Imports for consumption, value, million dollars	2,180	2,120	2,090	1,900	1,610
Exports, value, million dollars	65	69	70	59	47
Consumption, apparent, value, million dollars[3]	2,560	2,510	2,460	2,260	1,970
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	4,000	3,900	3,900	3,900	3,900
Net import reliance[5] as a percentage of apparent consumption (based on value)	83	82	82	82	79
Granite only, sold or used by producers:					
Quantity	593	526	484	430	400
Value, million dollars	130	115	108	105	99
Imports, value, million dollars	1,120	1,020	915	863	720
Exports, value, million dollars	21	22	19	17	13
Consumption, apparent, value, million dollars[3]	1,220	1,110	1,000	950	810
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	880	800	800	800	800
Net import reliance[5] as a percentage of apparent consumption (based on value)	89	90	89	89	88

Recycling: Small amounts of dimension stone were recycled, principally by restorers of old stone work.

Import Sources (2016–19 by value): All dimension stone: China, 25%; Brazil, 23%; Italy, 19%; India, 12%; and other, 21%. Granite only: Brazil, 45%; China, 23%; India, 17%; Italy, 7%; and other, 8%.

Tariff: Dimension stone tariffs ranged from free to 6.5% ad valorem, according to type, degree of preparation, shape, and size, for countries with normal trade relations in 2020. Most crude or roughly trimmed stone was imported at 3.7% ad valorem or less.

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STONE (DIMENSION)

Depletion Allowance: All dimension stone, 14% (domestic and foreign); slate used or sold as sintered or burned lightweight aggregate, 7.5% (domestic and foreign); dimension stone used for rubble and other nonbuilding purposes, 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The United States remained one of the world's leading markets for dimension stone. In 2020, total imports of dimension stone decreased in value by about 15% compared with the value in 2019. In 2020, increased demand for dimension stone for construction and refurbishment used in residential markets helped offset decreases in commercial markets. Both markets were affected because of the measures instituted to mitigate the spread of the global COVID-19 pandemic. These measures also led to increases in the home remodeling sector, with companies reporting a 40% to 50% increase in demand for remodeling projects. Dimension stone exports decreased to about $47 million. Apparent consumption, by value, was estimated to be $2.0 billion in 2020—a 13% decrease compared with that of 2019.

The dimension stone industry continued to be concerned with safety and health regulations and environmental restrictions in 2020, especially those concerning crystalline silica exposure. Beginning in 2016, the Occupational Safety and Health Administration (OSHA) finalized new regulations to further restrict exposure to crystalline silica at quarry sites and other industries that use materials containing it. Phased implementation of the new regulations was scheduled to take effect through 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2019	2020[e]	
United States	2,520	2,600	Adequate, except for certain special types and local shortages.
Other countries	NA	NA	
World total	NA	NA	

World Resources:[6] Dimension stone resources of the world are sufficient. Resources can be limited on a local level or occasionally on a regional level by the lack of a particular kind of stone that is suitable for dimension purposes.

Substitutes: Substitutes for dimension stone include aluminum, brick, ceramic tile, concrete, glass, plastics, resin-agglomerated stone, and steel.

[e]Estimated. NA Not available.

[1]See also Stone (Crushed).

[2]Includes granite, limestone, and other types of dimension stone.

[3]Defined as sold or used (value) + imports (value) – exports (value).

[4]Excludes office staff.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

STRONTIUM

(Data in metric tons of strontium content unless otherwise noted)

Domestic Production and Use: Although deposits of strontium minerals occur widely throughout the United States, none have been mined in the United States since 1959. Domestic production of strontium carbonate, the principal strontium compound, ceased in 2006. Virtually all the strontium mineral celestite consumed in the United States since 2006 is thought to have been used as an additive in drilling fluids for oil and natural gas wells. A few domestic companies produced small quantities of downstream strontium chemicals from imported strontium carbonate.

Based on import data, the estimated end-use distribution in the United States for strontium, including celestite and strontium compounds, was, in descending order, ceramic ferrite magnets and pyrotechnics and signals, 27% each; drilling fluids, 26%; and electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass, 5% each.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	4,420	11,300	16,900	7,960	1,300
Strontium compounds[2]	6,420	6,660	6,350	5,560	3,800
Exports, strontium compounds	91	36	32	20	30
Consumption, apparent:[3]					
Celestite	4,420	11,300	16,900	7,960	1,300
Strontium compounds	6,330	6,620	6,320	5,540	3,800
Total	10,700	17,900	23,200	13,500	5,100
Price, average value of celestite imports at port of exportation, dollars per ton	78	74	78	82	66
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2016–19): Celestite: Mexico, 100%. Strontium compounds: Mexico, 50%; Germany, 40%; China, 6%; and other, 4%. Total imports: Mexico, 81%; Germany, 15%; China, 2%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Celestite	2530.90.8010	Free.
Strontium compounds:		
Strontium metal	2805.19.1000	3.7% ad val.
Strontium oxide, hydroxide, peroxide	2816.40.1000	4.2% ad val.
Strontium nitrate	2834.29.2000	4.2% ad val.
Strontium carbonate	2836.92.0000	4.2% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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STRONTIUM

Events, Trends, and Issues: Apparent consumption of strontium declined by 63% in 2020 compared with that in 2019 because of the economic downturn caused by restrictions imposed worldwide as the result of the global COVID-19 pandemic. Many countries experienced significant industrial declines, and celestite production was estimated to have declined from most sources.

Imports of celestite, the most commonly used strontium mineral, decreased by 84%, likely the result of decreased natural-gas- and oil-drilling activity, which was at least partly caused by the pandemic restrictions. Nearly all celestite imports were from Mexico and were thought to be used as additives in drilling fluids for oil and natural gas exploration and production, which experienced declined activity. For these applications, celestite is ground but undergoes no chemical processing. A small quantity of high-value celestite imports were reported; these were most likely mineral specimens. Although no strontium carbonate was produced in the United States, celestite is the raw material from which strontium carbonate and other strontium compounds are produced.

Strontium carbonate is the most commonly traded strontium compound and is used as the raw material from which other strontium compounds are derived. Strontium carbonate is sintered with iron oxide to produce permanent ceramic ferrite magnets, and strontium nitrate contributes a brilliant red color to fireworks and signal flares. Smaller quantities of these and other strontium compounds were consumed in several other applications, including electrolytic production of zinc, glass production, master alloys, and pigments and fillers. Imports of strontium compounds decreased by 32% in 2020.

World Mine Production and Reserves:[4]

	Mine production[e]		Reserves[5]
	2019	2020	
United States	—	—	Quantitative estimates of reserves for most countries were not available.
Argentina	700	670	
China	50,000	50,000	
Iran	37,000	35,000	
Mexico	40,000	38,000	
Spain	90,000	86,000	
World total (rounded)	220,000	210,000	

World Resources:[5] World resources of strontium are thought to exceed 1 billion tons.

Substitutes: Barium can be substituted for strontium in ferrite ceramic magnets; however, the resulting barium composite will have reduced maximum operating temperature when compared with that of strontium composites. Substituting for strontium in pyrotechnics is hindered by difficulty in obtaining the desired brilliance and visibility imparted by strontium and its compounds. In drilling mud, barite is the preferred material, but celestite may substitute for some barite, especially when barite prices are high.

[e]Estimated. — Zero.

[1]The strontium content of celestite is 43.88%, assuming an ore grade of 92%, which was used to convert units of celestite to strontium content.

[2]Strontium compounds, with their respective strontium contents, in descending order, include metal (100.00%); oxide, hydroxide, and peroxide (70.00%); carbonate (59.35%); and nitrate (41.40%). These factors were used to convert gross weight of strontium compounds to strontium content.

[3]Defined as imports − exports.

[4]Gross weight of celestite in tons.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

SULFUR

(Data in thousand metric tons of sulfur content unless otherwise noted)

Domestic Production and Use: In 2020, recovered elemental sulfur and byproduct sulfuric acid were produced at 95 operations in 27 States. Total shipments were valued at about $320 million. Elemental sulfur production was estimated to be 7.6 million tons; Louisiana and Texas accounted for about 50% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 35 companies at 90 plants in 26 States. Byproduct sulfuric acid, representing about 6% of production of sulfur in all forms, was recovered at five nonferrous-metal smelters in four States by four companies. Domestic elemental sulfur provided 62% of domestic consumption, and byproduct sulfuric acid accounted for about 5%. The remaining 33% of sulfur consumed was provided by imported sulfur and sulfuric acid. About 90% of sulfur consumed was in the form of sulfuric acid.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production:					
Recovered elemental	9,070	9,070	9,000	8,110	7,600
Other forms	673	560	672	596	520
Total (rounded)	9,740	9,630	9,670	8,710	8,100
Shipments, all forms	9,750	9,680	9,690	8,700	8,100
Imports for consumption:					
Recovered elemental[e]	1,810	1,850	2,230	1,850	2,100
Sulfuric acid, sulfur content	1,050	954	997	971	1,200
Exports:					
Recovered elemental	2,060	2,340	2,390	2,200	1,500
Sulfuric acid, sulfur content	59	80	112	72	70
Consumption, apparent, all forms[1]	10,500	10,100	10,400	9,240	9,800
Price, reported average value, free on board, mine and (or) plant, dollars per ton of elemental sulfur	37.88	46.39	81.16	51.08	40.00
Stocks, producer, yearend	142	124	118	124	110
Employment, mine and (or) plant, number	2,500	2,400	2,400	2,400	2,400
Net import reliance[2] as a percentage of apparent consumption	7	4	7	6	17

Recycling: Typically, between 2.5 million tons and 5 million tons of spent sulfuric acid is reclaimed from petroleum refining and chemical processes during any given year.

Import Sources (2016–19): Elemental: Canada, 75%; Russia, 12%; Kazakhstan, 6%; and other, 7%. Sulfuric acid: Canada, 64%; Mexico, 17%; Spain, 6%; and other, 13%. Total sulfur imports: Canada, 71%; Russia 8%; Mexico, 7%; Kazakhstan, 4%; and other, 10%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–20**
Sulfur, crude or unrefined	2503.00.0010	Free.
Sulfur, all kinds, other	2503.00.0090	Free.
Sulfur, sublimed or precipitated	2802.00.0000	Free.
Sulfuric acid	2807.00.0000	Free.

Depletion Allowance: 22% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Total U.S. sulfur production in 2020 was estimated to have decreased by 7% from that of 2019, and shipments also decreased by 7% from those of 2019. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations decreased by 6%. Sulfur production decreased because of a decline in refinery capacity utilization as a result of decreased demand for refinery products owing to the global COVID-19 pandemic and processing of more sweet crude oil. Domestically, refinery sulfur production is expected to remain low as long as COVID-19 restrictions remain in place. Domestic byproduct sulfuric acid is expected to remain relatively constant, unless one or more of the remaining nonferrous-metal smelters close.

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SULFUR

Domestic phosphate rock consumption in 2020 was estimated to have remained the same as that in 2019, which resulted in the same consumption of sulfur to process the phosphate rock into phosphate fertilizers.

World sulfur production was slightly less than it was in 2019 as a result of decreased demand resulting from global COVID-19 pandemic restrictions, but production is likely to increase steadily for the foreseeable future. New sulfur demand associated with phosphate fertilizer projects is expected mostly in Africa, but sulfur demand likely will increase in Asia and Eastern Europe. A major change for 2020 was the implementation of new international standards limiting sulfur oxide emissions from ocean-going ships on January 1, 2020. The global sulfur content limit of marine fuels was reduced to 0.5% from 3.5%, which is likely to lead to increased sulfur recovery from fuels in North America, Asia, and Europe.

Contract sulfur prices in Tampa, FL, began 2020 at around $46 per long ton. The sulfur price decreased to $36 per long ton in mid-April, and then increased to $58 per long ton by the end of September. Fourth-quarter 2020 prices were set at $69 per long ton. The fourth-quarter price increase was a result of the decreased availability of sulfur owing to reduced output from natural gas and crude oil refining. In the past few years, sulfur prices have been variable, a result of the volatility in the demand for sulfur.

World Production and Reserves:

	Production—All forms		Reserves[3]
	2019	2020[e]	
United States	8,710	8,100	Reserves of sulfur in crude oil, natural gas, and sulfide ores are large. Because most sulfur production is a result of the processing of fossil fuels, supplies are expected to be adequate for the foreseeable future. Because petroleum and sulfide ores can be processed long distances from where they are produced, sulfur production may not be in the country to which the reserves were attributed. For instance, sulfur from Saudi Arabian oil may be recovered at refineries in the United States.
Australia	900	900	
Brazil	500	500	
Canada	6,940	6,300	
Chile	1,500	1,500	
China[4]	17,500	17,000	
Finland	766	770	
Germany	670	670	
India	3,600	3,600	
Iran	2,200	2,200	
Italy	550	550	
Japan	3,400	3,400	
Kazakhstan	3,500	3,500	
Korea, Republic of	3,080	3,100	
Kuwait	850	850	
Netherlands	510	510	
Poland	1,190	1,200	
Qatar	1,800	1,800	
Russia	7,560	7,500	
Saudi Arabia	6,500	6,500	
United Arab Emirates	3,300	3,300	
Other countries	4,500	4,300	
World total (rounded)	80,000	78,000	

World Resources:[3] Resources of elemental sulfur in evaporite and volcanic deposits, and sulfur associated with natural gas, petroleum, tar sands, and metal sulfides, total about 5 billion tons. The sulfur in gypsum and anhydrite is almost limitless, and 600 billion tons of sulfur is contained in coal, oil shale, and shale that is rich in organic matter. Production from these sources would require development of low-cost methods of extraction. The domestic sulfur resource is about one-fifth of the world total.

Substitutes: Substitutes for sulfur at present or anticipated price levels are not satisfactory; some acids, in certain applications, may be substituted for sulfuric acid, but usually at a higher cost.

[e]Estimated.

[1]Defined as shipments + imports – exports.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Sulfur production in China includes byproduct elemental sulfur recovered from natural gas and petroleum, the estimated sulfur content of byproduct sulfuric acid from metallurgy, and the sulfur content of sulfuric acid from pyrite.

TALC AND PYROPHYLLITE[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Three companies operated five talc producing mines in three States during 2020, and domestic production of crude talc was estimated to have decreased by 12% to 510,000 tons valued at almost $21 million. Talc was mined in Montana, Texas, and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 430,000 tons valued at about $100 million, a 17% decrease from those in 2019. Talc produced and sold in the United States was used in ceramics (including automotive catalytic converters) (22%), paint (19%), paper (17%), plastics (11%), rubber (4%), roofing (3%), and cosmetics (2%). The remaining 22% was for agriculture, export, insecticides, and other miscellaneous uses.

One company in North Carolina mined and processed pyrophyllite in 2020. Domestic production was withheld to avoid disclosing company proprietary data and was estimated to have decreased from that in 2019. Pyrophyllite was sold for refractory, paint, and ceramic products.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, mine	578	610	648	578	510
Sold by producers	528	528	547	515	430
Imports for consumption	378	336	313	281	210
Exports	239	220	273	234	180
Consumption, apparent[2]	667	644	586	562	459
Price, average, milled, dollars per metric ton[3]	197	214	227	240	240
Employment, mine and mill, number:[4]					
Talc	223	206	208	202	185
Pyrophyllite	30	31	30	31	31
Net import reliance[5] as a percentage of apparent consumption	21	18	7	8	6

Recycling: Insignificant.

Import Sources (2016–19): Pakistan, 42%; Canada, 27%; China, 18%; and other, 13%. Large quantities of crude talc are thought to have been mined in Afghanistan before being milled in and exported from Pakistan.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Natural steatite and talc:		
Not crushed, not powdered	2526.10.0000	Free.
Crushed or powdered	2526.20.0000	Free.
Talc, steatite, and soapstone; cut or sawed	6815.99.2000	Free.

Depletion Allowance: Block steatite talc: 22% (domestic), 14% (foreign). Other talc and pyrophyllite: 14% (domestic and foreign).

Government Stockpile: None.

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TALC AND PYROPHYLLITE

Events, Trends, and Issues: Canada, China, and Pakistan were the principal sources for United States talc imports in recent years. Imports from Pakistan have increased in recent years, and imports from China have stayed at about one-third of previous levels. Canada and Mexico continued to be the primary destinations for United States talc exports, collectively receiving about one-half of exports. Imports and exports of talc and related materials are estimated to have decreased by at least 20% in 2020 compared with those of 2019. Primarily owing to the global COVID-19 pandemic, U.S. talc consumption, production, and sales decreased in 2020 from those of 2019.

Ceramic tile and sanitaryware formulations and the technology for firing ceramic tile changed over recent decades, reducing the amount of talc required for the manufacture of some ceramic products. For paint, the industry shifted its focus to production of water-based paint (a product for which talc is not well suited because it is hydrophobic) from oil-based paint in order to reduce volatile emissions. Paper manufacturing began to decrease beginning in the 1990s, and some talc used for pitch control was replaced by chemical agents. For cosmetics, manufacturers of body dusting powders shifted some of their production from talc-based to corn-starch-based products. The paper industry has traditionally been the largest consumer of talc worldwide; however, plastics are expected to overtake paper as the predominant end use within the next several years, as papermakers in Asia make greater use of talc substitutes and as the use of talc in automobile plastics increases.

World Mine Production and Reserves: Reserves for India and the Republic of Korea were revised based on Government and industry sources.

	Mine production		Reserves[6]
	2019	2020[e]	
United States (crude)	578	510	140,000
Brazil (crude and beneficiated)[7]	660	650	45,000
Canada (unspecified minerals)	240	220	NA
China (unspecified minerals)	1,400	1,300	82,000
Finland	330	320	Large
France (crude)	450	430	Large
India[7]	920	900	106,000
Italy (includes steatite)	165	150	NA
Japan[7]	160	150	100,000
Korea, Republic of[7]	330	320	81,000
Pakistan	183	170	NA
Other countries (includes crude)[7]	728	700	Large
World total (rounded)[7]	6,140	5,800	Large

World Resources:[6] The United States is self-sufficient in most grades of talc and related minerals, but lower priced imports have replaced domestic minerals for some uses. Talc occurs in the United States from New England to Alabama in the Appalachian Mountains and the Piedmont region, as well as in California, Montana, Nevada, Texas, and Washington. Domestic and world identified resources are estimated to be approximately five times the quantity of reserves.

Substitutes: Substitutes for talc include bentonite, chlorite, feldspar, kaolin, and pyrophyllite in ceramics; chlorite, kaolin, and mica in paint; calcium carbonate and kaolin in paper; bentonite, kaolin, mica, and wollastonite in plastics; and kaolin and mica in rubber.

[e]Estimated. NA Not available.

[1]All statistics exclude pyrophyllite unless otherwise noted.

[2]Defined as sold by producers + imports – exports.

[3]Average ex-works unit value of milled talc sold by U.S. producers, based on data reported by companies.

[4]Includes only companies that mine talc or pyrophyllite. Excludes office workers and mills that process imported or domestically purchased material.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Includes pyrophyllite.

TANTALUM

(Data in metric tons of tantalum content unless otherwise noted)

Domestic Production and Use: Significant U.S. tantalum mine production has not been reported since 1959. Domestic tantalum resources are of low grade, some are mineralogically complex, and most are not commercially recoverable. Companies in the United States produced tantalum alloys, capacitors, carbides, compounds, and tantalum metal from imported tantalum ores and concentrates and tantalum-containing materials. Tantalum metal and alloys were recovered from foreign and domestic scrap. Domestic tantalum consumption was not reported by consumers. Major end uses for tantalum included alloys for gas turbines used in the aerospace and oil and gas industries; tantalum capacitors for automotive electronics, mobile phones, and personal computers; tantalum carbides for cutting and boring tools; and tantalum oxide (Ta_2O_5) was used in glass lenses to make lighter weight camera lenses that produce a brighter image. The value of tantalum consumed in 2020 was estimated to exceed $210 million as measured by the value of imports.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,060	1,460	1,660	1,380	1,300
Exports[1]	604	549	681	423	400
Shipments from Government stockpile	—	—	—	—	2
Consumption, apparent[2]	460	907	975	957	900
Price, tantalite, dollars per kilogram of Ta_2O_5 content[3]	193	193	214	161	158
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-containing electronic components and from tantalum-containing cemented carbide and superalloy scrap. The amount of tantalum recycled was not available, but it may be as much as 30% of apparent consumption.

Import Sources (2016–19): Tantalum ores and concentrates: Rwanda, 36%; Australia, 25%; Brazil, 14%; Congo (Kinshasa), 7%; and other, 18%. Tantalum metal and powder: China, 38%; Germany, 21%; Thailand, 13%; Kazakhstan, 12%; and other, 16%. Tantalum waste and scrap: Indonesia, 15%; China, 13%; Japan, 13%; Mexico, 10%; and other, 49%. Total: China, 26%; Germany, 11%; Australia, 10%; Indonesia, 10%, and other, 43%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Tantalum ores and concentrates	2615.90.6060	Free.
Tantalum oxide[5]	2825.90.9000	3.7% ad val.
Potassium fluorotantalate[5]	2826.90.9000	3.1% ad val.
Tantalum, unwrought:		
Powders	8103.20.0030	2.5% ad val.
Alloys and metal	8103.20.0090	2.5% ad val.
Tantalum, waste and scrap	8103.30.0000	Free.
Tantalum, other	8103.90.0000	4.4% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[6]

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Tantalum carbide powder	—	—	1.71	—	—
Tantalum niobium concentrate (gross weight)	59	—	—	—	—
Tantalum metal[7] (gross weight)	0.084	15.4	0.09	15.4	0.09
Tantalum alloy (gross weight)	0.0015	—	—	—	—

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TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption (measured in contained tantalum) was estimated to have decreased by 6% from that of 2019. Most of the tantalum imported was in the form of scrap followed by a slightly lesser quantity of metal and powder; imports of ores and concentrates decreased by almost 20% from that in 2019. Globally, consumption of tantalum decreased because of disruptions in transportation and electronics manufacturing supply chains caused by the global COVID-19 pandemic; a leading end use for tantalum was in capacitors. Significant production decreases by major aircraft manufacturers reduced tantalum consumption for superalloys.

World production was lower in part because of temporary mine closures in Brazil and Rwanda caused by the COVID-19 pandemic. Continued low prices for tantalum was also a factor. In Australia, lithium mines that had produced tantalum as a byproduct in 2019 remained on care-and-maintenance status in 2020 because of continued low prices for lithium. Production in Congo (Kinshasa) was estimated to have increased in 2020 based on reported ore production through August 2020; China was the main export destination. Brazil, Congo (Kinshasa), and Rwanda accounted for 77% of estimated global tantalum mine production in 2020.

The U.S. Department of Defense issued an interim rule effective October 1, 2020, amending the Defense Federal Acquisition Regulation Supplement to implement a section of the National Defense Authorization Act for Fiscal Year 2020 that prohibits the acquisition of tantalum metal and alloys from China, Iran, North Korea, and Russia.

World Mine Production and Reserves: Reserves for Australia and Brazil were revised based on Government and industry information.

	Mine production		Reserves[8]
	2019	2020[e]	
United States	—	—	—
Australia	67	30	[9]99,000
Brazil	430	370	40,000
Burundi	38	30	NA
China	76	70	NA
Congo (Kinshasa)	580	670	NA
Ethiopia	70	60	NA
Nigeria	180	160	NA
Russia	26	26	NA
Rwanda	336	270	NA
Other countries	45	35	NA
World total (rounded)	1,850	1,700	>140,000

World Resources:[8] Identified world resources of tantalum, most of which are in Australia, Brazil, and Canada, are considered adequate to supply projected needs. The United States has about 55,000 tons of tantalum resources in identified deposits, most of which were considered uneconomical at 2020 prices for tantalum.

Substitutes: The following materials can be substituted for tantalum, but a performance loss or higher costs may ensue: niobium and tungsten in carbides; aluminum, ceramics, and niobium in electronic capacitors; glass, molybdenum, nickel, niobium, platinum, stainless steel, titanium, and zirconium in corrosion-resistant applications; and hafnium, iridium, molybdenum, niobium, rhenium, and tungsten in high-temperature applications.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated tantalum content of niobium and tantalum ores and concentrates, unwrought tantalum alloys and powder, tantalum waste and scrap, and other tantalum articles. Synthetic concentrates and niobium ores and concentrates were assumed to contain 32% Ta_2O_5. Tantalum ores and concentrates were assumed to contain 37% Ta_2O_5. Ta_2O_5 is 81.897% Ta.

[2]Defined as production + imports – exports + adjustments for Government stock changes.

[3]Price is annual average price reported by CRU Group. The estimate for 2020 includes data available through October 2020.

[4]Defined as imports – exports + adjustments for Government stock changes.

[5]This category includes tantalum-containing material and other material.

[6]See Appendix B for definitions.

[7]Potential acquisitions are for unspecified tantalum materials; potential disposals are for tantalum scrap in the Government stockpile.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 44,400 tons.

TELLURIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2020, tellurium was recovered in the United States. One company in Texas was thought to export copper anode slimes to Mexico for recovery of commercial-grade tellurium. Downstream companies further refined imported commercial-grade metal to produce tellurium dioxide, high-purity tellurium, and tellurium compounds for specialty applications.

Tellurium was predominantly used in the production of cadmium telluride (CdTe) for thin-film solar cells. Another important end use was for the production of bismuth telluride (BiTe), which is used in thermoelectric devices for both cooling and energy generation. Other uses were as an alloying additive in steel to improve machining characteristics, as a minor additive in copper alloys to improve machinability without reducing conductivity, in lead alloys to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. It was used in the chemical industry as a vulcanizing agent and accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production. Other uses included those in photoreceptor and thermoelectric devices, blasting caps, and as a pigment to produce various colors in glass and ceramics.

Global consumption estimates of tellurium by end use are solar, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, refinery	W	W	W	W	W
Imports for consumption	73	163	192	59	7
Exports	3	2	4	1	[1]18
Consumption, apparent[2]	W	W	W	W	W
Price,[3] dollars per kilogram	36	38	73	60	55
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	>95	>95	>95	>95	>95

Recycling: For traditional metallurgical and chemical uses, there was little or no old scrap from which to extract secondary tellurium because these uses of tellurium are highly dispersive or dissipative. A very small amount of tellurium was recovered from scrapped selenium-tellurium photoreceptors employed in older plain-paper copiers in Europe. A plant in the United States recycled tellurium from CdTe solar cells; however, the amount recycled was limited because most CdTe solar cells were relatively new and had not reached the end of their useful life.

Import Sources (2016–19): Canada, 57%; China, 21%; Germany, 17%; the Philippines, 3%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2020, domestic tellurium content in anode slimes was estimated to have remained essentially unchanged from that in 2019. One domestic producer of anode slimes shipped at least a portion of its anode slimes to Mexico for treatment and refining. In 2020, the domestic average monthly price of tellurium generally decreased in the first 8 months of the year, from around $65 per kilogram in January to $55 per kilogram in August, after which the prices recovered to around $60 per kilogram in September.

Domestic imports of tellurium were estimated to have decreased by about 89% in 2020 from those of 2019, mostly as a result of a significant decrease in imports from Germany and Canada. During the first 8 months of 2020, the United States imported 0.025 ton (25 kilograms) of tellurium from Germany and 1 ton of tellurium from Canada. During the same period of 2019, the United States imported 22 tons of tellurium from Germany and 2 tons of tellurium from Canada. Domestic exports of tellurium had increased significantly in 2020 which may include misclassified exports.

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TELLURIUM

World production of tellurium was estimated to be about 490 tons. China was the leading producer of refined tellurium, recovering tellurium from copper anode slimes and from residues generated during the lead, nickel, precious metals, and zinc smelting processes. In late 2019, the Yunnan Provincial government in China announced an auction of 170 tons of tellurium from the defunct Fanya Metal Exchange with a starting price of $43 per kilogram (306 yuan per kilogram), or a total lot bid of $7.34 million (51.95 million yuan), and the tellurium was sold in December 2019. Demand in China for CdTe for solar panels increased in 2020 owing to increased investment in solar production projects. Production of tellurium increased at a Chinese firm to 6 tons per month, up from 1 to 2 tons per month in the previous year. Exports of CdTe from China also rose in the first 6 months of 2020, rising by 6% to over 300 tons.

A Canadian company announced in August that it would expand production of ultra-high purity (99.99999%) tellurium for semiconductor technologies, such as solid-state radiation detectors. Solid-state radiation detectors produce highly accurate images, and are used in healthcare, security, and military systems.

World Refinery Production and Reserves: The figures shown for reserves include only tellurium contained in copper reserves. These estimates assume that more than one-half of the tellurium contained in unrefined copper anodes is recoverable.

	Refinery production		Reserves[5]
	2019	2020[e]	
United States	W	W	3,500
Bulgaria	[e]4	5	NA
Canada	[e]40	35	800
China	[e]325	300	6,600
Japan	[e]50	50	—
Russia	52	50	NA
South Africa	[e]8	5	—
Sweden	41	40	670
Other countries[6]	NA	NA	19,000
World total (rounded)	520	490	31,000

World Resources:[5] Data on tellurium resources were not available. More than 90% of tellurium has been produced from anode slimes collected from electrolytic copper refining, and the remainder was derived from skimmings at lead refineries and from flue dusts and gases generated during the smelting of bismuth, copper, and lead-zinc ores. Potential sources of tellurium include bismuth telluride and gold telluride ores.

Substitutes: Several materials can replace tellurium in most of its uses, but usually with losses in efficiency or product characteristics. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and (or) selenium can act as vulcanization agents in place of tellurium. The selenides and sulfides of niobium and tantalum can serve as electrical-conducting solid lubricants in place of tellurides of those metals.

The selenium-tellurium photoreceptors used in some plain paper photocopiers and laser printers have been replaced by organic photoreceptors in newer devices. Amorphous silicon and copper indium gallium selenide were the two principal competitors of CdTe in thin-film photovoltaic solar cells. Bismuth selenide and organic polymers can be used to substitute for some BiTe thermal devices.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Includes material that may have been misclassified.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]Average annual price. Source: Argus Media group—Argus Metals International for 99.95% tellurium, in warehouse, Rotterdam.

[4]Defined as imports – exports + adjustments for industry stock changes. For 2020, exports were not included in the calculation.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]In addition to the countries listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland produced refined tellurium, but output was not reported and available information was inadequate to make reliable production estimates.

THALLIUM

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Small quantities of thallium are consumed annually, but variations in pricing and value data make it difficult to estimate the value of consumption. The primary end uses included the following: radioisotope thallium-201 used for medical purposes in cardiovascular imaging; thallium as an activator (sodium iodide crystal doped with thallium) in gamma radiation detection equipment; thallium-barium-calcium-copper-oxide high-temperature superconductors used in filters for wireless communications; thallium in lenses, prisms, and windows for infrared detection and transmission equipment; thallium-arsenic-selenium crystal filters for light diffraction in acousto-optical measuring devices; and thallium in mercury alloys for low-temperature measurements. Other uses include as an additive in glass to increase its refractive index and density, a catalyst for organic compound synthesis, and a component in high-density liquids for gravity separation of minerals.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	—	—	—	—	57
Waste and scrap	—	—	23	27	—
Other articles	193	—	41	38	—
Exports:					
Unwrought metal and powders	56	34	100	290	300
Waste and scrap	286	364	853	133	320
Other articles	973	1,560	[1]31,400	[1]79,000	500
Consumption, estimated[2]	193	—	64	65	57
Price, metal,[e, 3] dollars per kilogram	7,400	NA	NA	7,600	8,200
Net import reliance[4] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2016–19): Germany, 60%; China, 24%; Norway, 8%; and the United Kingdom, 8%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Unwrought and powders	8112.51.0000	4.0% ad val.
Waste and scrap	8112.52.0000	Free.
Other	8112.59.0000	4.0% ad val.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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THALLIUM

Events, Trends, and Issues: In 2020, imports of thallium unwrought metal and powder was 57 kilograms. Exports of unwrought thallium and powders were higher in 2020 compared with those of 2019. All exports of unwrought thallium and powders left the Cleveland, OH, and New Orleans, LA, customs districts and went to Taiwan. All exports of thallium waste and scrap left from the Laredo, TX, customs district and went to Mexico in 2020, the same as in 2019. Exports of other thallium articles (Schedule B number 8112.59.0000) returned to lower levels. In 2018 and 2019, reported exports of thallium articles were unusually high in quantity; these exports likely were misclassified material.

Demand for thallium for use in cardiovascular-imaging applications has declined owing to superior performance and availability of alternatives, such as the medical isotope technetium-99. A global shortage of technetium-99 from 2009 to 2011 had contributed to an increase in thallium consumption during that time period. Since 2011, consumption of thallium has declined significantly. Small quantities of thallium are used for research.

The leading global uses for thallium were gamma radiation detection equipment, high-temperature superconductors, infrared optical materials, low-melting glasses, photoelectric cells, and radioisotopes. Producers of these products were in China, Japan, the Republic of Korea, and the United States.

Thallium metal and its compounds are highly toxic materials and are strictly controlled to prevent harm to humans and the environment. Thallium and its compounds can be absorbed into the human body by skin contact, ingestion, or inhalation of dust or fumes. Under its national primary drinking water regulations for public water supplies, the U.S. Environmental Protection Agency has set an enforceable Maximum Contaminant Level of 2 parts per billion thallium in drinking water.

World Refinery Production and Reserves:[5] Thallium is produced commercially in only a few countries as a byproduct in the roasting of copper, lead, and zinc ores and is recovered from flue dust. Because most producers withhold thallium production data, global production data are limited. In 2020, global production of thallium was estimated to be less than 8,000 kilograms. China, Kazakhstan, and Russia were thought to be leading producers of primary thallium. Since 2005, substantial thallium-rich deposits have been identified in Brazil, China, North Macedonia, and Russia. Quantitative estimates of reserves are not available, owing to the difficulty in identifying deposits where thallium can be extracted economically. Previous estimates of reserves were based on the thallium content of zinc ores.

World Resources:[5] Although thallium is reasonably abundant in the Earth's crust, estimated at about 0.7 part per million, it exists mostly in association with potassium minerals in clays, granites, and soils, and it is not generally considered to be commercially recoverable from those materials. The major source of recoverable thallium is the trace amounts found in copper, lead, zinc, and other sulfide ores. World resources of thallium contained in identified zinc resources could be as much as 17 million kilograms; most are in Europe, Canada, and the United States. World identified resources of coal contain an estimated 630 million kilograms of thallium.

Substitutes: Although other materials and formulations can substitute for thallium in gamma radiation detection equipment and optics used for infrared detection and transmission, thallium materials are presently superior and more cost effective for these very specialized uses. The medical isotope technetium-99 can be used in cardiovascular-imaging applications instead of thallium.

Nonpoisonous substitutes, such as tungsten compounds, are being marketed as substitutes for thallium in high-density liquids for gravity separation of minerals.

[e]Estimated. NA Not available. — Zero.

[1]Includes material that may have been misclassified.

[2]Estimated to be equal to imports.

[3]Estimated price of 99.99%-pure granules in 100-gram lots.

[4]Defined as imports – exports. Consumption and exports of unwrought thallium were from imported material or from a drawdown in unreported inventories.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

THORIUM

(Data in kilograms, gross weight, unless otherwise noted)

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2020, monazite may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Essentially, all thorium compounds and alloys consumed by the domestic industry were derived from imports. The number of companies that processed or fabricated various forms of thorium for commercial use was not available. Thorium's use in most products was generally limited because of concerns over its naturally occurring radioactivity. Imports of thorium compounds are sporadic owing to changes in consumption and fluctuations in consumer inventory levels. The estimated value of thorium compounds imported for consumption by the domestic industry in 2020 was $55,000, compared with $213,000 in 2019.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, mine[1]	NA	NA	[2]520,000	[2]1,700,000	[2]600,000
Imports for consumption:					
Ore and concentrates (monazite)	16,000	—	1,000	—	—
Compounds (oxide, nitrate, etc.)	3,120	8,510	9,000	4,000	1,900
Exports:					
Ore and concentrates (monazite)	NA	NA	520,000	1,700,000	600,000
Compounds (oxide, nitrate, etc.)[3]	6,000	6,100	3,000	3,200	400
Consumption, apparent:[4]					
Ore and concentrates (monazite)	16,000	—	1,000	—	—
Compounds (oxide, nitrate, etc.)	([5])	2,410	6,000	800	1,500
Price, average value, compounds, India,[6] dollars per kilogram	65	73	72	72	NA
Net import reliance[7] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2016–19): Monazite: Canada, 100%. Thorium compounds: India, 82%; France, 17%; and the United Kingdom, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Thorium ore and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad val.

Depletion Allowance: Monazite, 22% on thorium content, and 14% on rare-earth and yttrium content (domestic); 14% (foreign).

Government Stockpile: None.

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THORIUM

Events, Trends, and Issues: Domestic demand for thorium alloys, compounds, and metals was limited. In addition to research purposes, various commercial uses of thorium included catalysts, high-temperature ceramics, magnetrons in microwave ovens, metal-halide lamps, nuclear medicine, optical coatings, tungsten filaments, and welding electrodes.

Exports of unspecified thorium compounds were estimated to be 400 kilograms in 2020. Because 99% of the exports were reported to have a unit value of less than $50 per kilogram, those quantities were not included in the total export estimate because it is likely that they were misclassified. Owing to potentially misclassified material and variations in the type and purity of thorium compounds, the unit value of exports varied widely by month and by exporting customs district.

Globally, monazite was produced primarily for its rare-earth-element content, and only a small fraction of the byproduct thorium produced was consumed. India was the leading producer of monazite. Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. In international trade, China was the leading importer of monazite; Brazil, Madagascar, Thailand, and Vietnam were China's leading import sources. The United States exported monazite to China and Hong Kong. Operators of the Eneabba mineral sands project (Australia), the Kvanefjeld project (Greenland), and the Steenkrampskraal Mine (South Africa) plan to start producing within the next year.

Several companies and countries were active in the pursuit of commercializing thorium as a fuel material for a new generation of nuclear reactors. Thorium-based nuclear research and development programs have been or are underway in Australia, Belgium, Brazil, Canada, China, Czechia, Denmark, Finland, France, Germany, India, Israel, Italy, Japan, the Netherlands, Norway, the Republic of Korea, Russia, the United Kingdom, and the United States.

World Refinery Production and Reserves:[8] Production and reserves are associated with the recovery of monazite in heavy-mineral-sand deposits. Without demand for the rare earths, monazite would probably not be recovered for its thorium content under current market conditions.

World Resources:[8] The world's leading thorium resources are found in placer, carbonatite, and vein-type deposits. Thorium is found in several minerals, including monazite, thorite, and thorianite. According to the Organisation for Economic Co-operation and Development's Nuclear Energy Agency, worldwide identified thorium resources were estimated to total 6.4 million tons of thorium. Thorium resources are found throughout the world, most notably in Australia, Brazil, India, and the United States. India has the largest resources (850,000 tons), followed by Brazil (630,000 tons) and Australia and the United States (600,000 tons each).

Substitutes: Nonradioactive substitutes have been developed for many applications of thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, yttrium, and zirconium can substitute for magnesium-thorium alloys in aerospace applications. Cerium and lanthanum can substitute for thorium in welding electrodes. Several replacement materials are in use as optical coatings instead of thorium fluoride.

[e]Estimated. NA Not available. — Zero.

[1]Monazite may have been produced as a separate concentrate or included as an accessory mineral in heavy-mineral concentrates.

[2]Estimates based on exports.

[3]Excludes estimates of material that may have been misclassified.

[4]Defined as production + imports – exports. Shown separately for ore and concentrates and for compounds. Production is only for ore and concentrates.

[5]The apparent consumption calculation yields negative values for thorium compounds in 2016.

[6]Based on U.S. Census Bureau customs data.

[7]Defined as imports – exports; however, a meaningful net import reliance could not be calculated owing to uncertainties in the classification of material being imported and exported.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

TIN

(Data in metric tons of tin content unless otherwise noted)

Domestic Production and Use: Tin has not been mined or smelted in the United States since 1993 and 1989, respectively. Twenty-five firms accounted for over 90% of the primary tin consumed domestically in 2020. The major uses for tin in the United States were tinplate, 21%; chemicals, 18%; solder, 15%; alloys, 10%; babbitt, brass and bronze, and tinning, 10%; and other, 26%. Based on the average S&P Global Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin in 2020 was $557 million, and the estimated value of tin recovered from old scrap domestically in 2020 was $174 million.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, secondary:[e]					
Old scrap	10,000	10,000	9,900	9,900	10,000
New scrap	8,000	8,000	8,000	8,000	8,000
Imports for consumption:					
Tin, refined	32,200	34,300	36,800	34,100	32,000
Tin, alloys, gross weight	1,910	1,550	1,430	1,020	700
Tin, waste and scrap, gross weight	27,200	52,100	47,700	30,400	23,000
Exports:					
Tin, refined	1,150	1,560	941	1,300	500
Tin, alloys, gross weight	1,040	966	885	1,200	1,100
Tin, waste and scrap, gross weight	4,570	3,460	5,980	2,470	1,300
Shipments from Government stockpile, gross weight	—	2	13	1	—
Consumption, apparent, refined[1]	41,800	42,400	42,300	42,600	41,000
Price, average, cents per pound:[2]					
New York dealer	839	937	936	868	790
London Metal Exchange (LME), cash	815	911	914	846	770
Stocks, consumer and dealer, yearend	6,370	6,660	10,100	10,200	11,000
Net import reliance[3] as a percentage of apparent consumption, refined	76	76	77	77	75

Recycling: About 18,000 tons of tin from old and new scrap was estimated to have been recycled in 2020. Of this, about 10,000 tons was recovered from old scrap at 2 detinning plants and about 75 secondary nonferrous metal-processing plants, accounting for 24% of apparent consumption.

Import Sources (2016–19): Refined tin: Indonesia, 24%; Malaysia, 21%; Peru, 20%; Bolivia, 17%; and other, 18%. Waste and scrap: Canada, 99%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Unwrought tin:		
Tin, not alloyed	8001.10.0000	Free.
Tin alloys, containing, by weight:		
5% or less lead	8001.20.0010	Free.
More than 5% but not more than 25% lead	8001.20.0050	Free.
More than 25% lead	8001.20.0090	Free.
Tin waste and scrap	8002.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4]

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Tin (gross weight)	4,015	40	—	—	4,034

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TIN

Events, Trends, and Issues: The estimated amount of tin recycled in 2020 remained essentially unchanged compared with that in 2019. Estimated annual average tin prices based on the first 11 months in 2020 were 790 and 770 cents per pound for the New York dealer price and LME cash price, respectively—a 9% decrease for both prices compared with those in 2019. In 2020, the monthly average New York dealer tin price peaked in November at 856 cents per pound, from a low monthly average price of 705 cents per pound in April.

Decline in global tin use began in 2019 and continued through 2020, likely exacerbated by the global COVID-19 pandemic that has caused disruptions in mining and manufacturing industries around the world. Solder remains the largest global use of tin. Owing to pandemic-related consumption of canned foods, tinplate usage is expected to increase despite years of stagnation. The use of tin in chemicals and tin alloys is expected to decline from that in 2019, matching the overall decline in demand for many durable goods in 2020.

Chinese demand for tin in the third quarter of 2020 reached 2019 levels, despite pandemic-related declines in the first half of 2020. China struggled to source an adequate supply of tin as global mine production only partially recovered in the third quarter. In Burma, further issues with mine flooding and border restrictions imposed because of the COVID-19 pandemic have tightened traditional tin ore sources. In late 2020, China's Yunnan Tin Company Limited began operations at a new smelter in Yunnan Province. The new smelter will replace an existing, and soon-to-be decommissioned, facility in the same Province.

World Mine Production and Reserves: Reserves for Australia, Brazil, Congo (Kinshasa), Malaysia, Peru, and Russia were revised based on information from company and Government reports.

	Mine production		Reserves[5]
	2019	2020[e]	
United States	—	—	—
Australia	7,740	6,800	[6]430,000
Bolivia[e]	17,000	15,000	400,000
Brazil	14,000	13,000	420,000
Burma	42,000	33,000	100,000
China	84,500	81,000	1,100,000
Congo (Kinshasa)[e]	12,200	17,000	160,000
Indonesia	77,500	66,000	800,000
Laos[e]	1,400	1,200	NA
Malaysia	3,610	3,300	150,000
Nigeria[e]	5,800	6,000	NA
Peru	19,900	18,000	140,000
Russia	1,800	2,500	280,000
Rwanda	2,300	1,200	NA
Vietnam	5,500	4,900	11,000
Other countries	549	400	350,000
World total (rounded)	296,000	270,000	4,300,000

World Resources:[5] Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those of the rest of the world. World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

Substitutes: Aluminum, glass, paper, plastic, or tin-free steel substitute for tin content in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, alternative copper-base alloys, and plastics for bronze; plastics for bearing metals that contain tin; and compounds of lead and sodium for some tin chemicals.

[e]Estimated. NA Not available. — Zero.

[1]Defined as production (old scrap) + refined tin imports – refined tin exports + adjustments for Government and industry stock changes. Excludes imports and exports of alloys, and waste and scrap.

[2]Source: S&P Global Platts Metals Week.

[3]Defined as imports – exports + adjustments for Government and industry stock changes, excluding imports and exports of waste and scrap.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant reserves were 250,000 tons.

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Titanium sponge metal was produced by two operations in Nevada and Utah. Production data were withheld to avoid disclosing company proprietary data. The facility in Salt Lake City, UT, with an estimated capacity of 500 tons per year, produced titanium that was further refined for use in electronics. Sponge operations in Henderson, NV, with an estimated capacity of 12,600 tons per year, were idled at yearend owing to market conditions. A third operation, in Rowley, UT, with an estimated capacity of 10,900 tons per year, remained on care-and-maintenance status since 2016.

Although detailed 2020 consumption data were withheld to avoid disclosing proprietary data, the majority of titanium metal was used in aerospace applications, and the remainder was used in armor, chemical processing, marine hardware, medical implants, power generation, consumer, and other applications. The value of imported sponge was about $206 million, a 24% decrease compared with imports in 2019.

In 2020, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3 billion. The estimated end-use distribution of TiO_2 pigment consumption was paints (including lacquers and varnishes), 60%; plastics, 20%; paper, 5%; and other, 15%. Other uses of TiO_2 included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	2016	2017	2018	2019[e]	2020[e]
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption	16,200	24,100	23,700	30,000	24,000
Exports	724	3,090	533	869	910
Consumption, reported	34,100	37,400	35,200	W	W
Price, dollars per kilogram, yearend	9.50	9.10	9.20	6.85	6.90
Stocks, industry, yearend[e]	25,100	13,200	10,700	W	W
Employment, number[e]	150	150	150	150	150
Net import reliance[2] as a percentage of reported consumption	45	88	73	>50	>50
Titanium dioxide pigment:					
Production	1,240,000	1,260,000	1,150,000	1,150,000	1,000,000
Imports for consumption	247,000	240,000	269,000	226,000	270,000
Exports	651,000	634,000	528,000	411,000	370,000
Consumption, apparent[3]	840,000	870,000	893,000	965,000	900,000
Producer price index (1982=100), yearend[4]	175	205	205	NA	NA
Employment, number[e]	3,110	3,110	3,050	3,050	3,100
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: About 45,000 tons of titanium scrap metal was consumed in 2020—35,000 tons by the titanium industry, 8,000 tons by the steel industry, less than 500 tons by the superalloy industry, and the remainder in other industries.

Import Sources (2016–19): Sponge metal: Japan, 90%; Kazakhstan, 7%; Ukraine, 2%; and other, 1%. Titanium dioxide pigment: Canada, 38%; China, 22%; Germany, 9%; Belgium, 4%; and other, 27%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Titanium oxides (unfinished TiO_2 pigments)	2823.00.0000	5.5% ad val.
TiO_2 pigments, 80% or more TiO_2	3206.11.0000	6.0% ad val.
TiO_2 pigments, other	3206.19.0000	6.0% ad val.
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3.7% ad val.
Unwrought titanium metal	8108.20.0010	15.0% ad val.
Titanium waste and scrap metal	8108.30.0000	Free.
Other titanium metal articles	8108.90.3000	5.5% ad val.
Wrought titanium metal	8108.90.6000	15.0% ad val.

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TITANIUM AND TITANIUM DIOXIDE

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: Owing to airline travel concerns and restrictions implemented to limit the spread of the global COVID-19 pandemic, domestic consumption of titanium sponge in 2020 decreased significantly compared with that of 2019. U.S. producers of titanium ingot continued to rely heavily on imports of titanium sponge and scrap. Imports of titanium sponge decreased by about 20%, and exports increased moderately. Japan (88%) and Kazakhstan (10%) were the leading import sources for titanium sponge in 2020. U.S. imports of titanium waste and scrap were about 18,000 tons. Germany (19%), Japan (18%), the United Kingdom (14%), and France (11%) were the leading import sources for titanium waste and scrap in 2020. At yearend, plans to idle the 12,600-ton-per-year sponge plant in Henderson, NV, left the 500-ton-per-year Salt Lake City, UT, plant as the only active domestic producer of titanium sponge. The U.S. Department of Commerce led investigations under section 232 of the Trade Expansion Act of 1962 that determined titanium sponge imports into the United States threatened to impair national security. In 2020, a working group was formed to explore measures to ensure access to titanium sponge in the United States for use for national defense and in critical industries during an emergency. In China, production of titanium sponge increased significantly in 2020, and projects to increase titanium sponge and titanium pigment capacity were expected in 2021.

Domestic production of TiO_2 pigment in 2020 was estimated to be about 1 million tons. Although heavily reliant on imports of titanium mineral concentrates, the United States was a net exporter of TiO_2 pigments. Following a record high of 743,000 tons in 2011, exports of titanium dioxide have followed a declining trend. Since 2011, an increasing percentage of domestic production has been used domestically in lieu of being exported.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production[e]		Capacity, 2020[5]	
	2019	2020	Sponge	Pigment
United States	W	W	13,100	1,370,000
Australia	—	—	—	260,000
Canada	—	—	—	104,000
China	85,000	110,000	158,000	4,000,000
Germany	—	—	—	472,000
India	250	250	500	108,000
Japan	49,000	50,000	68,800	314,000
Kazakhstan	16,000	15,000	26,000	1,000
Mexico	—	—	—	300,000
Russia	44,000	33,000	46,500	55,000
Saudi Arabia	100	500	15,600	210,000
Ukraine	8,000	6,000	12,000	120,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	784,000
World total (rounded)	[6]200,000	[6]210,000	341,000	8,400,000

World Resources:[7] Reserves and resources of titanium minerals are discussed in the Titanium Mineral Concentrates chapter.

Substitutes: Few materials possess titanium metal's strength-to-weight ratio and corrosion resistance. In high-strength applications, titanium competes with aluminum, composites, intermetallics, steel, and superalloys. Aluminum, nickel, specialty steels, and zirconium alloys may be substituted for titanium for applications that require corrosion resistance. Ground calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide as a white pigment.

[e]Estimated. E Net exporter. NA Not Available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also Titanium Mineral Concentrates.

[2]Defined as imports – exports.

[3]Defined as production + imports – exports.

[4]U.S. Department of Labor, Bureau of Labor Statistics.

[5]Yearend operating capacity.

[6]Excludes U.S. production.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

TITANIUM MINERAL CONCENTRATES[1]

(Data in thousand metric tons of TiO_2 content unless otherwise noted)

Domestic Production and Use: In 2020, one company was recovering ilmenite and rutile concentrates from its surface-mining operations near Nahunta, GA, and Starke, FL. A second company processed existing mineral sands mine tailings in Florida and South Carolina. Based on reported data through October 2020, the estimated value of titanium mineral and synthetic concentrates imported into the United States was $520 million. Abrasive sands, monazite, and zircon were coproducts of domestic mining operations. About 90% of titanium mineral concentrates were consumed by domestic titanium dioxide (TiO_2) pigment producers. The remaining 10% was used in welding-rod coatings and for manufacturing carbides, chemicals, and titanium metal.

Salient Statistics—United States:	2016	2017	2018	2019[e]	2020[e]
Production[2]	100	100	100	100	100
Imports for consumption	1,020	1,170	1,100	1,160	780
Exports, all forms[e]	5	6	32	8	19
Consumption, apparent[3]	1,100	1,300	1,200	1,300	900
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, f.o.b. Australia[4]	740	740	1,025	1,125	1,200
Ilmenite, bulk, minimum 54% TiO_2, f.o.b. Australia[4]	105	173	NA	NA	NA
Ilmenite, import	142	172	219	186	210
Slag, 80%–95% TiO_2[5]	612–682	621–700	699–738	742–897	640–1,020
Employment, mine and mill, number	155	286	299	310	260
Net import reliance[6] as a percentage of apparent consumption	91	92	91	92	88

Recycling: None.

Import Sources (2016–19): South Africa, 39%; Australia, 20%; Madagascar, 10%; Mozambique, 9%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Synthetic rutile	2614.00.3000	Free.
Ilmenite and ilmenite sand	2614.00.6020	Free.
Rutile concentrate	2614.00.6040	Free.
Titanium slag	2620.99.5000	Free.

Depletion Allowance: Ilmenite and rutile, 22% (domestic) and 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of titanium mineral concentrates is tied to production of TiO_2 pigments that are primarily used in paint, paper, and plastics. Demand for these primary uses are tied to changes in the gross domestic product. Demand in the first half of 2020 decreased sharply owing to restrictions implemented to limit the spread of the COVID-19 virus. In the second half of 2020, titanium producers reported that demand was recovering, led by demand for TiO_2 in paints and coatings. Domestic apparent consumption of titanium mineral concentrates in 2020 was estimated to have decreased by about 30% from that of 2019; however, inventory changes were not included in this calculation. Although small compared with apparent consumption, exports of titanium mineral concentrates increased substantially from those in the previous year owing to increased exports to China, India, and the Netherlands.

Australia, China, and South Africa were the leading producers of titanium mineral concentrates. China continued to be both the leading producer and consumer of titanium mineral concentrates. In 2020, China's imports of titanium mineral concentrates were about 3 million tons in gross weight, an increase of 19% compared with those in 2019. In Guangdong Province, capacity to produce up to 200,000 tons per year of synthetic rutile was being commissioned. As of October, Mozambique (36%), Australia (14%), Vietnam (11%), and Kenya (11%) were the leading sources of titanium mineral concentrates to China. In Saudi Arabia, owing to technical problems and COVID-19 pandemic concerns, commissioning of a project to produce up to 500,000 tons per year of titanium slag was delayed until 2021. Other projects were being developed in Australia, China, Malawi, Mozambique, Norway, Senegal, and Tanzania.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for Australia, Kenya, Madagascar, Mozambique, and South Africa were revised based on Government or industry reports.

	Mine production		Reserves[7]
	2019	2020[e]	
Ilmenite:			
United States[2, 8]	100	100	2,000
Australia	840	800	[9]150,000
Brazil	25	25	43,000
Canada[10]	680	680	31,000
China	2,300	2,300	230,000
India	162	160	85,000
Kenya	210	190	440
Madagascar[10]	280	300	23,000
Mozambique	590	600	26,000
Norway	400	400	37,000
Senegal	310	310	NA
South Africa[10]	1,100	1,000	35,000
Ukraine	490	470	5,900
Vietnam	160	160	1,600
Other countries	74	70	26,000
World total (ilmenite, rounded)[8]	7,700	7,600	700,000
Rutile:			
United States	([8])	([8])	([8])
Australia	200	200	[9]27,000
India	11	11	7,400
Kenya	74	74	170
Mozambique	6	6	890
Senegal	9	9	NA
Sierra Leone	129	120	490
South Africa	110	100	6,800
Ukraine	94	94	2,500
Other countries	21	20	400
World total (rutile, rounded)[8]	654	630	46,000
World total (ilmenite and rutile, rounded)	8,400	8,200	740,000

World Resources:[7] Ilmenite accounts for about 90% of the world's consumption of titanium minerals. World resources of anatase, ilmenite, and rutile total more than 2 billion tons.

Substitutes: Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings.

[e]Estimated. NA Not available.

[1]See also Titanium and Titanium Dioxide.

[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.

[3]Defined as production + imports – exports. Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.

[4]Source: Industrial Minerals (Fastmarkets IM); average of yearend price. Prices of ilmenite from Australia were discontinued at yearend 2017.

[5]Landed duty-paid value based on U.S. imports for consumption. Data series revised to reflect annual average unit value range of significant importing countries.

[6]Defined as imports – exports.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]U.S. rutile production and reserves data are included with ilmenite.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves for ilmenite and rutile were estimated to be 36 million and 8.2 million tons, respectively.

[10]Mine production is primarily used to produce titaniferous slag.

TUNGSTEN

(Data in metric tons of tungsten content unless otherwise noted)

Domestic Production and Use: There has been no known domestic commercial production of tungsten concentrates since 2015. Approximately six companies in the United States used chemical processes to convert tungsten concentrates, ammonium paratungstate (APT), tungsten oxide, and (or) scrap to tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals. Nearly 60% of the tungsten used in the United States was used in cemented carbide parts for cutting and wear-resistant applications, primarily in the construction, metalworking, mining, and oil and gas drilling industries. The remaining tungsten was used to make various alloys and specialty steels; electrodes, filaments, wires, and other components for electrical, electronic, heating, lighting, and welding applications; and chemicals for various applications. The estimated value of apparent consumption in 2020 was approximately $500 million.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Mine	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Concentrate	3,580	3,920	4,050	2,760	2,000
Other forms[1]	6,300	9,780	10,400	11,100	9,000
Exports:					
Concentrate	183	532	284	584	300
Other forms[2]	3,200	3,010	3,210	2,780	2,500
Shipments from Government stockpile:					
Concentrate	—	1,460	1,180	663	700
Other forms	—	—	—	—	20
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent,[3] all forms	W	W	W	W	W
Price,[4] concentrate, average U.S. spot market, dollars per metric ton unit of tungsten trioxide[5]	148	245	326	270	270
Stocks, industry, concentrate and other forms, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>25	>50	>50	>50	>50

Recycling: The estimated quantity of secondary tungsten produced and the amount consumed from secondary sources by processors and end users in 2020 were withheld to avoid disclosing company proprietary data.

Import Sources (2016–19): Tungsten contained in ores and concentrates, intermediate and primary products, wrought and unwrought tungsten, and waste and scrap: China, 32%; Bolivia, 9%; Germany, 9%; Austria, 5%; and other, 45%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Ores	2611.00.3000	Free.
Concentrates	2611.00.6000	37.5¢/kg tungsten content.
Tungsten oxides	2825.90.3000	5.5% ad val.
Ammonium tungstates	2841.80.0010	5.5% ad val.
Tungsten carbides	2849.90.3000	5.5% ad val.
Ferrotungsten	7202.80.0000	5.6% ad val.
Tungsten powders	8101.10.0000	7.0% ad val.
Tungsten waste and scrap	8101.97.0000	2.8% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7]

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Metal powder	107	—	125	—	125
Ores and concentrates	7,660	—	1,360	—	1,360
Tungsten alloys, gross weight[8]	6	5	—	5	—

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TUNGSTEN

Events, Trends, and Issues: World tungsten supply was dominated by production in China and exports from China. China's Government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate production, and placing constraints on mining and processing. In 2020, production of tungsten concentrate outside China was expected to remain at less than 20% of world production. Scrap continued to be an important source of raw material for the tungsten industry worldwide.

China was the world's leading tungsten consumer. Analysts forecast global tungsten consumption in 2020 will be less than that in 2019 as a result of the impacts of the global COVID-19 pandemic on the global economy and industrial production, particularly tungsten consuming end-use sectors such as the automotive, commercial aerospace, and oil and gas drilling industries. The decrease in tungsten consumption in 2020 is expected to result in a market surplus. During March and April 2020, most prices of tungsten concentrates and downstream tungsten materials decreased in response to reduced demand; prices then stabilized or gradually trended upward as the year progressed.

World Mine Production and Reserves: Reserves for Mongolia and Russia were revised based on Government reports.

	Mine production		Reserves[9]
	2019	2020[e]	
United States	—	—	NA
Austria	892	890	10,000
Bolivia	1,060	1,400	NA
China	69,000	69,000	1,900,000
Korea, North	1,130	500	29,000
Mongolia	1,900	1,900	4,300
Portugal	518	680	3,100
Russia	2,200	2,200	400,000
Rwanda	900	1,000	NA
Spain	603	800	54,000
Vietnam	4,500	4,300	95,000
Other countries	1,070	1,000	880,000
World total (rounded)	83,800	84,000	3,400,000

World Resources:[9] World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits. Canada, Kazakhstan, Russia, and the United States also have significant tungsten resources.

Substitutes: Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide, niobium carbide, or titanium carbide; ceramics; ceramic-metallic composites (cermets); and tool steels. Most of these options reduce, rather than replace, the amount of tungsten used. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels, although most molybdenum steels still contain tungsten; lighting based on carbon nanotube filaments, induction technology, and light-emitting diodes for lighting based on tungsten electrodes or filaments; depleted uranium or lead for tungsten or tungsten alloys in applications requiring high density or the ability to shield radiation; and depleted uranium alloys or hardened steel for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles. In some applications, substitution would result in increased cost or a loss in product performance.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Includes ammonium and other tungstates; ferrotungsten; tungsten carbides; tungsten metal powders; tungsten oxides, chloride, and other tungsten compounds; unwrought tungsten; wrought tungsten forms; and tungsten waste and scrap.

[2]Includes ammonium and other tungstates, ferrotungsten, tungsten carbides, tungsten metal powders, unwrought tungsten, wrought tungsten forms, and tungsten waste and scrap.

[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.

[4]Source: S&P Global Platts Metals Week.

[5]A metric ton unit of tungsten trioxide contains 7.93 kilograms of tungsten.

[6]Defined as imports – exports + adjustments for Government and industry stock changes.

[7]See Appendix B for definitions.

[8]Inventory includes tungsten alloys and tungsten-rhenium metal; potential acquisitions are tungsten-rhenium metal only.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

VANADIUM

(Data in metric tons of vanadium content unless otherwise noted)

Domestic Production and Use: Byproduct vanadium production in Utah from the mining of uraniferous sandstones on the Colorado Plateau ceased in the first quarter of 2020 owing to decreasing vanadium prices. An estimated 170 tons of contained vanadium with an estimated value of $1.4 million was produced in 2020. Secondary vanadium production continued primarily in Arkansas, Delaware, Ohio, Pennsylvania, and Texas, where processed waste materials (petroleum residues, spent catalysts, utility ash, and vanadium-bearing pig iron slag) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, vanadium metal, and vanadium pentoxide. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2020. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, mine, mill	—	—	—	460	170
Imports for consumption:					
Vanadium ores and concentrates	18	1	330	108	3
Ferrovanadium	1,590	2,810	2,970	2,280	1,600
Vanadium pentoxide, anhydride	2,460	3,400	4,600	3,660	2,800
Oxides and hydroxides, other	660	148	98	105	140
Aluminum-vanadium master alloys	157	288	281	222	180
Ash and residues	2,820	2,540	2,810	2,120	50
Vanadium chemicals[1]	555	607	515	201	230
Vanadium metal[2]	33	54	28	45	1
Exports:					
Vanadium ores and concentrates	260	37	29	57	30
Ferrovanadium	394	229	575	295	200
Vanadium pentoxide, anhydride	5	126	563	423	80
Oxides and hydroxides, other	81	148	53	750	80
Aluminum-vanadium master alloys	53	132	90	29	30
Ash and residues	123	322	287	256	60
Vanadium metal[2]	19	59	39	27	20
Consumption:					
Apparent[3]	7,360	8,780	9,980	7,350	4,800
Reported	4,610	4,670	5,640	4,840	4,400
Price, average, vanadium pentoxide,[4] dollars per pound	3.38	7.61	16.4	12.2	6.7
Stocks, yearend[5]	207	227	250	257	220
Net import reliance[6] as a percentage of apparent consumption	100	100	100	94	96

Recycling: The quantity of vanadium recycled from spent chemical process catalysts was significant and may compose as much as 40% of total vanadium catalysts.

Import Sources (2016–19): Ferrovanadium: Austria, 47%; Canada, 25%; Russia, 14%; Japan, 5%; and other, 9%. Vanadium pentoxide: Brazil, 41%; South Africa, 37%; China, 11%; Taiwan, 5%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Vanadium ores and concentrates	2615.90.6090	Free.
Vanadium bearing ash and residues	2620.40.0030	Free.
Vanadium bearing ash and residues, other	2620.99.1000	Free.
Chemical compounds:		
Vanadium pentoxide, anhydride	2825.30.0010	5.5% ad val.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad val.
Vanadium sulfates	2833.29.3000	5.5% ad val.
Vanadates	2841.90.1000	5.5% ad val.
Hydrides and nitrides of vanadium	2850.00.2000	5.5% ad val.
Ferrovanadium	7202.92.0000	4.2% ad val.
Vanadium metal	8112.92.7000	2.0% ad val.
Vanadium and articles thereof[7]	8112.99.2000	2.0% ad val.

Depletion Allowance: 22% (domestic), 14% (foreign).

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VANADIUM

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of vanadium in 2020 decreased by 35% from that of 2019. Among the major uses for vanadium, production of carbon, full-alloy, and high-strength low-alloy steels accounted for 18%, 45%, and 33%, respectively, of domestic consumption. The estimated average Chinese vanadium pentoxide price in 2020 decreased by 45% compared with the 2019 price, and the estimated United States ferrovanadium price decreased by 53% to $10.40 per pound in 2020 compared with that in 2019.

The implementation of the new high-strength rebar standards by the Standardization Administration of China continued to be enforced inconsistently. Larger mills in China began implementation in 2018; however, smaller mills have been slower to implement the new rebar standards. In addition, substitution of ferroniobium for ferrovanadium has caused lasting effects on mills, and mills were unlikely to switch back to using ferrovanadium owing to costly technical changes already incurred.

A vanadium processing facility in South Africa reopened in early 2020 under new management and began processing stockpiled materials. A producer in Brazil that started production in 2014 continued to be on track to reach vanadium production guidance for 2020 despite production delays caused by the global COVID-19 pandemic. However, some vanadium producers have reported that they were unlikely to reach their original anticipated production guidance and were unsure of the continuing effects of the pandemic.

World Mine Production and Reserves:

	Mine production		Reserves[8]
	2019	2020[e]	(thousand metric tons)
United States	460	170	45
Australia	—	—	[9]4,000
Brazil	5,940	6,600	120
China	54,000	53,000	9,500
Russia	18,400	18,000	5,000
South Africa	8,030	8,200	3,500
World total (rounded)	86,800	86,000	22,000

World Resources:[8] World resources of vanadium exceed 63 million tons. Vanadium occurs in deposits of phosphate rock, titaniferous magnetite, and uraniferous sandstone and siltstone, in which it constitutes less than 2% of the host rock. Significant quantities are also present in bauxite and carboniferous materials, such as coal, crude oil, oil shale, and tar sands. Because vanadium is typically recovered as a byproduct or coproduct, demonstrated world resources of the element are not fully indicative of available supplies. Although domestic resources and secondary recovery are adequate to supply a large portion of domestic needs, almost all of U.S. demand is currently met by foreign sources.

Substitutes: Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. Currently, no acceptable substitute for vanadium is available for use in aerospace titanium alloys.

[e]Estimated. — Zero.

[1]Includes vanadium chlorides, hydrides, nitrides, and sulfates, as well as vanadates of vanadium.

[2]Includes waste and scrap.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Price for 2016 is the U.S. annual average vanadium pentoxide price. The 2017 annual average vanadium pentoxide price includes U.S. monthly averages for January to June 2017 and China monthly average prices for July to December 2017. The prices for 2018–2020 are the China annual average vanadium pentoxide prices.

[5]Includes chlorides, ferrovanadium, vanadates, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.

[6]Defined as imports – exports + adjustments for industry stock changes.

[7]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 1.1 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies with mining and processing facilities in South Carolina and Virginia produced approximately 100,000 tons of vermiculite concentrate; actual data have been rounded to one significant digit to avoid disclosing company proprietary data. Flakes of raw vermiculite concentrate are micaceous in appearance and contain interlayer water in their structure. When the flakes are heated rapidly to a temperature above 870 °C, the water flashes into steam, and the flakes expand into accordionlike particles. This process is called exfoliation or expansion, and the resulting ultralightweight material is chemically inert, fire resistant, and odorless. Most of the vermiculite concentrate produced in the United States was shipped to 17 exfoliating plants in 11 States. The end uses for exfoliated vermiculite were estimated to be agriculture and horticulture, 48%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 14%; insulation, 11%; and other, 27%.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production[e, 1, 2]	100	100	100	100	100
Imports for consumption[e]	36	28	37	39	40
Exports[e]	21	16	14	9	10
Consumption:					
Apparent, concentrate[3]	120	110	120	130	130
Reported, exfoliated	68	72	76	74	70
Price, range of value, concentrate, ex-plant, dollars per ton	140–575	140–575	140–575	NA	NA
Employment, number[e]	62	63	66	73	73
Net import reliance[4] as a percentage of apparent consumption[e, 2]	10	10	20	20	20

Recycling: Insignificant.

Import Sources (2016–19): South Africa, 71%; Brazil, 25%; Zimbabwe, 2%; Kenya, 1%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Vermiculite, perlite and chlorites, unexpanded	2530.10.0000	Free.
Exfoliated vermiculite, expanded clays, foamed slag, and similar expanded materials	6806.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. exports and imports of vermiculite are not collected as a separate category by the U.S. Census Bureau. Despite the global COVID-19 pandemic, U.S. imports were estimated to be about 40,000 tons in 2020, essentially unchanged from those of 2019. Most imports came from South Africa and Brazil in 2020. One company announced price increases for vermiculite in 2020 but did not disclose specific price ranges.

A company in Brazil continued to expand production capacity at its vermiculite mine in central Brazil and continued with the development of another deposit near Brasilia to bring the company's total production capacity to 200,000 tons per year. Companies in China with significant vermiculite resources also were ramping up production, although processing operations continued to be somewhat constrained by increased enforcement of environmental regulations. Specific production data were not available for China.

Coarse-grade vermiculite remained in short supply. Sustained production at the 30,000-ton-per-year Namekara Mine in Uganda provides coarser grades to the market because it is considered to be one of the world's largest vermiculite deposits with significant portions of medium- and coarse-grade material. The Namekara deposit has enough resources for more than 50 years of production at previously announced rates. The company in Uganda pursued mine planning strategies after becoming the 100% owner of the mine.

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VERMICULITE

Exploration and development of vermiculite deposits containing medium, large, and premium (coarser) grades (mostly in China and South Africa) are likely to continue because of the higher demand for those grades. Finer grade production has exceeded consumption for several years. However, coarser grade (greater than 5-millimeter particle size) production has not been able to keep up with demand. Producers will continue to investigate ways to increase the use of the finer grades in existing products and in uses that require coarse material. Innovative applications continue to emerge, including the use of vermiculite to combat air pollution and absorb water in mines, replacing zeolites in ion-exchange columns, purifying wastewater, and containing or removing nuclear waste.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2019	2020[e]	
United States	[e, 2]100	[2]100	25,000
Brazil	50	50	6,600
Bulgaria	11	10	NA
China	NA	NA	NA
Egypt	8	8	NA
India	2	2	1,600
Russia	25	25	NA
South Africa	158	140	14,000
Uganda	7	7	NA
Zimbabwe	30	30	NA
Other countries	3	3	NA
World total (rounded)[6]	390	380	NA

World Resources:[5] In addition to the producing mines in South Carolina and Virginia, there are vermiculite occurrences in Colorado, Nevada, North Carolina, Texas, and Wyoming which contain estimated resources of 2 million tons to 3 million tons. Significant deposits have been reported in Australia, China, Russia, Uganda, and some other countries, but reserves and resource information comes from many sources and, in most cases, it is not clear whether the numbers refer to vermiculite alone or vermiculite plus other minerals and host rock and overburden.

Substitutes: Expanded perlite is a substitute for exfoliated vermiculite in lightweight concrete and plaster. Other denser but less costly alternatives in these applications include expanded clay, shale, slag, and slate. Alternate materials for loose-fill fireproofing insulation include fiberglass, perlite, and slag wool. In agriculture, substitutes include bark and other plant materials, peat, perlite, sawdust, and synthetic soil conditioners.

[e]Estimated. NA Not available.

[1]Concentrate sold or used by producers.

[2]Data are rounded to one significant digit to avoid disclosing company proprietary data.

[3]Defined as concentrate sold or used by producers + imports – exports.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Excludes China production.

WOLLASTONITE

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2020. U.S. production of wollastonite (sold or used by producers) was withheld to avoid disclosing company proprietary data but was estimated to have remained essentially unchanged from that of 2019. Economic resources of wollastonite typically form as a result of thermal metamorphism of siliceous limestone during regional deformation or chemical alteration of limestone by siliceous hydrothermal fluids along faults or contacts with magmatic intrusions. Deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah; however, New York is the only State where long-term continuous mining has taken place.

The U.S. Geological Survey does not collect consumption statistics for wollastonite, but consumption was estimated to have decreased in 2020, compared with that of 2019. Ceramics (frits, sanitaryware, and tile), friction products (primarily brake linings), metallurgical applications (flux and conditioner), paint (architectural and industrial paints), plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds), and miscellaneous uses (including adhesives, concrete, glass, and sealants) accounted for wollastonite sales in the United States.

In ceramics, wollastonite decreases shrinkage and gas evolution during firing; increases green and fired strength; maintains brightness during firing; permits fast firing; and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding, a source for calcium oxide, a slag conditioner, and protects the surface of molten metal during the continuous casting of steel. As an additive in paint, it improves the durability of the paint film, acts as a pH buffer, improves resistance to weathering, reduces gloss and pigment consumption, and acts as a flatting and suspending agent. In plastics, wollastonite improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, stable at high temperatures, and improves flexural and tensile strength.

Salient Statistics—United States: The United States was thought to be a net exporter of wollastonite in 2020. Comprehensive trade data were not available for wollastonite because it is imported and exported under generic Harmonized Tariff Schedule of the United States and Schedule B codes, respectively, that include multiple mineral commodities. Prices for domestically produced wollastonite were estimated to be between $360 to $390 per metric ton. Price data for globally produced wollastonite were unavailable. Products with finer grain sizes and acicular (highly elongated) particles sold for higher prices. Surface treatment, when necessary, also increased the selling price. Approximately 60 people were employed at wollastonite mines and mills in 2019 (excluding office workers).

Recycling: None.

Import Sources (2016–19): Comprehensive trade data were not available, but wollastonite was primarily imported from Canada, China, India, and Mexico.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

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WOLLASTONITE

Events, Trends, and Issues: Construction starts of new housing units through July 2020, increased by 4.7% compared with those during the same period in 2019, suggesting that sales of wollastonite to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, might have increased. However, sales of wollastonite to most other major markets in which wollastonite is used were estimated to have decreased. Owing to disruptions caused by the COVID-19 pandemic, production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, decreased in the first 7 months of 2020; plastics and rubber production decreased by 33% each; and primary iron and steel production decreased by 19% compared with those in the same period of 2019.

Globally, ceramics, polymers (such as plastics and rubber), and paint accounted for most wollastonite sales. Lesser global uses for wollastonite included miscellaneous construction products, friction materials, metallurgical applications, and paper. Global sales of wollastonite were estimated to be in the range of 830,000 to 880,000 tons, slightly lower than those in 2019.

World Mine Production and Reserves: More countries than those listed may produce wollastonite; however, many countries do not publish wollastonite production data.

	Mine production		Reserves[1]
	2019	2020[e]	
United States	W	W	World reserves of wollastonite exceed 100 million tons. Many deposits, however, have not been surveyed, precluding accurate estimates of reserves.
Canada	20,000	20,000	
China	890,000	890,000	
India	170,000	120,000	
Mexico	101,000	100,000	
Other countries	17,000	17,000	
World total (rounded)[2]	1,200,000	1,100,000	

World Resources:[1] Reliable estimates of wollastonite resources do not exist for most countries. Large deposits of wollastonite have been identified in China, Finland, India, Mexico, and the United States. Smaller, but significant, deposits have been identified in Canada, Chile, Kenya, Namibia, South Africa, Spain, Sudan, Tajikistan, Turkey, and Uzbekistan.

Substitutes: The acicular nature of many wollastonite products allows it to compete with other acicular materials, such as ceramic fiber, glass fiber, steel fiber, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene, in products where improvements in dimensional stability, flexural modulus, and heat deflection are sought. Wollastonite also competes with several nonfibrous minerals or rocks, such as kaolin, mica, and talc, which are added to plastics to increase flexural strength, and such minerals as barite, calcium carbonate, gypsum, and talc, which impart dimensional stability to plastics. In ceramics, wollastonite competes with carbonates, feldspar, lime, and silica as a source of calcium and silica. Its use in ceramics depends on the formulation of the ceramic body and the firing method.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

[2]Excludes U.S. production.

YTTRIUM[1]

[Data in metric tons of yttrium-oxide (Y_2O_3) equivalent content unless otherwise noted]

Domestic Production and Use: Yttrium is one of the rare-earth elements. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined in 2020 as a primary product at the Mountain Pass Mine in California, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Monazite, a rare-earth phosphate mineral, was produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Yttrium was estimated to represent about 0.12% of the rare-earth elements in the Mountain Pass bastnaesite ore. Insufficient information was available to determine the yttrium content of mine production.

The leading end uses of yttrium were in catalysts, ceramics, lasers, metallurgy, and phosphors. In ceramic applications, yttrium compounds were used in abrasives, bearings and seals, high-temperature refractories for continuous-casting nozzles, jet-engine coatings, oxygen sensors in automobile engines, and wear-resistant and corrosion-resistant cutting tools. In metallurgical applications, yttrium was used as a grain-refining additive and as a deoxidizer. Yttrium was used in heating-element alloys, high-temperature superconductors, and superalloys. In electronics, yttrium-iron garnets were components in microwave radar to control high-frequency signals. Yttrium was an important component in yttrium-aluminum-garnet laser crystals used in dental and medical surgical procedures, digital communications, distance and temperature sensing, industrial cutting and welding, nonlinear optics, photochemistry, and photoluminescence. Yttrium was used in phosphor compounds for flat-panel displays and various lighting applications.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production, mine	—	—	NA	NA	NA
Imports for consumption, yttrium, alloys, compounds, and metal[e, 2]	340	380	450	360	600
Exports, compounds[e, 3]	2	2	14	6	1
Consumption, apparent[e, 4]	300	400	500	400	600
Price, average, dollars per kilogram:[5]					
Yttrium oxide, minimum 99.999% purity	4	3	3	3	3
Yttrium metal, minimum 99.9% purity	35	35	36	34	34
Net import reliance[6, 7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Insignificant.

Import Sources (2016–19):[8] Yttrium compounds: China, 94%; the Republic of Korea, 2%; Japan, 1%; and other, 3%. Nearly all imports of yttrium metal and compounds are derived from mineral concentrates processed in China. Import sources do not include yttrium contained in value-added intermediates and finished products.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Rare-earth metals, unspecified, whether or not intermixed or interalloyed	2805.30.0090	5.0% ad val.
Mixtures of rare-earth oxides containing yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of rare-earth chlorides containing yttrium or scandium as the predominant metal	2846.90.2082	Free.
Yttrium-bearing materials and compounds containing by weight >19% to <85% Y_2O_3	2846.90.4000	Free.
Other rare-earth compounds, including yttrium and other compounds	2846.90.8000	3.7% ad val.

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YTTRIUM

Depletion Allowance: Monazite, thorium content, 22% (domestic), 14% (foreign); yttrium, rare-earth content, 14% (domestic and foreign); and xenotime, 14% (domestic and foreign).

Government Stockpile:[9]

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Yttrium	25	—	—	600	—

Events, Trends, and Issues: China produced most of the world's supply of yttrium from its weathered clay ion-adsorption ore deposits in the southern Provinces—primarily Fujian, Guangdong, and Jiangxi—and from a lesser number of deposits in Guangxi and Hunan Provinces. Yttrium was also produced from similar clay deposits in Burma.

Globally, yttrium was mainly consumed in the form of oxide compounds for ceramics and phosphors. Lesser amounts were consumed in electronic devices, lasers, optical glass, and metallurgical applications. The average prices for yttrium metal and yttrium oxide price were nearly unchanged compared with that of 2019. China's Ministry of Industry and Information Technology raised the rare-earth mining and separation quotas to record highs of 140,000 tons and 135,000 tons of rare-earth-oxide equivalent, respectively. The yttrium content of the production quota was not specified. In 2020, China's exports of yttrium compounds and metal were estimated to be 2,300 tons of yttrium-oxide equivalent, and the leading export destinations were, in descending order, Japan, the United States, Italy, and the Republic of Korea.

World Mine Production and Reserves:[10] World mine production of yttrium contained in rare-earth mineral concentrates was estimated to be 8,000 to 12,000 tons. Most of this production took place in China and Burma. Global reserves of yttrium oxide were estimated to be more than 500,000 tons. The leading countries for these reserves included Australia, Brazil, Canada, China, and India. Although mine production in Burma was significant, information on reserves in Burma was not available. Global reserves may be adequate to satisfy near-term demand at current rates of production; however, changes in economic conditions, environmental issues, or permitting and trade restrictions could affect the availability of many of the rare-earth elements, including yttrium.

World Resources:[10] Large resources of yttrium in monazite and xenotime are available worldwide in placer deposits, carbonatites, uranium ores, and weathered clay deposits (ion-adsorption ore). Additional resources of yttrium occur in apatite-magnetite-bearing rocks, deposits of niobium-tantalum minerals, nonplacer monazite-bearing deposits, sedimentary phosphate deposits, and uranium ores.

Substitutes: Substitutes for yttrium are available for some applications but generally are much less effective. In most uses, especially in electronics, lasers, and phosphors, yttrium is generally not subject to direct substitution by other elements. As a stabilizer in zirconia ceramics, yttrium oxide may be substituted with calcium oxide or magnesium oxide, but the substitutes generally impart lower toughness.

[e]Estimated. NA Not available. — Zero.

[1]See also Rare Earths; trade data for yttrium are included in the data shown for rare earths.

[2]Estimated from Trade Mining LLC and IHS Markit Ltd. shipping records.

[3]Includes data for the following Schedule B code: 2846.90.2015.

[4]Defined as imports – exports. Rounded to one significant digit. Yttrium consumed domestically was imported or refined from imported materials.

[5]Free on board China. Source: Argus Media group—Argus Metals International, London, United Kingdom.

[6]Defined as imports – exports.

[7]In 2018, 2019, and 2020, domestic production of mineral concentrates was stockpiled or exported. Consumers of compounds and metals were reliant on imports and stockpiled inventory of compounds and metals.

[8]Includes estimated yttrium-oxide equivalent content from the following Harmonized Tariff Schedule of the United States codes: 2846.90.2015, 2846.90.2082, 2846.90.4000, 2846.90.8050, and 2846.90.8060.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

ZEOLITES (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2020, six companies in the United States operated nine zeolite mines and produced an estimated 88,000 tons of natural zeolites, essentially unchanged from that of 2019. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. Minor quantities of erionite, ferrierite, mordenite, and (or) phillipsite also likely were produced. New Mexico was estimated to be the leading natural zeolite-producing State in 2020. The top three companies accounted for approximately 75% of total domestic production.

An estimated 77,000 tons of natural zeolites were sold in the United States during 2020, essentially unchanged compared with sales in 2019. Domestic uses were, in decreasing order by estimated quantity, animal feed, odor control, unclassified end uses (such as ice melt, soil amendment, and synthetic turf), water purification, pet litter, wastewater treatment, fungicide or pesticide carrier, oil and grease absorbent, air filtration and gas absorbent, fertilizer carrier, desiccant, and aquaculture. Animal feed, odor control, and water purification applications likely accounted for about 60% of the domestic sales tonnage.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, mine	75,200	82,400	86,100	87,800	88,000
Sales, mill	71,300	81,300	80,500	77,100	77,000
Imports for consumption[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Exports[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Consumption, apparent[1]	71,300	81,300	80,500	77,100	77,000
Price, range of value, dollars per ton[2]	100–400	100–300	[e]50–300	[e]50–300	50–300
Employment, mine and mill, number[e, 3]	115	110	110	120	120
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Zeolites used for desiccation, gas absorbance, wastewater cleanup, and water purification may be reused after reprocessing of the spent zeolites. Information about the quantity of recycled natural zeolites was unavailable.

Import Sources (2016–19): Comprehensive trade data were not available for natural zeolite minerals because they were imported and exported under generic Harmonized Tariff Schedule of the United States and Schedule B codes, respectively, that include multiple mineral commodities or under codes for finished products. Nearly all imports and exports were thought to be synthetic zeolites.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–30–20**
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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ZEOLITES (NATURAL)

Events, Trends, and Issues: Prior to the 1990s, annual output of natural zeolites in the United States was less than 15,000 tons. Production rose more than sixfold from 1990 through 2020 owing predominantly to increases in sales for animal feed applications, although sales for odor control and water purification also increased significantly. In contrast, sales for pet litter declined substantially during this period as a result of competition from other products. Owing to disruptions likely caused by the global COVID-19 pandemic, mine production during the first 6 months of 2020 was mixed compared with the same period of 2019. Some mines appeared to have cut production and others may have increased production.

World Mine Production and Reserves: Many countries either do not report production of natural zeolites or production is reported with a 2- to 3-year lag time. End uses for natural zeolites in countries that mine large tonnages of zeolite minerals typically include low-value, high-volume construction applications, such as dimension stone, lightweight aggregate, and pozzolanic cement. As a result, production data for some countries may not accurately indicate the quantities of natural zeolites used in the high-value applications that are reflected in the domestic data.

World reserves of natural zeolites have not been estimated. Deposits occur in many countries, but companies rarely publish reserves data. Further complicating estimates of reserves is the fact that much of the reported world production includes altered volcanic tuffs with low to moderate concentrations of zeolites that are typically used in high-volume construction applications. Some deposits should, therefore, be excluded from reserves estimates because it is the rock itself and not its zeolite content that makes the deposit valuable.

	Mine production[e]		Reserves[5]
	2019	2020	
United States	[6]87,800	88,000	Two of the leading companies in the United States reported combined reserves of 80 million tons in 2020; total U.S. reserves likely are substantially larger. World data are unavailable, but reserves are estimated to be large.
China	320,000	320,000	
Cuba	[6]53,000	53,000	
Hungary	29,000	29,000	
Indonesia	130,000	130,000	
Jordan	10,000	10,000	
Korea, Republic of	[6]144,000	140,000	
New Zealand	100,000	100,000	
Russia	35,000	35,000	
Slovakia	117,000	120,000	
Turkey	60,000	60,000	
Other countries	4,120	4,000	
World total (rounded)	1,090,000	1,100,000	

World Resources:[5] Recent estimates for domestic and global resources of natural zeolites are not available. Resources of chabazite and clinoptilolite in the United States are sufficient to satisfy foreseeable domestic demand.

Substitutes: For pet litter, zeolites compete with other mineral-based litters, such as those manufactured using bentonite, diatomite, fuller's earth, and sepiolite; organic litters made from shredded corn stalks and paper, straw, and wood shavings; and litters made using silica gel. Diatomite, perlite, pumice, vermiculite, and volcanic tuff compete with natural zeolite as lightweight aggregate. Zeolite desiccants compete against such products as magnesium perchlorate and silica gel. Zeolites compete with bentonite, gypsum, montmorillonite, peat, perlite, silica sand, and vermiculite in various soil amendment applications. Activated carbon, diatomite, or silica sand may substitute for zeolites in water-purification applications. As an oil absorbent, zeolites compete mainly with bentonite, diatomite, fuller's earth, sepiolite, and a variety of polymer and natural organic products. In animal feed, zeolites compete with bentonite, diatomite, fuller's earth, kaolin, silica, and talc as anticaking and flow-control agents.

[e]Estimated. E Net exporter.

[1]Defined as mill sales + imports – exports. Information about industry stocks was unavailable.

[2]Range of ex-works mine and mill unit values for individual natural zeolite operations, based on data reported by U.S. producers and U.S. Geological Survey estimates. Average unit values per ton for the past 5 years were $140 in 2016 and 2017, and an estimated $125 in 2018, 2019, and 2020. Prices vary with the percentage of zeolite present in the product, the chemical and physical properties of the zeolite mineral(s), particle size, surface modification and (or) activation, and end use.

[3]Excludes administration and office staff. Estimates based on data from the Mine Safety and Health Administration.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Reported figure.

ZINC

(Data in thousand metric tons of zinc content unless otherwise noted)

Domestic Production and Use: The value of zinc mined in 2020, based on zinc contained in concentrate, was about $1.6 billion. Zinc was mined in five States at 14 mines operated by five companies. Three smelter facilities, one primary and two secondary, operated by three companies, produced commercial-grade zinc metal. Of the total reported zinc consumed, most was used in galvanizing, followed by brass and bronze, zinc-based alloys, and other uses.

Salient Statistics—United States:	2016	2017	2018	2019	2020[e]
Production:					
Zinc in ores and concentrates	805	774	824	753	670
Refined zinc[1]	126	132	116	115	150
Imports for consumption:					
Zinc in ores and concentrates	(2)	7	(2)	(2)	4
Refined zinc	713	729	775	830	710
Exports:					
Zinc in ores and concentrates	597	682	806	796	560
Refined zinc	47	33	23	5	2
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent, refined zinc[3]	792	829	868	939	860
Price, average, cents per pound:					
North American[4]	101.4	139.3	141.0	124.1	109.0
London Metal Exchange (LME), cash	94.8	131.2	132.7	115.6	101.0
Stocks, reported producer and consumer, refined zinc, yearend	79	114	119	116	130
Employment, number:					
Mine and mill[5]	2,350	2,420	2,630	2,490	2,400
Smelter, primary	246	240	250	250	250
Net import reliance[6] as a percentage of apparent consumption:					
Ores and concentrates	E	E	E	E	E
Refined zinc	84	84	87	88	83

Recycling: In 2020, an estimated one-third of the refined zinc produced in the United States was recovered from secondary materials at both primary and secondary smelters. Secondary materials included galvanizing residues and crude zinc oxide recovered from electric arc furnace dust.

Import Sources (2016–19): Ores and concentrates: Peru, 98%; the Republic of Korea, 1%; other, 1%. Refined metal: Canada, 64%; Mexico, 14%; Peru, 7%; Spain, 7%; and other, 8%. Waste and scrap (gross weight): Canada, 65%; Mexico, 33%; and other, 2%. Combined total (includes gross weight of waste and scrap): Canada, 64%; Mexico, 14%; Peru, 8%; Spain, 7%; and other, 7%.

Tariff: Item	Number	Normal Trade Relations 12–31–20
Zinc ores and concentrates, Zn content	2608.00.0030	Free.
Zinc oxide; zinc peroxide	2817.00.0000	Free.
Unwrought zinc, not alloyed:		
Containing 99.99% or more zinc	7901.11.0000	1.5% ad val.
Containing less than 99.99% zinc:		
Casting-grade	7901.12.1000	3% ad val.
Other	7901.12.5000	1.5% ad val.
Zinc alloys	7901.20.0000	3% ad val.
Zinc waste and scrap	7902.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7]

		FY 2020		FY 2021	
Material	Inventory as of 9–30–20	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Zinc	7.25	—	7.25	—	7.25

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ZINC

Events, Trends, and Issues: Global zinc mine production in 2020 was estimated to be 12 million tons, a 6% decrease from that of 2019. Government-mandated lockdowns and a decrease in zinc prices following the onset of the global COVID-19 pandemic resulted in a decrease in zinc mine production in many countries, particularly in South America.

According to the International Lead and Zinc Study Group,[8] global refined zinc production in 2020 was estimated to increase slightly to 13.60 million tons, and metal consumption was estimated decrease by 5% to 12.98 million tons, resulting in a production-to-consumption surplus of about 620,000 tons of refined zinc.

Domestic zinc mine production decreased in 2020, owing partially to the closure of the Pend Oreille Mine in Washington State in 2019 after current reserves were exhausted and a decrease in production at the Red Dog Mine in Alaska related to the mining of lower grade ores after a change in the mine plan to manage water levels at the site. Refined zinc production increased after the reopening of an idled secondary zinc refinery in North Carolina in March. Apparent consumption of refined zinc decreased to an estimated 860,000 tons in 2020, consistent with a contraction in the domestic steel industry during the year as a result of the pandemic. The estimated annual average North American Special High Grade (SHG) zinc price decreased by 12% in 2020 from that in 2019 to $1.09 per pound.

World Mine Production and Reserves: Reserves for Canada, India, and Peru were revised based on Government or industry reports.

	Mine production[9]		Reserves[10]
	2019	2020[e]	
United States	753	670	11,000
Australia	1,330	1,400	[11]68,000
Bolivia	520	330	4,800
Canada	336	280	2,300
China	4,210	4,200	44,000
India	720	720	10,000
Kazakhstan	304	300	12,000
Mexico	677	600	22,000
Peru	1,400	1,200	20,000
Russia	260	260	22,000
Sweden	245	220	3,600
Other countries	1,950	2,000	34,000
World total (rounded)	12,700	12,000	250,000

World Resources:[10] Identified zinc resources of the world are about 1.9 billion tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; aluminum alloys, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-base alloys are major competitors for zinc-base diecasting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. E Net exporter. — Zero.

[1]Includes primary and secondary refined production.

[2]Less than ½ unit.

[3]Defined as refined production + refined imports – refined exports + adjustments for Government stock changes.

[4]Source: S&P Global Platts Metals Week, North American Special High Grade (SHG) zinc; based on the LME cash price plus premium.

[5]Includes mine and mill employment at all zinc-producing mines. Source: Mine Safety and Health Administration.

[6]Defined as imports – exports + adjustments for Government stock changes.

[7]See Appendix B for definitions.

[8]International Lead and Zinc Study Group, 2020, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 21, 5 p.

[9]Zinc content of concentrates and direct shipping ores.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant reserves were 24 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2020, one firm recovered zircon (zirconium silicate) from surface-mining operations in Florida and Georgia as a coproduct from the mining of heavy-mineral sands and the processing of titanium and zirconium mineral concentrates, and a second company processed existing mineral sands tailings in Florida. Zirconium metal and hafnium metal were produced from zirconium chemical intermediates by one producer in Oregon and one in Utah. Zirconium and hafnium are typically contained in zircon at a ratio of about 36 to 1. Zirconium chemicals were produced by the metal producer in Oregon and by at least 10 other companies. Ceramics, foundry sand, opacifiers, and refractories are the leading end uses for zircon. Other end uses of zircon include abrasives, chemicals (predominantly, zirconium basic sulfate and zirconium oxychloride octohydrate as intermediate chemicals), metal alloys, and welding rod coatings. The leading consumers of zirconium metal are the chemical process and nuclear energy industries. The leading use of hafnium metal is in superalloys.

Salient Statistics—United States:	**2016**	**2017**	**2018**	**2019**	**2020[e]**
Production, zirconium ores and concentrates (ZrO_2 content)[1]	W	[2]50,000	[3]100,000	[3]100,000	[3]<100,000
Imports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	24,900	24,300	26,400	22,600	20,000
Zirconium, unwrought, powder, and waste and scrap	1,040	899	1,880	1,820	3,000
Zirconium, wrought	195	282	284	289	300
Hafnium, unwrought, powder, and waste and scrap	180	113	41	32	20
Exports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	3,280	31,500	77,500	40,500	14,000
Zirconium, unwrought, powder, and waste and scrap	363	627	556	897	780
Zirconium, wrought	788	972	1,150	867	850
Consumption, apparent,[4] zirconium ores and concentrates (ZrO_2 content)[1]	W	[2]50,000	[3]100,000	[3]100,000	[3]<100,000
Price:					
Zircon, dollars per metric ton (gross weight):					
Australia, free on board[5]	975	975	NA	NA	NA
China, cost insurance and freight[6]	NA	1,295	1,625	1,585	1,500
Imported[7]	877	916	1,290	1,490	1,400
Zirconium, unwrought, import, China,[8] dollars per kilogram	33	12	13	14	6
Hafnium, unwrought,[6] dollars per kilogram	930	900	840	780	750
Net import reliance[9] as a percentage of apparent consumption:					
Zirconium ores and concentrates	<50	E	E	E	<25
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and (or) from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled. Hafnium metal recycling was insignificant.

Import Sources (2016–19): Zirconium ores and concentrates: South Africa, 55%; Senegal, 26%; Australia, 15%; Russia, 1%; and other, 3%. Zirconium, unwrought, including powder: China, 81%; Germany, 12%; Japan, 3%; France, 2%; and other, 2%. Zirconium, wrought: France, 63%; Germany, 18%; Belgium, 5%; Canada, 4%; and other, 10%. Hafnium, unwrought: Germany, 45%; France, 31%; China, 17%; the United Kingdom, 5%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–20**
Zirconium ores and concentrates	2615.10.0000	Free.
Ferrozirconium	7202.99.1000	4.2% ad val.
Zirconium, unwrought and powder	8109.20.0000	4.2% ad val.
Zirconium waste and scrap	8109.30.0000	Free.
Other zirconium articles	8109.90.0000	3.7% ad val.
Hafnium, unwrought, powder, and waste and scrap	8112.92.2000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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ZIRCONIUM AND HAFNIUM

Events, Trends, and Issues: The average unit value for imports of zircon concentrates decreased in 2020 after increasing for the past 3 years. Exports of zirconium ores and zircon concentrates decreased by an estimated 65% in 2020 from those in 2019. In August, new mining and heavy-mineral-processing operations were being commissioned near Jessup, GA.

Global zircon production was estimated to have decreased slightly in 2020 owing to the impact of the COVID-19 pandemic, reduced consumption, and power and labor issues.

During 2020, several large mining projects containing zirconium were in development but construction had not begun on any of them. In Western Australia, two companies announced a potential joint venture that would provide the funding needed for the first stage of construction at the Thunderbird mineral sands project if final agreements and approvals were reached. Regional or national government agencies in Australia indicated that they would provide financial support, such as loans, for the Coburn mineral sands project in Western Australia and the Dubbo polymetallic project in New South Wales.

World Mine Production and Reserves: World primary hafnium production data are not available and quantitative estimates of hafnium reserves are not available. Zirconium reserves for Australia were revised on the basis of Government reports. Zirconium reserves for Kenya and South Africa were revised on the basis of company reports.

	Zirconium ores and zircon concentrates, mine production (thousand metric tons, gross weight)		Zirconium reserves[10] (thousand metric tons, ZrO_2 content)[1]
	2019	2020[e]	
United States	[3]100	[3]<100	500
Australia	470	480	[11]43,000
China	140	140	500
Indonesia	34	60	NA
Kenya	29	25	55
Mozambique	100	125	1,800
Senegal	65	65	NA
South Africa	370	320	6,700
Other countries	112	110	11,000
World total (rounded)	1,420	1,400	64,000

World Resources:[10] Resources of zircon in the United States included about 14 million tons associated with titanium resources in heavy-mineral-sand deposits. Phosphate rock and sand and gravel deposits could potentially yield substantial amounts of zircon as a byproduct. World resources of hafnium are associated with those of zircon and baddeleyite. Quantitative estimates of hafnium resources are not available.

Substitutes: Chromite and olivine can be used instead of zircon for some foundry applications. Dolomite and spinel refractories can also substitute for zircon in certain high-temperature applications. Niobium (columbium), stainless steel, and tantalum provide limited substitution in nuclear applications, and titanium and synthetic materials may substitute in some chemical processing plant applications. Silver-cadmium-indium control rods are used in lieu of hafnium at numerous nuclear powerplants. Zirconium can be used interchangeably with hafnium in certain superalloys.

[e]Estimated. E Net Exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Calculated ZrO_2 content as 65% of gross production.

[2]Rounded to one significant digit to avoid disclosing company proprietary data.

[3]Rounded to nearest 100,000 to avoid disclosing company proprietary data.

[4]Defined as production + imports – exports.

[5]Source: Industrial Minerals (Fastmarkets IM), average of yearend price. Prices of zircon from Australia were discontinued at yearend 2017.

[6]Source: Argus Media group—Argus Metals International, average of yearend price.

[7]Unit value based on annual United States imports for consumption from Australia, Senegal, and South Africa.

[8]Unit value based on annual United States imports for consumption from China.

[9]Defined as imports – exports.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant reserves were 22.1 million tons gross weight.

APPENDIX A

Abbreviations and Units of Measure

1 carat (metric) (diamond)	= 200 milligrams
1 flask (fl)	= 76 pounds, avoirdupois, or 33.47 kilograms
1 karat (gold)	= one twenty-fourth part
1 kilogram (kg)	= 2.2046 pounds, avoirdupois
1 long ton (lt)	= 2,240 pounds, avoirdupois
1 long ton unit (ltu)	= 1% of 1 long ton, or 22.4 pounds, avoirdupois
long calcined ton (lct)	= excludes water of hydration
long dry ton (ldt)	= excludes excess free moisture
Mcf	= 1,000 cubic feet
1 metric ton (t)	= 2,204.6 pounds, avoirdupois, or 1,000 kilograms
1 metric ton (t)	= 1.1023 short ton
1 metric ton unit (mtu)	= 1% of 1 metric ton, or 10 kilograms
metric dry ton (mdt)	= excludes excess free moisture
1 pound (lb)	= 453.6 grams
psia	= pounds per square inch absolute
1 short ton (st)	= 2,000 pounds, avoirdupois
1 short ton unit (stu)	= 1% of 1 short ton, or 20 pounds, avoirdupois
short dry ton (sdt)	= excludes excess free moisture
1 troy ounce (tr oz)	= 1.09714 avoirdupois ounces, or 31.103 grams
1 troy pound	= 12 troy ounces

APPENDIX B

Definitions of Selected Terms Used in This Report

Terms Used for Materials in the National Defense Stockpile and Helium Stockpile

Inventory refers to the quantity of mineral materials held in the National Defense Stockpile or in the Federal Helium Reserve. Nonstockpile-grade materials may be included in the table; where significant, the quantities of these stockpiled materials are specified in the text accompanying the table.

Potential disposals indicate the total amount of a material in the National Defense Stockpile that the U.S. Department of Defense is permitted to dispose of under the Annual Materials Plan approved by Congress for the fiscal year. Congress has authorized disposal over the long term at rates designed to maximize revenue but avoid undue disruption to the usual markets and financial loss to the United States. Fiscal year (FY) 2020 is the period from October 1, 2019, through September 30, 2020. FY 2021 is the period from October 1, 2020, through September 30, 2021. Disposals are defined as any disposal or sale of National Defense Stockpile stock. For mineral commodities that have a disposal plan greater than the inventory, the actual quantity will be limited to the remaining disposal authority or inventory. Note that, unlike the National Defense Stockpile, helium stockpile sales by the Bureau of Land Management under the Helium Privatization Act of 1996 are permitted to exceed disposal plans.

Potential acquisitions indicate the maximum amount of a material that may be acquired by the U.S. Department of Defense for the National Defense Stockpile under the Annual Materials Plan approved by Congress for the fiscal year. FY 2020 is the period from October 1, 2019, through September 30, 2020. FY 2021 is the period from October 1, 2020, through September 30, 2021.

Depletion Allowance

The depletion allowance is a business tax deduction analogous to depreciation, but which applies to an ore reserve rather than equipment or production facilities. Federal tax law allows this deduction from taxable corporate income, recognizing that an ore deposit is a depletable asset that must eventually be replaced.

APPENDIX C

Reserves and Resources

Reserves data are dynamic. They may be reduced as ore is mined and (or) the feasibility of extraction diminishes, or more commonly, they may continue to increase as additional deposits (known or recently discovered) are developed, or currently exploited deposits are more thoroughly explored and (or) new technology or economic variables improve their economic feasibility. Reserves may be considered a working inventory of mining companies' supplies of an economically extractable mineral commodity. As such, the magnitude of that inventory is necessarily limited by many considerations, including cost of drilling, taxes, price of the mineral commodity being mined, and the demand for it. Reserves will be developed to the point of business needs and geologic limitations of economic ore grade and tonnage. For example, in 1970, identified and undiscovered world copper resources were estimated to contain 1.6 billion metric tons of copper, with reserves of about 280 million tons of copper. Since then, almost 580 million tons of copper have been produced worldwide, but world copper reserves in 2020 were estimated to be 870 million tons of copper, more than triple those of 1970, despite the depletion by mining of more than the original estimated reserves.

Future supplies of minerals will come from reserves and other identified resources, currently undiscovered resources in deposits that will be discovered in the future, and material that will be recycled from current in-use stocks of minerals or from minerals in waste disposal sites. Undiscovered deposits of minerals constitute an important consideration in assessing future supplies. Mineral-resource assessments have been carried out for small parcels of land being evaluated for land reclassification, for the Nation, and for the world.

Part A—Resource and Reserve Classification for Minerals[1]

Introduction

Through the years, geologists, mining engineers, and others operating in the minerals field have used various terms to describe and classify mineral resources, which as defined herein include energy materials. Some of these terms have gained wide use and acceptance, although they are not always used with precisely the same meaning.

The U.S. Geological Survey (USGS) collects information about the quantity and quality of all mineral resources. In 1976, the USGS and the U.S. Bureau of Mines developed a common classification and nomenclature, which was published as USGS Bulletin 1450–A—"Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey." Experience with this resource classification system showed that some changes were necessary in order to make it more workable in practice and more useful in long-term planning. Therefore, representatives of the USGS and the U.S. Bureau of Mines collaborated to revise Bulletin 1450–A. Their work was published in 1980 as USGS Circular 831—"Principles of a Resource/Reserve Classification for Minerals."

Long-term public and commercial planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. Thus, resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions. To best serve these planning needs, known resources should be classified from two standpoints: (1) purely geologic or physical and chemical characteristics—such as grade, quality, tonnage, thickness, and depth—of the material in place; and (2) profitability analyses based on costs of extracting and marketing the material in a given economy at a given time. The former constitutes important objective scientific information of the resource and a relatively unchanging foundation upon which the latter more valuable economic delineation can be based.

The revised classification system, designed generally for all mineral materials, is shown graphically in figures C1 and C2; its components and their usage are described in the text. The classification of mineral and energy resources is necessarily arbitrary because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy-fuel resources for the Nation or for specific areas.[1]

Resource and Reserve Definitions

A dictionary definition of resource, "something in reserve or ready if needed," has been adapted for mineral and energy resources to comprise all materials, including those only surmised to exist, that have present or anticipated future value.

Resource.—A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Original Resource.—The amount of a resource before production.

Identified Resources.—Resources for which location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified resources include economic, marginally economic, and subeconomic components. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into measured, indicated, and inferred.

[1]Based on U.S. Geological Survey Circular 831, 1980.

Demonstrated.—A term for the sum of measured plus indicated resources.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.—Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurements are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred.—Estimates are based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Reserve Base.—That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term “geologic reserve” has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.

Inferred Reserve Base.—The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit and for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence.

Reserves.—That part of the reserve base that could be economically extracted or produced at the time of determination. The term “reserves” need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as “extractable reserves” and “recoverable reserves” are redundant and are not a part of this classification system.

Marginal Reserves.—That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technological factors.

Economic.—This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Subeconomic Resources.—The part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Undiscovered Resources.—Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, undiscovered resources may be divided into two parts, as follows:

Hypothetical Resources.—Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources.—Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Restricted Resources or Reserves.—That part of any resource or reserve category that is restricted from extraction by laws or regulations. For example, restricted reserves meet all the requirements of reserves except that they are restricted from extraction by laws or regulations.

Other Occurrences.—Materials that are too low grade or for other reasons are not considered potentially economic, in the same sense as the defined resource, may be recognized and their magnitude estimated, but they are not classified as resources. A separate category, labeled “other occurrences,” is included in figures C1 and C2. In figure C1, the boundary between subeconomic and other occurrences is limited by the concept of current or potential feasibility of economic production, which is required by the definition of a resource. The boundary is obviously uncertain, but limits may be specified in terms of grade, quality, thickness, depth, extractable percentage, or other economic-feasibility variables.

Cumulative Production.—The amount of past cumulative production is not, by definition, a part of the resource. Nevertheless, a knowledge of what has been produced is important in order to understand current resources, in terms of both the amount of past production and the amount of residual or remaining in-place resource. A separate space for cumulative production is shown in figures C1 and C2. Residual material left in the ground during current or future extraction should be recorded in the resource category appropriate to its economic-recovery potential.

Figure C1.—Major Elements of Mineral-Resource Classification, Excluding *Reserve Base* and *Inferred Reserve Base*

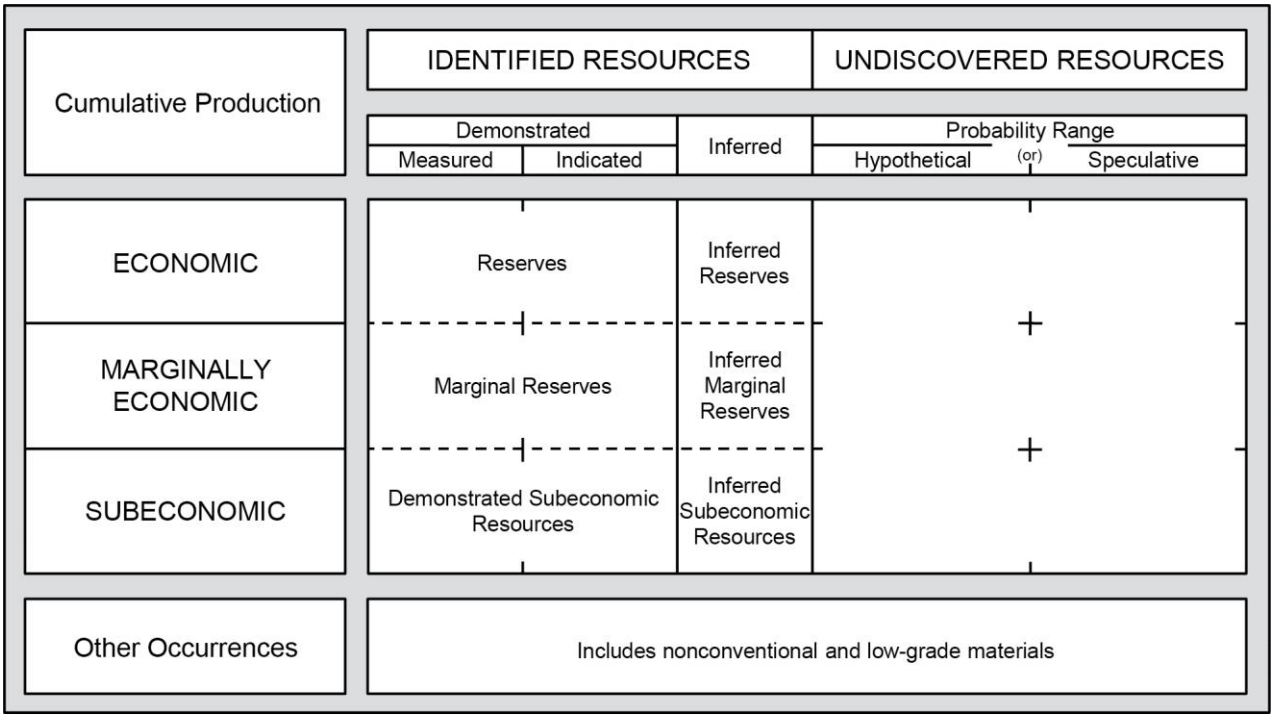
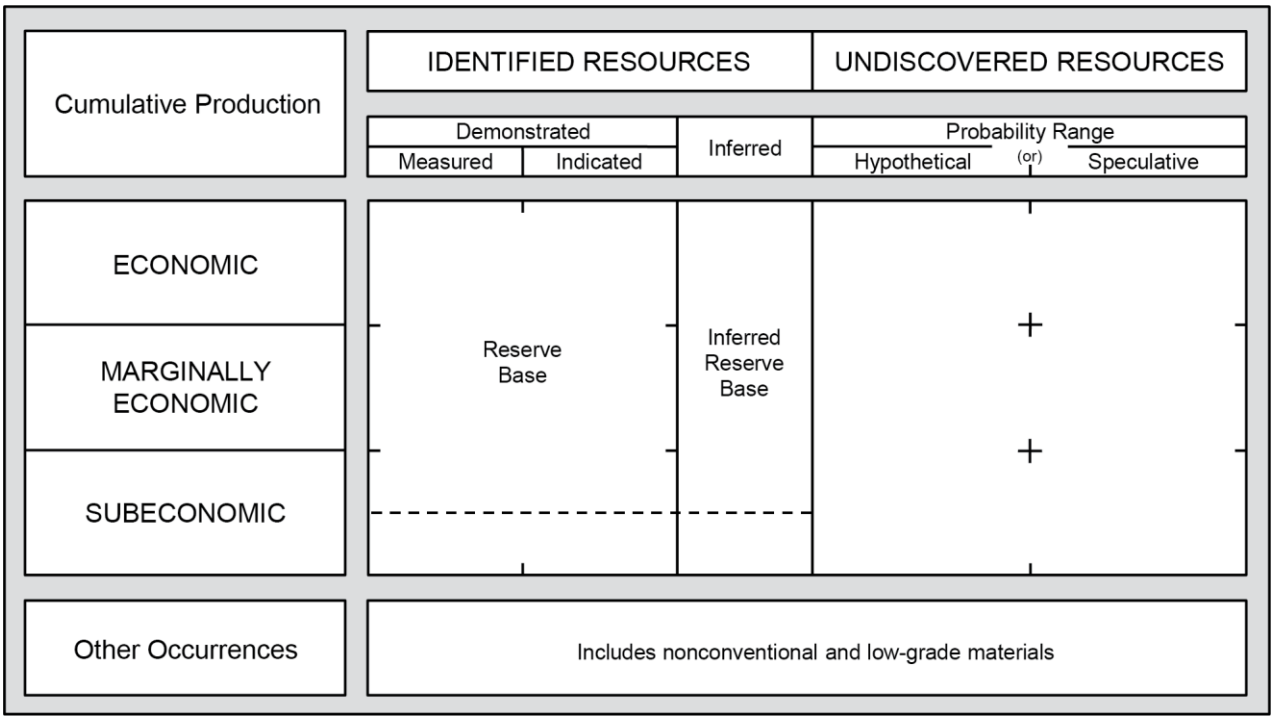


Figure C2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



Part B—Sources of Reserves Data

National information on reserves for most mineral commodities found in this report, including those for the United States, is derived from a variety of sources. The ideal source of such information would be comprehensive evaluations that apply the same criteria to deposits in different geographic areas and report the results by country. In the absence of such evaluations, national reserves estimates compiled by countries for selected mineral commodities are a primary source of national reserves information. Lacking national assessment information by governments, sources such as academic articles, company reports, presentations by company representatives, and trade journal articles, or a combination of these, serve as the basis for national information on reserves reported in the mineral commodity sections of this publication.

A national estimate may be assembled from the following: historically reported reserves information carried for years without alteration because no new information is available, historically reported reserves reduced by the amount of historical production, and company-reported reserves. International minerals availability studies conducted by the U.S. Bureau of Mines before 1996 and estimates of identified resources by an international collaborative effort (the International Strategic Minerals Inventory) are the bases for some reserves estimates. The USGS collects some qualitative information about the quantity and quality of mineral resources but does not directly measure reserves or resources, and companies or governments do not directly report information about reserves or resources to the USGS. Reassessment of reserves is a continuing process, and the intensity of this process differs by mineral commodity, country, and time period.

Some countries have specific definitions for reserves data, and reserves for each country are assessed separately, based on reported data and definitions. An attempt is made to make reserves consistent among countries for a mineral commodity and its byproducts. For example, the Australasian Joint Ore Reserves Committee (JORC) established the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code) that sets out minimum standards, recommendations, and guidelines for public reporting in Australasia of exploration results, mineral resources, and ore reserves. Companies listed on the Australian Securities Exchange and the New Zealand Stock Exchange are required to report publicly on ore reserves and mineral resources under their control, using the JORC Code.

Data reported for individual deposits by mining companies are compiled in Geoscience Australia’s national mineral resources database and used in the preparation of the annual national assessments of Australia’s mineral resources. Because of its specific use in the JORC Code, the term “reserves” is not used in the national inventory, where the highest category is “Economic Demonstrated Resources” (EDR). In essence, EDR combines the JORC Code categories “proved reserves” and “probable reserves,” plus measured resources and indicated resources. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term. Accessible Economic Demonstrated Resources represent the resources within the EDR category that are accessible for mining. Reserves for Australia in Mineral Commodity Summaries 2021 are Accessible EDR. For more information, see “Table 3. Australia’s Identified Mineral Resources as at December 2018,” which can be found at https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/aimr/mineral-resources.

In Canada, the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) provides definition standards for the classification of mineral resources and mineral reserves estimates into various categories. The category to which a resource or reserves estimate is assigned depends on the level of confidence in the geologic information available on the mineral deposit, the quality and quantity of data available on the deposit, the level of detail of the technical and economic information that has been generated about the deposit, and the interpretation of the data and information. For more information on the CIM definition standards, see https://mrmr.cim.org/en/standards/canadian-mineral-resource-and-mineral-reserve-definitions/.

In Russia, reserves for most minerals can appear in a number of sources, although no comprehensive list of reserves is published. Reserves data for a limited set of mineral commodities are available in the annual report "Gosudarstvennyi Doklad o Sostoyanii i Ispol'zovanii Mineral'no-Syryevyh Resursov Rossiyskoy Federatsii" (State Report on the State and Use of Mineral and Raw Materials Resources of the Russian Federation), which is published by Russia’s Ministry of Natural Resources and Environment. Reserves data for various minerals appear at times in journal articles, such as those in the journal "Mineral’nyye Resursy Rossii. Ekonomika i Upravleniye" (Mineral Resources of Russia. Economics and Management), which is published by the "OOO RG-Inform," a subsidiary of Rosgeologiya Holding. It is sometimes not clear if the reserves are being reported in ore or mineral content. It is also in many cases not clear which definition of reserves is being used, because the system inherited from the former Soviet Union has a number of ways in which the term “reserves” is defined, and these definitions qualify the percentage of resources that are included in a specific category. For example, the Soviet reserves classification system, besides the categories A, B, C1, and C2, which represent progressively detailed knowledge of a mineral deposit based on exploration data, has other subcategories cross imposed upon the system. Under the broad category reserves (zapasy), there are subcategories that include balance reserves (balansovyye zapasy, or economic reserves) and outside-the-balance reserves (zabalansovye zapasy, or subeconomic reserves), as well as categories that include explored, industrial, and proven reserves, and the reserves totals can vary significantly, depending on the specific definition of reserves being reported.

APPENDIX D

Country Specialists Directory

Minerals information country specialists at the U.S. Geological Survey collect and analyze information on the mineral industries of more than 170 nations throughout the world. The specialists are available to answer minerals-related questions concerning individual countries.

Africa and the Middle East

Algeria	Mowafa Taib
Angola	Meralis Plaza-Toledo
Bahrain	Philip A. Szczesniak
Benin	Meralis Plaza-Toledo
Botswana	Thomas R. Yager
Burkina Faso	Alberto A. Perez
Burundi	Thomas R. Yager
Cabo Verde	Meralis Plaza-Toledo
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Central African Republic	James J. Barry
Chad	Philip A. Szczesniak
Comoros	James J. Barry
Congo (Brazzaville)	James J. Barry
Congo (Kinshasa)	Thomas R. Yager
Côte d'Ivoire	Alberto A. Perez
Djibouti	Thomas R. Yager
Egypt	Mowafa Taib
Equatorial Guinea	Meralis Plaza-Toledo
Eritrea	Thomas R. Yager
Eswatini	James J. Barry
Ethiopia	Meralis Plaza-Toledo
Gabon	Alberto A. Perez
The Gambia	Meralis Plaza-Toledo
Ghana	Meralis Plaza-Toledo
Guinea	Alberto A. Perez
Guinea-Bissau	Meralis Plaza-Toledo
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Iraq	Philip A. Szczesniak
Israel	Philip A. Szczesniak
Jordan	Mowafa Taib
Kenya	Thomas R. Yager
Kuwait	Philip A. Szczesniak
Lebanon	Mowafa Taib
Lesotho	James J. Barry
Liberia	Meralis Plaza-Toledo
Libya	Mowafa Taib
Madagascar	Thomas R. Yager
Malawi	Thomas R. Yager
Mali	Alberto A. Perez
Mauritania	Mowafa Taib
Mauritius	James J. Barry
Morocco and Western Sahara	Mowafa Taib
Mozambique	Meralis Plaza-Toledo
Namibia	James J. Barry
Niger	Alberto A. Perez
Nigeria	Thomas R. Yager
Oman	Philip A. Szczesniak
Qatar	Philip A. Szczesniak
Reunion	James J. Barry
Rwanda	Thomas R. Yager
Sao Tome e Principe	Meralis Plaza-Toledo

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Syria	Mowafa Taib
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Bhutan	Ji Won Moon
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Cambodia	Ji Won Moon
China	Sean Xun
Fiji	Spencer D. Buteyn
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Indonesia	Jaewon Chung
Japan	Jaewon Chung
Korea, North	Jaewon Chung
Korea, Republic of	Jaewon Chung
Laos	Ji Won Moon
Malaysia	Spencer D. Buteyn
Mongolia	Jaewon Chung
Nauru	Spencer D. Buteyn
Nepal	Ji Won Moon
New Caledonia	Spencer D. Buteyn
New Zealand	Spencer D. Buteyn
Pakistan	Ji Won Moon
Papua New Guinea	Spencer D. Buteyn
Philippines	Ji Won Moon
Singapore	Spencer D. Buteyn
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Sri Lanka	Ji Won Moon
Taiwan	Jaewon Chung
Thailand	Ji Won Moon
Timor-Leste	Jaewon Chung
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Sweden	Joanna Goclawska
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Turkmenistan	Karine M. Renaud
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Uzbekistan	Elena Safirova

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MINERAL COMMODITY SUMMARIES 2022

Abrasives
Aluminum
Antimony
Arsenic
Asbestos
Barite
Bauxite
Beryllium
Bismuth
Boron
Bromine
Cadmium
Cement
Cesium
Chromium
Clays
Cobalt
Copper
Diamond
Diatomite
Feldspar
Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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science for a changing world

Cover: A photomicrograph showing the four primary phases of cement: alite, belite, aluminate, and ferrite. Clinker is the primary component of cement, which in turn is the key ingredient of concrete. Concrete is a universal construction material, which is used in varying quantities in virtually every construction project in the world. The use of cement and concrete dates to ancient civilizations, and those materials are used for bridges, buildings, highways, and numerous other infrastructure projects. Cement production and consumption trends in developed countries can be useful as national economic indicators and often reflect the transition from emerging economies to industrial economies. (Photograph from fig. 7–15 of the Portland Cement Association's "Microscopical Examination and Interpretation of Portland Cement and Clinker," second edition, 1999, by Donald H. Campbell; used with permission of the Portland Cement Association.)

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MINERAL COMMODITY SUMMARIES 2022

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Copper
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Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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This publication has been prepared by the National Minerals Information Center. Information about the Center and its products is available from the internet at https://www.usgs.gov/centers/nmic or by writing to Director, National Minerals Information Center, 988 National Center, Reston, VA 20192.

KEY PUBLICATIONS

Minerals Yearbook—These annual publications review the mineral industries of the United States and of more than 180 other countries. They contain statistical data on minerals and materials and include information on economic and technical trends and developments and are available at https://www.usgs.gov/centers/nmic/publications. The three volumes that make up the Minerals Yearbook are volume I, Metals and Minerals; volume II, Area Reports—Domestic; and volume III, Area Reports—International.

Mineral Commodity Summaries—Published on an annual basis, this report is the earliest Government publication to furnish estimates covering nonfuel mineral industry data and is available at https://www.usgs.gov/centers/nmic/mineral-commodity-summaries. Data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for more than 90 individual minerals and materials.

Mineral Industry Surveys—These periodic statistical and economic reports are designed to provide timely statistical data on production, shipments, stocks, and consumption of significant mineral commodities and are available at https://www.usgs.gov/centers/nmic/mineral-industry-surveys. The surveys are issued monthly, quarterly, or at other regular intervals.

Materials Flow Studies—These publications describe the flow of minerals and materials from extraction to ultimate disposition to help better understand the economy, manage the use of natural resources, and protect the environment and are available at https://www.usgs.gov/centers/nmic/materials-flow.

Recycling Reports—These studies illustrate the recycling of metal commodities and identify recycling trends and are available at https://www.usgs.gov/centers/nmic/recycling-statistics-and-information.

Historical Statistics for Mineral and Material Commodities in the United States (Data Series 140)—This report provides a compilation of statistics on production, trade, and use of approximately 90 mineral commodities since as far back as 1900 and is available at https://www.usgs.gov/centers/nmic/historical-statistics-mineral-and-material-commodities-united-states.

WHERE TO OBTAIN PUBLICATIONS

- *Mineral Commodity Summaries* and the *Minerals Yearbook* are sold by the U.S. Government Publishing Office. Orders are accepted over the internet at https://bookstore.gpo.gov, by email at ContactCenter@gpo.gov, by telephone toll free (866) 512–1800; Washington, DC, area (202) 512–1800, by fax (202) 512–2104, or through the mail (P.O. Box 979050, St. Louis, MO 63197–9000).

- All current and many past publications are available as downloadable Portable Document Format (PDF) files through https://www.usgs.gov/centers/nmic.

INTRODUCTION

Each mineral commodity chapter of the 2022 edition of the U.S. Geological Survey (USGS) Mineral Commodity Summaries (MCS) includes information on events, trends, and issues for each mineral commodity as well as discussions and tabular presentations on domestic industry structure, Government programs, tariffs, 5-year salient statistics, and world production, reserves, and resources. The MCS is the earliest comprehensive source of 2021 mineral production data for the world. More than 90 individual minerals and materials are covered by 2-page synopses.

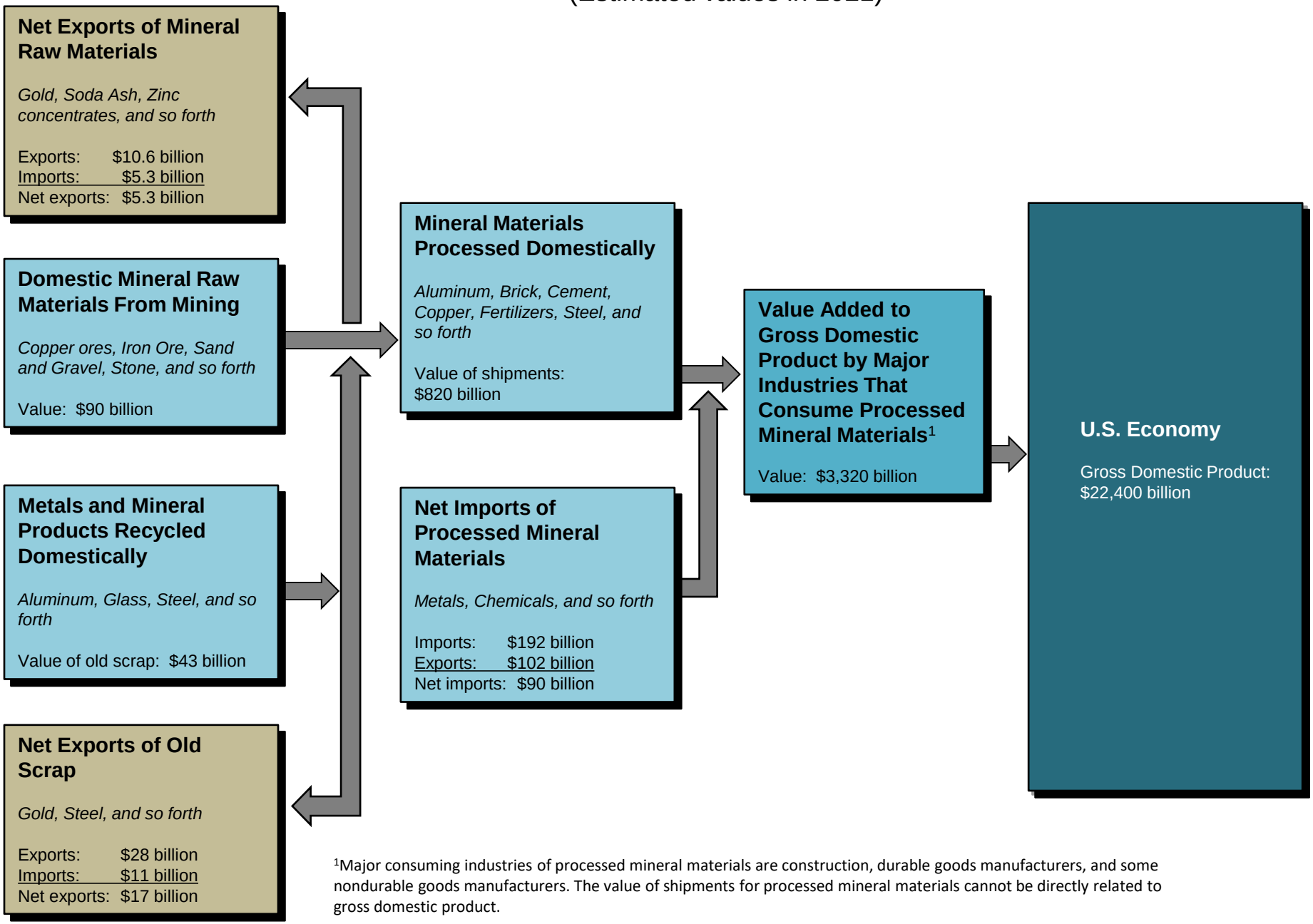
For mineral commodities for which there is a Government stockpile, detailed information concerning the stockpile status is included in the 2-page synopsis.

Abbreviations and units of measure and definitions of selected terms used in the report are in Appendix A and Appendix B, respectively. Reserves and resources information is in Appendix C, which includes “Part A—Resource and Reserve Classification for Minerals” and “Part B—Sources of Reserves Data.” A directory of USGS minerals information country specialists and their responsibilities is in Appendix D.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the MCS 2022 are welcomed.

Figure 1.—The Role of Nonfuel Minerals in the U.S. Economy

(Estimated values in 2021)



[1]Major consuming industries of processed mineral materials are construction, durable goods manufacturers, and some nondurable goods manufacturers. The value of shipments for processed mineral materials cannot be directly related to gross domestic product.

Sources: U.S. Geological Survey and U.S. Department of Commerce.

SIGNIFICANT EVENTS, TRENDS, AND ISSUES

In 2021, the estimated total value of nonfuel mineral production in the United States was $90.4 billion, an increase of 12% from the revised total of $80.7 billion in 2020. The estimated value of metals production increased by 23% to $33.8 billion. The increased price for copper, which was projected to be about $4.20 per pound in 2021, an alltime high, contributed to the increased value of metal production. The total value of industrial minerals production was $56.6 billion, a 6% increase from that in 2020. Of this total, $29.2 billion was construction aggregates production (construction sand and gravel and crushed stone). Crushed stone was the leading nonfuel mineral commodity in 2021 with a production value of more than $19.3 billion and accounted for 21% of the total value of U.S. nonfuel mineral production.

Increases in consumption of nonfuel mineral commodities in commercial construction, steel production, and automotive and transportation industry were attributed to the restarting of the economy after closure because of the global COVID-19 pandemic. For the metals sector, the copper, iron ore, steel, and zinc industries were particularly affected by increased demand from manufacturing. For the industrial minerals sector, the largest increases in production were in cement, crushed stone, sand and gravel, and soda ash, commodities that are closely tied to the performance of the construction industry.

Trade Issues

On October 31, 2021, it was announced the additional 10% and 25% ad valorem tariffs under section 232 of the Trade Expansion Act of 1962 (86 FR 64748) on aluminum and steel imports, respectively, from the European Union would be replaced with an import quota effective January 1, 2022. An agreement was reached between the United States and the European Union to remove the ad valorem tariff on aluminum and steel imports that was imposed in 2018 under the authority of section 232 of the Trade Expansion Act of 1962. Effective in January 2022, the tariff would only be applied on imports from countries in the European Union that exceed specified quotas.

The additional 25% ad valorem duty for products imported from China (Lists 1, 2, and 3) and the 7.5% ad valorem duty for products imported from China (List 4) imposed under section 301(b) of the Trade Act of 1974, (19 U.S.C. 2411, as amended) by the United States Trade Representative continued in 2021. Likewise, China imposed additional import duties for certain items originating in the United States.

In 2021, widespread supply chain disruptions were experienced by most industries, particularly in cargo transportation. In March, a large container ship blocked the Suez Canal for 6 days, severely delaying global trade. Delays in offloading ships at docks resulted from the lack of truck drivers to remove cargo containers, and ports ran out of space to store containers. Cargo ships were forced to remain at sea until space was available to unload them. Additionally, ongoing travel- and work-related restrictions put in place to mitigate the effects of the global COVID-19 pandemic continued throughout the year. Lockdowns took place in various countries as COVID-19 and its variants spread throughout the world.

U.S. ports continued to experience lengthy delays, especially at the Ports of Long Beach, CA, Los Angeles, CA, and Savannah, GA. Despite a Presidential order for ports to remain open 24 hours per day, worker, truck, and rail shortages and other logistic issues restricted easing of congestion.

U.S. Production and Consumption

As shown in figure 1, minerals remained fundamental to the U.S. economy, contributing to the real gross domestic product at several levels, including mining, processing, and manufacturing finished products. The estimated value of nonfuel minerals produced at mines in the United States in 2021 was $90.4 billion. The value of net exports of mineral raw materials increased to $5.3 billion from $4.0 billion in 2020. Domestically recycled products totaled $43 billion, and iron and steel scrap contributed $18 billion to that total. Domestic raw materials and domestically recycled materials were used to produce mineral materials worth $820 billion. These mineral materials as well as imports of processed mineral materials, which decreased by 9% in 2021, were, in turn, consumed by downstream industries creating an estimated value of $3.32 trillion in 2021, an 8% increase from that in 2020.

Figure 2 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2021, imports made up more than one-half of the U.S. apparent consumption for 47 nonfuel mineral commodities, and the United States was 100% net import reliant for 17 of those. Of the 35 minerals or mineral material groups identified as “critical minerals” published in the Federal Register on May 18, 2018 (83 FR 23295), the United States was 100% net import reliant for 14, and an additional 15 critical mineral commodities had a net import reliance greater than 50% of apparent consumption.

Additional information regarding critical minerals in the United States can be found in the “United States Critical Minerals Update” section that begins on page 17.

Figure 3 shows the countries that were sources of nonfuel mineral commodities for which the United States was greater than 50% net import reliant in 2021 and the number of mineral commodities for which each highlighted country was a leading supplier. China, followed by Canada, supplied the largest number of these nonfuel mineral commodities. The countries that were the leading sources of imported mineral commodities with greater than 50% net import reliance were: China, 25 mineral commodities; Canada, 16 mineral commodities; Germany, 11 mineral

commodities; South Africa, 10 mineral commodities; and Brazil and Mexico, 9 mineral commodities each.

The estimated value of U.S. metal mine production in 2021 was $33.8 billion, 23% higher than the revised value in 2020 (table 1). Principal contributors to the total value of metal mine production in 2021 were copper, 35%; gold, 31%; iron ore, 13%; and zinc, 7%. The estimated value of U.S. industrial minerals production in 2021, including construction aggregates, was $56.6 billion, about 6% more than the revised value of 2020 (table 1). The value of industrial minerals production in 2021 was dominated by crushed stone, 34%; cement (masonry and portland), 19%; and construction sand and gravel, 17%.

In 2021, U.S. production of 14 mineral commodities was valued at more than $1 billion each. These commodities were, in decreasing order of value, crushed stone, copper, cement, gold, construction sand and gravel, iron ore, salt, lime, industrial sand and gravel, zinc, soda ash, phosphate rock, palladium, and molybdenum.

In 2021, 13 States each produced more than $2 billion worth of nonfuel mineral commodities. These States were, in descending order of production value, Arizona, Nevada, Texas, California, Minnesota, Alaska, Utah, Florida, Missouri, Michigan, Wyoming, Georgia, and Montana (table 3, fig. 4).

The west region was the leading region in the production of the metals and metallic minerals and other industrial minerals production with a value of $28 billion and $10.4 billion, respectively, in 2021 (figs. 5, 6).

In 2021, there were seven States that produced more than $900 million worth of crushed stone. These States were, in descending order of production value, Texas, Pennsylvania, Florida, North Carolina, Georgia, Virginia, and Missouri (fig. 7).

Construction sand and gravel was produced in every State. California and Texas were the only two States that produced more than $1 billion worth of construction sand and gravel in 2021. Arizona, Utah, Washington, Ohio, New York, Colorado, Michigan, and Florida, in descending order of production value, were the other top 10 producing States (fig. 8).

The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) is responsible for the operational oversight of the National Defense Stockpile (NDS) of strategic and critical materials. Managing the security, environmentally sound stewardship, and ensuring the readiness of all NDS stocks is the mission of the DLA Strategic Materials. The NDS currently contains 46 unique commodities stored at 10 locations within the continental United States. In fiscal year 2021, approximately $4.95 million of new stocks were acquired and $75.45 million of excess materials were sold. Revenue from the Stockpile Sales Program fund the operation of the NDS and the acquisition of new stocks. As of September 30, 2021, the NDS inventory had a fair market value of $1.28 billion. For reporting purposes, NDS stocks are categorized as held in reserve or available for sale. The majority of stocks are held in reserve. Additional detailed information can be found in the “Government Stockpile” sections in the mineral commodity chapters that follow. Under the authority of the Defense Production Act of 1950 (Public Law 81–774), the USGS advises the DLA Strategic Materials on acquisitions and disposals of NDS mineral materials.

Figure 2.—2021 U.S. Net Import Reliance[1]

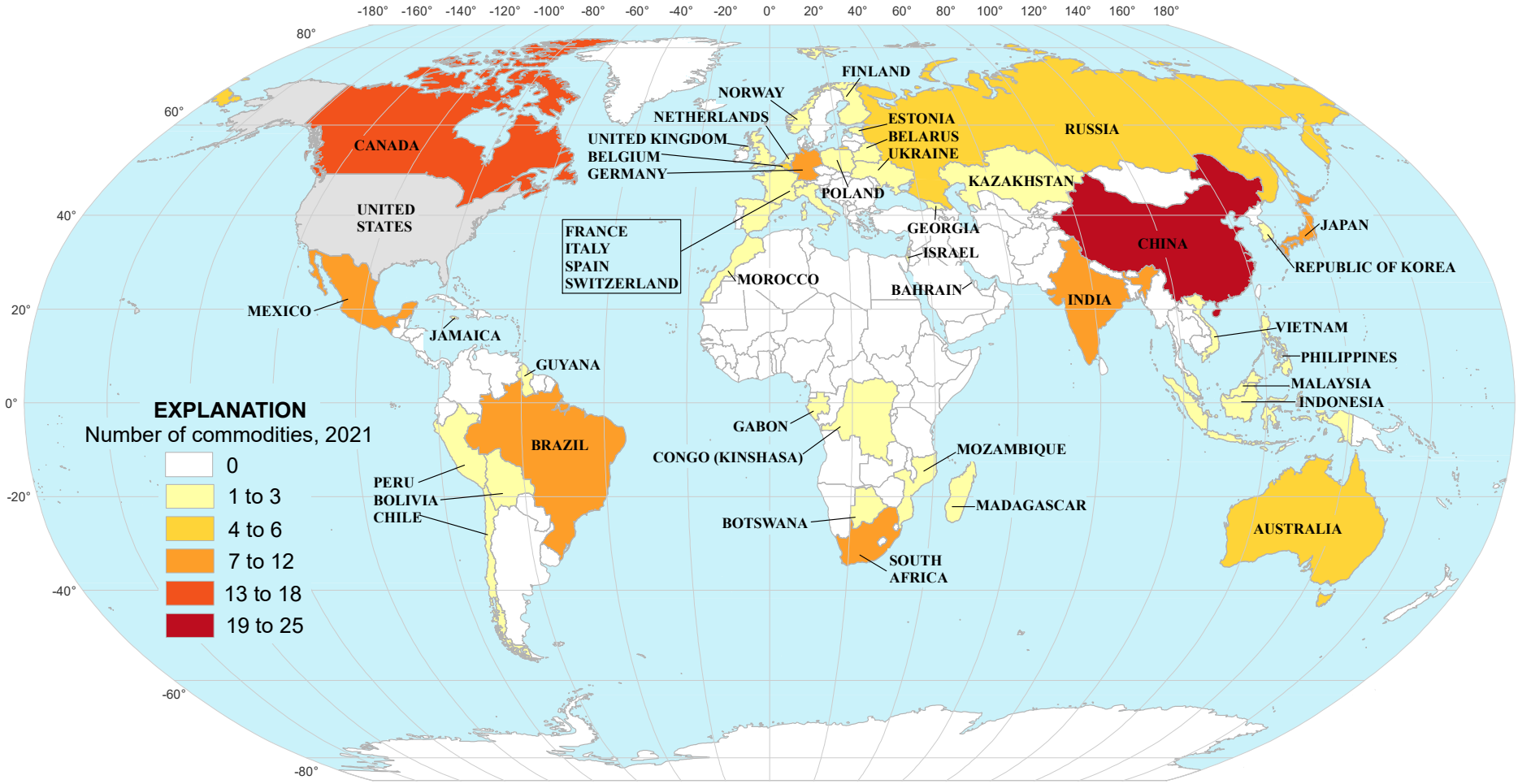
Commodity	Net import reliance as a percentage of apparent consumption	Major import sources (2017–20)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany, China
FLUORSPAR	100	Mexico, Vietnam, South Africa, Canada
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (NATURAL)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, France
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, India
NEPHELINE SYENITE	100	Canada
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	Germany
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
VANADIUM	100	Canada, China, Brazil, South Africa
YTTRIUM	100	China, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
TELLURIUM	>95	Canada, Germany, China, Philippines
POTASH	93	Canada, Russia, Belarus
IRON OXIDE PIGMENTS, natural and synthetic	91	China, Germany, Brazil
RARE EARTHS,[3] compounds and metals	>90	China, Estonia, Malaysia, Japan
TITANIUM, sponge	>90	Japan, Kazakhstan, Ukraine
BISMUTH	90	China, Republic of Korea, Mexico, Belgium
TITANIUM MINERAL CONCENTRATES	90	South Africa, Australia, Madagascar, Mozambique
ANTIMONY, metal and oxide	84	China, Belgium, India
STONE (DIMENSION)	84	China, Brazil, Italy, India
CHROMIUM	80	South Africa, Kazakhstan, Russia, Mexico
PEAT	80	Canada
SILVER	79	Mexico, Canada, Chile, Poland
TIN, refined	78	Indonesia, Peru, Malaysia, Bolivia
COBALT	76	Norway, Canada, Japan, Finland
DIAMOND (INDUSTRIAL), stones	76	South Africa, India, Congo (Kinshasa), Botswana
ZINC, refined	76	Canada, Mexico, Peru, Spain
ABRASIVES, crude fused aluminum oxide	>75	China, France, Bahrain, Russia
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Brazil, Guyana, Australia
SELENIUM	>75	Philippines, China, Mexico, Germany
RHENIUM	72	Chile, Canada, Kazakhstan, Japan
PLATINUM	70	South Africa, Germany, Switzerland, Italy
ALUMINA	58	Brazil, Australia, Jamaica, Canada
GARNET (INDUSTRIAL)	56	South Africa, China, India, Australia
MAGNESIUM COMPOUNDS	55	China, Brazil, Israel, Canada
ABRASIVES, crude silicon carbide	>50	China, Netherlands, South Africa
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
TUNGSTEN	>50	China, Bolivia, Germany, Canada
CADMIUM	<50	Australia, China, Germany, Peru
MAGNESIUM METAL	<50	Canada, Israel, Mexico
NICKEL	48	Canada, Norway, Finland, Australia
COPPER, refined	45	Chile, Canada, Mexico
ALUMINUM	44	Canada, United Arab Emirates, Russia, China
DIAMOND (INDUSTRIAL), bort, grit, dust, and powder	41	China, Ireland, Republic of Korea, Russia
LEAD, refined	38	Canada, Mexico, Republic of Korea, India
PALLADIUM	37	Russia, South Africa, Germany
FELDSPAR	32	Turkey
SILICON, metal and ferrosilicon	32	Russia, Brazil, Canada, Norway
SALT	29	Chile, Canada, Mexico, Egypt
MICA (NATURAL), scrap and flake	28	Canada, China, India
LITHIUM	>25	Argentina, Chile, China, Russia
BROMINE	<25	Israel, Jordan, China
ZIRCONIUM, ores and concentrates	<25	South Africa, Senegal, Australia, Russia
PERLITE	23	Greece, China, Mexico, Turkey
VERMICULITE	20	South Africa, Brazil

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum; rare earths, mineral concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zinc concentrates) or less than 20% net import reliant (abrasives, metallic; beryllium; cement; gypsum; iron and steel; iron and steel slag; lime; nitrogen (fixed)—ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]Listed in descending order of import share.

[3]Data include lanthanides.

Figure 3.—Major Import Sources of Nonfuel Mineral Commodities for Which the United States was Greater Than 50% Net Import Reliant in 2021



Source: U.S. Geological Survey

Table 1.—U.S. Mineral Industry Trends

	2017	2018	2019	2020	2021[e]
Total mine production (million dollars):					
Metals	26,800	28,000	26,900	27,500	33,800
Industrial minerals	52,800	56,300	55,800	53,200	56,600
Coal	26,100	27,200	25,500	16,800	18,700
Employment (thousands of workers):					
Coal mining, all employees	52	52	51	42	42
Nonfuel mineral mining, all employees	134	140	140	137	140
Chemicals and allied products, production workers	525	546	559	535	530
Stone, clay, and glass products, production workers	305	311	312	294	290
Primary metal industries, production workers	292	295	302	272	270
Average weekly earnings of workers (dollars):					
Coal mining, all employees	1,484	1,546	1,617	1,521	1,590
Chemicals and allied products, production workers	1,010	1,072	1,066	1,065	1,110
Stone, clay, and glass products, production workers	873	945	966	982	1,010
Primary metal industries, production workers	996	1,035	1,025	1,008	1,070

[e]Estimated.

Sources: U.S. Geological Survey, U.S. Department of Energy, and U.S. Department of Labor.

Table 2.—U.S. Mineral-Related Economic Trends

	2017	2018	2019	2020	2021[e]
Gross domestic product (billion dollars)	19,480	20,527	21,373	20,894	22,400
Industrial production (2017=100):					
Total index:	100	103	102	95	100
Manufacturing:	100	101	100	93	99
Nonmetallic mineral products	100	100	98	95	97
Primary metals:	100	103	99	86	97
Iron and steel	100	103	97	81	96
Aluminum	100	106	101	92	106
Nonferrous metals (except aluminum)	100	102	104	92	93
Chemicals	100	99	95	93	98
Mining:	100	113	120	103	105
Coal	100	98	92	69	76
Oil and gas extraction	100	116	129	122	121
Metals	100	99	96	94	91
Nonmetallic minerals	100	104	107	104	109
Capacity utilization (percent):					
Total industry:	76	79	77	72	75
Mining:	78	87	86	72	74
Metals	72	71	68	67	64
Nonmetallic minerals	88	89	89	85	88
Housing starts (thousands)	1,205	1,247	1,292	1,397	1,580
Light vehicle sales (thousands)	17,150	17,225	16,961	14,472	15,170
Highway construction, value, put in place (billion dollars)	90	91	100	101	99

[e]Estimated.

Sources: U.S. Department of Commerce and Federal Reserve Board.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Mineral Commodities Produced in 2021[p, 1, 2]

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Alabama	$1,860	16	2.06	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Alaska	3,890	6	4.30	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	9,960	1	11.00	Cement (portland), copper, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Arkansas	1,000	28	1.11	Bromine, cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California	5,270	4	5.83	Boron minerals, cement (portland), rare earths, sand and gravel (construction), stone (crushed).
Colorado	1,610	19	1.78	Cement (portland), gold, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Connecticut	183	43	0.20	Sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[6]	22	50	0.02	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida[6, 7]	2,400	8	2.65	Cement (masonry and portland), phosphate rock, sand and gravel (construction), stone (crushed).
Georgia[6, 7]	2,040	12	2.25	Cement (portland), clay (kaolin and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Hawaii	134	45	0.15	Sand and gravel (construction), stone (crushed).
Idaho	722	34	0.80	Lead, phosphate rock, sand and gravel (construction), silver, stone (crushed).
Illinois[6]	992	25	1.10	Cement (portland), magnesium compounds, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Indiana	1,160	26	1.28	Cement (portland), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa	959	29	1.06	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[6]	1,210	24	1.34	Cement (portland), helium (Grade-A), salt, sand and gravel (construction), stone (crushed).
Kentucky[6]	586	30	0.65	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Louisiana	661	35	0.73	Clay (common clay), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[6]	127	44	0.14	Cement (portland), peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[6]	461	32	0.51	Cement (masonry and portland), sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[6]	209	42	0.23	Clay (common clay), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	3,000	10	3.32	Cement (portland), iron ore, nickel sulfide concentrates, sand and gravel (construction), stone (crushed).
Minnesota[6]	4,010	5	4.44	Iron ore, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Mississippi[6]	200	41	0.22	Clay (bentonite and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	3,300	9	3.65	Cement (portland), lead, lime, sand and gravel (industrial), stone (crushed).
Montana	2,010	13	2.23	Copper, molybdenum mineral concentrates, palladium, platinum, sand and gravel (construction).

See footnotes at end of table.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Mineral Commodities Produced in 2021[p, 1, 2]—Continued

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Nebraska[6]	$220	39	0.24	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	9,350	2	10.30	Copper, gold, lime, silver, stone (crushed).
New Hampshire	95	47	0.10	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	396	38	0.44	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	1,290	23	1.43	Cement (portland), copper, potash, sand and gravel (construction), stone (crushed).
New York[6]	1,570	18	1.74	Cement (portland), salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina[6]	1,460	17	1.62	Clay (common clay), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[6]	65	48	0.07	Clay (common clay), lime, sand and gravel (construction), stone (crushed).
Ohio[6]	1,380	15	1.53	Cement (portland), lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	916	31	1.01	Cement (portland), iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon	595	36	0.66	Cement (portland), diatomite, perlite (crude), sand and gravel (construction), stone (crushed).
Pennsylvania[6]	1,950	14	2.15	Cement (masonry and portland), lime, sand and gravel (construction), stone (crushed).
Rhode Island[6]	66	49	0.07	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina[6]	953	22	1.05	Cement (masonry and portland), gold, sand and gravel (construction), stone (crushed).
South Dakota	495	37	0.55	Cement (portland), gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,550	21	1.71	Cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	5,760	3	6.37	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	3,750	7	4.15	Copper, magnesium metal, molybdenum mineral concentrates, potash, sand and gravel (construction).
Vermont[6]	112	46	0.12	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,550	20	1.72	Cement (portland), kyanite, lime, sand and gravel (construction), stone (crushed).
Washington	732	33	0.81	Cement (portland), diatomite, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
West Virginia	360	40	0.40	Cement (masonry and portland), lime, sand and gravel (construction), stone (crushed).
Wisconsin[6]	997	27	1.10	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	2,750	11	3.14	Cement (portland), clay (bentonite), helium (Grade-A), sand and gravel (construction), soda ash.
Undistributed	4,050	XX	4.48	
Total	90,400	XX	100.00	

[p]Preliminary. XX Not applicable.

[1]Includes data available through December 9, 2021.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Rank based on total, unadjusted State values.

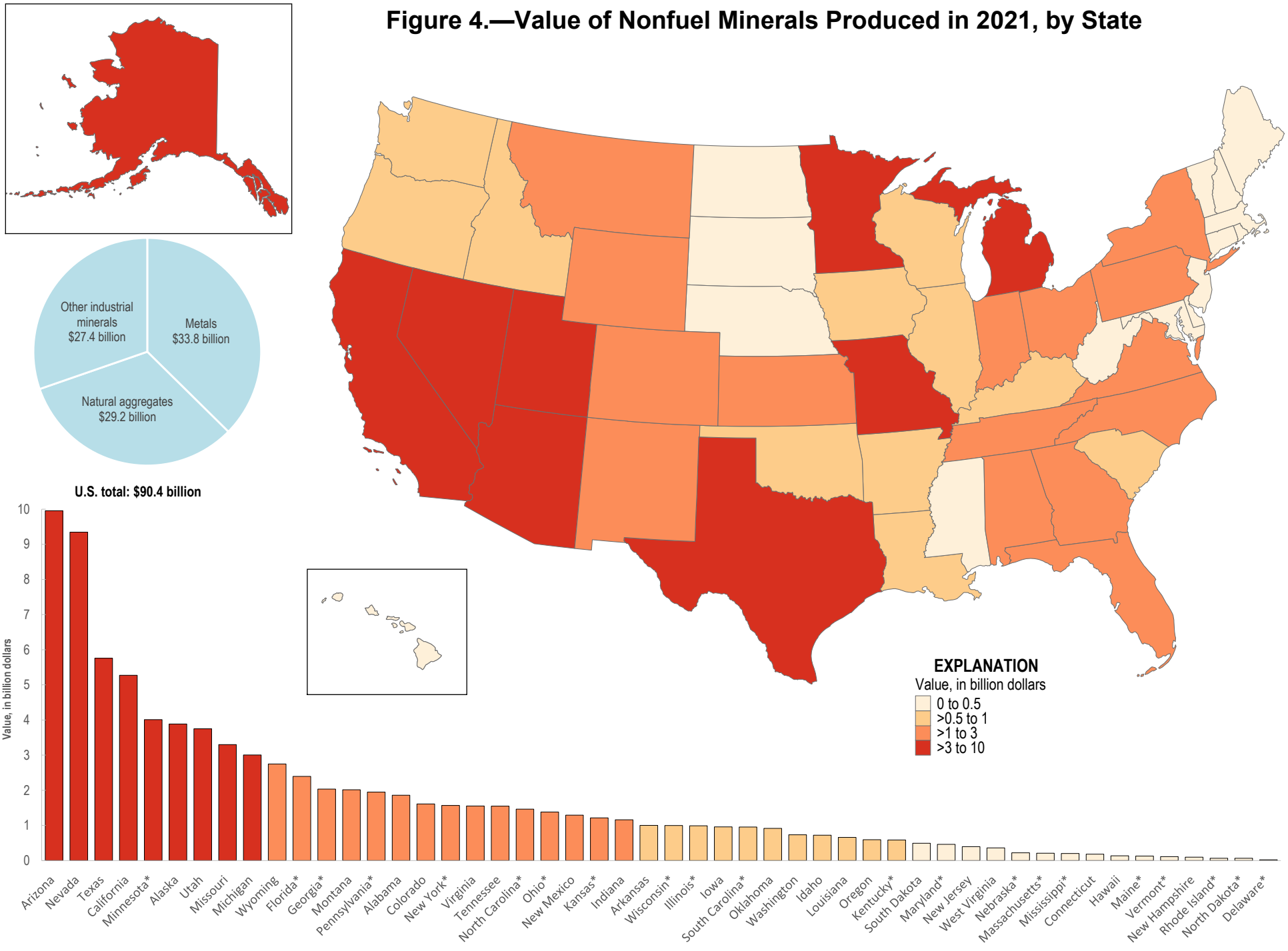
[4]"Percent of U.S. total" calculated to two decimal places.

[5]Listed in alphabetical order.

[6]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed."

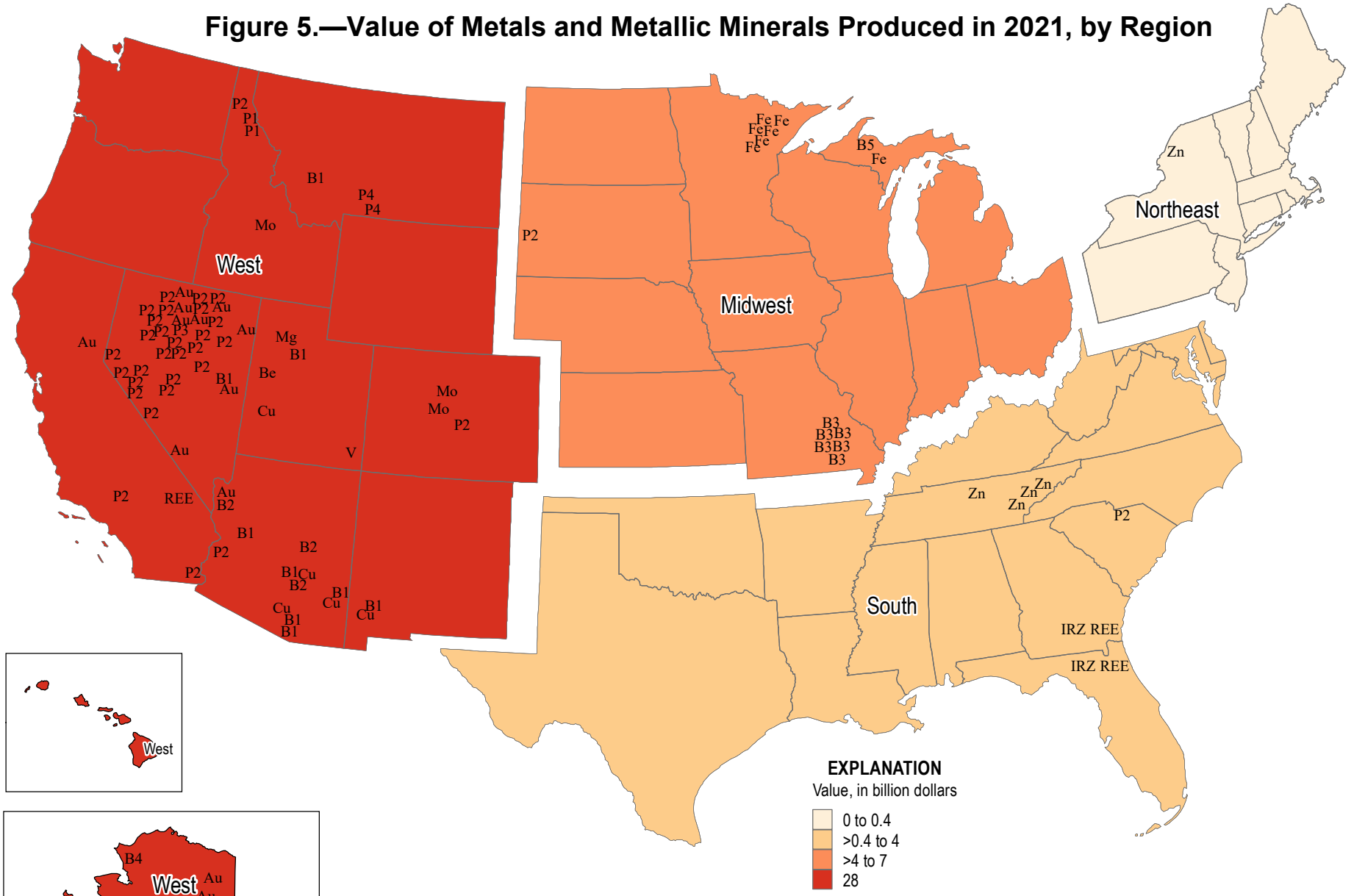
[7]Florida and Georgia also produce significant quantities of titanium and zirconium minerals concentrates, but breakdown by State is not available to avoid disclosing company proprietary data.

Figure 4.—Value of Nonfuel Minerals Produced in 2021, by State



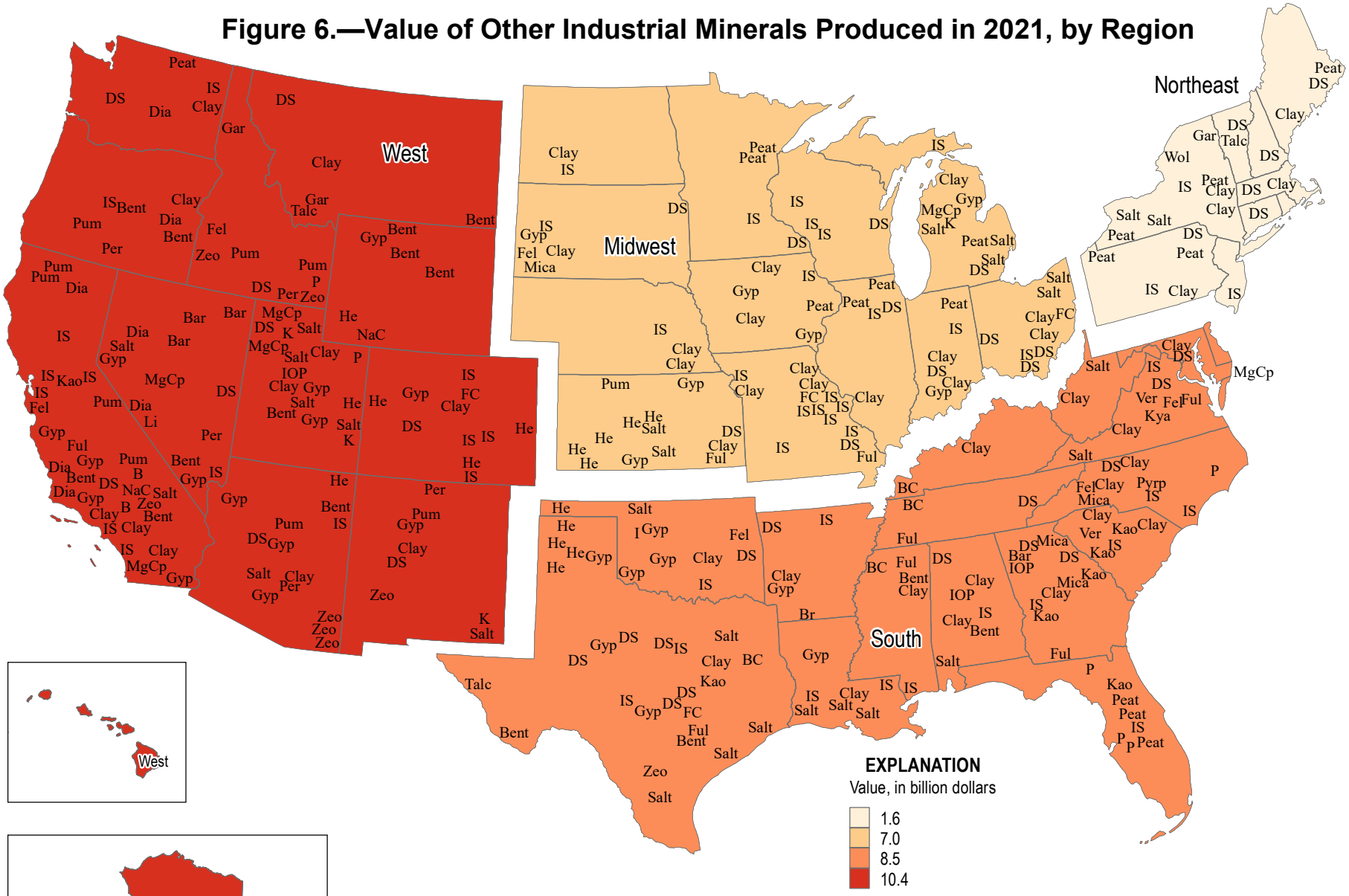
*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

Figure 5.—Value of Metals and Metallic Minerals Produced in 2021, by Region



Au	Gold	B6	Lead and zinc	Mo	Molybdenum	V	Vanadium
B1	Copper ± molybdenum ± gold and silver ± rhenium	Be	Beryllium	P1	Silver ± base metals ± gold	Zn	Zinc
B2	Copper ± silver	Cu	Copper	P2	Gold and silver		
B3	Lead and zinc ± copper ± silver	Fe	Iron ore	P3	Gold and silver ± base metals		
B4	Silver ± zinc ± lead and gold	IRZ	Ilmenite, rutile, and zircon	P4	Platinum and palladium ± gold and silver		
B5	Nickel, copper, cobalt, and gold	Mg	Magnesium	REE	Rare-earth elements		

Figure 6.—Value of Other Industrial Minerals Produced in 2021, by Region



B	Borates	DS	Dimension stone	I	Iodine	MgCp	Iodine	Pyrp	Pyrophyllite
Bar	Barite	FC	Fire clay	IOP	Iron oxide pigments	Mica	Mica	Salt	Salt
BC	Ball clay	Fel	Feldspar	IS	Industrial sand	NaC	Soda ash	Talc	Talc
Bent	Bentonite	Ful	Fuller's earth	K	Potash	P	Phosphate rock	Ver	Vermiculite
Br	Bromine	Gar	Garnet	Kao	Kaolin	Peat	Peat	Wol	Wollastonite
Clay	Common clay	Gyp	Gypsum	Kya	Kyanite	Per	Perlite	Zeo	Zeolites
Dia	Diatomite	He	Helium	Li	Lithium	Pum	Pumice		

Figure 7.—Value of Crushed Stone Produced in 2021, by State

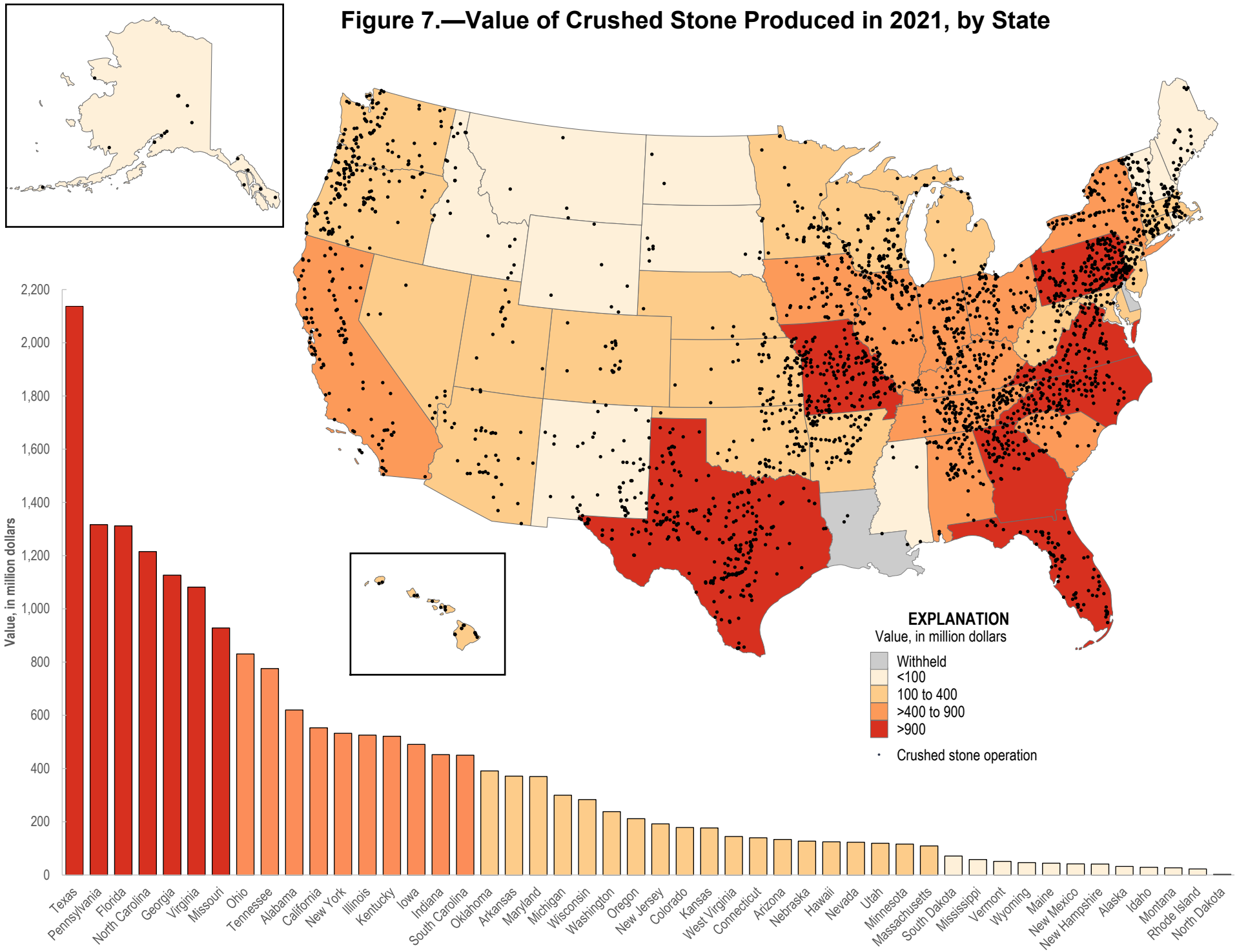
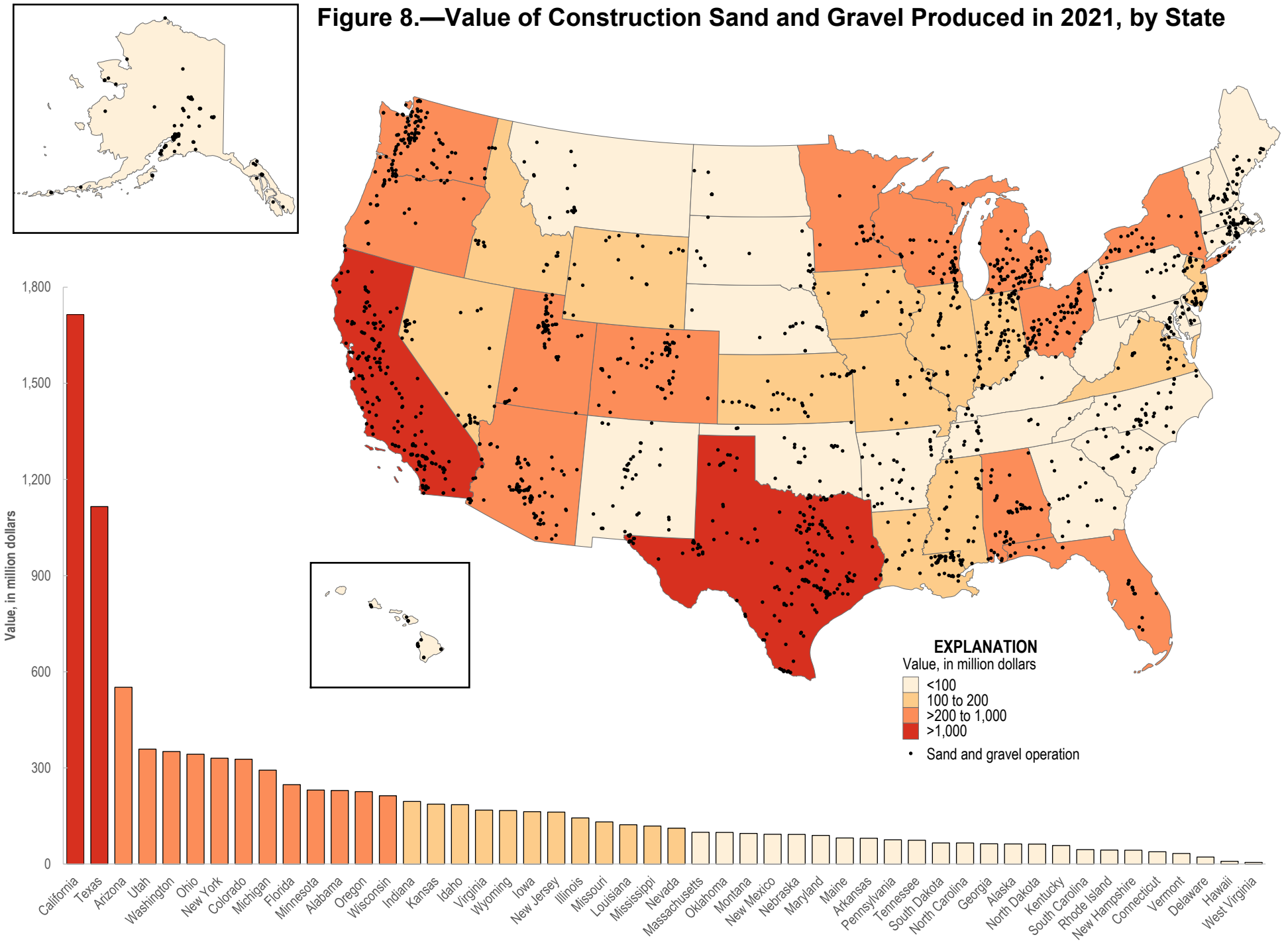


Figure 8.—Value of Construction Sand and Gravel Produced in 2021, by State



UNITED STATES CRITICAL MINERALS UPDATE

Critical Minerals and the U.S. Critical Minerals List

The Energy Act of 2020 (Public Law 116–260, December 27, 2020, 116th Cong.) defined critical minerals as those which are essential to the economic or national security of the United States; have a supply chain that is vulnerable to disruption; and serve an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the United States. The act further specified that critical minerals do not include fuel minerals; water, ice, or snow; or common varieties of sand, gravel, stone, pumice, cinders, and clay.

On May 7, 2021, Open-File Report 2021–1045, "Methodology and Technical Input for the 2021 Review and Revision of the U.S. Critical Minerals List" was published by the U.S. Geological Survey (USGS) as required by section 7002 of title VII of the Energy Act of 2020. The report documented the updated evaluation methodology and the resultant updated draft list of minerals recommended for inclusion in the U.S. critical minerals list (CML). Uranium was excluded by its definition as a fuel mineral in the Mining and Minerals Policy Act of 1970 [30 U.S.C. 21(a)].

On November 9, 2021, a proposed, revised U.S. CML was published in the Federal Register (86 FR 62199). This list contains 50 individual mineral commodities. It differs from the prior 2018 U.S. CML by individually listing the rare-earth elements and platinum-group elements by specific element forms, adding nickel and zinc, and removing helium, potash, rhenium, strontium, and uranium. As of the date of this publication, the proposed, revised U.S. CML has not yet been finalized. Following adjudication of public comments, a final, revised critical minerals list is anticipated to be posted to the Federal Register by the end of February 2022.

Supply Chain Security and U.S. Government Critical Minerals Initiatives

In 2021, several U.S. Government efforts were taken to strengthen U.S. critical mineral supply chains. Some examples of these are presented here. Additional information on specific mineral commodity initiatives may be found in the mineral commodity chapters that follow.

In 2020 and 2021, the U.S. Department of Defense awarded technology investment agreements to establish light-rare-earth-element separation facilities in Texas and California pursuant to section 303 of the Defense Production Act of 1950, as amended (50 U.S.C. 4533).

In April 2021, the U.S. Department of Energy (DOE) awarded $19 million for 13 projects to support production of rare-earth elements and critical minerals vital for the clean energy economy. Many of these awards were made to universities in traditional fossil-fuel-producing communities. In September 2021, the DOE awarded $30 million in funding for 13 national-lab- and university-led research projects focused on developing substitutes for, diversifying the supply of, and improving the reuse and recycling of rare-earth elements and platinum-group elements to support creating cleaner energy.

In September 2021, the U.S. Department of Defense's Office of Industrial Policy announced the kickoff of the "Critical Minerals from Coal Ash" pilot project, which was a 30-month project funded for $4 million to develop next-generation technologies for recovery of critical minerals, including rare-earth elements from domestic coal ash.

U.S. Production and Consumption of Critical Minerals in 2021

The United States was 100% net import reliant for 14 of the listed critical minerals or mineral groups. Despite not having mine production or refining, the United States did have secondary production for four critical minerals and thus net import reliance was less than 100%. Additionally, there was secondary production for another nine critical minerals that supplemented primary production (table 4).

China was the leading producing nation for 16 of the 32 listed critical minerals. The other leading producers of critical minerals were South Africa with four critical minerals; Australia, three critical minerals; Congo (Kinshasa), two critical minerals; and the United States, two critical minerals (table 4).

Figure 9 shows the trends in net import reliance for critical minerals over the past 20 years. For most critical minerals, the United States is heavily reliant on foreign sources for its consumption requirements; exceptions include beryllium, helium, and zirconium.

Trade

In November 2021, the U.S. Department of Commerce issued a notice of its final investigation into the effect of imports of vanadium on the national security of the United States under section 232 of the Trade Expansion Act of 1962 (86 FR 64748). The report concluded that current quantities of vanadium imports did not impair national security and no additional ad valorem duties were recommended.

Table 4.—Salient Critical Minerals Statistics in 2021[1]

(Metric tons, mine production, unless otherwise specified)

Critical mineral	United States					World			
	Primary production	Secondary production	Apparent consumption	Net import reliance as a percentage of apparent consumption	Primary import source (2017–20)	Leading producing country	Production in leading country	World production total	Percentage of world total
Aluminum (bauxite)	W	—	[2]3,600,000	>75	Jamaica	Australia	110,000,000	[3]390,000,000	28
Antimony	—	4,100	[4]28,000	84	China	China	60,000	110,000	55
Arsenic	—	—	[5]6,800	100	China	Peru	[6]27,000	[6]59,000	46
Barite	W	—	W	>75	China	China	2,800,000	[3]7,300,000	38
Beryllium	170	NA	200	16	Kazakhstan	United States	170	260	65
Bismuth[7]	—	80	810	90	China	China	16,000	19,000	84
Chromium	—	120,000	590,000	80	South Africa	South Africa	18,000,000	41,000,000	44
Cobalt	700	1,600	6,700	76	Norway	Congo (Kinshasa)	120,000	170,000	71
Fluorspar	NA	—	450,000	100	Mexico	China	5,400,000	8,600,000	63
Gallium	—	—	[2]16	100	China	China	420	430	98
Germanium[7]	—	W	[5]30	>50	China	China	95	[3]140	68
Graphite (natural)	—	—	45,000	100	China	China	820,000	1,000,000	82
Helium[8]	71	NA	40	E	Qatar	United States	71	160	44
Indium[7]	—	NA	[5]170	100	China	China	530	920	58
Lithium	W	W	[5]2,000	>25	Argentina	Australia	55,000	[3]100,000	55
Magnesium[7]	W	98,000	[2]50,000	<50	Canada	China	800,000	[3]950,000	84
Manganese	—	—	640,000	100	Gabon	South Africa	7,400,000	20,000,000	37
Niobium	—	NA	7,000	100	Brazil	Brazil	66,000	75,000	88
Palladium (platinum-group metal)	14	42	90	37	Russia	South Africa	80	200	40
Platinum (platinum-group metal)	4	7	37	70	South Africa	South Africa	130	180	72
Potash	480,000	—	7,400,000	93	Canada	Canada	14,000,000	46,000,000	30
Rare-earth elements[9]	43,000	—	[10]6,100	>90	China	China	168,000	280,000	60
Rhenium	9	NA	32	72	Chile	Chile	29	59	49
Scandium	—	—	NA	100	NA	China	NA	NA	NA
Strontium	—	—	4,800	100	Mexico	Spain	150,000	360,000	42
Tantalum	—	NA	710	100	China	Congo (Kinshasa)	700	2,100	33
Tellurium[7]	W	—	W	>95	Canada	China	340	[3]580	59
Tin	—	10,000	45,000	78	Indonesia	China	91,000	300,000	30
Titanium[7]	W	W	[2]W	>90	Japan	China	120,000	[3]210,000	57
Tungsten	—	W	W	>50	China	China	66,000	79,000	84
Vanadium	—	NA	3,600	100	Canada	China	73,000	110,000	66
Zirconium	[11]20,000	—	[11]30,000	<25	South Africa	Australia	400,000	1,200,000	33

E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Critical minerals as published in the Federal Register on May 18, 2018 (83 FR 23295). Not all critical minerals are listed here. Those not shown include mineral commodities for which not enough information is available regarding U.S. or world production. The critical minerals cesium, hafnium, and rubidium are not listed in the table because it is thought there is no U.S. production for these commodities.

[2]Reported consumption.

[3]Excludes U.S. production.

[4]Antimony in oxide and unwrought metal, powder.

[5]Estimated consumption.

[6]Arsenic trioxide.

[7]Refinery production.

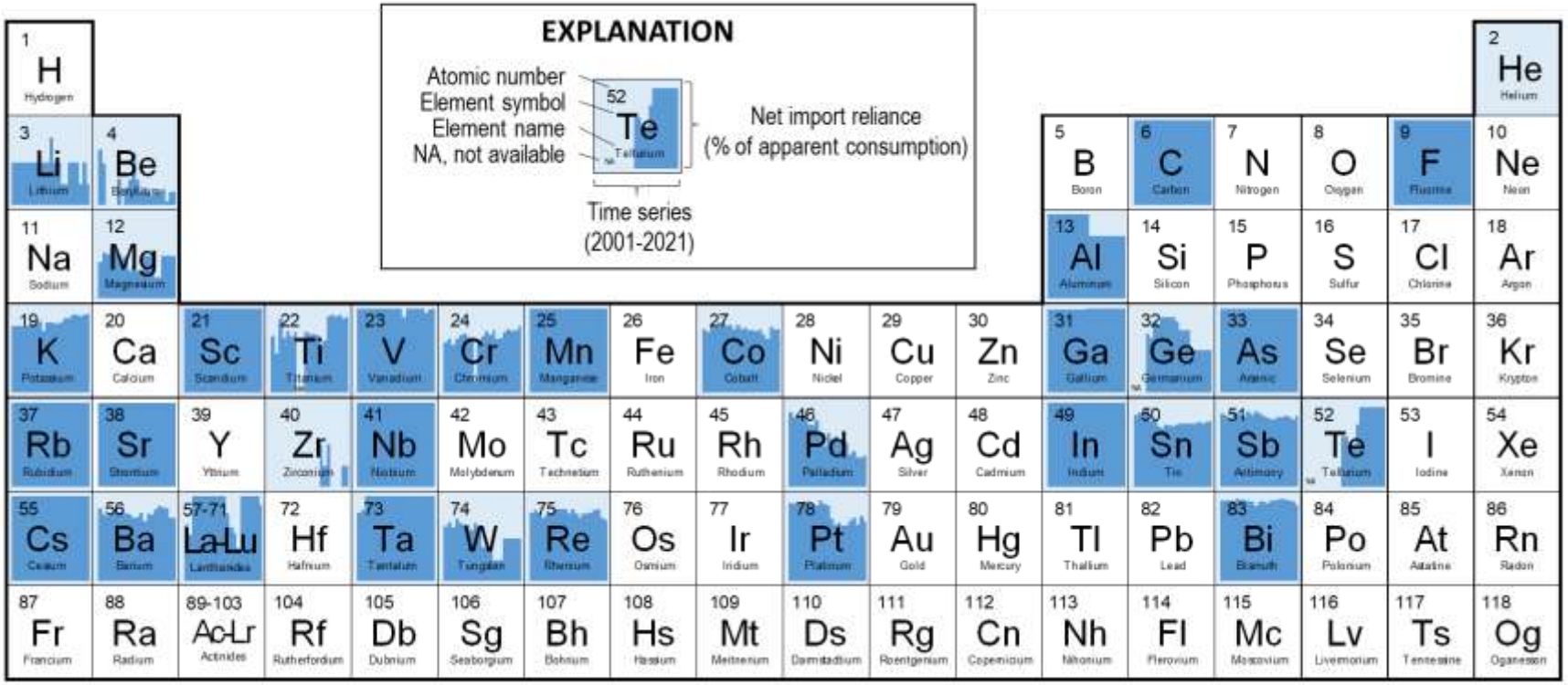
[8]Million cubic meters.

[9]Data include lanthanides and yttrium but exclude most scandium.

[10]Compounds and metals. The United States is a net exporter of mineral concentrates.

[11]Rounded to one significant digit to avoid disclosing company proprietary data.

Figure 9.—20-Year Trend of U.S. Net Import Reliance for Critical Minerals



For elements of the periodic table associated with mineral commodities identified as critical in 2018 (83 FR 23295), the figure displays the U.S. net import reliance (NIR) as a percent of apparent consumption from 2001 through 2021. Barite is listed under barium (Ba). Bauxite is listed under aluminum (Al). Fluorspar is listed under fluorine (F). Graphite (natural) is listed under carbon (C). Potash is listed under potassium (K). Rare earths are listed under lanthanides (La–Lu). Net import reliance data are not available (NA) for hafnium for 2001 through 2021, germanium prior to 2004, tellurium prior to 2010, and titanium for 2008 and 2009. For certain years, the NIR for barite, bauxite, germanium, lithium, magnesium, rare earths, tellurium, tungsten, and zirconium are rounded to avoid disclosing company proprietary data.

ABRASIVES (MANUFACTURED)

(Fused aluminum oxide, silicon carbide, and metallic abrasives)
(Data in metric tons unless otherwise noted)

Domestic Production and Use: Fused aluminum oxide was produced by two companies at three plants in the United States and Canada. Production of crude fused aluminum oxide had an estimated value of $3.0 million. Silicon carbide was produced by two companies at two plants in the United States. Production of crude silicon carbide had an estimated value of about $30 million. Metallic abrasives were produced by 11 companies in eight States. Production of metallic abrasives had an estimated value of about $100 million. Bonded and coated abrasive products accounted for most abrasive uses of fused aluminum oxide and silicon carbide. Metallic abrasives are used primarily for steel shot and grit and cut wire shot, which are used for sandblasting, peening, and stonecutting applications.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	10,000	10,000
Silicon carbide[2]	35,000	35,000	35,000	35,000	35,000
Metallic abrasives	179,000	180,000	177,000	176,000	180,000
Shipments, metallic abrasives	197,000	196,000	195,000	194,000	200,000
Imports for consumption:					
Fused aluminum oxide	206,000	192,000	184,000	121,000	110,000
Silicon carbide	137,000	146,000	131,000	88,000	90,000
Metallic abrasives	29,600	29,900	27,900	25,800	29,000
Exports:					
Fused aluminum oxide	15,500	20,100	18,400	11,400	11,000
Silicon carbide	6,100	10,100	11,500	8,300	12,000
Metallic abrasives	31,000	33,600	31,200	18,100	20,000
Consumption, apparent:					
Fused aluminum oxide[3]	191,000	172,000	166,000	110,000	100,000
Silicon carbide[4]	166,000	171,000	155,000	115,000	110,000
Metallic abrasives[5]	196,000	192,000	192,000	202,000	200,000
Price, average unit value of imports, dollars per ton:					
Fused aluminum oxide, regular	489	681	716	666	630
Fused aluminum oxide, high-purity	1,220	1,290	1,250	1,180	1,300
Silicon carbide, crude	479	670	701	628	530
Metallic abrasives	1,020	1,180	1,310	1,130	1,300
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>75	>75	>75	>75	>75
Silicon carbide	>75	>75	>75	>50	>50
Metallic abrasives	E	E	E	4	5

Recycling: Up to 30% of fused aluminum oxide may be recycled, and about 5% of silicon carbide is recycled.

Import Sources (2017–20): Fused aluminum oxide, crude: China,[7] 91%; France, 3%; Bahrain and Russia, 2% each; and other, 2%. Fused aluminum oxide, grain: Canada, 22%; Brazil, 19%; Austria, 15%; China,[7] 12%; and other, 32%. Silicon carbide, crude: China,[7] 88%; the Netherlands and South Africa, 4% each; and other 4%. Silicon carbide, grain: China,[7] 47%; Brazil, 21%; Russia, 9%; Norway, 7%; and other, 16%. Metallic abrasives: Canada, 33%; China,[7] 15%; Turkey, 12%; Germany, 10%; and other, 30%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Artificial corundum, crude	2818.10.1000	Free.
White, pink, ruby artificial corundum, greater than 97.5% aluminum oxide, grain	2818.10.2010	1.3% ad valorem.
Artificial corundum, not elsewhere specified or included, fused aluminum oxide, grain	2818.10.2090	1.3% ad valorem.
Silicon carbide, crude	2849.20.1000	Free.
Silicon carbide, grain	2849.20.2000	0.5% ad valorem.
Iron, pig iron, or steel granules	7205.10.0000	Free.

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ABRASIVES (MANUFACTURED)

Depletion Allowance: None.

Government Stockpile: None.

Events, Trends, and Issues: In 2021, China was the world's leading producer of abrasive fused aluminum oxide and abrasive silicon carbide. Imports, especially from China where operating costs were lower, continued to challenge abrasives producers in the United States and Canada. In recent years, imports of abrasives from Hong Kong have also increased. Foreign competition is expected to persist and continue to limit production in North America. The average unit value of imports had increased every year since 2016 for regular fused aluminum oxide and crude silicon carbide but have decreased since 2020. The average unit values of imports of regular fused aluminum oxide and crude silicon carbide during the first 7 months of 2021 were 6% and 14% lower, respectively, than those in 2020 and 13% and 33% lower, respectively, than those in 2019.

Abrasives consumption in the United States is greatly influenced by activity in the manufacturing sectors, particularly the aerospace, automotive, furniture, housing, and steel industries. Automobile and steel production were greatly affected by the global COVID-19 pandemic as well as a global semiconductor chip shortage, which in turn reduced the demand for metallic abrasives.

Domestic production remains consistent, although foreign trade continues to be negatively affected by the COVID-19 pandemic. Imports and exports showed signs of recovery from 2020, but they remained significantly below pre-pandemic levels. Additionally, a global container shortage arose that greatly delayed shipments and caused container prices to nearly double compared with prices in 2020.

World Production Capacity:

	Fused aluminum oxide[e]		Silicon carbide[e]	
	2020	2021	2020	2021
United States	60,000	60,000	40,000	40,000
Australia	50,000	50,000	—	—
Austria	60,000	60,000	—	—
Brazil	50,000	50,000	40,000	40,000
China	800,000	800,000	450,000	450,000
France	40,000	40,000	20,000	20,000
Germany	80,000	80,000	35,000	35,000
India	40,000	40,000	5,000	5,000
Japan	15,000	15,000	60,000	60,000
Mexico	—	—	45,000	45,000
Norway	—	—	80,000	80,000
Venezuela	—	—	30,000	30,000
Other countries	80,000	80,000	200,000	200,000
World total (rounded)	1,300,000	1,300,000	1,000,000	1,000,000

World Resources:[8] Although domestic resources of raw materials for fused aluminum oxide production are limited, adequate resources are available in the Western Hemisphere. Domestic resources are more than adequate for silicon carbide production.

Substitutes: Natural and manufactured abrasives, such as garnet, emery, or metallic abrasives, can be substituted for fused aluminum oxide and silicon carbide in various applications.

[e]Estimated. E Net exporter. — Zero.

[1]Production data for aluminum oxide are combined production data from the United States and Canada to avoid disclosing company proprietary data.

[2]Rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.

[3]Defined as imports – exports because production includes data from Canada; actual consumption is higher than that shown.

[4]Defined as production + imports – exports.

[5]Defined as shipments + imports – exports.

[6]Defined as imports – exports.

[7]Includes Hong Kong.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

ALUMINUM[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, three companies operated six primary aluminum smelters in five States. Two smelters operated at full capacity and four smelters operated at reduced capacity throughout the year. Another smelter remained on standby throughout the year, and one that had been on standby since 2015 was permanently shut down in December. Domestic smelters were operating at about 55% of capacity of 1.64 million tons per year at yearend 2021. Estimated primary production decreased by 13% compared with that in 2020 but estimated secondary production from new and old scrap increased by 5% compared with that in 2021. Based on published prices, the value of primary aluminum production was about $2.70 billion, 35% more than the value in 2020. The average annual U.S. market price increased by about 55% from that in 2020. Transportation applications accounted for 35% of domestic consumption; in descending order of consumption, the remainder was used in packaging, 23%; building, 16%; electrical, 9%; consumer durables, 7%; machinery, 7%; and other, 3%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Primary	741	891	1,093	1,012	880
Secondary (from old scrap)	1,590	1,570	1,540	1,420	1,500
Secondary (from new scrap)	2,050	2,140	1,920	1,630	1,700
Imports for consumption:					
Crude and semimanufactures	6,220	5,550	5,280	4,320	4,800
Scrap	700	695	596	542	700
Exports:					
Crude and semimanufactures	1,330	1,310	1,110	905	820
Scrap	1,570	1,760	1,860	1,850	2,000
Consumption, apparent[2]	5,680	4,900	4,980	3,980	4,300
Supply, apparent[3]	7,730	7,040	6,910	5,620	6,000
Price, ingot, average U.S. market (spot), cents per pound	98.3	114.7	99.5	89.7	140
Stocks, yearend:					
Aluminum industry	1,470	1,570	1,600	1,490	1,700
London Metal Exchange (LME), U.S. warehouses[4]	254	186	[e]120	235	100
Employment, number[5]	31,700	31,600	32,900	30,100	30,000
Net import reliance[6] as a percentage of apparent consumption	59	50	47	39	44

Recycling: In 2021, aluminum recovered from purchased scrap in the United States was about 3.2 million tons, of which about 53% came from new (manufacturing) scrap and 47% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 30% of apparent consumption.

Import Sources (2017–20): Canada, 50%; the United Arab Emirates, 9%; Russia, 6%; China,[7] 4%; and other, 31%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Aluminum, not alloyed:		
Unwrought (in coils)	7601.10.3000	2.6% ad valorem.
Unwrought (other than aluminum alloys)	7601.10.6000	Free.
Aluminum alloys, unwrought (billet)	7601.20.9045	Free.
Aluminum scrap:		
Used beverage container scrap	7602.00.0030	Free.
Industrial process scrap	7602.00.0091	Free.

Depletion Allowance: Not applicable.[1]

Government Stockpile: None.

Events, Trends, and Issues: In March, a primary aluminum smelter in Mount Holly, SC, signed a new power supply contract through the end of 2023. The contract would provide enough power for the 230,000-ton-per-year smelter to restart about 57,000 tons per year of capacity. The smelter had only been producing at a rate of 115,000 tons per year. The restart of the additional capacity was expected to be completed early in 2022 after maintenance was completed. In December, the temporary shutdown of a 146,000-ton-per-year smelter in Wenatchee, WA, was made permanent. The smelter last produced in 2015. Prices for aluminum generally trended upward throughout 2021 in the United States and in world markets. High power prices attributed to higher coal prices and shutdowns of powerplants complying with environmental regulations were cited for increased aluminum prices in China, the world's leading

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producer. Additionally, higher prices for alumina amid shutdowns of alumina refineries in Brazil and China in July and in Jamaica in August added pressure to production costs for smelters.

In June, the U.S. Department of Commerce (DOC) opened the Aluminum Import Monitoring and Analysis (AIM) system (https://www.trade.gov/aluminum) for submitting applications for required licenses to import covered aluminum products. The AIM system is intended to aid in enforcement of trade agreements and circumvent evasion of tariffs and quotas on aluminum and aluminum products. In October, an agreement was reached between the United States and the European Union to remove the 10% ad valorem tariff on aluminum imports that was imposed in 2018 under the authority of section 232 of the Trade Expansion Act of 1964. Effective in January 2022, the tariff would only be applied on imports from countries in the European Union that exceed specified quotas.

In 2021, the DOC issued final determinations of antidumping and countervailing duty investigations for aluminum foil imports and common alloy aluminum sheet imports. Foil imports from China between August 14, 2017, and December 31, 2018, had antidumping duty rates assessed that ranged from 23.62% to 47.57% and countervailing duty rates that ranged from 17.05% to 48.36%. Final countervailing determinations of aluminum foil imports from Oman and Turkey in 2019 were made by the U.S. International Trade Commission in September with countervailing duty rates set at 1.93% for imports from Oman and 2.6% for imports from Turkey. In October, the DOC issued final antidumping duty rates for aluminum foil imported between July 1, 2019, and June 30, 2020, ranging from 29.11% for Armenia, 13.93% to 63.05% for Brazil, 3.89% for Oman, and 62.18% for Russia. In March, the DOC issued its final determinations of an antidumping investigation of common alloy aluminum sheet imports from 18 countries and determined that imports produced in 16 countries were sold below fair market value. The countervailing duty investigation determined that producers in three countries also benefited from Government subsidy programs.

World Smelter Production and Capacity: Capacity data for Bahrain, China, the United Arab Emirates, and the United States were revised based on company and Government data.

	Smelter production		Yearend capacity	
	2020	2021[e]	2020	2021[e]
United States	1,012	880	1,790	1,640
Australia	1,580	1,600	1,720	1,720
Bahrain	1,550	1,500	1,550	1,550
Canada	3,120	3,100	3,270	3,270
China	37,100	39,000	42,300	43,000
Iceland	860	880	890	890
India	3,560	3,900	4,060	4,060
Norway	1,330	1,400	1,430	1,430
Russia	3,640	3,700	4,020	4,020
United Arab Emirates	2,520	2,600	2,700	2,780
Other countries	8,880	9,400	12,300	12,300
World total (rounded)	65,100	68,000	76,000	77,000

World Resources:[8] Global resources of bauxite are estimated to be between 55 billion and 75 billion tons and are sufficient to meet world demand for metal well into the future.

Substitutes: Composites can substitute for aluminum in aircraft fuselages and wings. Glass, paper, plastics, and steel can substitute for aluminum in packaging. Composites, magnesium, steel, and titanium can substitute for aluminum in ground transportation uses. Composites, steel, vinyl, and wood can substitute for aluminum in construction. Copper can replace aluminum in electrical and heat-exchange applications.

[e]Estimated.

[1]See also Bauxite and Alumina.

[2]Defined as primary production + secondary production from old scrap + imports – exports + adjustments for stock changes; excludes imported scrap.

[3]Defined as primary production + secondary production + imports – exports + adjustments for stock changes; excludes imported scrap.

[4]Includes aluminum alloy. Starting with 2019, also includes off-warrant stocks of primary and alloyed aluminum; estimated for 2019.

[5]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.

[6]Defined as imports – exports + adjustments for industry stock changes; excludes imported scrap.

[7]Includes Hong Kong.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

ANTIMONY

(Data in metric tons of contained antimony unless otherwise noted)

Domestic Production and Use: In 2021, no marketable antimony was mined in the United States. A mine in Nevada that had extracted about 800 tons of stibnite ore from 2013 through 2014 was placed on care-and-maintenance status in 2015 and had no reported production in 2021. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced in 2021 was about $47 million. Recycling supplied about 15% of estimated domestic consumption, and the remainder came mostly from imports. The value of antimony consumption in 2021 was about $320 million. In the United States, the leading uses of antimony were as follows: flame retardants, 40%; metal products, including antimonial lead and ammunition, 36%; and nonmetal products, including ceramics and glass and rubber products, 24%.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	621	331	377	254	460
Secondary	4,370	4,090	4,140	4,250	4,100
Imports for consumption:					
Ore and concentrates	61	96	121	105	29
Oxide	17,800	19,200	17,300	15,000	18,000
Unwrought, powder	6,810	6,320	6,670	5,520	7,700
Waste and scrap[1]	16	202	17	6	11
Exports:					
Ore and concentrates[1]	46	38	9	10	11
Oxide	1,600	1,750	1,570	1,230	1,600
Unwrought, powder	643	497	370	393	770
Waste and scrap[1]	11	9	14	11	130
Consumption, apparent[2]	27,400	27,700	26,400	23,400	28,000
Price, metal, average, dollars per pound[3]	3.77	3.81	3.04	2.67	5.20
Net import reliance[4] as a percentage of apparent consumption	82	84	83	81	84

Recycling: The bulk of secondary antimony is recovered at secondary lead smelters as antimonial lead, most of which was generated by, and then consumed by, the lead-acid battery industry.

Import Sources (2017–20): Ore and concentrates: China, 42%; Italy, 36%; India, 11%; Mexico, 4%; and other, 7%. Oxide: China,[5] 71%; Belgium, 10%; Bolivia, 6%; Thailand, 5%; and other, 8%. Unwrought metal and powder: China,[5] 37%; India, 24%; Vietnam, 11%; Burma, 9%; and other, 19%. Total metal and oxide: China,[5] 63%; Belgium, 7%; India, 6%; and other, 24%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Ore and concentrates	2617.10.0000	Free.
Antimony oxide	2825.80.0000	Free.
Antimony and articles thereof:		
Unwrought antimony; powder	8110.10.0000	Free.
Waste and scrap	8110.20.0000	Free.
Other	8110.90.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[6]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Antimony	90.12	1,100	—	1,100	—

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ANTIMONY

Events, Trends, and Issues: China continued to be the leading global antimony producer in 2021 and accounted for 55% of global mine production, followed by Russia, 23%, and Tajikistan, 12%. The supply of antimony raw materials and downstream production of antimony products was constrained in 2021 as a result of environmental audits in China and various temporary mine shutdowns to mitigate the spread of the global COVID-19 pandemic. The raw material shortage combined with the worldwide shipping delays caused a supply shortage of refined antimony on the market, and the antimony price reached a high of $6.65 per pound in October 2021 compared with the annual average price of $2.67 per pound in 2020.

World Mine Production and Reserves: Reserves for Australia and Burma were revised based on Government and industry reports.

	Mine production		Reserves[7]
	2020	2021[e]	
United States	—	—	[8]60,000
Australia	3,900	3,400	[9]100,000
Bolivia	2,600	2,700	310,000
Burma	2,200	2,000	140,000
Canada	2	2	78,000
China	61,000	60,000	480,000
Guatemala	80	80	NA
Iran	400	400	NA
Kazakhstan	100	100	NA
Kyrgyzstan	—	—	260,000
Mexico	700	700	18,000
Pakistan	17	20	26,000
Russia (recoverable)	25,000	25,000	350,000
Tajikistan	13,000	13,000	50,000
Turkey	1,330	1,300	100,000
Vietnam	390	400	NA
World total (rounded)	111,000	110,000	>2,000,000

World Resources:[7] U.S. resources of antimony are mainly in Alaska, Idaho, Montana, and Nevada. Principal identified world resources are in Australia, Bolivia, Burma, China, Mexico, Russia, South Africa, and Tajikistan. Additional antimony resources may occur in Mississippi Valley-type lead deposits in the Eastern United States.

Substitutes: Selected organic compounds and hydrated aluminum oxide are substitutes as flame retardants. Chromium, tin, titanium, zinc, and zirconium compounds substitute for antimony chemicals in enamels, paint, and pigments. Combinations of calcium, copper, selenium, sulfur, and tin are substitutes for alloys in lead-acid batteries.

[e]Estimated. NA Not available. — Zero.

[1]Gross weight.

[2]Defined as primary production + secondary production from old scrap + imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder + adjustments for Government stock changes.

[3]Antimony minimum 99.65%, cost, insurance, and freight. Source: Argus Media group—Argus Metals International.

[4]Defined as imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder + adjustments for Government stock changes.

[5]Includes Hong Kong.

[6]See Appendix B for definitions.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Company-reported probable reserves for the Stibnite Gold Project in Idaho.

[9]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 18,000 tons.

ARSENIC

(Data in metric tons of contained arsenic[1] unless otherwise noted)

Domestic Production and Use: Arsenic trioxide and primary arsenic metal have not been produced in the United States since 1985. The principal use for arsenic trioxide was for the production of arsenic acid used in the formulation of chromated copper arsenate (CCA) preservatives for the pressure treating of lumber used primarily in nonresidential applications. Seven companies produced CCA-treated wood in the United States in 2021. The grids in lead-acid storage batteries were strengthened by the addition of arsenic metal. Arsenic metal also was used as an antifriction additive for bearings, to harden lead shot, and in clip-on wheel weights. Arsenic compounds were used in herbicides and insecticides. High-purity (99.9999%) arsenic metal was used to produce gallium-arsenide (GaAs) semiconductors for solar cells, space research, and telecommunications. Arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide (InGaAs) was used for short-wave infrared technology. The value of arsenic compounds and metal imported domestically in 2021 was estimated to be about $8 million. Given that arsenic metal has not been produced domestically since 1985, it is likely that only a small portion of the material reported by the U.S. Census Bureau as arsenic exports was pure arsenic metal, and most of the material that was reported under this category reflects the gross weight of alloys, compounds, residues, scrap, and waste containing arsenic. Therefore, the estimated consumption reported under U.S. salient statistics reflects only imports of arsenic products.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Imports for consumption:					
Arsenic metal	942	929	391	522	750
Compounds	5,980	5,540	7,090	7,780	6,000
Exports, all forms of arsenic (gross weight)	698	107	56	29	40
Consumption, estimated, all forms of arsenic[2]	6,920	6,470	7,480	8,300	6,800
Price, average unit value of imports (free alongside ship),[3] dollars per kilogram:					
Arsenic metal (China)	1.56	1.43	1.93	1.51	1.28
Trioxide (China)	0.45	0.44	0.46	0.43	0.43
Trioxide (Morocco)	0.68	0.75	0.78	0.83	0.84
Net import reliance[4] as a percentage of estimated consumption, all forms of arsenic	100	100	100	100	100

Recycling: Arsenic metal was contained in new scrap recycled during GaAs semiconductor manufacturing. Arsenic-containing process water was internally recycled at wood treatment plants where CCA was used. Although scrap electronic circuit boards, relays, and switches may contain arsenic, no arsenic was known to have been recovered during the recycling process to recover other contained metals. No arsenic was recovered domestically from arsenic-containing residues and dusts generated at nonferrous smelters in the United States.

Import Sources (2017–20): Arsenic metal: China,[5] 95%; Japan, 4%; and other, 1%. Arsenic trioxide: China, 57%; Morocco, 38%; Belgium, 4%; and other, 1%. All forms of arsenic: China,[5] 60%; Morocco, 34%; Belgium, 3%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Arsenic metal	2804.80.0000	Free.
Arsenic acid	2811.19.1000	2.3% ad valorem.
Arsenic trioxide	2811.29.1000	Free.
Arsenic sulfide	2813.90.1000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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ARSENIC

Events, Trends, and Issues: Peru, China, and Morocco, in descending order, were the leading global producers of arsenic trioxide, accounting for about 98% of estimated world production. China and Morocco continued to supply about 90% of United States imports of arsenic trioxide in 2021. China was the leading world producer of arsenic metal and supplied about 94% of United States arsenic metal imports in 2021.

High-purity arsenic metal was used to produce GaAs, indium-arsenide, and InGaAs semiconductors that were used in biomedical, communications, computer, electronics, and photovoltaic applications. Total revenues from GaAs devices increased in 2021 because of fifth-generation (5G) technology that became standard for broadband cellular 5G networks and consumer devices. A variety of GaAs wafer manufacturers ranging from large, multinational corporations to small, privately owned companies competed in this industry, but the top six producers accounted for more than 75% of the market. China and Japan each produced about 30% of global GaAs, followed by Europe (20%), North America (15%), and the rest of the world (5%). See the Gallium chapter for additional details.

World Production and Reserves (gross weight):

	Production[e, 6] (arsenic trioxide)		Reserves[7]
	2020	2021	
United States	—	—	World reserves data are unavailable but are thought to be more than 20 times world production.
Belgium	1,000	1,000	
Bolivia	100	160	
China	24,000	24,000	
Japan	40	40	
Morocco	7,700	7,000	
Peru	27,000	27,000	
Russia	120	100	
World total (rounded)	60,000	59,000	

World Resources:[7] Arsenic may be obtained from copper, gold, and lead smelter flue dust, as well as from roasting arsenopyrite, the most abundant ore mineral of arsenic. Arsenic has been recovered from orpiment and realgar in China, Peru, and the Philippines and from copper-gold ores in Chile, and arsenic was associated with gold occurrences in Canada. Orpiment and realgar from gold mines in Sichuan Province, China, were stockpiled for later recovery of arsenic. Arsenic also may be recovered from enargite, a copper mineral. Arsenic trioxide was produced at the hydrometallurgical complex of Guemassa, near Marrakech, Morocco, from cobalt-arsenide ore from the Bou Azzer Mine.

Substitutes: Substitutes for CCA in wood treatment include alkaline copper quaternary, ammoniacal copper quaternary, ammoniacal copper zinc arsenate, alkaline copper quaternary boron-based preservatives, copper azole, copper citrate, and copper naphthenate. Treated wood substitutes include concrete, plastic composite material, plasticized wood scrap, or steel. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third-generation cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based integrated circuits are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. — Zero.

[1]Arsenic content of arsenic metal is 100%; arsenic content of arsenic compounds is 77.7% for arsenic acids, 60.7% for arsenic sulfides, and 75.71% for arsenic trioxide.

[2]Estimated to be the same as imports.

[3]Calculated from U.S. Census Bureau import data.

[4]Defined as imports.

[5]Includes Hong Kong.

[6]Includes calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide; inclusion of such materials would not duplicate reported arsenic trioxide production. Chile and Mexico were thought to be significant producers of commercial-grade arsenic trioxide but have reported no production in recent years.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

ASBESTOS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: The last U.S. producer of asbestos ceased operations in 2002 as a result of the decline in domestic and international asbestos markets associated with health and liability issues. The United States has since been wholly dependent on imports to meet manufacturing needs. All the asbestos fiber currently imported into and used within the United States consists of chrysotile. In 2021, domestic consumption of chrysotile was estimated to be 320 tons, and all imports originated from Brazil, based on data available through July. The chloralkali industry, which uses chrysotile to manufacture nonreactive semipermeable diaphragms that prevent chlorine generated at the anode of an electrolytic cell from reacting with sodium hydroxide generated at the cathode, has accounted for 100% of asbestos fiber consumption since at least 2015. In addition to asbestos fiber, a small, but unknown, quantity of asbestos is imported annually within manufactured products. According to the U.S. Environmental Protection Agency (EPA), the only imported items known to contain asbestos are brake blocks for use in the oil industry, preformed gaskets used in the exhaust system of a specific type of utility vehicle, rubber sheets for gasket fabrication (primarily used to create a chemical containment seal in the production of titanium dioxide), and some vehicle friction products.[1]

Salient Statistics—United States:[2]	2017	2018	2019	2020	2021[e]
Imports for consumption[3]	332	681	172	305	[4]100
Exports[5]	—	—	—	—	—
Consumption, estimated[6]	520	500	450	450	320
Price, average U.S. customs unit value, dollars per ton	1,870	1,670	1,570	2,110	2,000
Net import reliance[7] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Brazil, 80%; and Russia, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Crocidolite	2524.10.0000	Free.
Amosite	2524.90.0010	Free.
Chrysotile:		
Crudes	2524.90.0030	Free.
Milled fibers, group 3 grades	2524.90.0040	Free.
Milled fibers, group 4 and 5 grades	2524.90.0045	Free.
Other	2524.90.0055	Free.
Other, asbestos	2524.90.0060	Free.

Depletion Allowance: 22% (domestic), 10% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of asbestos fiber in the United States has decreased during the past several decades, falling from a record high of 803,000 tons in 1973 to approximately 520 tons or less in each year since 2017. This decline has taken place as a result of health and liability issues associated with asbestos use, leading to the displacement of asbestos from traditional domestic markets by substitutes, alternative materials, and new technology. The chloralkali industry is the only remaining domestic consumer of asbestos in mineral form. Asbestos diaphragms are used in at least 11 chloralkali plants in the United States and account for about one-third of domestic chlorine production.

The Frank R. Lautenberg Chemical Safety for the 21st Century Act, which amended the Toxic Substances Control Act of 1976 (TSCA), was signed into law in 2016. The legislation granted the EPA greater authority to evaluate the hazards posed by new chemicals as well as those already in the marketplace. The EPA issued the final risk evaluation report for chrysotile in 2020. The agency determined that the disposal, processing, and (or) use of chrysotile in the chloralkali industry and in all chrysotile-containing manufactured products that are currently imported into the United States (oil industry brake blocks, sheet and other gaskets, and some vehicle friction products) present unreasonable risks to human health. As required by the TSCA, the EPA will propose and finalize actions to address these risks by yearend 2022. The new regulations could include limitations or prohibitions on the disposal, distribution in commerce, manufacture, processing, or use of chrysotile.[1]

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ASBESTOS

Estimated worldwide consumption of asbestos fiber decreased from approximately 2 million tons in 2010 to roughly 1.2 million tons per year in the past several years. Asbestos-cement products, such as corrugated roofing tiles, pipes, and wall panels, are expected to continue to be the leading global market for asbestos.

In Brazil, a comprehensive national ban on asbestos was enacted in November 2017. A judicial injunction allowed the only asbestos producer in the country to continue operating until February 2019, when production ceased. In July 2019, the government of the State of Goias passed a law that authorized the extraction of asbestos in the State for export purposes, and ore processing was restarted in February 2020. In August 2021, the Federal Court of Uruacu ruled that the company must immediately suspend mining, processing, and export of asbestos.

At the former King Mine in Mashava, Zimbabwe, asbestos production from old tailings commenced in 2019. As of March 2020, the company had completed dewatering of the mining shafts and was in the process of selling real estate assets to fund the restart of mining operations and dewatering an additional asbestos mine in Zvishavane. At full capacity, the King Mine was expected to produce 75,000 tons per year of asbestos. Updates on the status of these projects were not available as of September 2021.

World Mine Production and Reserves:

	Mine production[e]		
	2020	2021	Reserves[8]
United States	—	—	Small
Brazil	[9]71,200	110,000	11,000,000
China	120,000	120,000	95,000,000
Kazakhstan	[10]227,000	250,000	Large
Russia	720,000	700,000	110,000,000
Zimbabwe	8,000	10,000	Large
World total (rounded)	1,100,000	1,200,000	Large

World Resources:[8] Reliable evaluations of global asbestos resources have not been published recently, and available information was insufficient to make accurate estimates for many countries. However, world resources are large and more than adequate to meet anticipated demand in the foreseeable future. Resources in the United States are composed mostly of short-fiber asbestos for which use in asbestos-based products is more limited than long-fiber asbestos.

Substitutes: Numerous materials substitute for asbestos. Substitutes include calcium silicate, carbon fiber, cellulose fiber, ceramic fiber, glass fiber, steel fiber, wollastonite, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene. Several nonfibrous minerals or rocks, such as perlite, serpentine, silica, and talc, are also considered to be possible asbestos substitutes for products in which the reinforcement properties of fibers are not required. Membrane cells and mercury cells are alternatives to asbestos diaphragms used in the chloralkali industry.

[e]Estimated. — Zero.

[1]Source: U.S. Environmental Protection Agency, 2020, Risk evaluation for asbestos, part I—Chrysotile asbestos: Washington, DC, EPA Document # EPA-740-R1-8012, December, 352 p.

[2]Includes asbestos fiber (chrysotile) only; excludes asbestos contained in manufactured products.

[3]Additional chrysotile imports were reported by the U.S. Census Bureau in some years, but existing asbestos bans and bill of lading information from a commercial trade database suggest that some shipments were misclassified.

[4]According to the U.S. Census Bureau, imports of chrysotile totaled 41 tons through July. Final 2021 imports may differ significantly from the provided estimate because chrysotile imports typically do not follow a predictable pattern throughout the year.

[5]Exports of asbestos reported by the U.S. Census Bureau were 143 tons in 2017, 235 tons in 2018, 2 tons in 2019, 1 ton in 2020, and 127 tons through July in 2021. These shipments likely consisted of materials misclassified as asbestos, reexports, and (or) waste products because the United States no longer mines asbestos.

[6]To account for year-to-year fluctuations in chrysotile imports owing to cycles of companies replenishing and drawing down stockpiles, consumption is estimated as a 5-year rolling average of imports for consumption. Information regarding the quantity of industry stocks was unavailable.

[7]Defined as imports – exports. The United States has been 100% net import reliant since 2002. All consumption of asbestos was from imports and unreported inventories.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Asbestos production permitted for export purposes only. Value shown is reported country exports.

[10]Reported.

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, one company in Nevada mined barite from two mines that operated intermittently, but mine production data were withheld to avoid disclosing company proprietary data. Another company in Nevada processed domestically mined barite from material that had been previously stockpiled. A third company's mining and processing assets in Nevada were reportedly idled and put up for sale. An estimated 1.5 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in eight States. Typically, more than 90% of the barite sold in the United States is used as a weighting agent in fluids used in the drilling of oil and natural gas wells. The majority of Nevada crude barite was ground in Nevada and then sold to companies drilling in the Central and Western United States. Because of the higher cost of rail and truck transportation compared to ocean freight, offshore drilling operations in the Gulf of Mexico and onshore drilling operations in other regions primarily used imported barite.

Barite also is used as a filler, extender, or weighting agent in products such as paints, plastics, and rubber. Some specific applications include use in automobile brake and clutch pads, in automobile paint primer for metal protection and gloss, as a weighting agent in rubber, and in the cement jacket around underwater petroleum pipelines. In the metal-casting industry, barite is part of the mold-release compounds. Because barite significantly blocks X-ray and gamma-ray emissions, it is used as aggregate in high-density concrete for radiation shielding around X-ray units in hospitals, nuclear powerplants, and university nuclear research facilities. Ultrapure barite is used as a contrast medium in X-ray and computed tomography examinations of the gastrointestinal tract.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Sold or used, mine	334	366	414	W	W
Ground and crushed[1]	2,030	2,420	2,350	1,410	1,500
Imports for consumption[2]	2,470	2,460	2,500	1,480	1,700
Exports[3]	116	67	38	48	45
Consumption, apparent (crude and ground)[4]	2,680	2,760	2,880	W	W
Price, average value, ground, ex-works, dollars per ton	179	176	179	183	180
Employment, mine and mill, number[e]	450	520	480	330	310
Net import reliance[5] as a percentage of apparent consumption	88	87	86	>75	>75

Recycling: None.

Import Sources (2017–20): China,[6] 41%; India, 28%; Morocco, 14%; Mexico, 13%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Ground barite	2511.10.1000	Free.
Crude barite	2511.10.5000	$1.25 per metric ton.
Barium compounds:		
Barium oxide, hydroxide, and peroxide	2816.40.2000	2% ad valorem.
Barium chloride	2827.39.4500	4.2% ad valorem.
Barium sulfate, precipitated	2833.27.0000	0.6% ad valorem.
Barium carbonate, precipitated	2836.60.0000	2.3% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic and global drilling rig counts, which have historically been a good barometer of barite consumption, generally increased throughout 2021. This trend was reflected in domestic sales of ground barite, which were estimated to have increased by 6% in 2021, attributed primarily to increased sales in Texas. World mine production was estimated to have increased by 8%. Despite modest increases in 2021, domestic and global production and consumption of barite were estimated to have remained well below the quantities attained prior to the global COVID-19 pandemic. Production in most leading barite-producing countries was estimated to have remained essentially unchanged compared with that in 2020 with the exception of Morocco. According to some domestic consumers, barite suppliers in Morocco were able to offer smaller shipments and shorter lead times than suppliers in China and India, which supported increased production. This allowed domestic consumers increased flexibility in responding to uncertainty in anticipated future consumption levels.

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BARITE

Barite trade was negatively affected by ongoing logistics issues. In addition to contributing to reduced consumption of transport fuels, which directly affected barite consumption, continued travel restrictions were a factor in some areas. For example, prior to the COVID-19 pandemic, production in Laos had begun to emerge as a potentially significant new source of global supply. In 2020 and 2021, barite exports from Laos, a landlocked country, were reportedly inhibited by border closures with neighboring countries. Domestic importers also noted cost increases per ton of barite because of increased land- and ocean-based freight rates. As a bulk commodity used primarily for its weight, transportation expenses are a substantial component of the final cost of barite used on a per ton basis. However, it is unclear if these cost increases affected sales prices.

In 2021, researchers at Purdue University filed a patent application for a barium sulfate (barite)-based formulation for white paint that had a higher reflectivity compared with all other white paints. The new formulation, which used a higher concentration of barite with a broader range of particle sizes, had an ambient-cooling effect when used on exterior surfaces.

World Mine Production and Reserves: In response to concerns about dwindling global reserves of 4.2-specific-gravity barite used by the oil and gas drilling industry, the American Petroleum Institute issued an alternate specification for 4.1-specific-gravity weighting agents in 2010. Estimated reserves data are included only if developed since the adoption of the 4.1-specific-gravity standard.

	Mine production		Reserves[7]
	2020	2021[e]	
United States	W	W	NA
China	[8]2,800	[8]2,800	36,000
India	1,600	1,600	51,000
Iran	202	200	100,000
Kazakhstan	445	450	85,000
Laos	180	110	NA
Mexico	323	320	NA
Morocco	410	1,100	NA
Pakistan	86	50	40,000
Russia	287	150	12,000
Turkey	180	180	35,000
Other countries	329	370	30,000
World total (rounded)	[9]6,840	[9]7,300	NA

World Resources:[7] In the United States, identified resources of barite are estimated to be 150 million tons, and undiscovered resources contribute an additional 150 million tons. The world's barite resources in all categories are about 2 billion tons, but only about 740 million tons are identified resources

Substitutes: In the oil- and gas-drilling industry, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. However, the use of substitutes has been in relatively small amounts, and barite remains the preferred choice for drilling applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Imported and domestic barite, crushed and ground, sold or used by domestic grinding establishments.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2511.10.1000, 2511.10.5000, and 2833.27.0000.

[3]Includes data for the following Schedule B codes: 2511.10.1000 and 2833.27.0000.

[4]Defined as sold or used by domestic mines + imports – exports.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]The China Industrial Minerals Yearbook estimated that production was closer to 4 million tons.

[9]Excludes U.S. production.

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise noted)

Domestic Production and Use: In 2021, the reported quantity of bauxite consumed was estimated to be 3.6 million tons, 8% more than that reported in 2020, with an estimated value of about $115 million. About 70% of the bauxite was refined by the Bayer process for alumina or aluminum hydroxide, and the remainder went to products such as abrasives, cement, chemicals, proppants, and refractories, and as a slag adjuster in steel mills. Alumina production was estimated to be 1 million tons, 25% less than that in 2020. One domestic alumina refinery with production capacity of 1.2 million tons per year accounted for all the production in 2021. Another alumina refinery with 500,000 tons per year of capacity was on care-and-maintenance status the entire year. About 55% of the alumina produced went to primary aluminum smelters, and the remainder went to nonmetallurgical products, such as abrasives, ceramics, chemicals, and refractories.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	4,350	3,980	4,620	3,760	3,600
Exports[2]	29	16	15	15	12
Stocks, industry, yearend[e, 2]	880	600	300	250	200
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	4,330	4,460	3,680	3,330	3,600
Price, average value of imports, free alongside ship (f.a.s.), dollars per ton	31	31	32	26	32
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[5]	1,430	1,570	1,410	1,340	1,000
Imports for consumption[5]	1,330	1,530	1,930	1,340	1,500
Exports[5]	481	288	200	162	190
Stocks, industry, yearend[5]	264	275	275	234	150
Consumption, apparent[3]	2,340	2,800	3,140	2,560	2,400
Price, average value of imports, f.a.s., dollars per ton	486	592	480	412	450
Net import reliance[4] as a percentage of apparent consumption	39	44	55	48	58

Recycling: None.

Import Sources (2017–20): Bauxite:[2] Jamaica, 62%; Brazil, 13%; Guyana, 8%; Australia, 6%; and other, 11%. Alumina:[5] Brazil, 54%; Australia, 20%; Jamaica, 12%; Canada, 5%; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Bauxite, calcined (refractory grade)	2606.00.0030	Free.
Bauxite, calcined (other)	2606.00.0060	Free.
Bauxite, crude dry (metallurgical grade)	2606.00.0090	Free.
Aluminum oxide (alumina)	2818.20.0000	Free.
Aluminum hydroxide	2818.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, one domestic alumina refinery produced alumina from imported bauxite. A 1.2-million-ton-per-year alumina refinery in Gramercy, LA, produced alumina for aluminum smelting and specialty-grade alumina. The Gramercy alumina refinery stopped production for about 1 week at the end of August as a precaution when Hurricane Ida approached the region, but restarted production soon afterwards. A 500,000-ton-per-year alumina refinery in Burnside, LA, was temporarily shut down in August 2020, and no plans have been announced regarding reopening. The average prices, f.a.s., for U.S. imports for consumption of crude dry bauxite and metallurgical-grade alumina during the first 9 months of 2021 were $32 per ton, 19% more than that in the same period in 2020, and $450 per ton, 18% more than that in the same period of 2020, respectively.

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BAUXITE AND ALUMINA[1]

In April 2021, a 2.8-million-ton-per-year alumina refinery in Shanxi Province, China, restarted production after being shut down in May 2019 after a spill from its red mud disposal impoundment. Flooding in Henan Province, China, was cited for several alumina refineries shutting down production for about 2 weeks in July. Environmental and safety audits were cited for several alumina refineries and bauxite mines shutting down production in several locations in China throughout the year, and production was not expected to restart at some locations until 2022. In Indonesia, a new 1-million-ton-per-year alumina refinery started production and shipped its first product in July. In July, a 3.5-million-ton-per-year alumina refinery in Brazil temporarily shut down about one-third of its capacity citing damage to equipment used to unload bauxite, but production was restarted in early October. In August, a 1.42-million-ton-per-year alumina refinery in Jamaica temporarily shut down after a fire caused major damage to its powerhouse.

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves: Reserves for Australia, Saudi Arabia, Vietnam, and some listed in "Other countries" were revised based on information from Government and other sources.

	Refinery and mine production				Bauxite reserves[6]
	Alumina[5]		Bauxite		
	2020	2021[e]	2020	2021[e]	
United States	1,340	1,000	W	W	20,000
Australia	20,800	21,000	104,000	110,000	[7]5,300,000
Brazil	10,300	11,000	31,000	32,000	2,700,000
Canada	1,520	1,500	—	—	—
China	73,100	74,000	92,700	86,000	1,000,000
Germany	1,900	1,900	—	—	—
Guinea	439	400	86,000	85,000	7,400,000
India	6,560	6,800	20,200	22,000	660,000
Indonesia	1,200	1,500	20,800	18,000	1,200,000
Ireland	1,880	1,900	—	—	—
Jamaica	1,620	1,200	7,550	5,800	2,000,000
Kazakhstan	1,400	1,500	5,000	5,200	160,000
Russia	2,870	3,100	5,570	6,200	500,000
Saudi Arabia	1,810	1,800	4,310	4,300	180,000
Spain	1,550	1,600	—	—	—
Ukraine	1,730	1,700	—	—	—
United Arab Emirates	1,920	2,000	—	—	—
Vietnam	1,400	1,400	3,500	3,500	5,800,000
Other countries	2,700	3,000	10,500	12,000	5,100,000
World total (rounded)	136,000	140,000	[8]391,000	[8]390,000	32,000,000

World Resources:[6] Bauxite resources are estimated to be between 55 billion and 75 billion tons, distributed in Africa (32%), Oceania (23%), South America and the Caribbean (21%), Asia (18%), and elsewhere (6%). Domestic resources of bauxite are inadequate to meet long-term U.S. demand, but the United States and most other major aluminum-producing countries have essentially inexhaustible subeconomic resources of aluminum in materials other than bauxite.

Substitutes: Bauxite is the only raw material used in the production of alumina on a commercial scale in the United States. Although currently not economically competitive with bauxite, vast resources of clay are technically feasible sources of alumina. Other raw materials, such as alunite, anorthosite, coal wastes, and oil shales, offer additional potential alumina sources. Synthetic mullite, produced from kaolin, bauxitic kaolin, kyanite, and sillimanite, substitutes for bauxite-based refractories. Silicon carbide and alumina zirconia can substitute for alumina and bauxite in abrasives but cost more.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also Aluminum. As a general rule, 4 tons of dried bauxite is required to produce 2 tons of alumina, which, in turn, produces 1 ton of aluminum.

[2]Includes all forms of bauxite, expressed as dry equivalent weights.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]Calcined equivalent weights.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 2.0 billion tons.

[8]Excludes U.S. production.

BERYLLIUM

(Data in metric tons of contained beryllium unless otherwise noted)

Domestic Production and Use: One company in Utah mined bertrandite ore and converted it, along with imported beryl, into beryllium hydroxide. Some of the beryllium hydroxide was shipped to the company's plant in Ohio, where it was converted into metal, oxide, and downstream beryllium-copper master alloy, and some was sold. Based on the estimated unit value for beryllium in imported beryllium-copper master alloy, beryllium apparent consumption of 200 tons was valued at about $120 million. Based on sales revenues, approximately 23% of beryllium products were used in industrial components; 17% each in aerospace and defense applications and in automotive electronics; 12% in consumer electronics; 11% in telecommunications infrastructure; 5% in energy applications; 1% in semiconductor applications; and 14% in other applications. Beryllium alloy strip and bulk products, the most common forms of processed beryllium, were used in all application areas. Most unalloyed beryllium metal and beryllium composite products were used in defense and scientific applications.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, mine shipments	150	165	160	165	170
Imports for consumption[1]	60	67	49	48	52
Exports[2]	38	30	37	25	27
Shipments from Government stockpile[3]	2	—	—	3	7
Consumption:					
Apparent[4]	179	202	167	196	200
Reported, ore	160	170	160	170	170
Price, annual average unit value, beryllium-copper master alloy,[5] dollars per kilogram of contained beryllium	640	590	620	620	610
Stocks, ore, consumer, yearend	30	30	35	30	30
Net import reliance[6] as a percentage of apparent consumption	16	18	4	16	16

Recycling: Beryllium was recovered from new scrap generated during the manufacture of beryllium products and from old scrap. Detailed data on the quantities of beryllium recycled are not available but may account for as much as 20% to 25% of total beryllium consumption. The leading U.S. beryllium producer established a comprehensive recycling program for all of its beryllium products, recovering approximately 40% of the beryllium content of the new and old beryllium alloy scrap.

Import Sources (2017–20):[1] Kazakhstan, 41%; Japan, 16%; Brazil, 11%; Latvia, 10%; and other, 22%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Beryllium ores and concentrates	2617.90.0030	Free.
Beryllium oxide and hydroxide	2825.90.1000	3.7% ad valorem.
Beryllium-copper master alloy	7405.00.6030	Free.
Beryllium-copper plates, sheets, and strip:		
Thickness of 5 millimeters (mm) or more	7409.90.1030	3.0% ad valorem.
Thickness of less than 5 mm:		
Width of 500 mm or more	7409.90.5030	1.7% ad valorem.
Width of less than 500 mm	7409.90.9030	3.0% ad valorem.
Beryllium:		
Unwrought, including powders	8112.12.0000	8.5% ad valorem.
Waste and scrap	8112.13.0000	Free.
Other	8112.19.0000	5.5% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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BERYLLIUM

Government Stockpile:[7] The Defense Logistics Agency Strategic Materials had a goal of retaining 47 tons of beryllium metal in the National Defense Stockpile.

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Beryl ore (gross weight)	1	—	—	—	—
Metal (all types)	57	—	7	—	7
Structured powder	7	—	—	—	—

Events, Trends, and Issues: Domestic beryllium consumption in 2021 was estimated to be about the same as that of 2020. During the first 6 months of 2021, the leading U.S. beryllium producer reported that net sales of its beryllium alloy strip and bulk products and beryllium metal and composite products were 19% higher than those during the first 6 months of 2020. Net sales of beryllium products increased primarily in the aerospace and defense, automotive, and industrial components markets. As various COVID-19 restrictions were lifted in 2021, it was reported that customer demand increased.

Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium in air, water, and other media. Industry is required to carefully control the quantity of beryllium dust, fumes, and mists in the workplace.

World Mine Production and Reserves:

	Mine production[8, 9] 2020	Mine production[8, 9] 2021[e]	Reserves[10]
United States	165	170	The United States has very little beryl that
Brazil	[e]3	3	can be economically hand sorted from
China	70	70	pegmatite deposits. The Spor Mountain
Madagascar	[e]1	1	area in Utah, an epithermal deposit,
Mozambique	[e]3	3	contains a large bertrandite resource,
Nigeria	[e]1	1	which is being mined. Proven and probable
Rwanda	[e]1	1	bertrandite reserves in Utah total about
Uganda	7	7	20,000 tons of contained beryllium. World
World total (rounded)	250	260	beryllium reserves are not available.

World Resources:[10] The world's identified resources of beryllium have been estimated to be more than 100,000 tons. About 60% of these resources are in the United States; by tonnage, the Spor Mountain area in Utah, the McCullough Butte area in Nevada, the Black Hills area in South Dakota, the Sierra Blanca area in Texas, the Seward Peninsula in Alaska, and the Gold Hill area in Utah account for most of the total.

Substitutes: Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. In some applications, certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium may be substituted for beryllium metal or beryllium composites. Copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys (copper-tin-phosphorus) may be substituted for beryllium-copper alloys, but these substitutions can result in substantially reduced performance. Aluminum nitride or boron nitride may be substituted for beryllium oxide.

[e]Estimated. — Zero.

[1]Includes estimated beryllium content of imported ores and concentrates, oxide and hydroxide, unwrought metal (including powders), beryllium articles, waste and scrap, beryllium-copper master alloy, and beryllium-copper plates, sheets, and strip.

[2]Includes estimated beryllium content of exported unwrought metal (including powders), beryllium articles, and waste and scrap.

[3]Change in total inventory level from prior yearend inventory.

[4]Defined as production + imports – exports + adjustments for Government and industry stock changes.

[5]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%. Rounded to two significant figures.

[6]Defined as imports – exports + adjustments for Government and industry stock changes.

[7]See Appendix B for definitions.

[8]In addition to the countries listed, Kazakhstan and Portugal may have produced beryl ore, but available information was inadequate to make reliable estimates of output. Other nations that produced gemstone beryl ore may also have produced some industrial beryl ore.

[9]Based on a beryllium content of 4% from bertrandite and beryl sources.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons, gross weight, unless otherwise noted)

Domestic Production and Use: The United States ceased production of primary refined bismuth in 1997 and is highly import reliant. Bismuth is contained in some lead ores mined domestically. However, the last domestic primary lead smelter closed at yearend 2013; since then, all lead concentrates have been exported for smelting.

About 60% of domestic bismuth consumption was for chemicals used in cosmetic, industrial, laboratory, and pharmaceutical applications. Bismuth use in pharmaceuticals included bismuth subsalicylate (the active ingredient in over-the-counter stomach remedies) and other compounds used to treat burns, intestinal disorders, and stomach ulcers. Bismuth is also used in industrial applications for the manufacture of ceramic glazes, crystalware, and pearlescent pigments.

Bismuth has a wide variety of metallurgical applications, including use as an additive to improve metal integrity of malleable cast iron in the foundry industry and as a nontoxic replacement for lead in brass, free-machining steels, and solders. The use of bismuth in brass for pipe fittings, fixtures, and water meters increased after 2014 when the definition of “lead-free” under the Safe Drinking Water Act was modified to reduce the maximum lead content of “lead-free” pipes and plumbing fixtures to 0.25% from 8%. The melting point of bismuth is relatively low at 271 degrees Celsius, and it is an important component of various fusible alloys, some of which have melting points below that of boiling water. These bismuth-containing alloys can be used in holding devices for grinding optical lenses, as plugs for abandoned oil wells, as a temporary filler to prevent damage to tubes in bending operations, as a triggering mechanism for fire sprinklers, and in other applications in which a low melting point is ideal. Bismuth-tellurium-oxide alloy film paste is used in the manufacture of semiconductor devices.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap	2,820	2,470	2,340	1,650	1,500
Exports, metal, alloys, and scrap	392	653	636	699	840
Consumption:					
Apparent[1]	2,530	2,040	1,690	1,200	810
Reported	694	570	548	513	500
Price, average,[2] dollars per pound	4.94	4.61	3.18	2.72	3.65
Stocks, yearend, consumer	489	346	443	271	200
Net import reliance[3] as a percentage of apparent consumption	97	96	95	93	90

Recycling: Bismuth-containing alloy scrap was recycled and thought to compose between 5% and 10% of U.S. bismuth apparent consumption.

Import Sources (2017–20): China,[4] 67%; the Republic of Korea, 16%; Mexico, 6%; Belgium, 5%; and other, 6%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Bismuth and articles thereof, including waste and scrap	8106.00.0000	Free.

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BISMUTH

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: The estimated annual average domestic dealer price for bismuth in 2021 was an estimated $3.65 per pound and increased for the first time since 2017. The price was an estimated 34% higher than that in 2020 and the highest price since 2018. Globally, excess stocks continued to keep prices low compared with those in 2007 through 2014 when the average annual dealer price traded above $7.84 per pound. Primary production tightened in early 2021 as mines continued to feel effects from shutdowns that began during the first of half of 2020 resulting from the global COVID-19 pandemic. Trade data through August 2021 were mixed when compared with the same period in 2020—whereas bismuth exports increased, imports for consumption decreased. Foreign buyers were reportedly stockpiling bismuth while prices were relatively low compared with previous higher prices.

World Refinery Production and Reserves: Available information was inadequate to make reliable estimates of reserves.

	Refinery production[e]		Reserves[5]
	2020	2021	
United States	—	—	Quantitative estimates of reserves were not available.
Bolivia	30	60	
Bulgaria	50	50	
Canada	35	30	
China	16,000	16,000	
Japan	570	600	
Kazakhstan	230	240	
Korea, Republic of	970	1,000	
Laos	1,000	1,000	
Mexico	10	10	
World total (rounded)	19,000	19,000	

World Resources:[5] World reserves of bismuth are usually estimated based on the bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores. In China and Vietnam, bismuth production is a byproduct or coproduct of tungsten and other metal ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines where bismuth has been the primary product. The Tasna Mine has been inactive since 1996.

Substitutes: Bismuth compounds can be replaced in pharmaceutical applications by alumina, antibiotics, calcium carbonate, and magnesia. Titanium dioxide-coated mica flakes and fish-scale extracts are substitutes in pigment uses. Cadmium, indium, lead, and tin can partially replace bismuth in low-temperature solders. Resins can replace bismuth alloys for holding metal shapes during machining, and glycerine-filled glass bulbs can replace bismuth alloys in triggering devices for fire sprinklers. Free-machining alloys can contain lead, selenium, or tellurium as a replacement for bismuth. Bismuth is an environmentally friendly substitute for lead in plumbing and many other applications, including fishing weights, hunting ammunition, lubricating greases, and soldering alloys.

[e]Estimated. — Zero.

[1]Defined as secondary production + imports – exports + adjustments for industry stock changes.

[2]Prices are based on 99.99%-purity metal at warehouse (Rotterdam) in minimum lots of 1 ton; source: Fastmarkets AMM.

[3]Defined as imports – exports + adjustments for industry stock changes.

[4]Includes Hong Kong.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

BORON

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies in southern California produced borates in 2021, and most of the boron products consumed in the United States were manufactured domestically. Estimated boron production decreased slightly in 2021 compared with 2020 production. U.S. boron production and consumption data were withheld to avoid disclosing company proprietary data. The leading boron producer mined borate ores, which contain the minerals kernite, tincal, and ulexite, by open pit methods and operated associated compound plants. Kernite was used to produce boric acid, tincal was used to produce sodium borate, and ulexite was used as a primary ingredient in the manufacture of a variety of specialty glasses and ceramics. A second company produced borates from brines extracted through solution-mining techniques. Boron minerals and chemicals were principally consumed in the north-central and eastern United States. In 2021, the glass and ceramics industries remained the leading domestic users of boron products, accounting for an estimated 65% of total borates consumption. Boron also was used as a component in abrasives, cleaning products, insecticides, and insulation and in the production of semiconductors.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	158	133	161	174	230
Boric acid	40	51	41	39	50
Colemanite (calcium borates)	58	73	42	18	5
Ulexite (sodium borates)	24	34	38	41	55
Exports:					
Boric acid	216	251	251	257	290
Refined borax	572	610	598	594	600
Consumption, apparent[1]	W	W	W	W	W
Price, average value of imports, cost, insurance, and freight, dollars per ton	392	404	373	380	390
Employment, number	1,300	1,350	1,350	1,330	1,330
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2017–20): All forms: Turkey, 88%; Bolivia, 5%; Chile, 3%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Natural borates:		
Sodium (ulexite)	2528.00.0005	Free.
Calcium (colemanite)	2528.00.0010	Free.
Boric acids	2810.00.0000	1.5% ad valorem.
Borates, refined borax:		
Anhydrous	2840.11.0000	0.3% ad valorem.
Non-anhydrous	2840.19.0000	0.1% ad valorem.

Depletion Allowance: Borax, 14% (domestic and foreign).

Government Stockpile: None.

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BORON

Events, Trends, and Issues: Elemental boron is a metalloid with limited commercial applications. Although the term "boron" is commonly referenced, it does not occur in nature in an elemental state. Boron combines with oxygen and other elements to form boric acid or inorganic salts called borates. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on their boric oxide (B_2O_3) content, varying by ore and compound and by the absence or presence of calcium and sodium. Four borate minerals—colemanite, kernite, tincal, and ulexite—account for 90% of the borate minerals used by industry worldwide. Although borates were used in more than 300 applications, more than three-quarters of world consumption was used in ceramics, detergents, fertilizers, and glass.

China, India, the Netherlands, Malaysia, and Mexico, in decreasing order of tonnage, are the countries that imported the largest quantities of refined borates from the United States in 2021. Because China has low-grade boron reserves and demand for boron is anticipated to rise in that country, imports to China from Chile, Russia, Turkey, and the United States were expected to remain steady during the next several years.

Continued investment in new borate refineries and the continued rise in demand were expected to fuel growth in world production for the next few years. Two Australia-based mine developers previously confirmed that production of high-quality boron products would be possible from their projects in California and Nevada, respectively. These companies continued to make progress on their respective projects by acquiring some of the permits necessary to begin and continue construction. The project in California was expected to begin production in 2021. However, construction was postponed to focus on expanding the company's boron production and product selection by adding additional specialty products for industries related to global decarbonization and food security. The Nevada project was expected to begin production by mid-2023. These companies have the potential to become substantial boron producers when their projects are fully developed.

World Production and Reserves: Reserves for Turkey were revised based on industry information.

	Production—All forms		Reserves[3]
	2020	2021[e]	
United States	W	W	40,000
Argentina, crude ore	71	71	NA
Bolivia, ulexite	200	210	NA
Chile, ulexite	350	300	35,000
China, boric oxide equivalent	380	380	24,000
Germany, compounds	120	120	NA
Peru, crude borates	110	50	4,000
Russia, datolite ore	80	80	40,000
Turkey, refined borates	2,000	1,700	1,200,000
World total[4]	XX	XX	XX

World Resources:[3] Deposits of borates are associated with volcanic activity and arid climates, with the largest economically viable deposits in the Mojave Desert of the United States, the Alpide belt along the southern margin of Eurasia, and the Andean belt of South America. U.S. deposits consist primarily of tincal, kernite, and borates contained in brines, and to a lesser extent, ulexite and colemanite. About 70% of all deposits in Turkey are colemanite, primarily used in the production of heat-resistant glass. At current levels of consumption, world resources are adequate for the foreseeable future.

Substitutes: The substitution of other materials for boron is possible in detergents, enamels, insulation, and soaps. Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamels can use other glass-producing substances, such as phosphates. Insulation substitutes include cellulose, foams, and mineral wools. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]World totals cannot be calculated because production and reserves are not reported in a consistent manner by all countries.

BROMINE

(Data in metric tons of contained bromine unless otherwise noted)

Domestic Production and Use: Bromine was recovered from underground brines by two companies in Arkansas. Bromine is one of the leading mineral commodities, in terms of value, produced in Arkansas. The two bromine companies in the United States account for a large percentage of world production capacity.

The leading global applications of bromine are for the production of brominated flame retardants (BFRs) and clear brine drilling fluids. Bromine compounds are also used in a variety of other applications, including industrial uses, as intermediates, and for water treatment. U.S. apparent consumption of bromine in 2021 was estimated to be greater than that in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	52,700	56,200	56,300	28,700	32,000
Exports, elemental bromine and compounds[2]	32,600	21,900	29,300	36,800	25,000
Consumption, apparent[3]	W	W	W	W	W
Price, average unit value of imports (cost, insurance, and freight), dollars per kilogram	2.30	2.21	2.31	2.73	2.66
Employment, number[e]	1,050	1,050	1,050	1,050	1,050
Net import reliance[4] as a percentage of apparent consumption	<25	<25	<25	E	<25

Recycling: Some bromide solutions were recycled to obtain elemental bromine and to prevent the solutions from being disposed of as hazardous waste. For example, hydrogen bromide is emitted as a byproduct in many organic reactions. This byproduct waste can be recycled with virgin bromine brines and used as a source of bromine production. Bromine contained in plastics can be incinerated as solid organic waste and the bromine can be recovered.

Import Sources (2017–20):[5] Israel, 78%; Jordan, 13%; China, 6%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Bromine	2801.30.2000	5.5% ad valorem.
Hydrobromic acid	2811.19.3000	Free.
Potassium or sodium bromide	2827.51.0000	Free.
Ammonium, calcium, or zinc bromide	2827.59.2500	Free.
Potassium bromate	2829.90.0500	Free.
Sodium bromate	2829.90.2500	Free.
Ethylene dibromide	2903.31.0000	5.4% ad valorem.
Methyl bromide	2903.39.1520	Free.
Dibromoneopentylglycol	2905.59.3000	Free.
Tetrabromobisphenol A	2908.19.2500	5.5% ad valorem.
Decabromodiphenyl and octabromodiphenyl oxide	2909.30.0700	5.5% ad valorem.

Depletion Allowance: Brine wells, 5% (domestic and foreign).

Government Stockpile: None.

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BROMINE

Events, Trends, and Issues: The United States maintained its position as one of the leading bromine producers in the world along with China, Israel, and Jordan. In 2021, the leading source of imports of bromine and bromide compounds (gross weight) was Israel. The average import value of bromine and bromine compounds decreased by about 3% in 2021 compared with that in 2020. Together, the leading imported bromine products in terms of both gross weight and bromine content were bromides and bromide oxides of ammonium, calcium, or zinc and bromides of sodium or potassium (over 90%). Total imports of bromine and bromine compounds (bromine content) increased by about 10% whereas total exports decreased by about 30% compared with that in 2020.

Global sales of bromine and bromine compounds increased in 2021 compared with those in 2020. Sales volumes increased for BFRs and clear brine fluids, the leading applications of bromine, compared with the previous year. Sales were driven, in particular, by strong demand in electronic, automotive, and construction industries, the leading consumers of BFRs. Although sales of clear brine drilling fluids increased compared with the previous year, demand had yet to return to pre-pandemic levels. In February 2021, Texas suffered a major power crisis, which resulted from three severe winter storms sweeping across the United States on February 10–11, 13–17, and 15–20. The storms caused a massive electricity generation failure in Texas, leading to shortages of water, food, and heat. Additionally, the winter storms adversely affected drilling production, drew down inventory stocks, and disrupted supply-chain logistics.

World Production and Reserves:

	Production		Reserves[6]
	2020	2021[e]	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	70,000	75,000	NA
India	3,300	3,000	NA
Israel	170,000	180,000	Large
Japan	20,000	20,000	NA
Jordan	84,000	110,000	Large
Ukraine	4,500	4,500	NA
World total (rounded)	[7]352,000	[7]390,000	Large

World Resources:[6] Bromine is found principally in seawater, evaporitic (salt) lakes, and underground brines associated with petroleum deposits. The Dead Sea, in the Middle East, is estimated to contain 1 billion tons of bromine. Seawater contains about 65 parts per million bromine, or an estimated 100 trillion tons. Bromine is also recovered from seawater as a coproduct during evaporation to produce salt.

Substitutes: Chlorine and iodine may be substituted for bromine in a few chemical reactions and for sanitation purposes. There are no comparable substitutes for bromine in various oil- and gas-well-completion and packer applications. Because plastics have a low ignition temperature, aluminum hydroxide, magnesium hydroxide, organic chlorine compounds, and phosphorus compounds can be substituted for bromine as fire retardants in some uses.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Includes data for the Harmonized Tariff Schedule of the United States codes shown in the "Tariff" section.

[2]Includes data for the following Schedule B numbers: 2801.30.2000, 2827.51.0000, 2827.59.0000, 2903.31.0000, and 2903.39.1520.

[3]Defined as production (sold or used) + imports – exports.

[4]Defined as imports – exports.

[5]Calculated using the gross weight of imports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production.

CADMIUM

(Data in metric tons of contained cadmium unless otherwise noted)

Domestic Production and Use: Two companies in the United States produced refined cadmium in 2021. One company, operating in Tennessee, recovered primary refined cadmium as a byproduct of zinc leaching from roasted sulfide concentrates. The other company, operating in Ohio, recovered secondary cadmium metal from spent nickel cadmium (NiCd) batteries. A cadmium concentrate was produced by one company in North Carolina that produced zinc from recycled electric-arc-furnace dust obtained from steel mills. Domestic production and consumption of cadmium were withheld to avoid disclosing company proprietary data. Cadmium metal and compounds are mainly consumed for alloys, coatings, NiCd batteries, pigments, and plastic stabilizers. For the past 5 years, the United States has been a net importer of unwrought cadmium metal and cadmium metal powders and a net exporter of wrought cadmium products and of cadmium pigments and preparations based on cadmium compounds.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, refined[1]	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	274	273	385	282	140
Wrought cadmium and other articles (gross weight)	2	1	21	3	1
Cadmium waste and scrap (gross weight)	20	20	86	90	150
Cadmium pigments and preparations based on cadmium compounds (gross weight)	158	310	108	69	90
Exports:					
Unwrought cadmium and powders	223	40	32	4	80
Wrought cadmium and other articles (gross weight)	205	99	84	480	210
Cadmium waste and scrap (gross weight)	(2)	(2)	6	(2)	(2)
Cadmium pigments and preparations based on cadmium compounds (gross weight)	617	565	795	2,120	560
Consumption, reported, refined	W	W	W	W	W
Price, metal, annual average,[3] dollars per kilogram	1.75	2.89	2.67	2.29	2.49
Net import reliance[4] as a percentage of apparent consumption	<25	<50	<50	<50	<50

Recycling: Secondary cadmium is mainly recovered from spent consumer and industrial NiCd batteries. Other waste and scrap from which cadmium can be recycled includes copper-cadmium alloy scrap, some complex nonferrous alloy scrap, cadmium-containing dust from electric arc furnaces, and cadmium telluride (CdTe) solar panels.

Import Sources (2017–20):[5] Australia, 29%; China,[6] 20%; Germany, 19%; Peru, 11%; and other, 21%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Cadmium oxide	2825.90.7500	Free.
Cadmium sulfide	2830.90.2000	3.1% ad valorem.
Pigments and preparations based on cadmium compounds	3206.49.6010	3.1% ad valorem.
Unwrought cadmium and powders	8107.20.0000	Free.
Cadmium waste and scrap	8107.30.0000	Free.
Wrought cadmium and other articles	8107.90.0000	4.4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most of the world's primary cadmium metal was produced in Asia, and leading global producers, in descending order of production, were China and the Republic of Korea, followed by Japan and Canada. A smaller amount of secondary cadmium metal was recovered from recycling NiCd batteries. Although detailed data on the global consumption of primary cadmium were not available, NiCd battery production was thought to have continued to account for most global cadmium consumption. Other end uses for cadmium and cadmium compounds included alloys, anticorrosive coatings, pigments, polyvinyl chloride (PVC) stabilizers, and semiconductors for solar cells and for radiation-detecting imaging equipment.

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CADMIUM

The average monthly cadmium price began 2021 averaging $2.12 per kilogram in January and trended upward to about $2.85 per kilogram in April and May before decreasing to $2.13 per kilogram in August. The resurgence of the delta variant of the COVID-19 virus in April through July in India affected economic activity and was likely a factor in the decrease in price. As a major consumer of cadmium but without significant production, India was an important determinant of cadmium prices in the spot market.

In March 2021, the U.S. Department of Energy Solar Energy Technologies Office initiated the Cadmium Telluride Photovoltaics (PV) Accelerator program, intended to enhance U.S. technology leadership and competitiveness in the CdTe PV industry. Program goals included achieving cell efficiencies above 26%, decreasing module costs to below $0.15 per watt before 2030, and increasing domestic CdTe PV material and module production. The National Renewable Energy Laboratory would provide resources and support for a consortium to bring together academic institutions, industry, and government to accomplish the program goals.

A major United States-based CdTe thin-film solar-cell producer began building a third manufacturing facility in Ohio. The new facility, to be completed in 2023, would add 3.3 gigawatts (GW) to the company's annual production capacity for a total of 6 GW and make it the largest vertically integrated solar manufacturing complex outside of China.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[7]
	2020	2021	
United States[1]	W	W	Quantitative estimates of reserves are not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Australia	348	300	
Canada	1,800	1,800	
China	10,000	10,000	
Germany	450	500	
Japan	1,880	1,900	
Kazakhstan	1,500	1,500	
Korea, Republic of	3,000	3,000	
Mexico	978	800	
Netherlands	880	900	
Norway	400	400	
Peru	700	600	
Russia	1,000	1,000	
Uzbekistan	400	400	
Other countries	520	600	
World total (rounded)[8]	24,000	24,000	

World Resources:[7] Cadmium is generally recovered from zinc ores and concentrates. Sphalerite, the most economically significant zinc ore mineral, commonly contains minor amounts of cadmium, which shares certain similar chemical properties with zinc and often substitutes for zinc in the sphalerite crystal lattice. The cadmium mineral greenockite is frequently associated with weathered sphalerite and wurtzite.

Substitutes: Lithium-ion and nickel-metal hydride batteries can replace NiCd batteries in many applications. Except where the surface characteristics of a coating are critical (for example, fasteners for aircraft), coatings of zinc, zinc nickel, aluminum, or tin can be substituted for cadmium in many plating applications. Cerium sulfide is used as a replacement for cadmium pigments, mostly in plastics. Barium-zinc or calcium-zinc stabilizers can replace barium-cadmium stabilizers in flexible PVC applications. Amorphous silicon and copper-indium-gallium-selenide photovoltaic cells compete with CdTe in the thin-film solar-cell market. Research efforts continued to advance new thin-film technology based on perovskite material as a potential substitute.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Cadmium metal produced as a byproduct of zinc refining plus metal from recycling.

[2]Less than ½ unit.

[3]Average free market price for 99.95% purity in 10-ton lots; cost, insurance, and freight; global ports. Source: Fastmarkets MB.

[4]Defined as imports of unwrought metal and metal powders – exports of unwrought metal and metal powders.

[5]Includes data for the following Harmonized Tariff Schedule of the United States code: 8107.20.0000.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Excludes U.S. production.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, U.S. portland cement production increased slightly to an estimated 90 million tons, and masonry cement production continued to remain steady at 2.4 million tons. Cement was produced at 96 plants in 34 States, and at 2 plants in Puerto Rico. Texas, Missouri, California, and Florida were, in descending order of production, the four leading cement-producing States and accounted for nearly 44% of U.S. production. Overall, the U.S. cement industry's growth continued to be constrained by closed or idle plants, underutilized capacity at others, production disruptions from plant upgrades, and relatively inexpensive imports. In 2021, shipments of cement were estimated to have increased slightly from those of 2020 and were valued at $13.4 billion. In 2021, an estimated 70% to 75% of sales were to ready-mixed concrete producers, 11% to concrete product manufacturers, 8% to 10% to contractors, and 5% to 12% to other customer types.

Salient Statistics—United States:[1]	2017	2018	2019	2020	2021[e]
Production:					
Portland and masonry cement[2]	86,356	86,368	87,233	[e]89,000	92,000
Clinker	76,678	77,112	78,858	79,000	79,000
Shipments to final customers, includes exports	97,935	99,419	102,823	105,000	107,000
Imports for consumption:					
Hydraulic cement	12,288	13,693	14,674	15,201	19,000
Clinker	1,209	967	1,160	1,534	2,000
Exports of hydraulic cement and clinker	1,035	919	1,024	888	1,000
Consumption, apparent[3]	97,160	98,400	101,600	[e]103,000	109,000
Price, average mill value, dollars per ton	117	121	123	[e]124	125
Stocks, cement, yearend	7,870	8,580	7,890	[e]7,750	8,000
Employment, mine and mill, number[e]	12,500	12,300	12,500	12,200	12,300
Net import reliance[4] as a percentage of apparent consumption	13	14	15	15	18

Recycling: Cement is not recycled, but significant quantities of concrete are recycled for use as a construction aggregate. Cement kilns can use waste fuels, recycled cement kiln dust, and recycled raw materials such as slags and fly ash. Various secondary materials can be incorporated as supplementary cementitious materials (SCMs) in blended cements and in the cement paste in concrete.

Import Sources (2017–20):[5] Canada, 32%; Turkey, 20%; Greece, 13%; China,[6] 8%; and other, 27%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Cement clinker	2523.10.0000	Free.
White portland cement	2523.21.0000	Free.
Other portland cement	2523.29.0000	Free.
Aluminous cement	2523.30.0000	Free.
Other hydraulic cement	2523.90.0000	Free.

Depletion Allowance: Not applicable. Certain raw materials for cement production have depletion allowances.

Government Stockpile: None.

Events, Trends, and Issues: The value of total construction put in place in the United States increased by about 7% during the first 9 months of 2021 compared with that in the same period in 2020. Residential construction spending increased, but nonresidential construction spending decreased. Despite weather-related declines in the beginning of the year, cement shipments increased slightly during the first 9 months of 2021 compared with those in the same period in 2020. The leading cement-consuming States continued to be Texas, California, and Florida, in descending order by tonnage.

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CEMENT

The increase in cement shipments was attributed to economic recovery from the global COVID-19 pandemic. However, growth continued to be constrained by increased costs for material and service inputs, labor and production shortages, ongoing logistical and shipping issues, and supply chain disruptions. The November 2021 passage of the Infrastructure Investment and Jobs Act was projected to support increased cement consumption.

Company merger-and-acquisition activity continued in 2021, with the final approval to combine the North American cement operations of a Brazilian cement company and a Canadian cement company into a joint venture. One United States cement company completed its purchase of a European cement company's western United States operations, and a Swiss cement company acquired a United States building products company. In 2019, one European cement company entered into an agreement to purchase a Mexican cement company's plant in Pennsylvania, but the transaction was abandoned after being challenged by regulatory authorities in 2021.

Cement plant upgrades were well underway at cement plants in Alabama and Indiana, with completion expected in 2022 and 2023, respectively. Several minor upgrades were ongoing at some other domestic plants, and upgrades also were announced for a few cement terminals. Numerous companies continued to make announcements aligned with the industry's commitment to sustainability, such as new blended cement product lines, renewable energy plans, decarbonization research initiatives, and other innovations. Many plants have installed emissions-reduction equipment to comply with the 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP). It remains possible that some kilns could be shut, idled, or used in a reduced capacity to comply with NESHAP, which would constrain U.S. clinker capacity.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2020	2021	2020	2021
United States (includes Puerto Rico)	89,000	92,000	100,000	100,000
Brazil	61,000	65,000	60,000	60,000
China	2,400,000	2,500,000	2,000,000	2,000,000
Egypt	42,000	40,000	48,000	48,000
India	295,000	330,000	280,000	280,000
Indonesia	65,000	66,000	78,000	79,000
Iran	68,000	62,000	81,000	81,000
Japan	51,000	52,000	53,000	54,000
Korea, Republic of	48,000	48,000	50,000	60,000
Mexico	48,000	50,000	42,000	42,000
Russia	56,000	56,000	80,000	80,000
Saudi Arabia	53,000	55,000	75,000	75,000
Turkey	72,000	76,000	92,000	92,000
Vietnam	98,000	100,000	90,000	90,000
Other countries (rounded)	760,000	810,000	600,000	600,000
World total (rounded)	4,200,000	4,400,000	3,700,000	3,700,000

World Resources: Not applicable. See Crushed Stone for cement raw-material resources.

Substitutes: Most portland cement is used to make concrete, mortars, or stuccos, and competes in the construction sector with concrete substitutes, such as aluminum, asphalt, clay brick, fiberglass, glass, gypsum (plaster), steel, stone, and wood. Certain materials, especially fly ash and ground granulated blast furnace slag, develop good hydraulic cementitious properties by reacting with lime, such as that released by the hydration of portland cement. Where readily available (including as imports), these SCMs are increasingly being used as partial substitutes for portland cement in many concrete applications and are components of finished blended cements.

[e]Estimated.

[1]Portland cement plus masonry cement unless otherwise noted; excludes Puerto Rico unless otherwise noted.

[2]Includes cement made from imported clinker.

[3]Defined as production of cement (including from imported clinker) + imports (excluding clinker) – exports + adjustments for stock changes.

[4]Defined as imports (cement and clinker) – exports.

[5]Hydraulic cement and clinker; includes imports into Puerto Rico.

[6]Includes Hong Kong.

CESIUM

(Data in metric tons of cesium oxide unless otherwise noted)

Domestic Production and Use: In 2021, no cesium was mined domestically, and the United States was 100% net import reliant for cesium minerals. Pollucite, mainly found in association with lithium-rich, lepidolite-bearing or petalite-bearing zoned granite pegmatites, is the principal cesium ore mineral. Cesium minerals are used as feedstocks to produce a variety of cesium compounds and cesium metal. The primary application for cesium, by gross weight, is in cesium formate brines used for high-pressure, high-temperature well drilling for oil and gas exploration and production. With the exception of cesium formate, cesium is used in relatively small-scale applications, using only a few grams for most applications. Owing to the lack of global availability of cesium, many applications have used mineral substitutes and the use of cesium in any particular application may no longer be viable.

Cesium metal is used in the production of cesium compounds and potentially in photoelectric cells. Cesium bromide is used in infrared detectors, optics, photoelectric cells, scintillation counters, and spectrophotometers. Cesium carbonate is used in the alkylation of organic compounds and in energy conversion devices, such as fuel cells, magneto-hydrodynamic generators, and polymer solar cells. Cesium chloride is used in analytical chemistry applications as a reagent, in high-temperature solders, as an intermediate in cesium metal production, in isopycnic centrifugation, as a radioisotope in nuclear medicine, as an insect repellent in agricultural applications, and in specialty glasses. Cesium hydroxide is used as an electrolyte in alkaline storage batteries. Cesium iodide is used in fluoroscopy equipment—Fourier-transform infrared spectrometers—as the input phosphor of X-ray image intensifier tubes, and in scintillators. Cesium nitrate is used as a colorant and oxidizer in the pyrotechnic industry, in petroleum cracking, in scintillation counters, and in X-ray phosphors. Cesium sulfates are soluble in water and are thought to be used primarily in water treatment, fuel cells, and to improve optical quality for scientific instruments.

Cesium isotopes, which are obtained as a byproduct in nuclear fission or formed from other isotopes, such as barium-131, are used in electronic, medical, metallurgical, and research applications. Cesium isotopes are used as an atomic resonance frequency standard in atomic clocks, playing a vital role in aircraft guidance systems, global positioning satellites, and internet and cellular telephone transmissions. Cesium clocks monitor the cycles of microwave radiation emitted by cesium's electrons and use these cycles as a time reference. Owing to the high accuracy of the cesium atomic clock, the international definition of 1 second is based on the cesium atom. The U.S. civilian time and frequency standard is based on a cesium fountain clock at the National Institute of Standards and Technology in Boulder, CO. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 25 USNO cesium fountain clocks.

A company in Richland, WA, produced a range of cesium-131 medical products for treatment of various cancers. Cesium-137 may be used in industrial gauges, in mining and geophysical instruments, and for sterilization of food, sewage, and surgical equipment. Because of the danger posed by the radiological properties of cesium-137, efforts to find substitutes in its applications continued.

Salient Statistics—United States: Consumption, import, and export data for cesium have not been available since the late 1980s. Because cesium metal is not traded in commercial quantities, a market price is unavailable. Only a few thousand kilograms of cesium chemicals are thought to be consumed in the United States every year. The United States was 100% net import reliant for its cesium needs.

In 2021, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $69.90, a 7.2% increase from $65.20 in 2020, and 99.98% (metal basis) cesium for $88.90, a 5.0% increase from $84.70 in 2020. In 2021, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, cesium chloride, and cesium iodide were $131.20, $75.90, $110.20, $112.00, and $127.60, respectively, with increases ranging from 4.1% to 9.3% from prices in 2020. The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $78.60 for 50 milliliters and $120.00 for 100 milliliters, and the price for 25 grams of cesium formate, 98% (metal basis), was $42.60. In 2020, the price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $77.80 for 50 milliliters and $119.00 for 100 milliliters, and the price for 25 grams of cesium formate, 98% (metal basis), was $41.40.

Recycling: Cesium formate brines are typically rented by oil and gas exploration clients. After completion of the well, the used cesium formate brine is returned and reprocessed for subsequent drilling operations. Cesium formate brines are recycled, recovering nearly 85% of the brines for recycling to be reprocessed for further use.

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CESIUM

Import Sources (2017–20): No reliable data have been available to determine the source of cesium ore imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of cesium ore.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Alkali metals, other	2805.19.9000	5.5% ad valorem.
Chlorides, other	2827.39.9000	3.7% ad valorem.
Bromides, other	2827.59.5100	3.6% ad valorem.
Iodides, other	2827.60.5100	4.2% ad valorem.
Sulfates, other	2833.29.5100	3.7% ad valorem.
Nitrates, other	2834.29.5100	3.5% ad valorem.
Carbonates, other	2836.99.5000	3.7% ad valorem.
Cesium-137, other	2844.40.0021	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic cesium occurrences will likely remain uneconomic unless market conditions change. No known human health issues are associated with naturally occurring cesium, and its use has minimal environmental impact. Manufactured radioactive isotopes of cesium have been known to cause adverse health effects. Certain cesium compounds may be toxic if consumed. Food that has been irradiated using the radioisotope cesium-137 has been found to be safe by the U.S. Food and Drug Administration.

During 2021, no primary cesium mine production was reported globally but cesium was thought to have been mined in China. Mine production of cesium from all countries, excluding China, ceased within the past two decades. Production in Namibia ceased in the early 2000s, followed by the Tanco Mine in Canada shutting down and later being sold after a mine collapse in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018, and the Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019. Recent reports indicate that with current processing rates for the only operating intermediate refinery in Germany, the world's stockpiles of cesium ore, excluding those in China, will be depleted within a few years.

A company completed an updated mineral resource estimate for the Karibib project in Namibia, reporting 8.9 million metric tons of measured and indicated resources containing 0.23% rubidium and 303 parts per million cesium. The company also reported 6.72 million metric tons of proven and probable reserves containing 2.26% rubidium and 320 parts per million cesium. Located in the Karibib Pegmatite Belt, lithium would be the primary product, with cesium, potassium, and rubidium as potential byproducts. Development of the Karibib project continued in 2021.

World Mine Production and Reserves:[1] There were no official sources for cesium production data in 2021. Cesium reserves are, therefore, estimated based on the occurrence of pollucite, a primary lithium-cesium-rubidium mineral. Most pollucite contains 5% to 32% cesium oxide. No reliable data are available to determine reserves for specific countries; however, Australia, Canada, China, and Namibia were thought to have reserves totaling less than 200,000 tons. Existing stockpiles at multiple former mine sites have continued feeding downstream refineries, though recent reports have indicated stockpiles will be depleted within a few years.

World Resources:[1] Cesium is associated with lithium-bearing pegmatites worldwide, and cesium resources have been identified in Australia, Canada, Namibia, the United States, and Zimbabwe. In the United States, pollucite occurs in pegmatites in Alaska, Maine, and South Dakota. Lower concentrations occur in brines in Chile and China and in geothermal systems in Germany, India, and China. China was thought to have cesium-rich deposits of geyserite, lepidolite, and pollucite, with concentrations highest in Yichun, Jiangxi Province, although no resource, reserve, or production estimates were available.

Substitutes: Cesium and rubidium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications. However, rubidium is mined from similar deposits, in relatively smaller quantities, as a byproduct of cesium production in pegmatites and as a byproduct of lithium production from lepidolite (hard-rock) mining and processing, making it no more readily available than cesium.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

CHROMIUM

(Data in thousand metric tons of contained chromium unless otherwise noted)

Domestic Production and Use: In 2021, the United States was expected to consume 5% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, chromium ferroalloys, chromium metal, and stainless steel. Imported chromite ore was consumed by one chemical company to produce chromium chemicals. Stainless-steel and heat-resisting-steel producers were the leading consumers of ferrochromium. Stainless steels and superalloys require the addition of chromium via ferrochromium or chromium-containing scrap. The value of chromium material consumption was expected to be about $850 million in 2021, as measured by the value of net imports, excluding stainless steel, and was a fourfold increase from $201 million in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021e
Production:					
Mine	—	—	—	—	—
Recycling[1]	152	139	135	116	120
Imports for consumption[2]	634	651	530	457	590
Exports	256	212	149	111	120
Shipments from Government stockpile	8	4	4	5	5
Consumption (includes recycling):					
Reported	516	459	480	379	360
Apparent[3]	541	583	520	465	590
Price, average annual unit value of imports, dollars per ton:					
Chromite ore (gross weight)	259	279	248	179	210
Ferrochromium (chromium content)[4]	2,547	2,549	2,094	1,878	2,400
Chromium metal (gross weight)	9,675	11,344	10,393	7,931	7,500
Stocks, consumer, yearend	6	5	5	6	6
Net import reliance[5] as a percentage of apparent consumption	72	76	73	75	80

Recycling: In 2021, recycled chromium (contained in reported stainless-steel scrap receipts) accounted for 20% of apparent consumption.

Import Sources (2017–20): Chromite (ores and concentrates): South Africa, 99%; and Canada, 1%.
Chromium-containing scrap:[6] United Kingdom, 53%; Canada, 28%; Japan, 9%; and other, 10%.
Chromium (primary metal):[7] Russia, 36%; United Kingdom, 23%; France, 21%; China,[8] 15%; and other, 5%.
Total imports: South Africa, 38%; Kazakhstan, 9%; Russia, 7%; Mexico, 6%; and other, 40%.

Tariff:[9] Item	Number	Normal Trade Relations 12–31–21
Chromium ores and concentrates:		
Cr_2O_3 not more than 40%	2610.00.0020	Free.
Cr_2O_3 more than 40% and less than 46%	2610.00.0040	Free.
Cr_2O_3 more than or equal to 46%	2610.00.0060	Free.
Ferrochromium:		
Carbon more than 4%	7202.41.0000	1.9% ad valorem.
Carbon more than 3%	7202.49.1000	1.9% ad valorem.
Carbon more than 0.5%	7202.49.5010	3.1% ad valorem.
Other	7202.49.5090	3.1% ad valorem.
Ferrosilicon chromium	7202.50.0000	10% ad valorem.
Chromium metal:		
Unwrought, powder	8112.21.0000	3% ad valorem.
Waste and scrap	8112.22.0000	Free.
Other	8112.29.0000	3% ad valorem.

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CHROMIUM

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[10, 11]

Material	Inventory as of 8–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Ferrochromium:					
High-carbon	25.6	—	[12]21.8	—	[12]21.8
Low-carbon	27.4	—	—	—	—
Chromium metal	3.62	—	0.454	—	0.454

Events, Trends, and Issues: Chromium is consumed in the form of ferrochromium to produce stainless steel. South Africa was the leading chromite ore producer. Ore production was estimated to increase in 2021 owing to recovery of the market following the COVID-19 pandemic. China was the leading ferrochromium- and stainless-steel-producing country, and the leading chromium-consuming country. Ferrochromium production is electrical-energy intensive, so stricter environmental standards could affect ferrochromium production in China.

From October 2020 to October 2021, the monthly average high-carbon ferrochromium price more than doubled. The price of chromium metal increased by 85% in October 2021 compared with the monthly average price in October 2020.

World Mine Production and Reserves:

	Mine production[13] 2020	Mine production[13] 2021[e]	Reserves[14] (shipping grade)[15]
United States	—	—	620
Finland	2,290	2,300	13,000
India	2,500	3,000	100,000
Kazakhstan	7,000	7,000	230,000
South Africa	13,200	18,000	200,000
Turkey	8,000	7,000	26,000
Other countries	3,980	4,100	NA
World total (rounded)	37,000	41,000	570,000

World Resources:[14] World resources are greater than 12 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries. World chromium resources are heavily geographically concentrated (95%) in Kazakhstan and southern Africa; United States chromium resources are mostly in the Stillwater Complex in Montana.

Substitutes: Chromium has no substitute in stainless steel, the leading end use, or in superalloys, the major strategic end use. Chromium-containing scrap can substitute for ferrochromium in some metallurgical uses.

[e]Estimated. NA Not available. — Zero.

[1]Recycling production is based on reported receipts of all types of stainless-steel scrap.

[2]Includes chromite ores, ferrochromium, chromium metal, and chromium chemicals.

[3]Defined as production (from mines and recycling) + imports – exports + adjustments for Government and industry stock changes.

[4]Excludes ferrochromium silicon.

[5]Defined as imports – exports + adjustments for Government and industry stock changes.

[6]Includes chromium metal scrap and stainless-steel scrap.

[7]Includes chromium metal, ferrochromium, and stainless steel.

[8]Includes Hong Kong.

[9]In addition to the tariff items listed, certain imported chromium materials (see 26 U.S.C., sec. 4661, 4662, and 4672) are subject to excise tax.

[10]See Appendix B for definitions.

[11]Units are thousand metric tons of material by gross weight.

[12]High-carbon and low-carbon ferrochromium, combined.

[13]Mine production units are thousand metric tons, gross weight, of marketable chromite ore.

[14]See Appendix C for resource and reserve definitions and information concerning data sources.

[15]Reserves units are thousand metric tons of shipping-grade chromite ore, which is deposit quantity and grade normalized to 45% Cr_2O_3, except for the United States where grade is normalized to 7% Cr_2O_3 and Finland where grade is normalized to 26% Cr_2O_3.

CLAYS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Production of clays (sold or used) in the United States was estimated to be 25 million tons valued at $1.5 billion in 2021, with about 120 companies operating clay and shale mines in 38 States. The leading 20 companies produced approximately 65% of the U.S. tonnage and 84% of the value for all types of clay. Principal domestic uses for specific clays were estimated to be as follows: ball clay—50% floor and wall tile and 18% sanitaryware; bentonite—50% pet waste absorbents and 22% drilling mud; common clay—45% brick, 28% lightweight aggregate, and 22% cement; fire clay—82% heavy clay and lightweight aggregates products (for example, brick, cement, and concrete) and 14% refractory products and miscellaneous uses; fuller's earth—81% absorbents (includes oil and grease absorbents, pet waste absorbents, and miscellaneous absorbents); and kaolin—30% paper coating and filling, 15% miscellaneous ceramics, and 15% refractory products.

Exports of clay and shale were estimated have increased by 16% in 2021 after decreasing by 13% in 2020. In 2021, the United States exported an estimated 800,000 tons of bentonite with Canada, Japan, and China, in decreasing order, being the leading destinations. About 2.3 million tons of kaolin was exported mainly as a paper coating and filler; a component in ceramic bodies; and fillers and extenders in paint, plastic, and rubber products, with China, Mexico, and Japan, in decreasing order, being the leading destinations. Lesser quantities of ball clay, fire clay, and fuller's earth were exported for ceramic, refractory, and absorbent uses, respectively.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production (sold or used):					
Ball clay[e]	1,270	1,110	1,060	1,080	1,100
Bentonite	4,450	4,570	4,520	4,240	4,300
Common clay	13,600	12,900	12,800	12,600	13,000
Fire clay	575	567	603	635	650
Fuller's earth[e, 1]	1,840	1,880	1,990	1,980	2,000
Kaolin[e]	5,450	5,350	5,060	4,570	4,100
Total[1, 2]	27,200	26,400	26,100	25,100	25,000
Imports for consumption:					
Artificially activated clays and earths	28	23	31	31	40
Kaolin	316	330	293	224	190
Other	86	68	66	28	40
Total[2]	430	421	389	284	270
Exports:					
Artificially activated clays and earths	147	149	138	127	140
Ball clay	83	90	85	68	130
Bentonite	961	845	906	728	800
Clays, not elsewhere classified	244	244	204	185	170
Fire clay[3]	225	250	194	190	190
Fuller's earth	78	70	73	77	80
Kaolin	2,310	2,390	2,280	1,980	2,300
Total[2]	4,040	4,030	3,880	3,360	3,900
Consumption, apparent[4]	23,600	22,800	22,600	22,100	21,000
Price, ex-works, average unit value, dollars per ton:					
Ball clay	49	55	56	58	64
Bentonite	99	98	98	96	94
Common clay	15	16	17	16	16
Fire clay	13	12	14	13	13
Fuller's earth[1]	93	88	88	89	88
Kaolin	158	160	162	160	160
Employment (excludes office workers), number:[e]					
Mine (may not include contract workers)	1,220	1,110	1,110	1,060	1,060
Mill	4,370	4,310	4,310	4,260	4,240
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2017–20): All clay types combined: Brazil, 70%; Mexico, 9%; China, 7%; and other, 14%.

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CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–21
Kaolin and other kaolinic clays, whether or not calcined	2507.00.0000	Free.
Bentonite	2508.10.0000	Free.
Fire clay	2508.30.0000	Free.
Common blue clay and other ball clays	2508.40.0110	Free.
Decolorizing earths and fuller's earth	2508.40.0120	Free.
Other clays	2508.40.0150	Free.
Chamotte or dinas earth	2508.70.0000	Free.
Activated clays and activated earths	3802.90.2000	2.5% ad valorem.
Expanded clays and other mixtures	6806.20.0000	Free.

Depletion Allowance: Ball clay, bentonite, fire clay, fuller's earth, and kaolin, 14% (domestic and foreign); clay used in the manufacture of common brick, lightweight aggregate, and sewer pipe, 7.5% (domestic and foreign); clay used in the manufacture of drain and roofing tile, flowerpots, and kindred products, 5% (domestic and foreign); clay from which alumina and aluminum compounds are extracted, 22% (domestic).

Government Stockpile: None.

Events, Trends, and Issues: In October 2021, a common clay producer headquartered in Tennessee finalized the acquisition of another common clay company headquartered in Georgia, which operated 20 plants throughout North America. In July 2021, a Georgia kaolin producer announced an agreement to purchase central Georgia assets that support the paper and board industry from another kaolin producer with North American headquarters in Georgia.

World Mine Production and Reserves:[6] Global reserves are large, but country-specific data were not available.

	Mine production					
	Bentonite		Fuller's earth		Kaolin	
	2020	2021[e]	2020	2021[e]	2020	2021[e]
United States	4,240	4,300	[1]1,980	[1]2,000	4,570	4,100
Brazil (beneficiated)	217	200	—	—	1,240	1,200
China	2,500	2,500	—	—	6,500	6,400
Czechia	226	230	—	—	[7]3,070	[7]3,100
Germany	360	350	—	—	870	800
Greece	[7]1,300	[7]1,300	34	30	—	—
India	3,500	3,500	730	730	[7]7,600	[7]7,600
Iran	425	420	—	—	1,800	1,800
Mexico	25	20	110	110	120	120
Senegal	—	—	117	120	—	—
Spain	221	220	590	590	[7]450	[7]450
Turkey	1,500	1,700	60	60	1,200	1,200
Ukraine	180	180	—	—	1,680	1,600
Uzbekistan	25	20	—	—	5,900	5,500
Other countries	3,480	3,500	313	310	11,400	11,000
World total (rounded)	18,200	18,000	[1]3,930	[1]4,000	46,400	45,000

World Resources:[6] Resources of all clays are extremely large.

Substitutes: Clays compete with calcium carbonate in filler and extender applications; diatomite, organic pet litters, polymers, silica gel, and zeolites as absorbents; and various siding and roofing types in building construction.

[e]Estimated. E Net exporter. — Zero.

[1]Does not include U.S. production of attapulgite.

[2]Data may not add to totals shown because of independent rounding.

[3]Includes refractory-grade kaolin.

[4]Defined as production (sold or used) + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Includes production of crude ore.

COBALT

(Data in metric tons of contained cobalt unless otherwise noted)

Domestic Production and Use: In 2021, the nickel-copper Eagle Mine in Michigan produced cobalt-bearing nickel concentrate, which was exported to Canada or overseas for processing. In Missouri, a company produced nickel-copper-cobalt concentrate from historic mine tailings and was building a hydrometallurgical processing plant near the mine site. Most U.S. cobalt supply consisted of imports and secondary (scrap) materials. Approximately six companies in the United States produced cobalt chemicals. An estimated 42% of the cobalt consumed in the United States was used in superalloys, mainly in aircraft gas turbine engines; 9% in cemented carbides for cutting and wear-resistant applications; 16% in various other metallic applications; and 33% in a variety of chemical applications. The total estimated value of cobalt consumed in 2021 was $340 million.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:[e]					
Mine	640	480	500	600	700
Secondary[1]	2,750	2,750	2,750	2,000	1,600
Imports for consumption	11,900	11,900	13,900	9,740	9,900
Exports	5,690	6,980	4,080	3,440	4,800
Consumption (includes secondary):					
Estimated[2]	9,240	9,290	9,050	7,300	6,600
Apparent[3]	8,950	7,680	12,500	8,500	6,700
Price, average, dollars per pound:					
U.S. spot, cathode[4]	26.97	37.43	16.95	15.70	23
London Metal Exchange (LME), cash	25.28	32.94	14.88	14.21	22
Stocks, yearend:					
Industry[e, 2, 5]	1,020	1,060	1,090	950	950
LME, U.S. warehouse	160	130	102	82	50
Net import reliance[6] as a percentage of apparent consumption	69	64	78	76	76

Recycling: In 2021, cobalt contained in purchased scrap represented an estimated 24% of cobalt estimated consumption.

Import Sources (2017–20): Cobalt contained in metal, oxide, and salts: Norway, 20%; Canada, 16%; Japan, 13%; Finland, 11%; and other, 40%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Cobalt ores and concentrates	2605.00.0000	Free.
Chemical compounds:		
Cobalt oxides and hydroxides	2822.00.0000	0.1% ad valorem.
Cobalt chlorides	2827.39.6000	4.2% ad valorem.
Cobalt sulfates	2833.29.1000	1.4% ad valorem.
Cobalt carbonates	2836.99.1000	4.2% ad valorem.
Cobalt acetates	2915.29.3000	4.2% ad valorem.
Unwrought cobalt, alloys	8105.20.3000	4.4% ad valorem.
Unwrought cobalt, other	8105.20.6000	Free.
Cobalt mattes and other intermediate products; cobalt powders	8105.20.9000	Free.
Cobalt waste and scrap	8105.30.0000	Free.
Wrought cobalt and cobalt articles	8105.90.0000	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7] See Lithium for statistics on lithium-cobalt oxide and lithium-nickel-cobalt-aluminum oxide.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cobalt	302	—	—	—	—
Cobalt alloys, gross weight[8]	11	50	—	50	—

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COBALT

Events, Trends, and Issues: Global cobalt mine and refinery production were forecast to increase to record high levels in 2021. The increase in raw materials feed was mainly from increased production at existing operations, although new production and restarts at suspended operations also contributed to supply. Congo (Kinshasa) continued to be the world's leading source of mined cobalt, supplying more than 70% of world cobalt mine production. With the exception of production in Morocco and artisanally mined cobalt in Congo (Kinshasa), most cobalt is mined as a byproduct of copper or nickel. China was the world's leading producer of refined cobalt, most of which was produced from partially refined cobalt imported from Congo (Kinshasa). China was the world's leading consumer of cobalt, with more than 80% of its consumption being used by the rechargeable battery industry.

World Mine Production and Reserves: Reserves for multiple countries were revised based on Government or industry reports.

	Mine production		Reserves[9]
	2020	2021[e]	
United States	600	700	69,000
Australia	5,630	5,600	[10]1,400,000
Canada	3,690	4,300	220,000
China	2,200	2,200	80,000
Congo (Kinshasa)	98,000	120,000	3,500,000
Cuba	3,800	3,900	500,000
Indonesia	1,100	2,100	600,000
Madagascar	850	2,500	100,000
Morocco	2,300	2,300	13,000
Papua New Guinea	2,940	3,000	47,000
Philippines	4,500	4,500	260,000
Russia	9,000	7,600	250,000
Other countries	7,640	6,600	610,000
World total (rounded)	142,000	170,000	7,600,000

World Resources:[9] Identified cobalt resources of the United States are estimated to be about 1 million tons. Most of these resources are in Minnesota, but other important occurrences are in Alaska, California, Idaho, Michigan, Missouri, Montana, Oregon, and Pennsylvania. With the exception of resources in Idaho and Missouri, any future cobalt production from these deposits would be as a byproduct of another metal. Identified world terrestrial cobalt resources are about 25 million tons. The vast majority of these resources are in sediment-hosted stratiform copper deposits in Congo (Kinshasa) and Zambia; nickel-bearing laterite deposits in Australia and nearby island countries and Cuba; and magmatic nickel-copper sulfide deposits hosted in mafic and ultramafic rocks in Australia, Canada, Russia, and the United States. More than 120 million tons of cobalt resources have been identified in polymetallic nodules and crusts on the floor of the Atlantic, Indian, and Pacific Oceans.

Substitutes: Depending on the application, substitution for cobalt could result in a loss in product performance or an increase in cost. The cobalt contents of lithium-ion batteries, the leading global use for cobalt, are being reduced; potential commercially available cobalt-free substitutes use iron and phosphorus. Potential substitutes in other applications include barium or strontium ferrites, neodymium-iron-boron alloys, or nickel-iron alloys in magnets; cerium, iron, lead, manganese, or vanadium in paints; cobalt-iron-copper or iron-copper in diamond tools; copper-iron-manganese for curing unsaturated polyester resins; iron, iron-cobalt-nickel, nickel, ceramic-metallic composites (cermets), or ceramics in cutting and wear-resistant materials; nickel-base alloys or ceramics in jet engines; nickel in petroleum catalysts; rhodium in hydroformylation catalysts; and titanium-base alloys in prosthetics.

[e]Estimated. — Zero.

[1]Estimated from consumption of purchased scrap.

[2]Includes reported data and U.S. Geological Survey estimates.

[3]Defined as secondary production + imports – exports + adjustments for Government and industry stock changes for refined cobalt.

[4]Source: Platts Metals Week. Cobalt cathode is refined cobalt metal produced by an electrolytic process.

[5]Stocks held by consumers and processors; excludes stocks held by trading companies and held for investment purposes.

[6]Defined as imports – exports + adjustments for Government and industry stock changes for refined cobalt.

[7]See Appendix B for definitions.

[8]Inventory is cobalt alloys; potential acquisitions are samarium-cobalt alloy; excludes potential disposals of aerospace alloys.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 560,000 tons.

COPPER

(Data in thousand metric tons of contained copper unless otherwise noted)

Domestic Production and Use: In 2021, the recoverable copper content of U.S. mine production was an estimated 1.2 million tons, unchanged from that in 2020, and was valued at an estimated $12 billion, 58% greater than $7.61 billion in 2020. Arizona was the leading copper-producing State and accounted for an estimated 71% of domestic output; copper was also mined in Michigan, Missouri, Montana, Nevada, New Mexico, and Utah. Copper was recovered or processed at 25 mines (19 of which accounted for 99% of mine production), 2 smelters, 2 electrolytic refineries, and 14 electrowinning facilities. An additional smelter and electrolytic refinery have been temporarily closed since October 2019. Refined copper and scrap were used at about 30 brass mills, 14 rod mills, and 500 foundries and miscellaneous consumers. Copper and copper alloy products were used in building construction, 46%; electrical and electronic products, 21%; transportation equipment, 16%; consumer and general products, 10%; and industrial machinery and equipment, 7%.[1]

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine, recoverable copper content	1,260	1,220	1,260	1,200	1,200
Refinery:					
Primary (from ore)	1,040	1,070	985	874	950
Secondary (from scrap)	40	41	44	43	50
Copper recovered from old (post-consumer) scrap[2]	146	149	[e]150	[e]150	160
Imports for consumption:					
Ore and concentrates	14	32	27	2	13
Refined	813	778	663	676	920
Exports:					
Ore and concentrates	237	253	353	383	360
Refined	94	190	125	41	50
Consumption:					
Reported, refined metal	1,800	1,820	1,830	1,710	1,800
Apparent, primary refined and old scrap[3]	1,860	1,830	1,810	1,650	2,000
Price, annual average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	285.4	298.7	279.6	286.7	430.0
COMEX, high-grade, first position	280.4	292.6	272.3	279.9	420.0
London Metal Exchange, grade A, cash	279.5	296.0	272.4	279.8	420.0
Stocks, refined, held by U.S. producers, consumers, and metal exchanges, yearend	265	244	111	118	80
Employment, mine and plant, number	10,500	11,700	12,000	11,000	11,000
Net import reliance[4] as a percentage of apparent consumption	36	33	37	38	45

Recycling: Old (post-consumer) scrap, converted to refined metal and alloys, provided an estimated 160,000 tons of copper. Purchased new (manufacturing) scrap, derived from fabricating operations, yielded an estimated 710,000 tons. Of the total copper recovered from scrap (including non-copper-base scrap), brass and wire-rod mills accounted for about 80%; smelters, refiners, and ingot makers, 15%; and miscellaneous chemical plants, foundries, and manufacturers, 5%. Copper recovered from scrap contributed about 32% of the U.S. copper supply.[5]

Import Sources (2017–20): Copper content of blister and anodes: Finland, 81%; Malaysia, 13%; and other, 6%. Copper content of matte, ash, and precipitates: Canada, 28%; Mexico, 20%; Belgium, 14%; Spain, 11%; and other, 27%. Copper content of ore and concentrates: Mexico, 97%; and other, 3%. Copper content of scrap: Canada, 54%; Mexico, 34%; and other, 12%. Refined copper: Chile, 62%; Canada, 23%; Mexico, 11%; and other, 4%. Refined copper accounted for 85% of all unmanufactured copper imports.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Copper ore and concentrates, copper content	2603.00.0010	1.7¢/kg on lead content.
Unrefined copper anodes	7402.00.0000	Free.
Refined copper and alloys, unwrought	7403.00.0000	1.0% ad valorem.
Copper wire rod	7408.11.0000	1.0% or 3.0% ad valorem.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

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COPPER

Events, Trends, and Issues: In the United States, mined copper production remained unchanged in 2021 from that in 2020. Production increased significantly at the Safford Mine in Arizona owing to the rampup of the Lone Star expansion that was completed in the second half of 2020. Operations at the Chino Mine in New Mexico, which had been suspended since April 2020 after multiple workers tested positive for COVID-19, restarted in the first quarter of 2021. At the Pinto Valley Mine in Arizona, optimization projects completed in 2020 and 2021 resulted in higher copper recovery and throughput rates. Production also increased at other domestic copper mines because of higher ore grades, but the increases were offset by significant decreases in output at several major mines in Arizona. The rampup of the Gunnison Mine in Arizona, which commenced production in late 2020, was delayed because of technical complications with the injection wells. Production at the Pumpkin Hollow Mine in Nevada, which started in late 2019 and was halted for several months in 2020 because of the COVID-19 pandemic, was expected to reach capacity in the third quarter of 2022. Refined copper production in the United States increased by an estimated 9% in 2021 compared with that in 2020, when operations at the smelter in Utah were affected by a rebuild of the flash converting furnace after an earthquake and a delayed restart following planned maintenance.

Based on data through October, the annual average COMEX copper price was projected to be about $4.20 per pound in 2021, an increase of 50% from that in 2020 and 5% greater than the previous alltime high of $4.01 per pound in 2011. Strong global manufacturing activity, constrained growth in world copper production, low stockpiles, and supply constraints owing to shipping delays contributed to the increased copper price.

World Mine and Refinery Production and Reserves: Reserves for multiple countries were revised based on company and (or) Government information.

	Mine production		Refinery production		Reserves[6]
	2020	2021[e]	2020	2021[e]	
United States	1,200	1,200	918	1,000	48,000
Australia	885	900	427	450	[7]93,000
Canada	585	590	[e]290	300	9,800
Chile	5,730	5,600	2,330	2,200	200,000
China	1,720	1,800	10,000	10,000	26,000
Congo (Kinshasa)	1,600	1,800	1,350	1,500	31,000
Germany	—	—	643	630	—
Indonesia	505	810	269	270	24,000
Japan	—	—	1,580	1,500	—
Kazakhstan	552	520	515	470	20,000
Korea, Republic of	—	—	671	650	—
Mexico	733	720	492	470	53,000
Peru	2,150	2,200	324	350	77,000
Poland	393	390	560	590	31,000
Russia	[e]810	820	1,040	920	62,000
Zambia	853	830	378	350	21,000
Other countries	2,840	2,800	3,450	4,300	180,000
World total (rounded)	20,600	21,000	25,300	26,000	880,000

World Resources:[6] A U.S. Geological Survey study of global copper deposits indicated that, as of 2015, identified resources contained 2.1 billion tons of copper, and undiscovered resources contained an estimated 3.5 billion tons.[8]

Substitutes: Aluminum substitutes for copper in automobile radiators, cooling and refrigeration tube, electrical equipment, and power cable. Titanium and steel are used in heat exchangers. Optical fiber substitutes for copper in telecommunications applications, and plastics substitute for copper in drain pipe, plumbing fixtures, and water pipe.

[e]Estimated. — Zero.

[1]Distribution reported by the Copper Development Association. Some electrical components are included in each end use.

[2]Copper converted to refined metal and alloys by brass and wire-rod mills, foundries, refineries, and other manufacturers.

[3]Primary refined production + copper in old scrap converted to refined metal and alloys + refined imports – refined exports ± refined stock changes.

[4]Defined as refined imports – refined exports ± adjustments for refined copper stock changes.

[5]Primary refined production + copper recovered from old and new scrap + refined imports – refined exports ± refined stock changes.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 23 million tons.

[8]Hammarstrom, J.M., Zientek, M.L., Parks, H.L., Dicken, C.L., and the U.S. Geological Survey Global Copper Mineral Resource Assessment Team, 2019, Assessment of undiscovered copper resources of the world, 2015 (ver.1.1, May 24, 2019): U.S. Geological Survey Scientific Investigations Report 2018–5160, 619 p., https://doi.org/10.3133/sir20185160.

DIAMOND (INDUSTRIAL)[1]

(Data in million carats unless otherwise noted)

Domestic Production and Use: In 2021, total domestic primary production of manufactured industrial diamond bort, grit, and dust and powder was estimated to be 140 million carats with a value of $42 million, a 7% increase compared with that in 2020. No industrial diamond stone was produced domestically. One company with facilities in Florida and Ohio and a second company in Pennsylvania accounted for all domestic primary production. At least four companies produced polycrystalline diamond from diamond powder. At least two companies recovered used industrial diamond material from used diamond drill bits, diamond tools, and other diamond-containing wastes for recycling. The major consuming sectors of industrial diamond are computer chip production; construction; drilling for minerals, natural gas, and oil; machinery manufacturing; stone cutting and polishing; and transportation (infrastructure and vehicles). Highway building, milling, and repair and stone cutting consumed most of the industrial diamond stone. About 94% of U.S. industrial diamond apparent consumption was synthetic industrial diamond because its quality can be controlled and its properties can be customized.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	41	184	114	130	140
Secondary	11	32	36	35	34
Imports for consumption	362	574	310	191	220
Exports	161	139	114	91	100
Consumption, apparent[2]	253	652	346	265	290
Price, unit value of imports, dollars per carat	0.16	0.12	0.14	0.19	0.21
Net import reliance[3] as a percentage of apparent consumption	79	67	57	38	41
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	87	—	—	—	—
Secondary	0.39	0.13	0.10	0.10	0.10
Imports for consumption	1.23	2.52	1.07	0.51	0.32
Exports	—	—	([4])	0.02	—
Consumption, apparent[2]	89.0	2.7	1.2	0.6	0.4
Price, unit value of imports, dollars per carat	12.9	2.9	5.8	8.4	12.0
Net import reliance[3] as a percentage of apparent consumption	1	95	91	83	76

Recycling: In 2021, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 34 million carats with an estimated value of $5.4 million. It was estimated that 98,000 carats of diamond stone were recycled with an estimated value of $150,000.

Import Sources (2017–20): Bort, grit, and dust and powder; natural and synthetic: China,[5] 81%; Ireland, 6%; the Republic of Korea, 6%; Russia, 4%; and other, 3%. Stones, primarily natural: South Africa, 24%; India, 18%; Congo (Kinshasa), 17%; Botswana, 10%; and other, 31%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Industrial Miners' diamonds, carbonados	7102.21.1010	Free.
Industrial Miners' diamonds, other	7102.21.1020	Free.
Industrial diamonds, simply sawn, cleaved, or bruted	7102.21.3000	Free.
Industrial diamonds, not worked	7102.21.4000	Free.
Grit or dust and powder of natural diamonds, 80 mesh or finer	7105.10.0011	Free.
Grit or dust and powder of natural diamonds, over 80 mesh	7105.10.0015	Free.
Grit or dust and powder of synthetic diamonds, coated with metal	7105.10.0020	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, 80 mesh or finer	7105.10.0030	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, over 80 mesh	7105.10.0050	Free.

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DIAMOND (INDUSTRIAL)

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most natural industrial diamond is produced as a byproduct of mining gem-quality diamond. Global natural industrial diamond production increased slightly during 2021. This increase was the result of mines returning to normal operation after the global COVID-19 pandemic caused reduced production in 2020. The most significant recoveries in rough diamond production were in Angola, Botswana, and Canada. Recovery from the effects of the pandemic have been hampered by mine closures and lower output as mines approach the ends of their lives. The world's largest diamond mines have matured and are past their peak production levels, and several of the largest diamond mines are expected to close by the end of 2025. As these mines are depleted, global production is expected to decline in quantity and the global supply of crude natural diamond (including gem-quality and industrial diamond) is forecasted to steadily decrease to about 120 million carats in 2030.

In 2021, U.S. synthetic-industrial-diamond producers did not manufacture any diamond stone and the combined apparent consumption of all types of industrial diamond decreased. Domestic and global demand for synthetic diamond grit and powder is expected to remain greater than that for natural diamond material. The average unit value of all types of natural and synthetic industrial diamond imports increased by 6%. In 2021, China was the leading producing country of synthetic industrial diamond, followed by the United States, Russia, Ireland, and South Africa, in descending order of quantity. These five countries produced about 99% of the world's synthetic industrial diamond. Synthetic diamond accounted for more than 99% of global industrial diamond production and consumption. Worldwide production of manufactured industrial diamond totaled more than 14.7 billion carats.

The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and is expected to remain a significant producer and exporter of synthetic industrial diamond as well. U.S. demand for industrial diamond is likely to be strong in the construction sector as the United States continues building, milling, and repairing the Nation's highway system. Industrial diamond coats the cutting edge of saws used to cut concrete in highway construction and repair work.

World Natural Industrial Diamond Mine Production and Reserves: Reserves for Australia, Botswana, Russia, and South Africa were revised based on Government and company information.

	Mine production		Reserves[6]
	2020	2021[e]	
United States	—	—	NA
Australia	11	8	[7]11
Botswana	5	6	300
Congo (Kinshasa)	10	11	150
Russia	14	15	1,100
South Africa	2	2	120
Zimbabwe	2	2	NA
Other countries	1	1	120
World total (rounded)	45	45	1,800

World Resources:[6] Natural diamond deposits have been discovered in more than 35 countries. Natural diamond accounts for about 4% of all industrial diamond used, synthetic diamond accounts for the remainder. At least 15 countries have the technology to produce synthetic diamond.

Substitutes: Materials that can compete with industrial diamond in some applications include manufactured abrasives, such as cubic boron nitride, fused aluminum oxide, and silicon carbide. Globally, synthetic diamond, rather than natural diamond, is used for about 99% of industrial applications.

[e]Estimated. NA Not available. — Zero.

[1]See Gemstones for information on gem-quality diamond.

[2]Defined as manufactured diamond production + secondary diamond production + imports – exports.

[3]Defined as imports – exports.

[4]Less than 500 carats.

[5]Includes Hong Kong.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 10 million carats.

DIATOMITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, production of diatomite, also known as diatomaceous earth, was estimated to be 830,000 tons with an estimated processed value of $274 million, free on board (f.o.b.) plant. Six companies produced diatomite at 12 mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Approximately 55% of diatomite is used in filtration products. The remaining 45% is used in absorbents, fillers, lightweight aggregates, and other applications. A small amount, less than 1%, is used for specialized pharmaceutical and biomedical purposes. The unit value of diatomite varied widely in 2021, from approximately $10 per ton when used as a lightweight aggregate in portland cement concrete to more than $1,000 per ton for limited specialty markets, including art supplies, cosmetics, and deoxyribonucleic acid (DNA) extraction.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[1]	768	957	768	822	830
Imports for consumption	9	9	10	14	14
Exports	87	68	68	66	70
Consumption, apparent[2]	690	898	710	770	770
Price, average value, f.o.b. plant, dollars per ton	360	330	340	330	330
Employment, mine and plant, number[e]	360	370	370	370	370
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2017–20): Canada, 68%; Mexico, 12%; Germany, 10%; Argentina, 4%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Siliceous fossil meals, including diatomite	2512.00.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced diatomite sold or used by producers in 2021 was essentially unchanged compared with that in 2020. Apparent domestic consumption in 2021 was the same at an estimated 770,000 tons; exports were estimated to have increased by 6%. The United States remained the leading global producer and consumer of diatomite. Filtration (including the purification of beer, liquors, and wine and the cleansing of greases and oils) continued to be the leading end use for diatomite. An important application for diatomite is the removal of microbial contaminants, such as bacteria, protozoa, and viruses in public water systems. Other applications for diatomite include filtration of human blood plasma, pharmaceutical processing, and use as a nontoxic insecticide. Domestically, diatomite used in the production of cement was the second-ranked use. Despite disruptions caused by the global COVID-19 pandemic, the production of diatomite through 2021 remained about the same as that in 2020.

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DIATOMITE

In 2021, the United States accounted for an estimated 36% of total world production; followed by Denmark with 17%; Turkey with 9%; China with 6%; and Argentina, Mexico, and Peru, each with 4%. Smaller quantities of diatomite were mined in 21 additional countries.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States[1]	822	830	250,000
Argentina	94	90	NA
China	140	140	110,000
Denmark[5] (processed)	400	400	NA
France	75	75	NA
Germany	52	50	NA
Japan	40	40	NA
Korea, Republic of	26	50	NA
Mexico	96	100	NA
New Zealand	40	40	NA
Peru	91	90	NA
Russia	51	50	NA
Spain	50	50	NA
Turkey	220	200	44,000
Other countries	120	120	NA
World total (rounded)	2,320	2,300	Large

World Resources:[4] Diatomite deposits form from an accumulation of amorphous hydrous silica cell walls of dead diatoms in oceanic and fresh waters. Diatomite is also known as kieselguhr (Germany), tripolite (after an occurrence near Tripoli, Libya), and moler (an impure Danish form). Because U.S. diatomite occurrences are at or near Earth's surface, recovery from most deposits is achieved through low-cost, open pit mining. Outside the United States, however, underground mining is fairly common owing to deposit location and topographic constraints. World resources of crude diatomite are adequate for the foreseeable future.

Substitutes: Many materials can be substituted for diatomite. However, the unique properties of diatomite assure its continued use in many applications. Expanded perlite and silica sand compete for filtration. Filters made from manufactured materials, notably ceramic, polymeric, or carbon membrane filters and filters made with cellulose fibers, are becoming competitive as filter media. Alternate filler materials include clay, ground limestone, ground mica, ground silica sand, perlite, talc, and vermiculite. For thermal insulation, materials such as various clays, exfoliated vermiculite, expanded perlite, mineral wool, and special brick can be used. Transportation costs will continue to determine the maximum economic distance that most forms of diatomite may be shipped and still remain competitive with alternative materials.

[e]Estimated. E Net exporter. NA Not available.

[1]Processed ore sold or used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes sales of moler production.

FELDSPAR AND NEPHELINE SYENITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: U.S. feldspar production in 2021 had an estimated value of $43 million. Two leading companies mined and processed about 60% of production; five other companies supplied the remainder. The five leading producing States were California, North Carolina, Oklahoma, South Dakota, and Virginia. Feldspar processors reported joint product recovery of mica and silica sand. Nepheline syenite produced in the United States was not included in production figures because the material was not considered to be marketable as a flux and was mostly used in construction applications.

Feldspar is ground to about 20 mesh for glassmaking and to 200 mesh or finer for most ceramic and filler applications. It was estimated that domestically produced feldspar was transported by ship, rail, or truck to at least 30 States and to foreign destinations, including Canada and Mexico. In pottery and glass, feldspar and nepheline syenite function as a flux. The estimated 2021 end-use distribution of domestic feldspar and nepheline syenite was glass, 65%, and ceramic tile, pottery, and other uses, 35%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, feldspar, marketable[1]	440	550	450	430	400
Imports for consumption:					
Feldspar	290	181	64	43	190
Nepheline syenite	1,460	1,070	508	503	520
Exports, feldspar	5	4	4	3	4
Consumption, apparent:[1, 2]					
Feldspar only	730	730	510	470	590
Feldspar and nepheline syenite	2,200	1,800	1,000	980	1,100
Price, average value, dollars per ton:					
Feldspar only, marketable production	62	97	107	108	110
Nepheline syenite, average unit value of imports	61	76	156	163	170
Employment, mine, preparation plant, and office, number[e]	240	240	240	240	220
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	39	24	12	8	32
Nepheline syenite	100	100	100	100	100

Recycling: Feldspar and nepheline syenite are not recycled by producers; however, glass container producers use cullet (recycled container glass), thereby reducing feldspar and nepheline syenite consumption.

Import Sources (2017–20): Feldspar: Turkey, 98%; and other, 2%. Nepheline syenite: Canada, 100%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Feldspar	2529.10.0000	Free.
Nepheline syenite	2529.30.0010	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, estimated domestic production and sales of feldspar decreased by about 6%, and the average unit value of sales slightly increased compared with that in 2020. Estimated imports of feldspar were more than fourfold those in 2020, and nepheline syenite imports increased by an estimated 3% in 2021. Imports of nepheline syenite reported by the U.S. Census Bureau in 2017 and 2018 were unusually high.

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FELDSPAR AND NEPHELINE SYENITE

Domestic feldspar consumption has been gradually shifting toward glass from ceramics. A growing segment in the glass industry was solar glass, used in the production of solar panels. Glass—including beverage containers (more than one-half of the feldspar consumed by the glass industry), plate glass, and fiberglass insulation for housing and building construction—continued to be the leading end use of feldspar in the United States.

In the United States, residential construction, in which feldspar is a raw material commonly used in the manufacture of plate glass, ceramic tiles and sanitaryware, and insulation, increased by 17% during the first 10 months of 2021 compared with that in the same period in 2020. Production and sales of feldspar are expected to increase into 2022, owing in part to low mortgage interest rates, increased demand for single-family homes as the global COVID-19 pandemic made multifamily homes less desirable, and supply shortages of materials needed in new residential construction.

A company based in Canada continued development of a feldspar-quartz-kaolin project in Idaho that contained high-grade potassium feldspar. Production was expected to be about 30,000 tons per year of potassium feldspar during a 25-year mine life. For several years, the operation has produced a low-iron and trace-element feldspathic sand product from old mine tailings, which was sold to ceramic tile producers.

World Mine Production and Reserves:[4] Reserves data for Czechia and Thailand were revised based on industry and Government information.

	Mine production		Reserves[5]
	2020	2021[e]	
United States[1]	430	400	NA
Brazil (beneficiated, marketable)	300	300	150,000
China	2,500	2,600	NA
Czechia	419	420	22,000
India	6,000	6,200	320,000
Iran	2,400	2,400	630,000
Italy	2,200	2,200	NA
Korea, Republic of	415	420	180,000
Mexico	300	500	NA
Poland	405	350	NA
Russia	300	350	NA
Spain (includes pegmatites)	650	800	NA
Thailand	1,200	1,300	220,000
Turkey	5,000	7,800	240,000
Other countries	1,920	1,900	NA
World total (rounded)	24,400	28,000	Large

World Resources:[5] Identified and undiscovered resources of feldspar are more than adequate to meet anticipated world demand. Quantitative data on resources of feldspar existing in feldspathic sands, granites, and pegmatites generally have not been compiled. Ample geologic evidence indicates that resources are large, although not always conveniently accessible to the principal centers of consumption.

Substitutes: Imported nepheline syenite was the major alternative material for feldspar. Feldspar can be replaced in some of its end uses by clays, electric furnace slag, feldspar-silica mixtures, pyrophyllite, spodumene, or talc.

[e]Estimated. NA Not available.

[1]Rounded to two significant digits to avoid disclosing company proprietary data.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]Feldspar only.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

FLUORSPAR

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, minimal fluorspar (calcium fluoride, CaF_2) was produced in the United States. One company sold fluorspar from stockpiles produced as a byproduct of its limestone quarrying operation in Cave-in-Rock, IL, and continued development of its fluorspar mine in Kentucky. In May, a second company, in Utah, began site preparations for the construction of a plant to produce metallurgical-grade fluorspar briquets. An estimated 22,000 tons of fluorosilicic acid (FSA), equivalent to about 36,000 tons of fluorspar grading 100% CaF_2, was recovered from three phosphoric acid plants processing phosphate rock and was primarily used in water fluoridation. A company in Aurora, NC, continued construction on a plant to produce hydrofluoric acid (HF) from FSA which was expected to begin operation in 2022. The U.S. Department of Energy continued to produce aqueous HF as a byproduct of the conversion of depleted uranium hexafluoride to depleted uranium oxide at plants in Paducah, KY, and Portsmouth, OH.

U.S. fluorspar consumption was satisfied by imports. Domestically, production of HF in Louisiana and Texas was by far the leading use for acid-grade fluorspar. Hydrofluoric acid is the primary feedstock for the manufacture of virtually all fluorine-bearing chemicals, particularly refrigerants and fluoropolymers, and is also a key ingredient in the processing of aluminum and uranium. Fluorspar was also used in cement production, in enamels, as a flux in steelmaking, in glass manufacture, in iron and steel casting, and in welding rod coatings.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorosilicic acid from phosphate rock	40	33	29	22	22
Imports for consumption:					
Acid grade	331	381	346	414	430
Metallurgical grade	70	78	59	65	40
Total fluorspar imports	401	459	405	480	470
Hydrofluoric acid	123	122	124	103	110
Aluminum fluoride	21	26	38	21	20
Cryolite	10	17	21	26	46
Exports, fluorspar, all grades[1]	11	9	8	9	17
Consumption, apparent[2]	390	450	398	470	450
Price, average unit value of imports, cost, insurance, and freight, dollars per ton:					
Acid grade	267	276	304	310	330
Metallurgical grade	237	258	292	149	160
Employment, mine, number[e]	19	16	14	14	14
Net import reliance[2] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Synthetic fluorspar may be produced from neutralization of waste in the enrichment of uranium, petroleum alkylation, and stainless-steel pickling; however, undesirable impurities constrain use. Primary aluminum producers recycle HF and fluorides from smelting operations.

Import Sources (2017–20):[3] Mexico, 66%; Vietnam, 16%; South Africa, 7%; Canada, 4%; and other, 7%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Metallurgical grade (less than 97% CaF_2)	2529.21.0000	Free.
Acid grade (97% or more CaF_2)	2529.22.0000	Free.
Natural cryolite	2530.90.1000	Free.
Hydrogen fluoride (hydrofluoric acid)	2811.11.0000	Free.
Aluminum fluoride	2826.12.0000	Free.
Sodium hexafluoroaluminate (synthetic cryolite)	2826.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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FLUORSPAR

Events, Trends, and Issues: Global mine production was estimated to have increased in 2021 primarily owing to the continued rampup of production at mines in Canada, Mongolia, and South Africa. Globally, several projects to produce HF from FSA also continued to progress.

Some countries continued to phase down production, consumption, and imports of non-feedstock hydrofluorocarbons (HFCs) used as aerosols, propellants, and refrigerants owing to HFCs' high global warming potential. Consumption of fluorspar in Europe decreased since the European Union's fluorinated greenhouse gas (also known as F-Gas) regulation went into effect in 2015 and several producers discontinued production of HFCs. Subsequent price increases and lack of availability have reportedly led to a resurgence in illegal imports and sales of these materials. Previous phasedowns of chlorofluorocarbons and hydrochlorofluorocarbons led to similar activity.

In response to the American Innovation and Manufacturing Act, in October, the U.S. Environmental Protection Agency established the Allowance Allocation and Trading Program as part of its final rule to phase down the production and consumption of non-feedstock HFCs by 85% over the next 15 years. The rule set baseline production and consumption levels from which reductions will be made and established a methodology for allocating and trading HFC allowances. In a related action, the White House established an interagency task force on illegal HFC trade.

The State Intellectual Property Office of China invalidated a U.S. company's patent on a manufacturing process used to produce hydrofluoroolefins (HFOs). HFOs have increasingly been adopted as low-global-warming-potential alternatives to HFCs.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States	NA	NA	4,000
Canada	100	140	NA
China	[5]5,400	[5]5,400	42,000
Germany	80	80	NA
Iran	56	56	3,400
Kazakhstan	77	77	NA
Mexico	915	990	68,000
Mongolia	685	800	22,000
Morocco	82	80	210
Pakistan	55	70	NA
South Africa	330	420	41,000
Spain	131	130	10,000
Vietnam	220	220	5,000
Other countries	110	110	120,000
World total (rounded)	8,240	8,600	320,000

World Resources:[4, 6] Large quantities of fluorine are present in phosphate rock. Current U.S. reserves of phosphate rock are estimated to be 1 billion tons, containing about 72 million tons of 100% fluorspar equivalent assuming an average fluorine content of 3.5% in the phosphate rock. World reserves of phosphate rock are estimated to be 71 billion tons, containing about 5 billion tons of 100% fluorspar equivalent.

Substitutes: FSA is used to produce aluminum fluoride (AlF_3) and HF. Because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. Aluminum smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand, and titanium dioxide have been used as substitutes for fluorspar fluxes.

[e]Estimated. NA Not available.

[1]Includes data for the following Schedule B codes: 2529.21.0000 and 2529.22.0000.

[2]Defined as total fluorspar imports – exports.

[3]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2529.21.0000 and 2529.22.0000.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]As reported by China's Ministry of Natural Resources. Likely excludes production from operations that did not meet the Government's minimum mining and processing requirements. The China Non-Metallic Minerals Industry Association estimated that actual production was closer to 6 million tons.

[6]Measured as 100% CaF_2.

GALLIUM

(Data in kilograms of contained gallium unless otherwise noted)

Domestic Production and Use: No domestic primary (low-purity, unrefined) gallium has been recovered since 1987. Globally, primary gallium is recovered as a byproduct of processing bauxite and zinc ores. One company in Utah recovered and refined high-purity gallium from imported primary low-purity gallium metal and new scrap. Imports of gallium metal and gallium arsenide (GaAs) wafers were valued at about $3 million and $200 million, respectively. GaAs was used to manufacture compound semiconductor wafers used in integrated circuits (ICs) and optoelectronic devices, which include laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells. Gallium nitride (GaN) principally was used to manufacture optoelectronic devices. ICs accounted for 77% of domestic gallium consumption, optoelectronic devices accounted for 21%, and research and development accounted for 2%. About 81% of the gallium consumed in the United States was contained in GaAs, GaN, and gallium phosphide (GaP) wafers. Gallium metal, triethyl gallium, and trimethyl gallium, used in the epitaxial layering process to fabricate epiwafers for the production of ICs and LEDs, accounted for most of the remainder. Optoelectronic devices were used in aerospace applications, consumer goods, industrial equipment, medical equipment, and telecommunications equipment. Uses of ICs included defense applications, high-performance computers, and telecommunications equipment.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	20,200	32,000	5,740	4,460	10,600
Gallium arsenide wafers (gross weight)	803,000	444,000	272,000	178,000	270,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	17,900	15,000	14,900	15,700	16,000
Price, imports, dollars per kilogram:					
High-purity, refined[1]	477	508	573	596	570
Low-purity, primary[2]	124	185	153	163	200
Stocks, consumer, yearend	2,840	2,920	2,850	2,920	2,800
Net import reliance[3] as a percentage of reported consumption	100	100	100	100	100

Recycling: Old scrap, none. Substantial quantities of new scrap generated in the manufacture of GaAs-based devices were reprocessed to recover high-purity gallium at one facility in Utah.

Import Sources (2017–20): Metal: China,[4] 53%; the United Kingdom, 11%; Germany, 9%; Ukraine, 7%; and other, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3.0% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Imports of gallium metal and GaAs wafers continued to account for all U.S. consumption of gallium. In 2021, gallium metal imports increased by an estimated 140% from those of 2020 owing to increased imports from Canada, Japan, and Singapore. Beginning in 2019, U.S. gallium metal imports decreased substantially from previous years when higher tariffs were placed on China's gallium exports to the United States.

Primary low-purity (99.99%-pure) gallium prices in China increased by an estimated 25% in 2021, to $345 per kilogram in October from approximately $275 per kilogram at yearend 2020. This followed a 96% increase in China's primary low-purity gallium prices in 2020, to $275 per kilogram in December from $140 per kilogram in January. The increases in China's gallium prices resulted from several issues. Environmental restrictions placed on Chinese bauxite production in 2019 compelled the country's alumina refineries to import bauxite with lower gallium content from abroad, which increased gallium extraction costs. When the global COVID-19 pandemic reduced gallium demand in early to mid-2020, Chinese gallium producers slowed or shut down operations. Chinese gallium supply was scarce when gallium demand resumed in the second half of 2020, and gallium prices increased significantly in the last quarter of 2020, continuing through 2021.

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GALLIUM

China's primary low-purity gallium production capacity has been approximately 650,000 kilograms per year since 2020, following an expansion from 140,000 kilograms per year in 2010. China accounted for approximately 84% of worldwide low-purity gallium capacity.

The remaining primary low-purity gallium producers outside of China most likely restricted output owing to a large surplus of primary gallium that began in 2012. These producers included Japan, the Republic of Korea, and Russia. Germany and Kazakhstan ceased primary production in 2016 and 2013, respectively. However, owing to the increase in gallium prices in 2020 and 2021, Germany announced that it would restart primary gallium production by the end of 2021. Hungary and Ukraine were thought to have ceased primary production in 2015 and 2019, respectively. High-purity refined gallium production in 2021 was estimated to be about 225,000 kilograms, a 5% increase from that in 2020. China, Japan, Slovakia, and the United States were the known principal producers of high-purity refined gallium. The United Kingdom ceased high-purity refined gallium production in 2018. Gallium was recovered from new scrap in Canada, China, Germany, Japan, Slovakia, and the United States. World primary low-purity gallium production capacity in 2021 was estimated to be 774,000 kilograms per year; high-purity refined gallium production capacity, 325,000 kilograms per year; and secondary high-purity gallium production capacity, 273,000 kilograms per year.

World Production and Reserves:

	Primary production		Reserves[5]
	2020	2021[e]	
United States	—	—	Quantitative estimates of reserves are not available.
China	317,000	420,000	
Japan	3,000	3,000	
Korea, Republic of	2,000	2,000	
Russia	5,000	5,000	
World total (rounded)	327,000	430,000	

World Resources:[5] Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of processing bauxite, and the remainder is produced from zinc-processing residues. The average gallium content of bauxite is 50 parts per million. U.S. bauxite deposits consist mainly of subeconomic resources that are not generally suitable for alumina production owing to their high silica content. Some domestic zinc ores contain up to 50 parts per million gallium and could be a significant resource, although no gallium is currently recovered from domestic ores. Gallium contained in world resources of bauxite is estimated to exceed 1 million tons, and a considerable quantity could be contained in world zinc resources. However, less than 10% of the gallium in bauxite and zinc resources is potentially recoverable.

Substitutes: Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third generation (3G) cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based ICs are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. NA Not available. — Zero.

[1]Estimated based on the average unit values of U.S. imports for 99.999%- and 99.99999%-pure gallium.

[2]Estimated based on the average unit values of U.S. imports for 99.99%-pure gallium.

[3]Defined as imports – exports. Excludes gallium arsenide wafers.

[4]Includes Hong Kong.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: In 2021, garnet for industrial use was mined by four firms—one in Idaho, one in Montana, and two in New York. One processing facility operated in Oregon and another operated in Pennsylvania. The estimated value of crude garnet production was about $15 million, and refined material sold or used had an estimated value of $53 million. The major end uses of garnet were, in descending percentage of consumption, for abrasive blasting, water-filtration media, water-jet-assisted cutting, and other end uses, such as in abrasive powders, nonslip coatings, and sandpaper. Domestic industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, filtration plants, glass polishing, the petroleum industry, shipbuilders, textile stonewashing, and wood-furniture-finishing operations.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Crude	92,900	101,000	104,000	101,000	75,000
Refined, sold or used	84,100	166,000	147,000	146,000	120,000
Imports for consumption[2]	50,400	265,000	208,000	115,000	110,000
Exports	17,700	14,200	12,600	13,600	15,000
Consumption, apparent[3]	126,000	352,000	300,000	202,000	170,000
Price, average import unit value, dollars per ton	306	215	214	250	325
Employment, mine and mill, number[e]	140	170	160	130	120
Net import reliance[4] as a percentage of apparent consumption	26	71	65	50	56

Recycling: Garnet was recycled at a plant in Oregon with a recycling capacity of 16,000 tons per year and at a plant in Pennsylvania with a recycling capacity of 25,000 tons per year. Garnet can be recycled multiple times without degradation of its quality. Most recycled garnet is from blast cleaning and water-jet-assisted cutting operations.

Import Sources (2017–20):[e] South Africa, 43%; China,[5] 22%; India, 20%; Australia, 12%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Emery, natural corundum, natural garnet, and other natural abrasives, crude	2513.20.1000	Free.
Emery, natural corundum, natural garnet, and other natural abrasives, other than crude	2513.20.9000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2021, estimated domestic production of crude garnet concentrates decreased by 26% compared with production in 2020. This decrease was due to lower production levels from a mine in Montana, although most other U.S. garnet mines also produced less compared with that in 2020. U.S. garnet production was estimated to be about 7% of total global garnet production. The 2021 estimated domestic sales or use of refined garnet decreased by about 16% compared with sales in 2020.

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GARNET (INDUSTRIAL)

Garnet imports in 2021 were estimated to have decreased slightly compared with those in 2020. This decrease was attributed to lower imports of garnet from Australia, China, and India. In 2021, the average unit value of garnet imports was $325 per ton, an increase of 30% compared with the average unit value in 2020. In the United States, most domestically produced crude garnet concentrate was priced at about $206 per ton. U.S. exports in 2021 were estimated to have increased by 11%.

During 2021, the United States consumed about 170,000 tons of garnet. This was a 16% decrease from that of 2020.

The U.S. natural gas and petroleum industry is one of the leading garnet-consuming industries, using garnet for cleaning drill pipes and well casings. Natural gas and petroleum producers also use garnet as a reservoir-fracturing proppant, alone or mixed with other proppants. During 2021, the number of drill rigs operating in the United States was 339 rigs at the beginning of the year, increasing through the year to 508 rigs at the end of September, likely indicating that more garnet was consumed in well drilling.

The garnet market is very competitive. To increase profitability and remain competitive with imported material, production may be restricted to only high-grade garnet ores or as a byproduct of other salable mineral products that occur with garnet, such as kyanite, marble, metallic ore minerals, mica minerals, sillimanite, staurolite, or wollastonite.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	101,000	75,000	5,000,000
Australia	360,000	360,000	Moderate to large
China	310,000	310,000	Moderate to large
India	130,000	130,000	13,000,000
South Africa	140,000	140,000	NA
Other countries	60,000	60,000	6,500,000
World total (rounded)	1,100,000	1,100,000	Moderate to large

World Resources:[6] World resources of garnet are large and occur in a wide variety of rocks, particularly gneisses and schists. Garnet also occurs in contact-metamorphic deposits in crystalline limestones, pegmatites, and serpentinites and in vein deposits. In addition, alluvial garnet is present in many heavy-mineral sand and gravel deposits throughout the world. Large domestic resources of garnet also are concentrated in coarsely crystalline gneiss near North Creek, NY; other significant domestic resources of garnet occur in Idaho, Maine, Montana, New Hampshire, North Carolina, and Oregon. In addition to those in the United States, major garnet deposits exist in Australia, Canada, China, India, and South Africa, where they are mined for foreign and domestic markets; deposits in Russia and Turkey also have been mined in recent years, primarily for internal markets. Additional garnet resources are in Chile, Czechia, Pakistan, Spain, Thailand, and Ukraine; small mining operations have been reported in most of these countries.

Substitutes: Other natural and manufactured abrasives can substitute to some extent for all major end uses of garnet. In many cases, however, using the substitutes would entail sacrifices in quality or cost. Fused aluminum oxide and staurolite compete with garnet as a sandblasting material. Ilmenite, magnetite, and plastics compete as filtration media. Corundum, diamond, and fused aluminum oxide compete for lens grinding and for many lapping operations. Emery is a substitute in nonskid surfaces. Fused aluminum oxide, quartz sand, and silicon carbide compete for the finishing of plastics, wood furniture, and other products.

[e]Estimated. NA Not available.

[1]Excludes gem and synthetic garnet.

[2]Sources: U.S. Census Bureau and Trade Mining, LLC; data adjusted by the U.S. Geological Survey.

[3]Defined as crude production + imports – exports.

[4]Defined as imports – exports.

[5]Includes Hong Kong.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

GEMSTONES[1]

(Data in million dollars unless otherwise noted)

Domestic Production and Use: The combined value of U.S. natural and synthetic gemstone output in 2021 was an estimated $95 million, a 25% increase compared with that in 2020. Domestic gemstone production included agate, beryl, coral, diamond, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise, and many other gem materials. In descending order of production value, Arizona led the Nation in natural gemstone production and Oregon was second. The other top producing States were Arkansas, California, Colorado, Idaho, Maine, Montana, Nevada, New York, North Carolina, Tennessee, and Utah. These 13 States produced 96% of U.S. natural gemstones. Synthetic gemstones were manufactured by five companies in California, North Carolina, New York, Maryland, and Arizona, in decreasing order of production value. U.S. synthetic gemstone production increased by 29% compared with that in 2020. Major gemstone end uses were carvings, gem and mineral collections, and jewelry.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:[2]					
Natural[3]	9.2	9.5	9.2	9.8	10
Laboratory-created (synthetic)	55	65	94	66	85
Imports for consumption	24,900	27,700	24,400	16,300	24,000
Exports, excluding reexports	2,440	1,850	1,020	1,320	900
Consumption, apparent[4]	22,500	25,900	23,500	15,100	23,000
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,120	1,120	1,120	1,100	1,100
Net import reliance[5] as a percentage of apparent consumption	99	99	99	99	99

Recycling: Gemstones are often recycled by being resold as estate jewelry, reset, or recut, but this report does not account for those stones.

Import Sources (2017–20, by value): Diamond: India, 41%; Israel, 31%; Belgium, 12%; South Africa, 4%; and other, 12%. Diamond imports accounted for an average of 90% of the total value of gem imports.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Coral and similar materials, unworked	0508.00.0000	Free.
Imitation gemstones	3926.90.4000	2.8% ad valorem.
Pearls, imitation, pearl beads, not strung	7018.10.1000	4.0% ad valorem.
Imitation gemstones, glass beads	7018.10.2000	Free.
Pearls, natural, graded and temporarily strung	7101.10.3000	Free.
Pearls, natural, other	7101.10.6000	Free.
Pearls, cultured	7101.21.0000	Free.
Diamonds, unworked or sawn	7102.31.0000	Free.
Diamonds, ½ carat or less	7102.39.0010	Free.
Diamonds, cut, more than ½ carat	7102.39.0050	Free.
Other nondiamond gemstones, unworked	7103.10.2000	Free.
Other nondiamond gemstones, uncut	7103.10.4000	10.5% ad valorem.
Rubies, cut	7103.91.0010	Free.
Sapphires, cut	7103.91.0020	Free.
Emeralds, cut	7103.91.0030	Free.
Other nondiamond gemstones, cut	7103.99.1000	Free.
Other nondiamond gemstones, worked	7103.99.5000	10.5% ad valorem.
Synthetic gemstones, cut but not set	7104.90.1000	Free.
Synthetic gemstones, other	7104.90.5000	6.4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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GEMSTONES

Events, Trends, and Issues: During 2021, the U.S. and global gemstone and jewelry industries began recovering from the effects of the COVID-19 pandemic restrictions, lockdowns, and temporary mine and store closings. The largest production decreases in 2020 were from Australia, Botswana, Canada, and Russia. Total world diamond production during 2021 increased slightly from 2020 levels and was driven by the reopening of profitable mines that were suspended in 2020. Production would need to increase by up to 2% per year during the next 3 to 5 years to allow the market to fully rebalance.

New sales platforms were established during 2020 and remained in place during 2021 in the rough diamond market to overcome travel constraints and streamline the journey from the mine to the jeweler. Online auctions gained a higher share of rough diamond sales and offset deficits in traditional sales channels. Many jewelry stores successfully shifted sales to their websites. Global gemstone sales are expected to increase at a steady rate over the next 5 years.

In 2021, U.S. imports for consumption of gemstones were about $24 billion, which was a 49% increase compared with $16.3 billion in 2020. These imports consisted of about $21 billion in gem-quality diamonds, which was a 49% increase compared with $14.3 billion in 2020, and about $2.9 billion in nondiamond gemstones, which was a 51% increase compared with $1.9 billion in 2020. The increase in U.S. gem production combined with the growth in U.S. gem imports and the decrease in gem exports produced a 52% increase in apparent consumption to a value of $23 billion. The United States was the leading global market in terms of sales. The United States is expected to continue to dominate global gemstone demand.

World Gem Diamond Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2020	2021[e]	
United States	—	—	World reserves of diamond-bearing deposits are substantial. No reserves data are available for other gemstones.
Angola	6,960	7,100	
Australia	219	220	
Botswana	11,900	12,000	
Brazil	125	130	
Canada	13,100	13,000	
Congo (Kinshasa)	2,550	2,600	
Guinea	103	100	
Lesotho	481	490	
Namibia	1,550	1,600	
Russia	17,500	18,000	
Sierra Leone	513	520	
South Africa	6,780	6,900	
Tanzania	110	110	
Zimbabwe	267	270	
Other countries	142	140	
World total (rounded)	62,300	63,000	

World Resources:[7] Most diamond ore bodies have a diamond content that ranges from less than 1 carat per ton to about 6 carats per ton of ore. The major diamond reserves are in southern Africa, Australia, Canada, and Russia.

Substitutes: Glass, plastics, and other materials are substituted for natural gemstones. Synthetic gemstones (manufactured materials that have the same chemical and physical properties as natural gemstones) are common substitutes. Simulants (materials that appear to be gems but differ in chemical and physical characteristics) also are frequently substituted for natural gemstones.

[e]Estimated.

[1]Excludes industrial diamond and industrial garnet. See Diamond (Industrial) and Garnet (Industrial).

[2]Estimated minimum production.

[3]Includes production of freshwater shell.

[4]Defined as production (natural and synthetic) + imports – exports (excluding reexports).

[5]Defined as imports – exports (excluding reexports).

[6]Data in thousands of carats of gem diamond.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

GERMANIUM

(Data in kilograms of contained germanium unless otherwise noted)

Domestic Production and Use: In 2021, zinc concentrates containing germanium were produced at mines in Alaska and Tennessee. Germanium-containing concentrates in Alaska were exported to a refinery in Canada for processing and germanium recovery. A zinc smelter in Clarksville, TN, produced and exported germanium leach concentrates recovered from processing zinc concentrates from the Middle Tennessee mine complex. Germanium in the form of compounds and metal was imported into the United States for further processing by industry. A company in Utah produced germanium wafers for solar cells used in satellites from imported and recycled germanium. A refinery in Oklahoma recovered germanium from industry-generated scrap and produced germanium tetrachloride for the production of fiber optics. The estimated value of germanium consumed in 2021, based on the annual average germanium metal price, was $36 million, 15% more than that in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery:					
Primary	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Germanium metal	11,100	11,900	14,000	18,300	13,000
Germanium dioxide[e, 1]	12,000	12,200	21,000	12,000	17,000
Exports[e, 2]	3,670	4,880	4,600	7,100	6,600
Shipments from Government stockpile	—	—	—	—	—
Consumption, estimated[3]	30,000	30,000	30,000	30,000	30,000
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,082	1,543	1,236	1,046	1,200
Germanium dioxide	731	1,084	913	724	770
Net import reliance[5] as a percentage of estimated consumption	>50%	>50%	>50%	>50%	>50%

Recycling: Worldwide, it has been estimated that about 30% of the total germanium consumed is produced from recycled materials. During the manufacture of most optical devices, more than 60% of the germanium metal used is routinely recycled as new scrap. Germanium scrap is also recovered from the windows in decommissioned tanks and other military vehicles. The United States has the capability to recycle new and old scrap.

Import Sources (2017–20):[6] Germanium metal: China, 53%; Belgium, 22%; Germany, 11%; Russia, 9%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad valorem.
Metal, unwrought	8112.92.6000	2.6% ad valorem.
Metal, powder	8112.92.6500	4.4% ad valorem.
Metal, wrought	8112.99.1000	4.4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile:[7]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Germanium metal	14,000	—	—	—	5,000
Germanium scrap (gross weight)	6,170	—	3,000	—	—
Germanium wafers (each)	68,700	—	—	—	—

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GERMANIUM

Events, Trends, and Issues: The major global end uses for germanium were electronics and solar applications, fiber-optic systems, infrared optics, polymerization catalysts, and other uses (such as chemotherapy, metallurgy, and phosphors).

Prices for germanium dioxide and metal trended upward during 2021. During the first 10 months of the year, the price for germanium metal (minimum 99.999% purity) increased by 21% to $1,315 per kilogram from $1,090 per kilogram, and the price for germanium dioxide (minimum 99.999% purity) increased by 15% to $825 per kilogram from $720 per kilogram.

In 2021, a high-purity metals and compounds producer with a germanium wafer production facility in Utah acquired a Germany-based manufacturer of multijunction germanium solar cells for space and terrestrial applications. An advanced materials producer with a germanium production facility in Oklahoma announced that a new generation of solar arrays using germanium substrates were produced for the International Space Station to replace the existing silicon-based solar arrays. Similar germanium solar cell technology would also be used to power the National Aeronautics and Space Administration's Gateway space station currently under development.

China was a leading global exporter of germanium in 2021. Exports of unwrought germanium, germanium powders, and germanium waste and scrap (China's export code 8112.99.10) for the year through September were 27,800 kilograms, 24% more than exports in the same period in 2020. Nearly all exports were sent to Russia, Germany, Hong Kong, Belgium, Japan, and the United States, in descending order of quantity.

World Refinery Production and Reserves:

	Refinery production[e, 8]		Reserves[9]
	2020	2021	
United States	W	W	Data on the recoverable germanium content of zinc ores are not available.
China	95,000	95,000	
Russia	5,000	5,000	
Other countries[10]	40,000	40,000	
World total (rounded)[11]	140,000	140,000	

World Resources:[9] The available resources of germanium are associated with certain zinc and lead-zinc-copper sulfide ores. Substantial U.S. reserves of recoverable germanium are contained in zinc deposits in Alaska, Tennessee, and Washington. Based on an analysis of zinc concentrates, U.S. reserves of zinc may contain as much as 2,500 tons of germanium. Because zinc concentrates are shipped globally and blended at smelters, however, the recoverable germanium in zinc reserves cannot be determined. On a global scale, as little as 3% of the germanium contained in zinc concentrates is recovered. Significant amounts of germanium are contained in ash and flue dust generated in the combustion of certain coals for power generation.

Substitutes: Silicon can be a less-expensive substitute for germanium in certain electronic applications. Some metallic compounds can be substituted in high-frequency electronics applications and in some light-emitting-diode applications. Zinc selenide and germanium glass substitute for germanium metal in infrared applications systems, but often at the expense of performance. Antimony and titanium are substitutes for use as polymerization catalysts.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Data have been adjusted to exclude low-value shipments, then multiplied by 69% to account for germanium content.

[2]Includes Schedule B numbers: 8112.92.6100, 8112.99.1000, and 2825.60.0000. Data have been adjusted to exclude low-value shipments. Oxide data have been multiplied by 69% to account for germanium content.

[3]Estimated consumption of germanium contained in metal and germanium dioxide.

[4]Average European price for minimum 99.999% purity. Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports + adjustments for Government stock changes.

[6]Import sources are based on gross weight of wrought and unwrought germanium metal and germanium metal powders.

[7]See Appendix B for definitions.

[8]Includes primary and secondary production.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Includes Belgium, Canada, Germany, Japan, and Ukraine.

[11]Excludes U.S. production.

GOLD

(Data in metric tons[1] of contained gold unless otherwise noted)

Domestic Production and Use: In 2021, domestic gold mine production was estimated to be 180 tons, 7% less than that in 2020, and the value was estimated to be about $10 billion. Gold was produced at more than 40 lode mines in 11 States, at several large placer mines in Alaska, and at numerous smaller placer mines (mostly in Alaska and in the Western States). Nevada was the leading gold-producing State, accounting for about 74% of total domestic production. About 6% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper ores. The top 26 operations yielded about 98% of the mined gold produced in the United States. Commercial-grade gold was produced at about 15 refineries. A few dozen companies, out of several thousand companies and artisans, dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and Providence, RI, areas, with lesser concentrations in California, Florida, and Texas. Estimated global gold consumption was jewelry, 47%; physical bar, 21%; central banks and other institutions, 14%; official coins and medals and imitation coins, 10%; electrical and electronics, 7%; and other, 1%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine	237	226	200	193	180
Refinery:					
Primary	207	205	205	181	180
Secondary (new and old scrap)	119	117	116	92	90
Imports for consumption[2]	255	213	199	545	190
Exports[2]	461	474	360	297	400
Consumption, reported[3]	159	154	151	185	250
Stocks, Treasury, yearend[4]	8,130	8,130	8,130	8,130	8,130
Price, dollars per troy ounce[5]	1,261	1,272	1,395	1,774	1,800
Employment, mine and mill, number[6]	11,900	12,200	12,400	12,500	12,400
Net import reliance[7] as a percentage of apparent consumption[8]	E	E	E	47	E

Recycling: In 2021, an estimated 90 tons of new and old scrap was recycled, equivalent to about 36% of reported consumption. The domestic supply of gold from recycling decreased slightly compared with that of 2020.

Import Sources (2017–20): Ores and concentrates: Greece, 48%; Ireland, 37%; Canada, 11%; and Germany, 4%. Dore: Mexico, 45%; Colombia and Peru, 11% each; Canada, 7%; and other, 26%. Bullion: Switzerland, 34%; Canada, 24%; Singapore, 7%; and other, 35%. Combined total: Mexico, 22%; Switzerland, 21%; Canada, 17%; Peru, 8%; and other, 32%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Precious metal ore and concentrates:		
Gold content of silver ores	2616.10.0080	0.8 ¢/kg on lead content.
Gold content of other ores	2616.90.0040	1.7 ¢/kg on lead content.
Gold bullion	7108.12.1013	Free.
Gold dore	7108.12.1020	Free.
Gold scrap	7112.91.0000	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of gold (see salient statistics above), and the U.S. Department of Defense administers a Governmentwide secondary precious-metals recovery program.

Events, Trends, and Issues: The estimated gold price in 2021 was slightly higher than the previous record-high annual price in 2020.The Engelhard daily price of gold in 2021 fluctuated in the first and second quarters. Early in the year, the gold price was about $1,840 per troy ounce before decreasing in March and increasing through May. Several factors were reported to have caused the increase in price: gold demand for safe-haven buying increased owing to the continued global COVID-19 pandemic, global investor uncertainty, and the U.S. Federal Reserve Board low interest rates. The price decreased slightly from June through October and then increased in November.

In 2021, worldwide gold mine production was estimated to be slightly less than that in 2020. Decreased gold mine production in Papua New Guinea, Russia, and the United States more than offset production increases in China, Ghana, Indonesia, South Africa, and Tanzania.

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GOLD

In the first 9 months of 2021, global consumption of gold in physical bars increased by about 58%, in jewelry by 49%, in industrial applications by 16%, in electronics by about 13%, and in official coins and medals and imitation coins by about 6% compared with that in the first 9 months of 2020. Global investments in gold-based exchange-traded funds decreased by almost 116%, while gold holdings in central banks doubled during the same period.

World Mine Production and Reserves: Reserves for Australia, Papua New Guinea, Peru, Russia, and South Africa were revised based on Government and (or) industry reports

	Mine production		Reserves[9]
	2020	2021[e]	
United States	193	180	3,000
Argentina	59	60	1,600
Australia	328	330	[10]11,000
Brazil	78	80	2,400
Burkina Faso	58	60	NA
Canada	170	170	2,200
China	365	370	2,000
Colombia	48	50	NA
Ghana	125	130	1,000
Indonesia	86	90	2,600
Kazakhstan	63	60	1,000
Mexico	102	100	1,400
Papua New Guinea	54	50	1,100
Peru	87	90	2,000
Russia	305	300	6,800
South Africa	96	100	5,000
Sudan	90	90	NA
Tanzania	47	50	NA
Uzbekistan	101	100	1,800
Other countries	572	570	9,200
World total (rounded)	3,030	3,000	54,000

World Resources:[9] An assessment of U.S. gold resources indicated 33,000 tons of gold in identified (15,000 tons) and undiscovered (18,000 tons) resources.[11] Nearly one-quarter of the gold in undiscovered resources was estimated to be contained in porphyry copper deposits. The gold resources in the United States, however, are only a small portion of global gold resources.

Substitutes: Base metals clad with gold alloys are widely used to economize on gold in electrical and electronic products and in jewelry; many of these products are continually redesigned to maintain high-utility standards with lower gold content. Generally, palladium, platinum, and silver may substitute for gold.

[e]Estimated. E Net exporter. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Includes refined bullion, dore, ores, concentrates, and precipitates. Excludes waste and scrap, official monetary gold, gold in fabricated items, gold in coins, and net bullion flow (in tons) to market from foreign stocks at the New York Federal Reserve Bank.

[3]Includes gold used in the production of consumer purchased bar, coins, and jewelry. Excludes gold as an investment (except consumer purchased bar and coins). Source: World Gold Council.

[4]Includes gold in Exchange Stabilization Fund. Stocks were valued at the official price of $42.22 per troy ounce.

[5]Engelhard's average gold price quotation for the year. In 2021, the price was estimated by the U.S. Geological Survey based on data from January through November.

[6]Data from the Mine Safety and Health Administration.

[7]Defined as imports – exports.

[8]Defined as mine production + secondary production + imports – exports.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 4,000 tons.

[11]U.S. Geological Survey National Mineral Resource Assessment Team, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

GRAPHITE (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, natural graphite was not produced in the United States; however, approximately 95 U.S. companies, primarily in the Great Lakes and Northeastern regions and Alabama and Tennessee, consumed 45,000 tons valued at an estimated $41 million. The major uses of natural graphite were batteries, brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2021, U.S. natural graphite imports were an estimated 53,000 tons, which were about 57% flake and high-purity, 42% amorphous, and 1% lump and chip graphite.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine	—	—	—	—	—
Imports for consumption	51,900	70,700	50,300	36,000	53,000
Exports	13,900	9,950	5,890	5,930	8,400
Consumption, apparent[1]	38,000	60,700	44,400	30,000	45,000
Price, average value of imports, dollars per ton at foreign ports:					
Flake	1,390	1,520	1,350	1,540	1,600
Lump and chip (Sri Lanka)	1,900	1,890	2,380	2,940	2,700
Amorphous	451	319	498	687	630
Net import reliance[1] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Refractory brick and linings, alumina-graphite refractories for continuous metal castings, magnesia-graphite refractory brick for basic oxygen and electric arc furnaces, and insulation brick led the way in the recycling of graphite products. Recycling of refractory graphite material is increasing, with material being recycled into products such as brake linings and thermal insulation. Recovering high-quality flake graphite from steelmaking kish is technically feasible, but currently not practiced. The abundance of graphite in the world market inhibits increased recycling efforts. Information on the quantity and value of recycled graphite is not available.

Import Sources (2017–20): China, 33%; Mexico, 21%; Canada, 17%; India, 9%; and other, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Crystalline flake (not including flake dust)	2504.10.1000	Free.
Powder	2504.10.5000	Free.
Other	2504.90.0000	Free.

Depletion Allowance: Lump and amorphous, 22% (domestic) and flake, 14% (domestic); 14% (foreign).

Government Stockpile:[2]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Graphite	—	—	—	900	—

Events, Trends, and Issues: U.S. natural graphite exports decreased each year from 2017 to 2019, remained essentially unchanged in 2020, and then increased by 41% in 2021. This was still an overall 40% decline for the 5-year period of 2017 to 2021. U.S. imports for consumption and apparent consumption peaked in 2018, and imports and apparent consumption declined during 2019 and 2020. During 2021, U.S. imports for consumption and apparent consumption increased by 48% and 50%, respectively, as recovery from the COVID-19 pandemic began.

During 2021, China was the world's leading graphite producer, producing an estimated 79% of total world output. Approximately 24% of production in China was amorphous graphite and about 76% was flake. China produced some large flake graphite, but much of its flake graphite production was very small, in the +200-mesh range. China also processed most of the world's spherical graphite. Globally, during 2021, graphite supplies began recovering from the effects that the global COVID-19 pandemic had during 2020. In 2021, global graphite production was estimated to have increased by 7.6% from 2020 production. In China, the recovery was quick, which was demonstrated by China's pattern of exports. Chinese producers quickly increased production after a few months of closures in 2020. This allowed China to gain a more dominant position in the market for 2021 and slowed down the diversification of the supply chain.

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GRAPHITE (NATURAL)

North America produced only 1.2% of the world's graphite supply with production in Canada and Mexico. Two companies were developing graphite mining projects in the United States—one in Alabama and one in Alaska.

Large graphite deposits were being developed in Madagascar, northern Mozambique, Namibia, and south-central Tanzania. A graphite mine in Mozambique in a high-grade graphite deposit was reportedly the largest natural graphite mine globally. The mine was expected to operate for about 50 years.

A U.S. automaker continued building a large plant to manufacture lithium-ion electric vehicle batteries. The completed portion of the plant was operational, and it produced battery cells, battery packs, drive units, and energy storage products. At full capacity, the plant was expected to require 35,200 tons per year of spherical graphite for use as anode material for lithium-ion batteries.

An Australian company was producing purified coated spherical graphite for use as lithium-ion battery anode material from its plant in Vidalia, LA, challenging China's hold on global production of purified coated spherical graphite.

New thermal technology and acid-leaching techniques have enabled the production of higher purity graphite powders that are likely to lead to development of new applications for graphite in high-technology fields. Innovative refining techniques have made the use of graphite possible in carbon-graphite composites, electronics, foils, friction materials, and specialty lubricant applications. Flexible graphite product lines are likely to be the fastest growing market. Large-scale fuel-cell applications are being developed that could consume as much graphite as all other uses combined.

World Mine Production and Reserves: Reserves for Tanzania were revised based on information reported by graphite-producing companies and Government reports.

	Mine production		Reserves[3]
	2020	2021[e]	
United States	—	—	([4])
Austria	500	500	([4])
Brazil	63,600	68,000	70,000,000
Canada	8,000	8,600	([4])
China	762,000	820,000	73,000,000
Germany	300	300	([4])
India	6,000	6,500	8,000,000
Korea, North	8,100	8,700	2,000,000
Madagascar	20,900	22,000	26,000,000
Mexico	3,300	3,500	3,100,000
Mozambique	28,000	30,000	25,000,000
Norway	12,000	13,000	600,000
Russia	25,000	27,000	([4])
Sri Lanka	4,000	4,300	1,500,000
Tanzania	—	150	18,000,000
Turkey	2,500	2,700	90,000,000
Ukraine	16,000	17,000	([4])
Uzbekistan	100	110	7,600,000
Vietnam	5,000	5,400	([4])
World total (rounded)	966,000	1,000,000	320,000,000

World Resources:[3] Domestic resources of graphite are relatively small, but the rest of the world's identified resources exceed 800 million tons of recoverable graphite.

Substitutes: Synthetic graphite powder, scrap from discarded machined shapes, and calcined petroleum coke compete for use in iron and steel production. Synthetic graphite powder and secondary synthetic graphite from machining graphite shapes compete for use in battery applications. Finely ground coke with olivine is a potential competitor in foundry-facing applications. Molybdenum disulfide competes as a dry lubricant but is more sensitive to oxidizing conditions.

[e]Estimated. — Zero.

[1]Defined as imports – exports.

[2]See Appendix B for definitions.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Included with "World total."

GYPSUM

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, domestic production of crude gypsum was estimated to be 23 million tons with a value of about $210 million. The leading crude gypsum-producing States were estimated to be California, Iowa, Kansas, Nevada, Oklahoma, Texas, and Utah. Overall, 47 companies produced or processed gypsum in the United States at 52 mines in 16 States. The majority of domestic consumption, which totaled approximately 43 million tons, was used by agriculture, cement production, and manufacturers of wallboard and plaster products. Small quantities of high-purity gypsum, used in a wide range of industrial processes, accounted for the remaining tonnage. At the beginning of 2021, the production capacity of 63 operating gypsum panel manufacturing plants in the United States was about 34.1 billion square feet[1] per year. Total wallboard sales in 2021 were estimated to be 28.0 billion square feet.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Crude	20,700	21,100	21,700	21,200	23,000
Synthetic[2]	20,700	16,600	14,400	13,000	13,000
Calcined[3]	17,800	17,500	17,900	17,900	19,000
Wallboard products sold, million square feet[1]	25,000	23,700	25,900	26,200	28,000
Imports, crude, including anhydrite	4,800	5,210	6,140	6,030	6,900
Exports, crude, not ground or calcined	36	36	37	32	35
Consumption, apparent[4]	46,200	42,900	42,200	40,200	43,000
Price, average, dollars per metric ton:					
Crude, free on board (f.o.b.) mine	7.5	8.3	8.6	8.6	9
Calcined, f.o.b. plant	30	32	34	5	37
Employment, mine and calcining plant, number[e]	4,500	4,500	4,500	4,500	4,500
Net import reliance[5] as a percentage of apparent consumption	10	12	15	15	16

Recycling: Approximately 700,000 tons of gypsum scrap that was generated by wallboard manufacturing was recycled onsite. The recycling of wallboard from new construction and demolition sources also took place, although those amounts are unknown. Recycled gypsum was used primarily for agricultural purposes and feedstock for the manufacture of new wallboard. Other potential markets for recycled gypsum include athletic-field marking, cement production (as a stucco additive), grease absorption, sludge drying, and water treatment.

Import Sources (2017–20): Mexico, 36%; Spain, 32%; Canada, 29%; and other, 3%.

Tariff:	**Item**	**Number**	**Normal Trade Relations 12–31–21**
Gypsum; anhydrite		2520.10.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. crude gypsum production increased by an estimated 8%, and apparent consumption increased by 7% compared with that in 2020. U.S. gypsum imports increased by an estimated 14% compared with those in 2020. Exports, although very low compared with imports and often subject to wide fluctuations, increased by an estimated 9%.

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GYPSUM

Demand for gypsum depends principally on construction industry activity, particularly in the United States, where the majority of gypsum consumed is used for agriculture, building plasters, the manufacture of portland cement, and wallboard products. Despite disruptions caused by the global COVID-19 pandemic, the production of gypsum was not affected.

The United States, the world's leading crude gypsum producer, produced an estimated 23 million tons. Iran was the second-leading producer with an estimated 16 million tons of crude production, followed by China with 13 million tons. Increased use of wallboard in Asia, coupled with new gypsum product plants, spurred increased production in the region. As wallboard becomes more widely used, worldwide gypsum production is expected to increase.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	21,200	23,000	700,000
Algeria	2,500	2,500	NA
Brazil	2,000	2,000	450,000
Canada	2,400	2,900	450,000
China	12,600	13,000	NA
France	1,890	1,900	350,000
Germany	4,500	4,500	NA
India	1,500	1,500	37,000
Iran	16,000	16,000	NA
Japan	4,300	4,300	NA
Mexico	5,400	5,400	NA
Oman	10,200	10,000	NA
Pakistan	2,210	2,200	6,000
Russia	4,200	4,200	NA
Saudi Arabia	3,300	3,300	NA
Spain	11,000	11,000	NA
Thailand	9,800	9,800	1,700
Turkey	7,500	9,300	200,000
Other countries	21,700	22,000	NA
World total (rounded)	144,000	150,000	Large

World Resources:[6] Reserves are large in major producing countries, but data for most are not available. Domestic gypsum resources are adequate but unevenly distributed. Large imports from Canada augment domestic supplies for wallboard manufacturing in the United States, particularly in the eastern and southern coastal regions. Imports from Mexico supplement domestic supplies for wallboard manufacturing along portions of the United States western seaboard. Large gypsum deposits occur in the Great Lakes region, the midcontinent region, and several Western States. Foreign resources are large and widely distributed; 78 countries were thought to produce gypsum in 2021.

Substitutes: In such applications as stucco and plaster, cement and lime may be substituted for gypsum; brick, glass, metallic or plastic panels, and wood may be substituted for wallboard. Gypsum has no practical substitute in the manufacturing of portland cement. Synthetic gypsum generated by various industrial processes, including flue gas desulfurization of smokestack emissions, is very important as a substitute for mined gypsum in wallboard manufacturing, cement production, and agricultural applications (in descending order by tonnage). In 2021, synthetic gypsum was estimated to account for about 30% of the total domestic gypsum supply.

[e]Estimated. NA Not available.

[1]The standard unit used in the U.S. wallboard industry is square feet; multiply square feet by 9.29×10^{-2} to convert to square meters. Source: The Gypsum Association.

[2]Synthetic gypsum used; the majority of these data were obtained from the American Coal Ash Association.

[3]From domestic crude and synthetic gypsum.

[4]Defined as domestic crude production + synthetic used + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

HELIUM

(Data in million cubic meters of contained helium gas[1] unless otherwise noted)

Domestic Production and Use: The estimated value of Grade-A helium (99.997% or greater) extracted during 2021 by private industry was about $540 million. Fifteen plants (one in Arizona, two in Colorado, five in Kansas, one in New Mexico, one in Oklahoma, four in Texas, and one in Utah) extracted helium from natural gas and produced crude helium that ranged from 50% to 99% helium. One plant in Colorado and another in Wyoming extracted helium from natural gas and produced Grade-A helium. Three plants in Kansas and one in Oklahoma accepted crude helium from other producers and the Bureau of Land Management (BLM) pipeline and purified it to Grade-A helium. In 2021, estimated domestic apparent consumption of Grade-A helium was 40 million cubic meters (1.4 billion cubic feet), and it was used for, in descending order by estimated quantity, magnetic resonance imaging, lifting gas, analytical and laboratory applications, electronics and semiconductor manufacturing, welding, engineering and scientific applications, and various other minor applications.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Helium extracted from natural gas[2]	81	76	72	76	71
Withdrawn from storage[3]	22	22	17	7	6
Grade-A helium sales	103	98	89	83	77
Imports for consumption	19	8	7	7	9
Exports[e, 4]	74	66	56	50	46
Consumption, apparent[5]	48	40	40	40	40
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

In fiscal year (FY) 2021, the price for crude helium to Government users was $3.61 per cubic meter ($100.00 per thousand cubic feet). The BLM does not post a conservation helium price; conservation helium prices were last posted by the Federal Government in 2018. The estimated price for private industry's Grade-A helium was about $7.57 per cubic meter ($210 per thousand cubic feet), with some producers posting surcharges to this price.

Recycling: In the United States, helium used in large-volume applications is seldom recycled. Some low-volume or liquid boil-off recovery systems are used. In the rest of the world, helium recycling is more common.

Import Sources (2017–20): Qatar, 65%; Algeria, 12%; Canada, 11%; Portugal, 7%; and other, 5%.

Tariff:	Item	Number	Normal Trade Relations 12–31–21
Helium		2804.29.0010	3.7% ad valorem.

Depletion Allowance: Allowances are applicable to natural gas from which helium is extracted, but no allowance is granted directly to helium.

Government Stockpile:[7] Under the Helium Stewardship Act of 2013, the BLM manages the Federal Helium Program, which includes all operations of the Cliffside Field helium storage reservoir, in Potter County, TX, and the Government's crude helium pipeline system. Private firms that sell Grade-A helium to Federal agencies are required to purchase a like amount of (in-kind) crude helium from the BLM. The law mandated that the BLM sell at auction Federal Conservation helium stored in Bush Dome at the Cliffside Field. The last auction was completed in summer 2018. The remaining conservation helium is about 85.7 million cubic meters (3.09 billion cubic feet). The Helium Stewardship Act requires that the BLM dispose of all helium assets including the Cliffside Field helium storage reservoir and pipeline system. The BLM will continue to make in-kind helium available to Federal customers until summer 2022. In FY 2021, privately owned companies purchased about 5.88 million cubic meters (0.212 billion cubic feet) of in-kind crude helium. During FY 2021, the BLM's Amarillo Field Office, Helium Operations, accepted about 8.0 million cubic meters (0.288 billion cubic feet) of private helium for storage and redelivered nearly 18.7 million cubic meters (0.674 billion cubic feet). As of September 30, 2021, about 82.1 million cubic meters (2.96 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

	Inventory	Authorized	Disposal plan	
Material	as of 9–30–21	for disposal	FY 2022	FY 2023
Helium	85.7	85.7	5.88	79.2

Events, Trends, and Issues: Helium production in 2021 decreased in the United States owing to several unplanned shutdowns taking place, including the BLM Crude Helium Enrichment Unit. As of September 2021, the BLM completed sales of the remaining Federal helium inventory and transferred responsibility for the sale of the remaining assets to the General Services Administration. Federal in-kind users were to have access to helium until

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HELIUM

September 30, 2022. In Russia, a 60-million-cubic-meter-per-year helium-processing plant was commissioned. The first of three 20-million-cubic-meter-per-year trains started production in fall 2021; the next train was scheduled to be completed in February 2022.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

World Mine Production and Reserves:[9] Reserves for the United States and Poland were revised based on Government information.

	Mine production		Reserves[10]
	2020	2021[e]	
United States (extracted from natural gas)	76	71	8,500
United States (from Cliffside Field)	7	6	86
Algeria	14	14	1,800
Australia	4	4	NA
Canada	<1	<1	NA
China	1	1	NA
Poland	1	1	24
Qatar	51	51	Large
Russia	5	9	1,700
World total (rounded)	160	160	NA

World Resources:[10] Section 16 of Public Law 113–40 required the U.S. Geological Survey (USGS) to complete a national helium gas assessment. The USGS and the BLM coordinated efforts to complete this assessment, which was published by the USGS in fall 2021.[11] The mean volume of recoverable helium within the known geologic natural gas reservoirs in the United States was estimated to be 8,490 million cubic meters (306 billion cubic feet). This does not include the remaining 85.7 million cubic meters (3 billion cubic feet) in the Federal helium inventory. The estimated mean for the Alaska region was 1.11 million cubic meters (0.04 billion cubic feet); the Gulf Coast region, 12.5 million cubic meters (0.45 billion cubic feet); the Midcontinent region, 4,330 million cubic meters (156 billion cubic feet); the North Central region, 52.7 million cubic meters (1.9 billion cubic feet); and the Rocky Mountain region 4,110 million cubic meters (148 billion cubic feet).

Helium resources of the world, exclusive of the United States, were estimated to be about 31.3 billion cubic meters (1.13 trillion cubic feet). The locations and volumes of the major deposits, in billion cubic meters, are Qatar, 10.1; Algeria, 8.2; Russia, 6.8; Canada, 2.0; and China, 1.1. As of December 31, 2021, the BLM had analyzed about 22,720 gas samples from the United States and 26 other countries in a program to identify world helium resources.

Substitutes: Nothing substitutes for helium in cryogenic applications if temperatures below −429 degrees Fahrenheit are required. Argon can be substituted for helium in welding, and hydrogen can be substituted for helium in some lighter-than-air applications in which the flammable nature of hydrogen is not objectionable. Hydrogen is also being investigated as a substitute for helium in deep-sea diving applications below 305 meters (1,000 feet).

[e]Estimated. E Net exporter. NA Not available.

[1]Measured at 101.325 kilopascals absolute (14.696 psia) and 15 degrees Celsius (°C) [59 degrees Fahrenheit (°F)]; 27.737 cubic meters of helium = 1,000 cubic feet of helium at 101.325 kilopascals absolute (14.696 psia) and 21.1 °C (70 °F).

[2]Both Grade-A and crude helium.

[3]Extracted from natural gas in prior years.

[4]Substantial increases in exports reported in recent years suggested that the data may be incorrect. The Census Bureau was reviewing the export data. Exports were estimated to result in an apparent consumption of 40 million cubic meters for 2018–2021.

[5]Grade-A helium. Defined as sales + imports – exports.

[6]Defined as imports – exports.

[7]See Appendix B for definitions.

[8]Supervisory General Engineer, Helium Resources Division, Bureau of Land Management, Amarillo Field Office, Helium Operations, Amarillo, TX.

[9]Production and reserves outside of the United States were estimated.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]Brennan, S.T., Rivera, J.L., Varela, B.A., and Park, A.J., 2021, National assessment of helium resource within known natural gas reservoirs: U.S. Geological Survey Scientific Investigations Report 2021–5085, 5 p., https://doi.org/10.3133/sir20215085.

INDIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Indium was not recovered from ores in the United States in 2021. Several companies produced indium products—including alloys, compounds, high-purity metal, and solders—from imported indium metal. Production of indium tin oxide (ITO) continued to account for most global indium consumption. ITO thin-film coatings were primarily used for electrically conductive purposes in a variety of flat-panel displays—most commonly liquid crystal displays (LCDs). Other indium end uses included alloys and solders, compounds, electrical components and semiconductors, and research. Estimated domestic consumption of refined indium was 170 tons in 2021. The estimated value of refined indium consumed domestically in 2021, based on the average free on board U.S. warehouse price, was about $37 million.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery	—	—	—	—	—
Imports for consumption	127	125	95	115	170
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	127	125	95	115	170
Price, annual average, dollars per kilogram:					
New York dealer[2]	363	375	390	395	NA
Free on board U.S. warehouse[3]	206	285	182	161	220
Duties unpaid in warehouse, Rotterdam[4]	205	281	177	158	210
Net import reliance[5] as a percentage of estimated consumption	100	100	100	100	100

Recycling: Indium is most commonly recovered from ITO scrap in Japan and the Republic of Korea. A significant quantity of scrap was recycled domestically; however, data on the quantity of secondary indium recovered from scrap were not available.

Import Sources (2017–20): China,[6] 31%; Canada, 23%; Republic of Korea, 20%; France, 9%; and other, 17%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Unwrought indium, including powders, waste, and scrap	8112.92.3000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The New York dealer price of indium from the listed source was discontinued in 2021. In 2021, the average annual free on board U.S. warehouse price was an estimated $220 per kilogram, 37% greater than in 2020. The average monthly price was $187 per kilogram in January and increased throughout most of the year to a weekly average price of $270 per kilogram at the beginning of October. The 2021 estimated annual average Rotterdam price of indium (duties unpaid in the warehouse) was $210 per kilogram, 33% greater than that in 2020. The average monthly Rotterdam price of indium (duties unpaid in the warehouse) price began the year at $184 per kilogram in January then generally increased throughout the remainder of the year to a daily average of $235 per kilogram at the beginning of October.

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INDIUM

Demand for indium in Europe has been reduced during the global COVID-19 pandemic restrictions, but demand began to increase in May, when China's exports of indium to Europe increased sharply. Several European buyers started to build up indium stocks to ensure they had enough supply, owing to the prevalence of shipping delays in 2021.

The leading producer of tin in China announced that it produced 34.88 tons of indium in the first 6 months of 2021, with a reported capacity of 60 tons per year of indium. Other producers in China also announced the resumption of production of indium, accounting for an additional 50 to 60 tons per year of capacity, after shutting down to perform maintenance in the beginning of July.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[7]
	2020	2021	
United States	—	—	Quantitative estimates of
Belgium	20	20	reserves are not available.
Canada	66	60	
China	540	530	
France	38	35	
Japan	66	60	
Korea, Republic of	210	200	
Peru	12	10	
Russia	5	5	
World total (rounded)	960	920	

World Resources:[7] Indium is most commonly recovered from the zinc-sulfide ore mineral sphalerite. The indium content of zinc deposits from which it is recovered ranges from less than 1 part per million to 100 parts per million. Although the geochemical properties of indium are such that it occurs in trace amounts in other base-metal sulfides—particularly chalcopyrite and stannite—most deposits of these minerals are subeconomic for indium recovery.

Substitutes: Antimony tin oxide coatings have been developed as an alternative to ITO coatings in LCDs and have been successfully annealed to LCD glass; carbon nanotube coatings have been developed as an alternative to ITO coatings in flexible displays, solar cells, and touch screens; poly(3,4-ethylene dioxythiophene) (PEDOT) has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes; and copper or silver nanowires have been explored as a substitute for ITO in touch screens. Graphene has been developed to replace ITO electrodes in solar cells and also has been explored as a replacement for ITO in flexible touch screens. Researchers have developed a more adhesive zinc oxide nanopowder to replace ITO in LCDs. Hafnium can replace indium in nuclear reactor control rod alloys.

[e]Estimated. NA Not available. — Zero.

[1]Estimated to equal imports.

[2]Price is based on 99.99%-minimum-purity indium; delivered duty paid U.S. buyers; in minimum lots of 50 kilograms. Source: S&P Global Platts Metals Week; price was discontinued as of September 11, 2020.

[3]Price is based on 99.99%-minimum-purity indium, free on board U.S. warehouse. Source: Argus Media group—Argus Metals International.

[4]Price is based on 99.99%-minimum-purity indium, duties unpaid in warehouse (Rotterdam). Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

IODINE

(Data in metric tons of elemental iodine unless otherwise noted)

Domestic Production and Use: Iodine was produced from brines in 2021 by three companies operating in Oklahoma. U.S. iodine production in 2021 was withheld to avoid disclosing company proprietary data but was estimated to have been less than that in 2020. The average annual cost, insurance, and freight unit value of iodine imports in 2021 was estimated to be $32 per kilogram, a slight increase from that of 2020.

Because domestic and imported iodine was used by downstream manufacturers to produce many intermediate iodine compounds, it was difficult to establish an accurate end-use pattern. Crude iodine and inorganic iodine compounds were thought to account for more than 50% of domestic iodine consumption in 2021. Worldwide, the leading uses of iodine and its compounds were X-ray contrast media, pharmaceuticals, liquid crystal displays (LCDs), and iodophors, in descending order of quantity consumed. Other applications of iodine included animal feed, biocides, fluoride derivatives, food supplements, and nylon.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	W	W	W	W	W
Imports for consumption	4,170	4,930	4,300	4,570	4,100
Exports	1,230	1,190	1,230	1,130	1,200
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	4,500	4,620	4,000	3,750	4,000
Price, crude iodine, average unit value of imports (cost, insurance, and freight), dollars per kilogram	19.55	22.46	26.38	31.57	32
Employment, number[e]	60	60	60	60	60
Net import reliance[2] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled.

Import Sources (2017–20): Chile, 89%; Japan, 10%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IODINE

Events, Trends, and Issues: According to trade publications, spot prices for iodine crystal averaged about $36 per kilogram during the first 9 months of 2021. This was slightly less than the 2020 annual average of $36.49 per kilogram. Prices were still considerably less than the historically high levels of $65 to $85 per kilogram in late 2012 and early 2013.

As in recent years, Chile was the world's leading producer of iodine, followed by Japan and the United States. Excluding production in the United States, Chile accounted for about two-thirds of world production in 2021. Most of the world's iodine supply comes from three areas: the Chilean desert nitrate mines, the gasfields and oilfields in Japan, and the iodine-rich brine wells in northwestern Oklahoma.

Following the global COVID-19 pandemic in 2020, global demand for iodine applications increased throughout 2021. One U.S. company was in negotiations with partners to build a new iodine plant with construction expected to begin by the end of 2021.

World Mine Production and Reserves: China and Iran also produce crude iodine, but output is not officially reported, and available information was inadequate to make reliable estimates of output.

	Mine production		Reserves[3]
	2020	2021[e]	
United States	W	W	250,000
Azerbaijan	180	200	170,000
Chile	20,200	22,000	610,000
Indonesia	31	30	100,000
Japan	8,880	9,000	4,900,000
Russia	3	3	120,000
Turkmenistan	600	600	70,000
World total (rounded)	[4]29,900	[4]32,000	6,200,000

World Resources:[3] Seawater contains 0.06 part per million iodine, and the oceans are estimated to contain approximately 90 billion tons of iodine. Seaweeds of the Laminaria family are able to extract and accumulate up to 0.45% iodine on a dry basis. Although not as economical as the production of iodine as a byproduct of gas, nitrates, and oil, the seaweed industry represented a major source of iodine prior to 1959 and remains a large resource.

Substitutes: No comparable substitutes exist for iodine in many of its principal applications, such as in animal feed, catalytic, nutritional, pharmaceutical, and photographic uses. Bromine and chlorine could be substituted for iodine in biocide, colorant, and ink, although they are usually considered less desirable than iodine. Antibiotics can be used as a substitute for iodine biocides.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Excludes U.S. production.

IRON ORE[1]

(Data in thousand metric tons of usable ore unless otherwise noted)

Domestic Production and Use: In 2021, mines in Michigan and Minnesota shipped 98% of the domestic usable iron ore products, which were consumed in the steel industry in the United States, with an estimated value of $4.3 billion, a 23% increase from $3.5 billion in 2020. The remaining 2% of domestic iron ore was produced for nonsteel end uses. Seven open pit iron ore mines (each with associated concentration and pelletizing plants) and four iron metallic plants—one direct-reduced iron (DRI) plant in Louisiana and three hot-briquetted iron (HBI) plants in Indiana, Ohio, and Texas—operated during the year to supply steelmaking raw materials. The United States was estimated to have produced 1.8% and consumed 1.4% of the world's iron ore output.

Salient Statistics—United States:[2]	2017	2018	2019	2020	2021[e]
Production:					
Iron ore	47,900	49,500	46,900	38,100	46,000
Iron metallics	3,250	3,560	3,660	3,500	3,800
Shipments	46,900	50,400	47,000	38,000	44,000
Imports for consumption	3,720	3,790	3,980	3,240	3,900
Exports	10,600	12,700	11,400	10,400	13,000
Consumption:					
Reported	34,400	36,600	34,800	NA	NA
Apparent[3]	40,100	41,400	39,100	31,100	36,000
Price, average value reported by mines, dollars per ton	78.54	93.00	92.94	91.27	94.00
Stocks, mine, dock, and consuming plant, yearend	3,930	3,100	3,470	3,290	4,000
Employment, mine, concentrating and pelletizing plant, number	4,630	4,860	4,960	4,300	4,200
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None. See Iron and Steel Scrap.

Import Sources (2017–20): Brazil, 55%; Canada, 22%; Sweden, 8%; Russia, 4%; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Iron ores and concentrates:		
Concentrates	2601.11.0030	Free.
Coarse ores	2601.11.0060	Free.
Other ores	2601.11.0090	Free.
Pellets	2601.12.0030	Free.
Briquettes	2601.12.0060	Free.
Sinter	2601.12.0090	Free.
Roasted iron pyrites	2601.20.0000	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Significant increases in production, shipments, and trade in 2021 were due to recovery from the effects of the global COVID-19 pandemic, which lowered steel production and consumption globally in 2020. Domestic iron ore production was estimated to be 46 million tons in 2021, a 21% increase from 38.1 million tons in 2020. Total raw steel production was estimated to have increased to 87 million tons in 2021 from 72.7 million tons in 2020. The share of steel produced by basic oxygen furnaces, the process that uses iron ore, continued to decline from 37.3% in 2015 to an estimated 28% in 2021 owing to increased use of electric arc furnaces because of their energy efficiency, reduced environmental impacts, and the ready supply of scrap.

Overall, global prices trended upward to an average unit value of $178.27 per ton in the first 9 months of 2021, a 64% increase from the 2020 annual average of $108.92 per ton and a 90% increase from the 2019 annual average of $93.85 per ton. Based on reported prices for iron ore fines (62% iron content) imported into China (cost, insurance, and freight into Tianjin Port), the highest monthly average price during the first 9 months of 2021 was $214.43 per ton in June compared with the high of $155.43 per ton in December 2020. The lowest monthly average price during the same period in 2021 was $124.52 per ton in September compared with the low of $84.73 per ton in April 2020. The prices trended upward owing to a reduced supply of higher grade iron ore products and demand for higher grade ore to reduce greenhouse gas emissions in steel production.

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IRON ORE

One company commenced production at a HBI plant in Ohio in late 2020, making it the fourth iron metallics facility operating in the United States. From 2009 to 2013, no iron metallics plants operated domestically. In December 2020, one iron ore mining company acquired all the domestic iron and steel operations from another company, consolidating all domestic iron ore mines, blast furnaces, and basic oxygen furnace steelmaking mills under the control of two companies. Globally, estimated iron ore production in 2021 increased by 4% from that of 2020. Global finished steel consumption was forecast by the World Steel Association[5] to increase by 4.5% in 2021 and increase by 2.2% in 2022.

World Mine Production and Reserves: Reserves for Australia, Peru, and Turkey were revised based on Government and public sources.

	Mine production				Reserves[6] (million metric tons)	
	Usable ore		Iron content			
	2020	2021[e]	2020	2021[e]	Crude ore	Iron content
United States	38,100	46,000	24,100	29,000	3,000	1,000
Australia	912,000	900,000	565,000	560,000	[7]51,000	[7]25,000
Brazil	388,000	380,000	247,000	240,000	34,000	15,000
Canada	60,100	68,000	36,100	41,000	6,000	2,300
Chile	15,600	19,000	9,890	12,000	NA	NA
China	360,000	360,000	225,000	220,000	20,000	6,900
India	204,000	240,000	127,000	150,000	5,500	3,400
Iran	49,500	50,000	32,500	33,000	2,700	1,500
Kazakhstan	62,900	64,000	12,700	13,000	2,500	900
Mexico	14,900	17,000	9,380	11,000	NA	NA
Peru	13,300	16,000	8,890	11,000	2,600	1,500
Russia	100,000	100,000	69,500	71,000	25,000	14,000
South Africa	55,600	61,000	35,400	39,000	1,000	670
Sweden	35,800	40,000	25,400	28,000	1,300	600
Turkey	15,400	16,000	8,570	8,900	130	38
Ukraine	78,800	81,000	49,300	51,000	[8]6,500	[8]2,300
Other countries	69,500	90,000	40,000	58,000	18,000	9,500
World total (rounded)	2,470,000	2,600,000	1,520,000	1,600,000	180,000	85,000

World Resources:[6] U.S. resources are estimated to be 110 billion tons of iron ore containing about 27 billion tons of iron. U.S. resources are mainly low-grade taconite-type ores from the Lake Superior district that require beneficiation and agglomeration prior to commercial use. World resources are estimated to be greater than 800 billion tons of crude ore containing more than 230 billion tons of iron.

Substitutes: The only source of primary iron is iron ore, used directly as direct-shipping ore or converted to briquettes, concentrates, DRI, iron nuggets, pellets, or sinter. DRI, iron nuggets, and scrap are extensively used for steelmaking in electric arc furnaces and in iron and steel foundries. Technological advancements have been made that allow hematite to be recovered from tailings basins and pelletized.

[e]Estimated. E Net exporter. NA Not available.

[1]Data are for iron ore used as a raw material in steelmaking unless otherwise noted. See also Iron and Steel and Iron and Steel Scrap.

[2]Except where noted, salient statistics are for all forms of iron ore used in steelmaking and do not include iron metallics, which include DRI, HBI, and iron nuggets.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 24 billion tons of crude ore and 11 billion tons of contained iron.

[8]For Ukraine, reserves consist of the A and B categories of the Soviet reserves classification system.

IRON OXIDE PIGMENTS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Iron oxide pigments (IOPs) were mined domestically by two companies in Alabama and Georgia. Mine production, which was withheld to avoid disclosing company proprietary data, remained about the same in 2021 as that in 2020. Five companies, including the two producers of natural IOPs, processed and sold about 18,000 tons of finished natural and synthetic IOPs with an estimated value of $13 million. About 48% of natural and synthetic finished IOPs were used in concrete and other construction materials; 17% in industrial chemicals; 14% in foundry sands and other foundry uses; 5% each in animal feed and paint and coatings; 3% each in plastics and glass and ceramics; and the remaining 5% in other uses.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOPs	47,300	48,200	19,200	18,300	18,000
Imports for consumption	179,000	179,000	159,000	173,000	190,000
Exports, pigment grade	13,500	11,100	11,200	9,300	9,400
Consumption, apparent[1]	213,000	216,000	167,000	182,000	200,000
Price, average value, dollars per kilogram[2]	1.46	1.58	0.69	0.72	0.70
Employment, mine and mill, number	60	60	55	47	47
Net import reliance[3] as a percentage of apparent consumption	78	78	89	90	91

Recycling: None.

Import Sources (2017–20): Natural: Cyprus, 40%; Spain, 31%; France, 14%; Austria, 13%; and other, 2%. Synthetic: China, 46%; Germany, 33%; Brazil, 7%; and other, 14%. Total: China, 45%; Germany, 32%; Brazil, 7%; and other, 16%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Natural:		
Micaceous iron oxides	2530.90.2000	2.9% ad valorem.
Earth colors	2530.90.8015	Free.
Iron oxides and hydroxides containing 70% or more by weight Fe_2O_3:		
Synthetic:		
Black	2821.10.0010	3.7% ad valorem.
Red	2821.10.0020	3.7% ad valorem.
Yellow	2821.10.0030	3.7% ad valorem.
Other	2821.10.0040	3.7% ad valorem.
Earth colors	2821.20.0000	5.5% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IRON OXIDE PIGMENTS

Events, Trends, and Issues: In 2021, domestic mine production of crude and finished natural IOPs remained approximately the same as 2020 production. Imports of natural and synthetic pigments were estimated to have increased by 10% in 2021, owing in part to low mortgage interest rates and increased demand for single-family homes as the global COVID-19 pandemic made multifamily homes less desirable. In the United States, residential construction, in which IOPs are commonly used to color concrete block and brick, ready-mixed concrete, and roofing tiles, increased during the first 9 months of 2021 compared with that in the same period in 2020. Housing starts increased by about 20% in 2021 compared with those in 2020.

Exports of pigment-grade IOPs increased by 3% during the first 9 months of 2021 compared with those during the same period in 2020, mostly owing to an increase in exports to Argentina, Poland, and South Africa. Approximately 80% of pigment-grade IOPs exports went to Mexico, China, Germany, Thailand, Belgium, and Brazil, in descending order of quantity. Exports of other grades of iron oxides and hydroxides decreased by 25% during the first 9 months of 2021 compared with those in the same period in 2020. About 89% of exports of other grades of iron oxides and hydroxides went to Mexico, Canada, Ireland, Belgium, and the Republic of Korea, in descending order of quantity.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States	W	W	Moderate
Cyprus (umber)	3,500	3,500	Moderate
France	6,000	6,000	NA
Germany[5]	400,000	400,000	Moderate
India (ocher)	2,500,000	2,500,000	37,000,000
Italy	30,000	30,000	NA
Pakistan (ocher)	120,000	120,000	100,000
Spain (ocher and red iron oxide)	9,000	9,000	Large
World total (rounded)	[6]NA	[6]NA	Large

World Resources:[4] Domestic and world resources for production of IOPs are adequate. Adequate resources are available worldwide for the manufacture of synthetic IOPs.

Substitutes: Milled IOPs are thought to be the most commonly used natural minerals for pigments. Because IOPs are color stable, low cost, and nontoxic, they can be economically used for imparting black, brown, red, and yellow coloring in large and relatively low-value applications. Other minerals may be used as colorants, but they generally cannot compete with IOPs because of their higher costs and more limited availability. Synthetic IOPs are widely used as colorants and compete with natural IOPs in many color applications. Organic colorants are used for some colorant applications, but many of the organic compounds fade over time from exposure to sunlight.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Defined as sold or used finished natural and synthetic iron oxide pigments + imports – exports.

[2]Average unit value for finished iron oxide pigments sold or used by U.S. producers.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes natural and synthetic iron oxide pigments.

[6]A significant number of other countries, including Austria, Azerbaijan, Brazil, China, Honduras, Iran, Kazakhstan, Lithuania, Paraguay, Russia, South Africa, Turkey, Ukraine, and the United Kingdom, are thought to produce iron oxide pigments, but output was not reported, and no basis was available to make reliable estimates of production.

IRON AND STEEL[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: The U.S. iron and steel industry produced raw steel in 2021 with an estimated value of about $110 billion, a 21% increase from $91 billion in 2020. Pig iron and raw steel was produced by three companies operating integrated steel mills in 11 locations. Raw steel was produced by 50 companies at 101 minimills. Combined production capacity was about 106 million tons. Indiana accounted for an estimated 27% of total raw steel production, followed by Ohio, 11%; Pennsylvania, 5%; Illinois and Texas, 4% each; and Michigan, 3%; with no other State having more than 3% of total domestic raw steel production. Construction accounted for an estimated 47% of total domestic shipments by market classification, followed by transportation (predominantly automotive), 25%; machinery and equipment, 9%; appliances and energy, 5% each; and other applications, 9%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Pig iron production[2]	22.4	24.1	22.3	18.3	22
Raw steel production	81.6	86.6	87.8	72.7	87
Distribution of raw steel production, percent:					
Basic oxygen furnaces	32	32	30	29	29
Electric arc furnaces	68	68	70	71	71
Continuously cast steel, percent	99.6	98.2	99.8	99.8	99.8
Shipments, steel mill products	82.5	86.4	87.3	73.5	88
Imports, steel mill products:					
Finished	26.8	23.3	19.1	14.6	18
Semifinished	7.8	7.3	6.2	5.3	6.7
Total	34.6	30.6	25.3	20.0	25
Exports, steel mill products:					
Finished	9.4	7.9	6.6	6.7	8.1
Semifinished	0.1	0.1	0.1	0.1	0.1
Total	9.5	8.0	6.7	6.8	8.3
Stocks, service centers, yearend[3]	7.0	7.3	7.4	5.8	5.8
Consumption, apparent (steel)[4]	99.4	101	99.6	82.9	98
Producer price index for steel mill products (1982=100)[5]	187.4	211.1	204.0	184.4	348.5
Employment, average, number:					
Iron and steel mills[5]	80,600	82,100	85,700	83,200	86,000
Steel product manufacturing[6]	54,300	56,700	57,800	54,900	57,000
Net import reliance[7] as a percentage of apparent consumption	18	15	12	8	10

Recycling: See Iron and Steel Scrap and Iron and Steel Slag.

Import Sources (2017–20): Canada, 19%; Brazil, 15%; Mexico, 12%; the Republic of Korea, 9%; and other, 45%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Carbon steel:		
Semifinished	7207.00.0000	Free.
Flat, hot-rolled	7208.00.0000	Free.
Flat, cold-rolled	7209.00.0000	Free.
Galvanized	7210.00.0000	Free.
Bars and rods, hot-rolled	7213.00.0000	Free.
Structural shapes	7216.00.0000	Free.
Stainless steel:		
Semifinished	7218.00.0000	Free.
Flat-rolled sheets	7219.00.0000	Free.
Bars and rods	7222.00.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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IRON AND STEEL

Events, Trends, and Issues: The World Steel Association[8] forecast global finished steel consumption to increase by 4.5% in 2021 and by 2.2% in 2022 owing to rebounding demand from the effects of the global COVID-19 pandemic. Global recovery started in late 2020, as manufacturing ramped up in developed countries, through the second half of 2021, when supply chain disruptions affected delivery and demand. In 2021, U.S. apparent consumption of iron and steel increased by 22% from that in 2020. The automotive sector drove domestic increases in steel consumption and there were increases in demand in the construction sector. The potential for infrastructure stimulus programs could speed economic recovery and increase steel demand; however, the effects would take months to years before they become fully realized.

China's steel demand decreased in June 2021 owing to a variety of factors including pandemic closures and other effects, weak real estate activity, poor weather conditions, reduced investment infrastructure, and reduced exports. Steel consumption in the European Union continued to increase throughout the year owing to increased exports from Germany and increasing construction activity in Italy. Despite worsening pandemic conditions in Asia, steel demand remained unchanged owing to increases in Japan's automotive and machinery sectors and an increase in construction activity in the Republic of Korea. Generally, South America experienced a significant decrease in steel demand owing to pandemic conditions in 2020; however, the increased activity in the construction and automotive sectors led to a recovery in steel consumption to pre-pandemic levels.

World Production:

	Pig iron		Raw steel	
	2020	2021[e]	2020	2021[e]
United States[1]	18	22	73	87
Brazil	25	30	31	39
China	888	880	1,060	1,100
Germany	22	25	40	44
India	68	79	100	120
Iran	3	3	29	30
Italy	3	4	20	23
Japan	62	68	83	92
Korea, Republic of	45	50	67	73
Mexico	2	3	17	19
Russia	52	53	72	73
Taiwan	13	14	21	21
Turkey	10	12	36	42
Ukraine	20	21	21	21
Vietnam	10	10	17	17
Other countries	71	99	108	120
World total (rounded)	1,310	1,400	1,790	1,900

World Resources: Not applicable. See Iron Ore and Iron and Steel Scrap for steelmaking raw-material resources.

Substitutes: Iron is the least expensive and most widely used metal. In most applications, iron and steel compete either with less expensive nonmetallic materials or with more expensive materials that have a performance advantage. Iron and steel compete with lighter materials, such as aluminum and plastics in the automotive industry; aluminum, concrete, and wood in construction; and aluminum, glass, paper, and plastics in containers.

[e]Estimated.

[1]Production and shipments data source is the American Iron and Steel Institute; see also Iron and Steel Scrap and Iron Ore.

[2]More than 95% of pig iron production is transported in molten form to steelmaking furnaces at the same site.

[3]Steel mill products. Source: Metals Service Center Institute.

[4]Defined as steel shipments + imports of finished steel mill products – exports of steel mill products + adjustments for industry stock changes.

[5]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331200.

[6]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331100.

[7]Defined as imports of finished steel mill products – total exports + adjustments for industry stock changes.

[8]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

IRON AND STEEL SCRAP[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: In 2021, the total value of domestic purchases of iron and steel scrap (receipts of ferrous scrap by all domestic consumers from brokers, dealers, and other outside sources) and exports was estimated to be $27 billion, nearly double the $14.0 billion in 2020 and 68% more than the $15.8 billion in 2019. U.S. apparent consumption of steel, the leading end use for iron and steel scrap, was estimated to have increased by 18% to 98 million tons in 2021 from 82.9 million tons in 2020. Manufacturers of pig iron, raw steel, and steel castings accounted for almost all scrap consumption by the domestic steel industry, using scrap together with pig iron and direct-reduced iron to produce steel products for the appliance, construction, container, machinery, oil and gas, transportation, and various other consumer industries. The ferrous castings industry consumed most of the remaining scrap to produce cast iron and steel products. Relatively small quantities of steel scrap were used for producing ferroalloys, for the precipitation of copper, and by the chemical industry; these uses collectively totaled less than 1 million tons.

During 2021, estimated raw steel production increased by 19% to 87 million tons, from 72.7 million tons in 2020, and net shipments of steel mill products were an estimated 88 million tons, up by 20% from 73.5 million tons in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Home scrap	5.6	5.8	5.3	4.8	4.2
Purchased scrap[2]	55	59	55	53	55
Imports for consumption[3]	4.6	5.0	4.3	4.5	6.2
Exports[3]	15	17	18	17	19
Consumption:					
Reported	50	52	48	45	46
Apparent[4]	50	52	49	45	46
Price, average, delivered, No. 1 heavy melting composite price, dollars per ton[5]	265	326	249	228	435
Stocks, consumer, yearend	4.5	5.1	4.0	4.0	4.4
Employment, dealers, brokers, processors, number[e]	27,000	27,000	26,000	24,000	25,000
Net import reliance[6] as a percentage of reported consumption	E	E	E	E	E

Recycling: Recycled iron and steel scrap is a vital raw material for the production of new steel and cast iron products. The steel and foundry industries in the United States have been structured to recycle scrap and, as a result, are highly dependent upon scrap. Recycling 1 ton of steel conserves 1.1 tons of iron ore, 0.6 ton of coking coal, and 0.05 ton of limestone. Recycling of scrap also conserves energy because the remelting of scrap requires much less energy than the production of iron or steel products from iron ore.

Overall, the scrap recycling rate in the United States has averaged between 80% and 90% during the past decade, with automobiles making up the primary source of old steel scrap. Recycling of automobiles is nearly 100% each year, with rates fluctuating slightly owing to the rate of new vehicle production and general economic trends. More than 15 million tons of steel is recycled from automobiles annually, the equivalent of approximately 12 million cars, from more than 7,000 vehicle dismantlers and 350 car shredders in North America. The recycling of steel from automobiles is estimated to save the equivalent energy necessary to power 18 million homes every year.

Recycling rates, which fluctuate annually, were estimated to be 98% for structural steel from construction, 88% for appliances, 71% for rebar and reinforcement steel, and 70% for steel packaging. The recycling rates for appliance, can, and construction steel are expected to increase in the United States and in emerging industrial countries at an even greater rate. Public interest in recycling continues, and recycling is becoming more profitable and convenient as environmental regulations for primary production increase. Also, consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment

Recycled scrap consists of approximately 58% post-consumer (old, obsolete) scrap, 24% new scrap (produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

Import Sources (2017–20): Canada, 70%; Mexico, 11%; the United Kingdom, 6%; Sweden, 5%; and other, 8%.

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IRON AND STEEL SCRAP

Tariff: Item	Number	Normal Trade Relations 12–31–21
Ferrous waste and scrap:		
Stainless steel	7204.21.0000	Free.
Turnings, shavings, chips, milling waste, sawdust, filings, trimmings, and stampings:		
No. 1 bundles	7204.41.0020	Free.
No. 2 bundles	7204.41.0040	Free.
Borings, shovelings, and turnings	7204.41.0060	Free.
Other	7204.41.0080	Free.
Other:		
No. 1 heavy melting	7204.49.0020	Free.
No. 2 heavy melting	7204.49.0040	Free.
Cut plate and structural	7204.49.0060	Free.
Shredded	7204.49.0070	Free.
Remelting scrap ingots	7204.50.0000	Free.
Powders, of pig iron, spiegeleisen, iron, or steel:		
Alloy steel	7205.21.0000	Free.
Other	7205.29.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In 2021, steel mill production capacity utilization rebounded from the lowest monthly rate since July 2009, reaching 54.6% in May 2020, into the normal historical range for operating rates reaching 76.6% in January and continuing to increase to 84.8% in the second half of 2021. Composite prices published for No. 1 heavy melting steel scrap increased significantly in 2021, rising from $194.01 per ton in July 2020 to a peak of $454.38 per ton in July 2021. The annual average price delivered in the first 8 months of 2021 increased to $408.54 per ton compared with the full-year annual average of $227.62 per ton in 2020, contributing to the significant increase in the total estimated value of domestic purchases and exports of iron and steel scrap in 2021.

In the first 8 months of 2021, Mexico and Turkey were the primary destinations for exports of ferrous scrap, by tonnage, accounting for 18% of total exports each, followed by Malaysia, 10%; Vietnam, 9%; and Bangladesh and Taiwan, 8% each. The value of exported scrap increased to an estimated $8.1 billion in 2021 from $4.8 billion in 2020. In the first 8 months of 2021, Canada was the leading source of imports of ferrous scrap, by tonnage, accounting for 67% of total imports, following by Mexico, 10%; the United Kingdom, 7%; the Netherlands, 6%; and Sweden, 3%.

The World Steel Association[7] forecast global finished steel consumption to increase by 4.5% in 2021 and by 2.2% in 2022 owing to rebounding demand from the effects of the global COVID-19 pandemic. Global recovery started in late 2020, as manufacturing ramped up in developed countries, through the second half of 2021, when supply chain disruptions affected delivery and demand. These factors are expected to be relieved in 2022 and increase recovery momentum. The automotive sector was the leading cause of domestic increases in steel consumption.

World Mine Production and Reserves: Not applicable. See Iron and Steel and Iron Ore.

World Resources: Not applicable. See Iron and Steel and Iron Ore.

Substitutes: An estimated 3.5 million tons of direct-reduced iron was consumed in the United States in 2021 as a substitute for iron and steel scrap, up from 3.3 million tons in 2020.

[e]Estimated. E Net exporter.

[1]See also Iron and Steel and Iron Ore.

[2]Defined as net receipts + exports – imports.

[3]Excludes used rails for rerolling and other uses, and ships, boats, and other vessels for scrapping.

[4]Defined as home scrap + purchased scrap + imports – exports + adjustments for industry stock changes.

[5]Source: Fastmarkets AMM

[6]Defined as imports – exports + adjustments for industry stock changes.

[7]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

IRON AND STEEL SLAG

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: Iron and steel (ferrous) slags are formed by the combination of slagging agents and impurities during the production of crude (or pig) iron and crude steel. The slags are tapped separately from the metals, then cooled and processed, and are primarily used in the construction industry. Data are unavailable on actual U.S. ferrous slag production, but domestic slag sales[1] in 2021 were estimated to be 17 million tons valued at about $460 million. Blast furnace slag was about 49% of the tonnage sold and accounted for 87% of the total value of slag, most of which was granulated. Steel slag produced from basic oxygen and electric arc furnaces accounted for the remainder of sales. Slag was processed by 28 companies servicing active iron and steel facilities or reprocessing old slag piles at about 124 processing plants (including some iron and steel plants with more than one slag-processing facility) in 33 States, including facilities that import and grind unground slag to sell as ground granulated blast furnace slag (GGBFS).

Air-cooled iron slag and steel slag are used primarily as aggregates in concrete (air-cooled iron slag only); asphaltic paving, fill, and road bases; both slag types also can be used as a feed for cement kilns. Almost all GGBFS is used as a partial substitute for portland cement in concrete mixes or in blended cements. Pelletized slag is generally used for lightweight aggregate but can be ground into material similar to GGBFS. Actual prices per ton ranged from a few cents for some steel slags at a few locations to about $120 or more for some GGBFS in 2021. Owing to low unit values, most slag types can be shipped only short distances by truck, but rail and waterborne transportation allow for greater travel distances. Because much higher unit values make it economical to ship GGBFS longer distances, much of the GGBFS consumed in the United States is imported.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production (sales)[1, 2]	16.2	16.8	[e]16	[e]13	17
Imports for consumption[3]	2.1	2.2	1.8	2.3	2.2
Exports	([4])	([4])	([4])	([4])	([4])
Consumption, apparent[5]	16.2	16.8	[e]16	[e]13	17
Price, average value, free on board plant, dollars per ton[6]	24.50	26.50	27.50	25.50	27.00
Employment, number[e]	1,500	1,500	1,500	1,500	1,500
Net import reliance[7] as a percentage of apparent consumption	13	13	10	14	11

Recycling: Following removal of entrained metal, slag can be returned to the blast and steel furnaces as ferrous and flux feed, but data on these returns are incomplete. Entrained metal, particularly in steel slag, is routinely recovered during slag processing for return to the furnaces and is an important revenue source for slag processors; data on metal returns are unavailable.

Import Sources (2017–20): Japan, 42%; Brazil, 18%; China, 11%; Italy, 10%; and other, 19%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Granulated slag	2618.00.0000	Free.
Slag, dross, scalings, and other waste from manufacture of iron and steel:		
Ferrous scale	2619.00.3000	Free.
Other	2619.00.9000	Free.

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IRON AND STEEL SLAG

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The availability of steel slag is tied closely to the rates of raw steel production and the cost consideration of recovering slag for use in low-value downstream applications. The majority of U.S. steel slag production is from electric arc furnaces, which accounted for approximately 71% of U.S. steel production in 2021 owing to the overall cost benefits of environmental factors, such as feedstock and power consumption, and the price and availability of ferrous scrap feedstock. In recent years, the percentage of basic oxygen furnace steel production has continued to decline as capacity has idled or closed; however, slag stockpiling at furnaces allow for processing of slag for years after closures. The World Steel Association[8] forecast global finished steel consumption to increase by 4.5% in 2021 and by 2.2% in 2022 owing to rebounding demand from the effects of the global COVID-19 pandemic.

During 2021, domestic GGBFS remained in limited supply because granulation cooling was known to be available at only two active U.S. blast furnaces while, elsewhere, only one domestic plant produced pelletized slag in limited supply. Grinding of granulated blast furnace slag was only done domestically by cement companies. Supply constraints appear to have limited domestic consumption of GGBFS in recent years. Following declines in value and production in 2020, owing to the effects and availability caused by closures related to the COVID-19 pandemic, steel production rates increased through 2021 leading to increased availability of steel slag.

The domestic supply of fly ash, which is used as an additive in concrete production, continues to decrease, owing to restrictions of mercury and carbon dioxide (CO_2) emissions at coal-fired powerplants, powerplant closures, and conversion of powerplants to natural gas. Mercury emission restrictions on cement plants, enacted in 2015, may reduce the demand for fly ash as a raw material in clinker manufacture, and air-cooled and steel slags are used as substitute raw materials. Demand for GGBFS is likely to increase because its use in cement yields a beneficial product in many applications and reduces the unit CO_2 emissions in the production of the cement.

World Production and Reserves: Because slag is not mined, the concept of reserves does not apply. World production data for slag were unavailable, but iron slag from blast furnaces may be estimated to be 25% to 30% of crude (pig) iron production and steel furnace slag may be estimated to be 10% to 15% of raw steel production. In 2021, world iron slag production was estimated to be between 340 million and 410 million tons, and steel slag production was estimated to be between 190 million and 280 million tons.

World Resources: Not applicable.

Substitutes: In the construction sector, ferrous slags compete with natural aggregates (crushed stone and construction sand and gravel) but are far less widely available than the natural materials. As a cementitious additive in blended cements and concrete, GGBFS mainly competes with fly ash, metakaolin, and volcanic ash pozzolans. In this respect, GGBFS reduces the amount of portland cement per ton of concrete, thus allowing more concrete to be made per ton of portland cement. Slags (especially steel slag) can be used as a partial substitute for limestone and some other natural raw materials for clinker (cement) manufacture and compete in this use with fly ash and bottom ash. Some other metallurgical slags, such as copper slag, can compete with ferrous slags in some specialty markets, such as a ferrous feed in clinker manufacture, but are generally in much more restricted supply than ferrous slags.

[e]Estimated.

[1]Processed slag sold during the year, excluding entrained metal.

[2]Data include sales of domestic and imported granulated blast furnace slag and exclude sales of pelletized slag.

[3]U.S. Census Bureau data adjusted by the U.S. Geological Survey to remove nonslag materials (such as cenospheres, fly ash, and silica fume) and slags or other residues of other metallurgical industries (especially copper slag), whose unit values are outside the range expected for granulated slag. In some years, tonnages may be underreported.

[4]Less than 50,000 tons.

[5]Defined as sales – exports.

[6]Rounded to the nearest $0.50 per ton.

[7]Defined as imports – exports.

[8]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

KYANITE AND RELATED MINERALS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In Virginia, one firm with integrated mining and processing operations produced an estimated 81,000 tons of kyanite worth $30 million from two hard-rock open pit mines and synthetic mullite by calcining kyanite. Two other companies, one in Alabama and another in Georgia, produced synthetic mullite from materials mined from four sites; each company sourced materials from one site in Alabama and one site in Georgia. Synthetic mullite production data are withheld to avoid disclosing company proprietary data. Commercially produced synthetic mullite is made by sintering or fusing such feedstock materials as kyanite, kaolin, bauxite, or bauxitic kaolin. Natural mullite occurrences typically are rare and not economical to mine.

Of the kyanite-mullite output, 90% was estimated to have been used in refractories and 10% in other uses, including abrasive products, such as motor vehicle brake shoes and pads and grinding and cutting wheels; ceramic products, such as electrical insulating porcelains, sanitaryware, and whiteware; foundry products and precision casting molds; and other products. An estimated 60% to 70% of the refractory use was by the iron and steel industries, and the remainder was by industries that manufacture cement, chemicals, glass, nonferrous metals, and other materials.

Andalusite was commercially mined from an andalusite-pyrophyllite-sericite deposit in North Carolina and processed as a blend of primarily andalusite for use by producers of refractories in making firebrick. Another company mined mineral sands within the southeastern United States; product blends that included kyanite and (or) sillimanite were marketed to the abrasive, foundry, and refractory industries.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Kyanite, mine	[1]91,300	[1]89,200	[1]91,300	[1]67,100	81,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	7,420	8,590	6,960	710	1,000
Exports (kyanite)	42,400	43,000	40,100	37,400	45,000
Consumption, apparent[2]	W	W	W	W	W
Price, average value of exports (free alongside ship),[3, 4] dollars per metric ton	350	347	358	369	369
Employment, number:[e]					
Kyanite, mine, office, and plant	140	150	150	140	140
Synthetic mullite, office and plant	200	200	200	200	200
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2017–20):[4] South Africa, 77%; Peru, 12%; France, 7%; United Kingdom, 3%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

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KYANITE AND RELATED MINERALS

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, increased by about 20% in the first 8 months of 2021 compared with that of the same period in 2020, indicating a similar change in consumption of kyanite-mullite refractories. Total world steel production increased by about 11% during the first 8 months of 2021 compared with that of the same period in 2020. The increase in world steel production during the first 8 months of 2021 was the result of economic recovery from the global COVID-19 pandemic. The steel industry continued to be the largest market for refractories.

In January 2021, a company in South Africa that accounted for nearly one-third of global andalusite output announced that a new investor and owner had been approved. In mid-2019, the company entered into business rescue proceedings attributed to financial problems but was expected to emerge from business rescue status and be transferred to the new owner.

Despite strong demand, andalusite output was hindered by several challenges that contributed to a prolonged and uneven recovery period from the pandemic. Although many countries declared mining essential, production efforts were constrained by ongoing logistical and shipping issues, renewed COVID-19 outbreaks, and supply chain disruptions. If andalusite producers are unable to meet demand, market participants may consider alternatives such as bauxite and mullite, although these materials experienced similarly problematic market conditions in 2021.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States (kyanite)	[1]67,100	81,000	Large
India (kyanite and sillimanite)	61,000	70,000	7,200,000
Peru (andalusite)	[e]40,000	40,000	NA
South Africa (andalusite)	180,000	190,000	NA
World total (rounded)	[7]NA	[7]NA	NA

World Resources:[6] Large resources of kyanite and related minerals are known to exist in the United States. The chief resources are in deposits of micaceous schist and gneiss, mostly in the Appalachian Mountains and in Idaho. Other resources are in aluminous gneiss in southern California. These resources are not economical to mine at present. The characteristics of kyanite resources in the rest of the world are thought to be similar to those in the United States. Significant resources of andalusite are known to exist in China, France, Peru, and South Africa; kyanite resources have been identified in Brazil, India, and Russia; and sillimanite has been identified in India.

Substitutes: Two types of synthetic mullite (fused and sintered), superduty fire clays, and high-alumina materials are substitutes for kyanite in refractories. Principal raw materials for synthetic mullite are bauxite, kaolin and other clays, and silica sand.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Source: Virginia Department of Mines, Minerals and Energy.

[2]Defined as production + imports – exports.

[3]Calculated from U.S. Census Bureau export data.

[4]Includes data for the following Harmonized Tariff Schedule of the United States code: 2508.50.0000.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]In addition to the countries listed, France continued production of andalusite, and Cameroon and China produced kyanite and related minerals. Output was not reported quantitatively, and no reliable basis was available for estimation of output levels.

LEAD

(Data in thousand metric tons of contained lead unless otherwise noted)

Domestic Production and Use: Lead was produced domestically by five lead mines in Missouri plus as a byproduct at two zinc mines in Alaska and two silver mines in Idaho. The value of the lead in concentrates of ore mined in 2021 was an estimated $750 million, 21% more than that in 2020. Nearly all lead concentrate production has been exported since the last primary lead refinery closed in 2013. The value of the secondary lead produced in 2021 was $2.4 billion, 17% more than that in 2020. The lead-acid battery industry accounted for an estimated 92% of reported U.S. lead consumption during 2021. Lead-acid batteries were primarily used as starting-lighting-ignition (SLI) batteries for automobiles, as industrial-type batteries for standby power for computer and telecommunications networks, and for motive power. During the first 9 months of 2021, 107 million lead-acid automotive batteries were shipped by North American producers, 8% more than those shipped in the same period of 2020.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine, lead in concentrates	310	280	274	306	300
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,140	1,140	1,070	1,030	990
Imports for consumption:					
Lead in concentrates	([1])	—	([1])	([1])	—
Refined metal, unwrought (gross weight)	658	563	501	382	620
Exports:					
Lead in concentrates	269	251	259	265	250
Refined metal, unwrought (gross weight)	24	70	25	17	22
Consumption, apparent[2]	1,770	1,640	1,550	1,400	1,600
Price, average, cents per pound:[3]					
North American market	114.5	110.9	99.9	91.3	110
London Metal Exchange (LME), cash	105.1	101.8	91.0	82.7	99
Employment, mine and mill (average), number[4]	1,890	1,860	1,690	1,810	1,900
Net import reliance[5] as a percentage of apparent consumption, refined metal	36	30	31	26	38

Recycling: In 2021, about 990,000 tons of secondary lead was produced, an amount equivalent to 62% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2017–20): Refined metal: Canada, 43%; Mexico, 19%; the Republic of Korea, 17%; India, 4%; and other, 17%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Lead ores and concentrates, lead content	2607.00.0020	1.1¢/kg on lead content.
Refined lead	7801.10.0000	2.5% on the value of the lead content.
Antimonial lead	7801.91.0000	2.5% on the value of the lead content.
Alloys of lead	7801.99.9030	2.5% on the value of the lead content.
Other unwrought lead	7801.99.9050	2.5% on the value of the lead content.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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LEAD

Events, Trends, and Issues: During the first 10 months of 2021, the average LME cash price for lead was 98.9 cents per pound, 20% more than the average price in 2020, owing to the worldwide shipping delays and decreased supply of the refined lead available on the market. The average monthly LME cash price peaked in August at 110.2 cents per pound and declined through November. Global stocks of lead in LME-approved warehouses were 57,800 tons in November 2021, which was 57% less than those at yearend 2020.

In 2021, domestic mine production was estimated to have decreased slightly from that in the previous year. Domestic production of secondary lead decreased by 4% from that in the previous year owing to a reduction in production of several secondary lead smelters and a closure of one secondary lead smelter in South Carolina in 2021. U.S. apparent consumption of refined lead increased by 14% from that in the previous year, and the net import reliance increased from 26% to 38%, owing to the forementioned domestic secondary plants' closures and subsequent 62% increase in the imports of the refined lead. In the first 9 months of 2021, 25.5 million spent SLI lead-acid batteries were exported, 29% more than that in the same time period in 2020.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2021 was forecast to increase by 4.4% to 12.4 million tons and metal consumption to increase by 5.5% to 12.4 million tons.

World Mine Production and Reserves: Reserves estimates for Australia and Peru were revised based on new information from Government reports.

	Mine production		Reserves[7]
	2020	2021[e]	
United States	306	300	5,000
Australia	494	500	[8]37,000
Bolivia	65	90	1,600
China	1,900	2,000	18,000
India	204	210	2,500
Kazakhstan	30	40	2,000
Mexico	260	270	5,600
Peru	242	280	6,400
Russia	210	210	4,000
Sweden	70	70	1,100
Tajikistan	46	46	NA
Turkey	63	60	860
Other countries	490	220	5,900
World total (rounded)	4,380	4,300	90,000

World Resources:[7] Identified world lead resources total more than 2 billion tons. In recent years, significant lead resources have been identified in association with zinc and (or) silver or copper deposits in Australia, China, Ireland, Mexico, Peru, Portugal, Russia, and the United States (Alaska).

Substitutes: Substitution by plastics has reduced the use of lead in cable covering and cans. Tin has replaced lead in solder for potable water systems. The electronics industry has moved toward lead-free solders and flat-panel displays that do not require lead shielding. Steel and zinc are common substitutes for lead in wheel weights.

[e]Estimated. NA Not available. — Zero.

[1]Less than ½ unit.

[2]Defined as primary refined production + secondary refined production from old scrap + refined imports – refined exports.

[3]Source: S&P Global Platts Metals Week.

[4]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct. Data from the Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]International Lead and Zinc Study Group, 2021, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 12, [5] p.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 12 million tons.

LIME[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, an estimated 17 million tons of quicklime and hydrated was produced (excluding independent commercial hydrators[2]), valued at about $2.3 billion. Twenty-eight companies produced lime, which included 18 companies with commercial sales and 10 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 73 primary lime plants (plants operating quicklime kilns) in 28 States and Puerto Rico. One primary lime plant was idle in 2021. Five of the 28 companies operated only hydrating plants in nine States. In 2021, the five leading U.S. lime companies produced quicklime or hydrated in 22 States and accounted for about 78% of U.S. lime production. Principal producing States were, in alphabetical order, Alabama, Kentucky, Missouri, Ohio, and Texas. Major markets for lime were, in descending order of consumption, steelmaking, chemical and industrial applications (such as the manufacture of fertilizer, glass, paper and pulp, and precipitated calcium carbonate, and in sugar refining), flue gas treatment, construction, water treatment, and nonferrous-metal mining.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[2, 3]	17,600	18,000	16,900	15,800	17,000
Imports for consumption	367	370	342	308	330
Exports	391	424	347	266	310
Consumption, apparent[4]	17,600	18,000	16,900	15,900	17,000
Price, average value, dollars per ton at plant:					
Quicklime	120.8	125.2	128.3	132.1	140
Hydrated	147.1	151.6	154.6	156.4	160
Net import reliance[5] as a percentage of apparent consumption	E	E	E	<1	<1

Recycling: Large quantities of lime are regenerated by paper mills. Some municipal water-treatment plants regenerate lime from softening sludge. Quicklime is regenerated from waste hydrated lime in the carbide industry. Data for these sources were not included as production in order to avoid duplication.

Import Sources (2017–20): Canada, 90%; Mexico, 7%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Calcined dolomite	2518.20.0000	3% ad valorem.
Quicklime	2522.10.0000	Free.
Slaked lime	2522.20.0000	Free.
Hydraulic lime	2522.30.0000	Free.

Depletion Allowance: Limestone produced and used for lime production, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, domestic lime production was estimated to have increased by 8% from that in 2020. In 2020, a decline in lime production was a result of plants temporarily closing as a result of the global COVID-19 pandemic. As the economy continues to rebound from the effects of the pandemic, so does the lime industry. In Michigan, one sugar company announced plans to construct a desugarization facility to produce an additional 40,000 tons of refined sugar annually. The San Bernardino County, CA, government approved plans to build a lime plant near a limestone quarry at Trona, CA. In 2021, a total of 73 quicklime plants were in operation along with 10 hydrating plants. Hydrated lime is a dry calcium hydroxide powder made from reacting quicklime with a controlled amount of water in a hydrator. It is used in chemical and industrial, construction, and environmental applications.

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LIME

World Lime Production and Limestone Reserves:

	Production[6]		Reserves[7]
	2020	2021[e]	
United States	15,800	17,000	Adequate for all countries listed.
Australia	1,980	2,000	
Belgium[8]	1,500	1,500	
Brazil	8,000	8,100	
Bulgaria	1,280	1,400	
Canada (shipments)	2,060	2,000	
China	310,000	310,000	
France	2,600	2,600	
Germany	7,100	7,100	
India	15,000	16,000	
Iran	3,600	3,600	
Italy[8]	3,400	3,500	
Japan (quicklime only)	5,820	7,000	
Korea, Republic of	5,100	5,200	
Malaysia	1,480	1,500	
Poland (hydrated and quicklime)	1,680	1,700	
Romania	1,280	1,500	
Russia (industrial and construction)	11,400	11,000	
Slovenia	1,200	1,200	
South Africa	1,200	1,200	
Spain	1,700	1,800	
Turkey	4,700	4,700	
Ukraine	2,340	2,300	
United Kingdom	1,500	1,500	
Other countries	15,000	15,000	
World total (rounded)	427,000	430,000	

World Resources:[7] Domestic and world resources of limestone and dolomite suitable for lime manufacture are very large.

Substitutes: Limestone is a substitute for lime in many applications, such as agriculture, fluxing, and sulfur removal. Limestone, which contains less reactive material, is slower to react and may have other disadvantages compared with lime, depending on the application; however, limestone is considerably less expensive than lime. Calcined gypsum is an alternative material in industrial plasters and mortars. Cement, cement kiln dust, fly ash, and lime kiln dust are potential substitutes for some construction uses of lime. Magnesium hydroxide is a substitute for lime in pH control, and magnesium oxide is a substitute for dolomitic lime as a flux in steelmaking.

[e]Estimated. E Net exporter.

[1]Data are for quicklime, hydrated lime, and refractory dead-burned dolomite. Includes Puerto Rico.

[2]To avoid double counting quicklime production, excludes independent commercial hydrators that purchase quicklime for hydration.

[3]Sold or used by producers.

[4]Defined as production + imports – exports. Includes some double counting based on nominal, undifferentiated reporting of company export sales as U.S. production.

[5]Defined as imports – exports.

[6]Only countries that produced 1 million tons of lime or more are listed separately.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Includes hydraulic lime.

LITHIUM

(Data in metric tons of contained lithium unless otherwise noted)

Domestic Production and Use: The only lithium production in the United States was from one brine operation in Nevada. Two companies produced a wide range of downstream lithium compounds in the United States from domestic or imported lithium carbonate, lithium chloride, and lithium hydroxide. Domestic production data were withheld to avoid disclosing company proprietary data.

Although lithium markets vary by location, global end-use markets are estimated as follows: batteries, 74%; ceramics and glass, 14%; lubricating greases, 3%; continuous casting mold flux powders, 2%; polymer production, 2%; air treatment, 1%; and other uses, 4%. Lithium consumption for batteries has increased significantly in recent years because rechargeable lithium batteries are used extensively in the growing market for electric vehicles and portable electronic devices, and increasingly are used in electric tools, and grid storage applications. Lithium minerals were used directly as ore concentrates in ceramics and glass applications.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	W	W	W	W	W
Imports for consumption	3,330	3,420	2,620	2,460	2,500
Exports	1,960	1,660	1,660	1,170	1,900
Consumption, estimated[1]	3,000	3,000	2,000	2,000	2,000
Price, annual average, battery-grade lithium carbonate, dollars per metric ton[2]	15,000	17,000	12,700	8,000	17,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>50	>50	>25	>50	>25

Recycling: One domestic company has recycled lithium metal and lithium-ion batteries since 1992 at its facility in British Columbia, Canada. In 2015, the company began operating the first U.S. recycling facility for lithium-ion vehicle batteries in Lancaster, OH. About 25 companies in North America and Europe recycle lithium batteries or plan to do so. Partnerships between automobile companies and battery recyclers have been made to supply the automobile industry with a source of battery materials.

Import Sources (2017–20): Argentina, 54%; Chile, 37%; China, 5%; Russia, 3%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Lithium oxide and hydroxide	2825.20.0000	3.7% ad valorem.
Lithium carbonate:		
U.S. pharmaceutical grade	2836.91.0010	3.7% ad valorem.
Other	2836.91.0050	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4, 5]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Lithium-cobalt oxide	752	—	—	—	—
Lithium-nickel-cobalt-aluminum oxide	2,698	—	—	—	—

Events, Trends, and Issues: Excluding U.S. production, worldwide lithium production in 2021 increased by 21% to approximately 100,000 tons from 82,500 tons in 2020 in response to strong demand from the lithium-ion battery market and increased prices of lithium. Global consumption of lithium in 2021 was estimated to be 93,000 tons, a 33% increase from 70,000 tons in 2020.

Spot lithium carbonate prices in China (cost, insurance, and freight [c.i.f.] North Asia) increased from approximately $7,000 per ton in January to about $26,200 per ton in November. For fixed contracts, the annual average U.S. lithium carbonate price was $17,000 per ton in 2021, more than double that in 2020. Spot lithium hydroxide prices in China (c.i.f. North Asia) increased from approximately $9,000 per ton in January to about $27,400 per ton in November. Spot spodumene (6% lithium oxide) prices in China (c.i.f. China) increased from approximately $450 per ton in January to about $2,300 per ton in November. Spot lithium metal (99.9% lithium) prices in China increased from approximately $77,000 per ton in January to about $97,000 per ton in July.

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LITHIUM

Four mineral operations in Australia, two brine operations each in Argentina and Chile, and two brine and one mineral operation in China accounted for the majority of world lithium production. Additionally, smaller operations in Brazil, China, Portugal, the United States, and Zimbabwe also contributed to world lithium production. Owing to the resurgence in demand and increased prices of lithium in 2021, established lithium operations worldwide resumed capacity expansion plans which were postponed in 2020 in response to the global COVID-19 pandemic.

Lithium supply security has become a top priority for technology companies in Asia, Europe, and the United States. Strategic alliances and joint ventures among technology companies and exploration companies continued to be established to ensure a reliable, diversified supply of lithium for battery suppliers and vehicle manufacturers. Brine-based lithium sources were in various stages of development in Argentina, Bolivia, Chile, China, and the United States; mineral-based lithium sources were in various stages of development in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Finland, Germany, Mali, Namibia, Peru, Portugal, Serbia, Spain, the United States, and Zimbabwe; lithium-clay sources were in various stages of development in Mexico and the United States; and a searlesite source was in development in the United States.

World Mine Production and Reserves: Reserves for Argentina, Australia, and "Other countries" were revised based on new information from Government and industry sources.

	Mine production		Reserves[6]
	2020	2021[e]	
United States	W	W	750,000
Argentina	5,900	6,200	2,200,000
Australia	39,700	55,000	[7]5,700,000
Brazil	1,420	1,500	95,000
Chile	21,500	26,000	9,200,000
China	13,300	14,000	1,500,000
Portugal	348	900	60,000
Zimbabwe	417	1,200	220,000
Other countries[8]	—	—	2,700,000
World total (rounded)	[9]82,500	[9]100,000	22,000,000

World Resources:[6] Owing to continuing exploration, identified lithium resources have increased substantially worldwide and total about 89 million tons. Identified lithium resources in the United States—from continental brines, geothermal brines, hectorite, oilfield brines, pegmatites, and searlesite—are 9.1 million tons. Identified lithium resources in other countries have been revised to 80 million tons. Identified lithium resources are distributed as follows: Bolivia, 21 million tons; Argentina, 19 million tons; Chile, 9.8 million tons; Australia, 7.3 million tons; China, 5.1 million tons; Congo (Kinshasa), 3 million tons; Canada, 2.9 million tons; Germany, 2.7 million tons; Mexico, 1.7 million tons; Czechia, 1.3 million tons; Serbia, 1.2 million tons; Russia, 1 million tons; Peru, 880,000 tons; Mali, 700,000 tons; Zimbabwe, 500,000 tons; Brazil, 470,000 tons; Spain, 300,000 tons; Portugal, 270,000 tons; Ghana, 130,000 tons; Austria, 60,000 tons; and Finland, Kazakhstan, and Namibia, 50,000 tons each.

Substitutes: Substitution for lithium compounds is possible in batteries, ceramics, greases, and manufactured glass. Examples are calcium, magnesium, mercury, and zinc as anode material in primary batteries; calcium and aluminum soaps as substitutes for stearates in greases; and sodic and potassic fluxes in ceramics and glass manufacture.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as production + imports – exports + adjustments for Government and industry stock changes. Rounded to one significant digit to avoid disclosing company proprietary data.

[2]Lithium carbonate, contract price, delivered Europe and United States. Source: Fastmarkets IM.

[3]Defined as imports – exports + adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]Units are kilograms, gross weight.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee or equivalent reserves were 3.8 million tons.

[8]Other countries with reported reserves include Austria, Canada, Congo (Kinshasa), Czechia, Finland, Germany, Mali, Mexico, and Serbia.

[9]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

[Data in thousand metric tons of contained magnesium oxide (MgO) unless otherwise noted][2]

Domestic Production and Use: Seawater and natural brines accounted for about 64% of U.S. magnesium compound production in 2021. The value of shipments of all types of magnesium compounds was estimated to be $390 million, a 7% increase from the revised value in 2020. Magnesium oxide and other compounds were recovered from seawater by one company in California and another company in Delaware, from well brines by one company in Michigan, and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada.

In the United States, about 78% of magnesium compounds were consumed in the form of caustic-calcined magnesia, magnesium chloride, magnesium hydroxide, and magnesium sulfates across the following industries and uses, in descending order, environmental, agricultural, chemical, and deicing. The remaining magnesium compounds were consumed for refractories in the form of dead-burned magnesia, fused magnesia, and olivine. Across all industries, the leading magnesium compounds consumed, in descending order, were magnesium oxide (caustic-calcined magnesia, dead burned magnesia, and fused magnesia), magnesium hydroxide, and magnesium chloride.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	438	405	376	363	390
Shipments (gross weight)	616	610	563	547	590
Imports for consumption	436	551	564	480	560
Exports	103	116	88	66	90
Consumption, apparent[3]	771	840	852	777	860
Employment, plant, number[e]	260	270	270	260	270
Net import reliance[4] as a percentage of apparent consumption	43	52	56	53	55

Recycling: Some magnesia-based refractories are recycled, either for reuse as refractory material or for use as construction aggregate.

Import Sources (2017–20): Caustic-calcined magnesia: China,[5] 71%; Canada, 20%; Israel, 4%; Australia, 3%; and other, 2%. Crude magnesite: China,[5] 86%; Singapore, 11%; Pakistan, 2%; and other, 1%. Dead-burned and fused magnesia: China,[5] 69%; Brazil, 13%; Turkey, 5%; Mexico, 4%; and other, 9%. Magnesium chloride: Israel, 63%; the Netherlands, 23%; China,[5] 5%; India, 3%; and other, 6%. Magnesium hydroxide: Mexico, 54%; the Netherlands, 15%; Israel, 11%; Austria, 9%; and other, 11%. Magnesium sulfates: China,[5] 58%; India, 14%; Germany, 10%; Canada, 5%; and other, 13%. Total imports: China,[5] 56%; Brazil, 10%; Israel, 10%; Canada, 7%; and other, 17%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Crude magnesite	2519.10.0000	Free.
Dead-burned and fused magnesia	2519.90.1000	Free.
Caustic-calcined magnesia	2519.90.2000	Free.
Kieserite	2530.20.1000	Free.
Epsom salts	2530.20.2000	Free.
Magnesium hydroxide and peroxide	2816.10.0000	3.1% ad valorem.
Magnesium chloride	2827.31.0000	1.5% ad valorem.
Magnesium sulfate (synthetic)	2833.21.0000	3.7% ad valorem.

Depletion Allowance: Brucite, 10% (domestic and foreign); dolomite, magnesite, and magnesium carbonate, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign); and olivine, 22% (domestic) and 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, consumption of dead-burned and fused magnesia increased in the United States and globally by an estimated 20% and 8%, respectively, compared with that in 2020, as the demand for steel recovers from disruptions caused by the COVID-19 pandemic. Demand, and subsequent consumption, for all magnesium compounds has increased following the general trend of the manufacturing industry.

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MAGNESIUM COMPOUNDS

An Austria-based magnesia and refractories producer sold two of its magnesia product subsidiaries to a private equity firm. The subsidiaries, located in Ireland and Norway, produced magnesia-based products used in the agricultural, environmental, hydrometallurgical, pulp and paper, and refractory industries.

A Turkish steelmaker purchased one of Turkey's largest magnesite producers that was a major regional and international source of magnesite. The magnesite producer holds more than 40% of Turkey's magnesite reserves and operates three plants with an annual capacity of 1.2 million tons. The purchase of the magnesite producer will provide refractory materials vital to its steelmaking process.

China remains the leading producer of magnesia and magnesite and was the principal exporter of magnesia to the United States and much of the world. As demand was beginning to recover, supply and shipping constraints were adversely affecting the availability of imported sources of magnesia. In China, power-intensive activities such as mineral processing were adversely affected by power outages resulting from a resurging demand for power, coal shortages, and newly enforced emission standards. The resulting decreased magnesia supply in China affected prices and availability of all grades of magnesia in the world market.

World Magnesite Mine Production and Reserves:[6] In addition to magnesite, vast reserves exist in well and lake brines and seawater from which magnesium compounds can be recovered. Reserves for Australia and Turkey were revised based on information from Government and industry sources.

	Mine production[e]		Reserves[7]
	2020	2021	
United States	W	W	35,000
Australia	700	770	[8]290,000
Austria	790	870	49,000
Brazil	1,800	2,000	200,000
China	19,000	21,000	1,000,000
Greece	500	550	280,000
Russia	1,000	1,100	2,300,000
Slovakia	480	530	370,000
Spain	650	720	35,000
Turkey	1,470	1,600	110,000
Other countries	920	1000	2,600,000
World total (rounded)	[9]27,000	[9]30,000	7,200,000

World Resources:[7] Resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread. Identified world magnesite and brucite resources total 13 billion tons and several million tons, respectively. Resources of dolomite, forsterite, magnesium-bearing evaporite minerals, and magnesia-bearing brines are estimated to constitute a resource of billions of tons. Magnesium hydroxide can be recovered from seawater. Serpentine could be used as a source of magnesia but global resources, including in tailings of asbestos mines, have not been quantified but are thought to be very large.

Substitutes: Alumina, chromite, and silica substitute for magnesia in some refractory applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See also Magnesium Metal.

[2]Reported as magnesium content through Mineral Commodity Summaries 2016. Based on input from consumers, producers, and others involved in the industry, reporting magnesium compound data in terms of contained magnesium oxide was determined to be more useful than reporting in terms of magnesium content. Calculations were made using the following magnesium oxide (MgO) contents: magnesite, 47.8%; magnesium chloride, 42.3%; magnesium hydroxide, 69.1%; and magnesium sulfate, 33.5%.

[3]Defined as production + imports – exports.

[4]Defined as imports – exports.

[5]Includes Hong Kong.

[6]Gross weight of magnesite (magnesium carbonate) in thousand tons.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 37 million tons.

[9]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, primary magnesium was produced by one company in Utah at an electrolytic process smelter that recovered magnesium from brines from the Great Salt Lake. Secondary magnesium was recovered from scrap at smelters that produced magnesium ingot and castings and from aluminum alloy scrap at secondary aluminum smelters. Primary magnesium production in 2021 was estimated to have decreased significantly from that in 2020. Information regarding U.S. primary magnesium production was withheld to avoid disclosing company proprietary data. The leading use for primary magnesium metal, which accounted for 45% of reported consumption, was in castings, principally used for the automotive industry. Aluminum-base alloys that were used for packaging, transportation, and other applications accounted for 35% of primary magnesium metal consumption; desulfurization of iron and steel, 16%; and all other uses, 4%. About 31% of the secondary magnesium was consumed for structural uses, and about 69% was used in aluminum alloys.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	112	109	101	100	98
Imports for consumption	42	47	59	61	48
Exports	14	12	10	15	8
Consumption:					
Reported, primary	65	51	52	50	50
Apparent[2]	W	W	W	W	W
Price, annual average:[3]					
U.S. spot Western, dollars per pound	2.15	2.17	2.45	2.49	3.90
European free market, dollars per metric ton	2,265	2,550	2,425	2,149	5,500
Stocks, producer, yearend	W	W	W	W	W
Employment, number[e]	400	400	400	400	400
Net import reliance[4] as a percentage of apparent consumption	<25	<50	<50	<50	<50

Recycling: In 2021, about 29,000 tons of secondary magnesium was recovered from old scrap and 69,000 tons was recovered from new scrap. Aluminum-base alloys accounted for about 57% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 43%.

Import Sources (2017–20): Canada, 20%; Israel, 15%; Mexico, 11%; and other, 54%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Unwrought metal	8104.11.0000	8.0% ad valorem.
Unwrought alloys	8104.19.0000	6.5% ad valorem.
Scrap	8104.20.0000	Free.
Powders and granules	8104.30.0000	4.4% ad valorem.
Wrought metal	8104.90.0000	14.8¢/kg on Mg content + 3.5% ad valorem.

Depletion Allowance: Dolomite, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: On September 29, the producer of primary magnesium in Utah declared force majeure, citing equipment failures. Details on the amount of capacity affected and an expected restart date were not reported by the company. A decrease in spot prices in the United States for magnesium imports in the second quarter was attributed to abundant supplies of secondary magnesium favored by secondary aluminum producers. But the average spot price for imported magnesium in the United States increased from $2.06 per pound at the end of June to $2.18 per pound at the end of August, attributed to contracted deliveries being exhausted with strong demand from aluminum smelters and diecasters. The shutdown of capacity in Utah was cited as the reason for the average price of imports into the United States increasing to $5.13 per pound at the end of September and $7.63 per pound at the end of October.

Environmental regulations and power shortages were cited as the reason for raw material shortages, increased power prices, and decreased magnesium production in China, leading to increased magnesium prices in China and Europe. Decreased coal production and increased prices for raw materials such as ferrosilicon starting in April, and strong

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demand for coal by powerplants in the summer months caused prices to continue to rise. Strong demand for magnesium by aluminum smelters and diecasters was also cited for tight supplies, contributing to price increases in the early part of the second quarter of the year. Constrained shipping, high freight rates, and stockpiling by speculators were also cited as reasons for increasing magnesium prices and supply shortages. In August and September, many smelters in China closed capacity to comply with energy consumption targets, leading to further shortages and increased prices. Spot magnesium prices generally trended upward in China and Europe starting in March. The price range in Europe for the first 3 months was $2,600 to $2,700 per metric ton. At the end of June, the price range in Europe increased to between $3,500 and $3,700 per metric ton and, by the end of August, the price ranged between $4,100 and $4,500 per metric ton. At the end of September, the price range in Europe increased to between $10,000 and $11,500 per metric ton and, by mid-October, the price ranged from $12,000 to $15,000 per metric ton. In late October, the price range started to decrease and was $7,700 to $9,500 per metric ton by mid-November.

On March 1, the Government of China removed a 15% tax on magnesium produced in six jurisdictions in the western part of the country. The tax exemption was part of a policy to encourage development of the magnesium industry in the western part of China and increase consumption.

One company obtained a location in Ohio to build a pilot plant to test magnesium production from dolomite. A company in Australia planned to construct a 3,000-ton-per-year smelter to recover magnesium from coal fly ash. A company in Quebec, Canada, planned to construct a primary magnesium smelter to produce magnesium from serpentine-bearing asbestos tailings. The same company in Canada completed construction of an 18,000-ton-per-year secondary magnesium smelter at the same location and started production during the year.

The use of magnesium in automobile parts continued to increase as automobile manufacturers sought to decrease vehicle weight for increased fuel efficiency. Magnesium castings have substituted for aluminum, iron, and steel in some automobiles. The substitution of aluminum for steel in automobile sheet continued to increase consumption of magnesium in aluminum alloy sheet. A shortage of computer chips was cited for some automobile manufacturers decreasing production despite strong demand, resulting in some diecasters decreasing magnesium consumption.

World Primary Production and Reserves:

	Smelter production		Reserves[5]
	2020	2021[e]	
United States	W	W	Magnesium metal can be derived from seawater, natural brines, dolomite, serpentine, and other minerals. The reserves for this metal are sufficient to supply current and future requirements.
Brazil	18	20	
China	886	800	
Israel	19	22	
Kazakhstan	16	20	
Russia	48	60	
Turkey	12	15	
Ukraine	6	10	
World total (rounded)[6]	1,000	950	

World Resources:[5] Resources from which magnesium may be recovered range from large to virtually unlimited and are globally widespread. Resources of dolomite, serpentine, and magnesium-bearing evaporite minerals are enormous. Magnesium-bearing brines are estimated to constitute a resource in the billions of tons, and magnesium could be recovered from seawater along world coastlines.

Substitutes: Aluminum and zinc may substitute for magnesium in castings and wrought products. The relatively light weight of magnesium is an advantage over aluminum and zinc in castings and wrought products in most applications; however, its high cost is a disadvantage relative to these substitutes. For iron and steel desulfurization, calcium carbide may be used instead of magnesium. Magnesium is preferred to calcium carbide for desulfurization of iron and steel because calcium carbide produces acetylene in the presence of water.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See also Magnesium Compounds.

[2]Defined as primary production + secondary production from old scrap + imports – exports + adjustments for industry stock changes.

[3]Source: S&P Global Platts Metals Week.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Excludes U.S. production.

MANGANESE

(Data in thousand metric tons, gross weight, unless otherwise noted)

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by six companies with plants principally in the East and Midwest. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Manganese ferroalloys were produced at two plants. Additional quantities of ore were used for nonmetallurgical purposes such as in the production of animal feed, brick colorant, dry cell batteries, and fertilizers.

Salient Statistics—United States:[1]	2017	2018	2019	2020	2021[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ores and concentrates	297	440	434	367	460
Ferromanganese	331	427	332	223	320
Silicomanganese	351	412	351	269	270
Exports:					
Manganese ores and concentrates	1	3	1	1	1
Ferromanganese	9	10	5	5	11
Silicomanganese	8	4	2	2	4
Shipments from Government stockpile:[2]					
Manganese ore	—	—	—	—	2
Ferromanganese and manganese metal, electrolytic	12	13	10	54	17
Consumption, reported:					
Manganese ore[3]	378	369	442	378	390
Ferromanganese	345	348	336	325	330
Silicomanganese	[4]141	[4]139	[4]143	229	230
Consumption, apparent, manganese content[5]	715	796	748	620	640
Price, average, manganese content, cost, insurance, and freight, China, dollars per metric ton unit[6]	5.97	7.16	5.63	4.59	5.20
Stocks, producer and consumer, yearend:					
Manganese ore[3]	148	191	175	143	170
Ferromanganese	17	27	44	35	35
Silicomanganese	11	21	39	31	31
Net import reliance[7] as a percentage of apparent consumption, manganese content	100	100	100	100	100

Recycling: Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.

Import Sources (2017–20): Manganese ore: Gabon, 67%; South Africa, 18%; Mexico, 11%; and other, 4%. Ferromanganese: Australia, 20%; South Africa, 20%; Norway, 16%; Malaysia, 14%; and other, 30%. Silicomanganese: Georgia, 27%; Australia, 21%; South Africa, 21%; and other, 31%. Manganese contained in principal manganese imports:[8] Gabon, 23%; South Africa, 19%; Australia, 13%; Georgia, 9%; and other, 36%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Ores and concentrates:		
Containing less than 47% manganese	2602.00.0040	Free.
Containing 47% or more of manganese	2602.00.0060	Free.
Manganese dioxide	2820.10.0000	4.7% ad valorem.
High-carbon ferromanganese	7202.11.5000	1.5% ad valorem.
Ferrosilicon manganese (silicomanganese)	7202.30.0000	3.9% ad valorem.
Metal, unwrought:		
Flake containing at least 99.5% manganese	8111.00.4700	14% ad valorem.
Other	8111.00.4900	14% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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MANGANESE

Government Stockpile:[9]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Manganese ore, metallurgical grade	291	—	292	—	292
Ferromanganese, high-carbon	119	—	45	—	45
Manganese metal, electrolytic	—	5	—	5	—

Events, Trends, and Issues: Global production of steel, the leading use of manganese, increased in 2021 compared with production in 2020 owing to increased demand following the negative effects of the global COVID-19 pandemic. Global production of manganese ore was estimated to be about 6% more than that in 2020. The leading countries for manganese ore production were, in descending order on a contained-weight basis, South Africa, Gabon, and Australia. On a contained-weight basis, total U.S. manganese imports were estimated to have increased by approximately 20% in 2021 compared with those in 2020. By October 2021, average spot market prices for manganese ore from China had increased by 13% compared with the annual average spot price in 2020.

World Mine Production (manganese content) and Reserves: Reserves for Australia and South Africa were revised based on Government and industry sources.

	Mine production 2020	Mine production 2021[e]	Reserves[10]
United States	—	—	—
Australia	3,330	3,300	[11]270,000
Brazil	494	400	270,000
Burma	254	250	NA
China	1,340	1,300	54,000
Côte d'Ivoire	525	500	NA
Gabon	3,310	3,600	61,000
Georgia	186	190	NA
Ghana	637	640	13,000
India	632	600	34,000
Kazakhstan, concentrate	158	160	5,000
Malaysia	347	360	NA
Mexico	198	200	5,000
South Africa	6,500	7,400	640,000
Ukraine, concentrate	578	670	140,000
Vietnam	121	120	NA
Other countries	260	260	Small
World total (rounded)	18,900	20,000	1,500,000

World Resources:[10] Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs. South Africa accounts for about 30% of the world's manganese reserves.

Substitutes: Manganese has no satisfactory substitute in its major applications.

[e]Estimated. NA Not available. — Zero.

[1]Manganese content typically ranges from 35% to 54% for manganese ore and from 74% to 95% for ferromanganese.

[2]Defined as stockpile shipments – receipts.

[3]Exclusive of ore consumed directly at iron and steel plants and associated yearend stocks.

[4]Imports more nearly represent amount consumed than does reported consumption.

[5]Defined as imports – exports + adjustments for Government and industry stock changes. Manganese content based on estimates of average content for all significant components—including ore, manganese dioxide, ferromanganese, silicomanganese, and manganese metal—except imports, for which content is reported.

[6]For average metallurgical-grade ore containing 44% manganese. Source: CRU Group.

[7]Defined as imports – exports + adjustments for Government and industry stock changes.

[8]Includes imports of ferromanganese, manganese ore, silicomanganese, synthetic manganese dioxide, and unwrought manganese metal.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 91 million tons, gross weight.

MERCURY

(Data in metric tons of contained mercury unless otherwise noted)

Domestic Production and Use: Mercury has not been produced as a principal mineral commodity in the United States since 1992. In 2021, mercury was recovered as a byproduct from processing gold-silver ore at several mines in Nevada; however, production data were not reported. Secondary, or recycled, mercury was recovered from batteries, compact and traditional fluorescent lamps, dental amalgam, medical devices, and thermostats, as well as mercury-contaminated soils. The U.S. Environmental Protection Agency (EPA) reported a revised domestic production of 45 tons in 2018 (the last year for which data were available), and about 82 tons of mercury was stored by manufacturers or producers. The reported domestic consumption of mercury and mercury in compounds in products was 16 tons. The leading domestic end uses of mercury and mercury compounds were dental amalgam (43%); relays, sensors, switches, and valves (41%); bulbs, lamps, and lighting (8%); formulated products (buffers, catalysts, fixatives, and vaccination uses) (7%); and batteries and other end uses (1%). A large quantity of mercury (about 245 tons) is used in manufacturing processes such as catalysts or as a cathode in the chlorine-caustic soda (chloralkali) process. Almost all the mercury is reused in the process. The leading manufacturing processes that use mercury are mercury-cell chloralkali plants. In 2021, only one mercury-cell chloralkali plant operated in the United States. Until December 31, 2012, domestic- and foreign-sourced mercury was refined and then exported for global use, primarily for small-scale gold mining in many parts of the world. Beginning January 1, 2013, export of elemental mercury from the United States was banned, with some exceptions, under the Mercury Export Ban Act of 2008. Effective January 1, 2020, exports of five mercury compounds were added to that ban.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption, metal (gross weight)	20	6	9	3	2
Exports, metal (gross weight)	—	—	—	—	—
Price, average value, dollars per flask, 99.99%:[1]					
European Union[2]	1,041	1,100	NA	NA	NA
Global locations[3]	1,273	2,709	2,550	NA	NA
Net import reliance[4] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: In 2021, eight facilities operated by six companies in the United States accounted for most of the secondary mercury produced and were authorized by the U.S. Department of Energy (DOE) to temporarily store mercury until the DOE's long-term facility opens. Mercury-containing automobile convenience switches, barometers, compact and traditional fluorescent bulbs, computers, dental amalgam, medical devices, and thermostats were collected by smaller companies and shipped to the refining companies for retorting to reclaim the mercury. In addition, many collection companies recovered mercury when retorting was not required. With the rapid phasing out of compact and traditional fluorescent lighting for light-emitting-diode (LED) lighting, an increased quantity of mercury was being recycled.

Import Sources (2017–20): Canada, 51%; France, 26%; China, 16%; Switzerland, 5%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Mercury	2805.40.0000	1.7% ad valorem.
Amalgams	2843.90.0000	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5] The Defense Logistics Agency Strategic Materials held and managed an inventory of 4,437 tons of mercury in storage at the Hawthorne Army Depot in Hawthorne, NV. On December 3, 2019, the DOE selected a site near Andrews, TX, to store up to 6,800 tons of mercury. Sales of mercury from the stockpiles remained suspended.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Mercury	4,437	—	—	—	—

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MERCURY

Events, Trends, and Issues: Owing to mercury toxicity and concerns for the environment and human health, overall mercury use has declined in the United States and worldwide. Mercury continues to be released to the environment from numerous sources, including mercury-containing car switches when automobiles (those produced prior to 2003) are scrapped without recovering the switches for recycling, coal-fired powerplant emissions, incineration of mercury-containing medical devices, and naturally occurring sources. Mercury is no longer used in most batteries and paints manufactured in the United States. Some button-type batteries, cleansers, fireworks, folk medicines, grandfather clocks, pesticides, and skin-lightening creams and soaps may still contain mercury. Mercury compounds were used as catalysts in the coal-based manufacture of vinyl chloride monomer in China. In some parts of the world, mercury was used in the recovery of gold in artisanal and small-scale mining operations. Conversion to nonmercury technology for chloralkali production and the ultimate closure of the world's mercury-cell chloralkali plants may release a large quantity of mercury to the global market for recycling, sale, or, owing to export bans in Europe and the United States, long-term storage.

Byproduct mercury production is expected to continue from large-scale domestic and foreign gold-silver mining and processing, as is secondary production of mercury from an ever-diminishing supply of mercury-containing products. Domestic mercury consumption will continue to decline owing to increased use of LED lighting and consequent reduced use of conventional fluorescent tubes and compact fluorescent bulbs and continued substitution of non-mercury-containing products in control, dental, and measuring applications.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	NA	NA	Quantitative estimates of reserves are not available. China, Kyrgyzstan, and Peru are thought to have the largest reserves.
China	2,200	2,000	
Kyrgyzstan	15	15	
Mexico (net exports)	40	40	
Norway	20	20	
Peru (exports)	30	30	
Tajikistan	178	170	
Other countries	11	11	
World total (rounded)[7]	2,490	2,300	

World Resources:[6] China, Kyrgyzstan, Mexico, Peru, Russia, Slovenia, Spain, and Ukraine have most of the world's estimated 600,000 tons of mercury resources. Mexico reclaims mercury from Spanish colonial silver-mining waste. In Spain, once a leading producer of mercury, mining at its centuries-old Almaden Mine stopped in 2003. In the United States, mercury occurrences are in Alaska, Arkansas, California, Nevada, and Texas. The declining consumption of mercury, except for small-scale gold mining, indicates that these resources are sufficient for centuries of use.

Substitutes: Ceramic composites substitute for the dark-gray mercury-containing dental amalgam. "Galinstan," an alloy of gallium, indium, and tin, replaces the mercury used in traditional mercury thermometers, and digital thermometers have replaced traditional thermometers. At chloralkali plants around the world, mercury-cell technology is being replaced by newer diaphragm and membrane-cell technology. LEDs that contain indium substitute for mercury-containing fluorescent lamps. Lithium, nickel-cadmium, and zinc-air batteries replace mercury-zinc batteries in the United States; indium compounds substitute for mercury in alkaline batteries; and organic compounds are being used instead of mercury fungicides in latex paint.

[e]Estimated. NA Not available. — Zero.

[1]Some international data and dealer prices are reported in flasks. One metric ton (1,000 kilograms) = 29.0082 flasks, and 1 flask = 76 pounds, or 34.47 kilograms, or 0.03447 metric ton.

[2]Average annual price of minimum 99.99% mercury. Source: Argus Media group—Argus Metals International. Price discontinued on May 1, 2018.

[3]Average midpoint of free market 99.99% mercury in warehouse, global locations. Source: Metal Bulletin. Price discontinued on December 1, 2019.

[4]Defined as imports – exports + adjustments for Government stock changes.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data source.

[7]Excludes U.S. production.

MICA (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Scrap and flake mica production, excluding low-quality sericite, was estimated to be 43,000 tons valued at $4.8 million. Mica was mined in Georgia, North Carolina, and South Dakota. Scrap mica was recovered principally from mica and sericite schist and as a byproduct from the production of feldspar and kaolin and the beneficiation of industrial sand. Eight companies produced an estimated 64,000 tons of ground mica valued at about $20 million from domestic and imported scrap and flake mica. Most of the domestic production was processed into small-particle-size mica by either wet or dry grinding. Primary uses were joint compound, oil-well-drilling additives, paint, roofing, and rubber products.

A minor amount of sheet mica has been produced as incidental production from feldspar mining in North Carolina in the past several years. Data on sheet mica production were not available in 2021. The domestic consuming industry was dependent on imports to meet demand for sheet mica. Most sheet mica was fabricated into parts for electrical and electronic equipment.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Scrap and flake:					
Production:[e, 1]					
Sold and used	40,000	42,000	40,100	34,600	43,000
Ground	69,700	68,400	61,300	59,800	64,000
Imports[2]	29,700	28,100	27,300	19,400	22,000
Exports[3]	6,790	6,030	5,500	4,000	5,000
Consumption, apparent[e, 4]	62,900	64,100	61,900	50,000	60,000
Price, average, dollars per metric ton:[e]					
Scrap and flake	165	125	118	111	110
Ground:					
Dry	292	308	316	300	300
Wet	424	422	394	338	350
Net import reliance[5] as a percentage of apparent consumption	36	34	35	31	28
Sheet:					
Sold and used	W	W	W	W	NA
Imports[6]	1,850	1,890	3,150	2,850	3,800
Exports[7]	704	686	779	527	670
Consumption, apparent[e, 4]	1,150	1,200	2,370	2,320	3,100
Price, average value, muscovite and phlogopite mica, dollars per kilogram:[e]					
Block	W	W	W	W	W
Splittings	1.66	1.65	1.66	1.57	1.60
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Scrap and flake: Canada, 43%; China, 34%; India, 8%; and other, 15%. Sheet: China, 63%; Brazil, 14%; Belgium, 5%; India, 4%; and other, 14%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Split block mica	2525.10.0010	Free.
Mica splittings	2525.10.0020	Free.
Unworked, other	2525.10.0050	Free.
Mica powder	2525.20.0000	Free.
Mica waste	2525.30.0000	Free.
Plates, sheets, and strips of agglomerated or reconstituted mica	6814.10.0000	2.7% ad valorem.
Worked mica and articles of mica, other	6814.90.0000	2.6% ad valorem.

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MICA (NATURAL)

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic production of scrap and flake mica was estimated to have increased by 24% in 2021, compared with that in 2020, and apparent consumption of scrap and flake mica increased by 20%. Apparent consumption of sheet mica was estimated to have increased by 34% in 2021. Increased production and consumption of scrap and flake mica reflected the recovery from the effects of the COVID-19 pandemic of some of industries that use mica, primarily for use in oil-well-drilling fluid and joint compound. No environmental concerns are associated with the manufacture and use of mica products. Supplies of sheet mica for United States consumption were expected to continue to be from imports, primarily from Belgium, Brazil, China, and India.

World Mine Production and Reserves: World production of sheet mica has remained steady; however, reliable production data for some countries that were thought to be major contributors to the world total were unavailable.

	Scrap and flake			Sheet		
	Mine production		Reserves[8]	Mine production[e]		Reserves[8]
	2020	2021[e]		2020	2021	
United States	34,600	43,000	Large	W	NA	Very small
Canada	15,000	15,000	Large	NA	NA	NA
China	95,000	95,000	Large	NA	NA	NA
Finland	64,900	65,000	Large	NA	NA	NA
France	19,000	19,000	Large	NA	NA	NA
India	15,000	15,000	Large	1,000	1,000	110,000
Korea, Republic of	21,000	22,000	11,000,000	—	—	NA
Madagascar	33,000	35,000	Large	—	—	NA
Turkey	4,140	4,000	620,000	—	—	NA
Other countries	51,000	50,000	Large	200	200	Moderate
World total (rounded)	353,000	360,000	Large	NA	NA	NA

World Resources:[8] Resources of scrap and flake mica are available in clay deposits, granite, pegmatite, and schist, and are considered more than adequate to meet anticipated world demand in the foreseeable future. World resources of sheet mica have not been formally evaluated because of the sporadic occurrence of this material. Large deposits of mica-bearing rock are known to exist in countries such as Brazil, India, and Madagascar. Limited resources of sheet mica are available in the United States. Domestic resources were subeconomic because of the high cost of the hand labor required to mine and process sheet mica from pegmatites.

Substitutes: Some lightweight aggregates, such as diatomite, perlite, and vermiculite, may be substituted for ground mica when used as filler. Ground synthetic fluorophlogopite, a fluorine-rich mica, may replace natural ground mica for uses that require the thermal and electrical properties of mica. Many materials can be substituted for mica in numerous electrical, electronic, and insulation uses. Substitutes include acrylic, cellulose acetate, fiberglass, fishpaper, nylatron, nylon, phenolics, polycarbonate, polyester, styrene, polyvinyl chloride, and vulcanized fiber. Mica paper made from scrap mica can be substituted for sheet mica in electrical and insulation applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Excludes low-quality sericite used primarily for brick manufacturing.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0050, <$6.00 per kilogram; 2525.20.0000; and 2525.30.0000.

[3]Includes data for the following Schedule B codes: 2525.10.0000, <$6.00 per kilogram; 2525.20.0000; and 2525.30.0000.

[4]Defined as sold or used by producing companies + imports – exports.

[5]Defined as imports – exports.

[6]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0010; 2525.10.0020; 2525.10.0050, >$6.00 per kilogram; 6814.10.0000; and 6814.90.0000.

[7]Includes data for the following Schedule B codes: 2525.10.0000, >$6.00 per kilogram; 6814.10.0000; and 6814.90.0000.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

MOLYBDENUM

(Data in metric tons of contained molybdenum unless otherwise noted)

Domestic Production and Use: U.S. mine production of molybdenum in 2021 decreased by 6% to an estimated 48,000 tons compared with that in the previous year. Molybdenum ore was produced as a primary product at two mines—both in Colorado—whereas seven copper mines (four in Arizona and one each in Montana, Nevada, and Utah) recovered molybdenite concentrate as a byproduct. Three roasting plants converted molybdenite concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced. Metallurgical applications accounted for more than 88% of the total molybdenum consumed.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine	40,700	41,400	43,600	51,100	48,000
Imports for consumption	36,000	37,500	34,200	24,700	29,000
Exports	43,200	48,400	67,200	62,400	66,000
Consumption:					
Reported[1]	17,400	16,700	16,400	15,800	16,000
Apparent[2]	34,200	31,400	10,500	13,300	13,000
Price, average value, dollars per kilogram[3]	18.06	27.04	26.50	19.90	36
Stocks, consumer materials	2,010	1,940	1,980	1,980	1,700
Employment, mine and plant, number	940	940	950	950	950
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Molybdenum is recycled as a component of catalysts, ferrous scrap, and superalloy scrap. Ferrous scrap consists of revert, new, and old scrap. Revert scrap refers to remnants manufactured in the steelmaking process. New scrap is generated by steel mill customers and recycled by scrap collectors and processors. Old scrap is largely molybdenum-bearing alloys recycled after serving their useful life. The amount of molybdenum recycled as part of new and old steel and other scrap may be as much as 30% of the apparent supply of molybdenum. There are no processes for the separate recovery and refining of secondary molybdenum from its alloys. Molybdenum is not recovered separately from recycled steel and superalloys, but the molybdenum content of the recycled alloys is significant, and the molybdenum content is reused. Recycling of molybdenum-bearing scrap will continue to be dependent on the markets for the principal alloy metals in which molybdenum is contained, such as iron, nickel, and chromium.

Import Sources (2017–20): Ferromolybdenum: Chile, 58%; the Republic of Korea, 35%; Canada, 3%; and other, 4%. Molybdenum ores and concentrates: Peru, 58%; Chile, 17%; Canada, 12%; Mexico, 12%; and other, 1%. Total: Peru, 42%; Chile, 26%; Canada, 10%; Mexico, 8%; and other, 14%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Molybdenum ore and concentrates, roasted	2613.10.0000	12.8¢/kg + 1.8% ad valorem.
Molybdenum ore and concentrates, other	2613.90.0000	17.8¢/kg.
Molybdenum chemicals:		
Molybdenum oxides and hydroxides	2825.70.0000	3.2% ad valorem.
Molybdates of ammonium	2841.70.1000	4.3% ad valorem.
Molybdates, all others	2841.70.5000	3.7% ad valorem.
Molybdenum pigments, molybdenum orange	3206.20.0020	3.7% ad valorem.
Ferroalloys, ferromolybdenum	7202.70.0000	4.5% ad valorem.
Molybdenum metals:		
Powders	8102.10.0000	9.1¢/kg + 1.2% ad valorem.
Unwrought	8102.94.0000	13.9¢/kg + 1.9% ad valorem.
Wrought bars and rods	8102.95.3000	6.6% ad valorem.
Wrought plates, sheets, strips, etc.	8102.95.6000	6.6% ad valorem.
Wire	8102.96.0000	4.4% ad valorem.
Waste and scrap	8102.97.0000	Free.
Other	8102.99.0000	3.7% ad valorem.

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MOLYBDENUM

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, the estimated average molybdic oxide price increased by 81% compared with that in 2020, and U.S. estimated mine production of molybdenum decreased by 6% from that in 2020. The decrease in production was mainly the result of one byproduct mine in Utah decreasing its production by almost more than 70%. This decrease in production in Utah was offset by production increases at other molybdenum producers.

Estimated U.S. imports for consumption increased by 18% compared with those in 2020. U.S. exports increased by 5% from those in 2020. Apparent consumption in 2021 was essentially unchanged compared with that in 2020.

Global molybdenum production in 2021 increased slightly compared with that in 2020. In descending order of production, China, Chile, the United States, Peru, and Mexico provided 93% of total global production. Chinese molybdenum imports continued to be at historically high levels as China continued to focus on infrastructure growth to support its COVID-19 recovery. A major producer in China increased its molybdenum concentrate production in 2021 after having suspended its production for 6 months in 2020 following a tailings leakage accident. Many Chinese producers also continued to limit their molybdenum exports citing higher freight costs owing to container shortages and shipping delays. These factors all continued to contribute to decade-high molybdenum prices.

World Mine Production and Reserves: The reserves data for Mongolia, Peru, Russia, and Turkey were revised on the basis of new information from company and Government reports.

	Mine production		Reserves[5]
	2020	2021[e]	(thousand metric tons)
United States	51,100	48,000	2,700
Argentina	—	—	100
Armenia	[e]8,700	8,200	150
Canada	2,530	1,700	96
Chile	59,400	51,000	1,400
China	[e]120,000	130,000	8,300
Iran	[e]1,400	1,400	43
Korea, Republic of	411	400	NA
Mexico	16,600	18,000	130
Mongolia	2,890	2,900	NA
Peru	32,200	32,000	2,300
Russia	[e]2,700	2,800	430
Turkey	—	—	360
Uzbekistan	[e]200	200	60
World total (rounded)	298,000	300,000	16,000

World Resources:[5] Identified resources of molybdenum in the United States are about 5.4 million tons, and in the rest of the world, about 20 million tons. Molybdenum occurs as the principal metal sulfide in large low-grade porphyry molybdenum deposits and as an associated metal sulfide in low-grade porphyry copper deposits. Resources of molybdenum are adequate to supply world needs for the foreseeable future.

Substitutes: There is little substitution for molybdenum in its major application in steels and cast irons. In fact, because of the availability and versatility of molybdenum, industry has sought to develop new materials that benefit from its alloying properties. Potential substitutes include boron, chromium, niobium (columbium), and vanadium in alloy steels; tungsten in tool steels; graphite, tantalum, and tungsten for refractory materials in high-temperature electric furnaces; and cadmium-red, chrome-orange, and organic-orange pigments for molybdenum orange.

[e]Estimated. E Net exporter. NA Not available. — Zero.

[1]Reported consumption of primary molybdenum products.

[2]Defined as production + imports – exports + adjustments for concentrate, consumer, and product producer stock changes.

[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide, as reported by CRU Group.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

NICKEL

(Data in metric tons of contained nickel unless otherwise noted)

Domestic Production and Use: In 2021, the underground Eagle Mine in Michigan produced approximately 18,000 tons of nickel in concentrate, which was exported to smelters in Canada and overseas. A company in Missouri recovered metals, including nickel, from mine tailings as part of the Superfund Redevelopment Initiative. Nickel in crystalline sulfate was produced as a byproduct of smelting and refining platinum-group-metal ores mined in Montana.

In the United States, the leading uses for primary nickel are alloys and steels, electroplating, and other uses including catalysts and chemicals. Stainless and alloy steel and nickel-containing alloys typically account for more than 85% of domestic consumption.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine	22,100	17,600	13,500	16,700	18,000
Refinery, byproduct	W	W	W	W	W
Imports:					
Ores and concentrates	64	3	4	95	24
Primary	150,000	144,000	119,000	105,000	110,000
Secondary	38,100	45,100	37,700	31,800	35,000
Exports:					
Ores and concentrates	20,000	18,000	14,300	13,400	15,000
Primary	11,000	9,780	12,800	11,300	10,000
Secondary	51,500	59,400	47,800	34,100	29,000
Consumption:					
Reported, primary	105,000	107,000	105,000	[e]84,000	82,000
Reported, secondary, purchased scrap	133,000	123,000	111,000	[e]99,000	110,000
Apparent, primary[1]	140,000	136,000	106,000	94,100	100,000
Apparent, total[2]	273,000	259,000	217,000	[e]190,000	210,000
Price, average annual, London Metal Exchange (LME), cash:					
Dollars per metric ton	10,403	13,114	13,903	13,772	18,000
Dollars per pound	4.719	5.948	6.306	6.25	8.3
Stocks, yearend:					
Consumer	14,600	16,300	13,400	13,000	13,000
LME U.S. warehouses	3,780	2,268	1,974	1,734	1,500
Net import reliance[3] as a percentage of total apparent consumption	51	52	49	49	48

Recycling: Nickel in alloyed form was recovered from the processing of nickel-containing waste, including flue dust, grinding swarf, mill scale, and shot blast generated during the manufacturing of stainless steel; filter cakes, plating solutions, spent catalysts, spent pickle liquor, sludges, and all types of spent nickel-containing batteries. Nickel-containing alloys and stainless-steel scrap were also melted and used to produce new alloys and stainless steel. The U.S. Department of Energy's ReCell Center continued to investigate methods to more effectively recover raw materials, including nickel, from recycled batteries. In 2021, recycled nickel in all forms accounted for approximately 52% of apparent consumption.

Import Sources (2017–20): Nickel contained in ferronickel, metal, oxides, and salt: Canada, 43%; Norway, 10%; Finland, 9%; Australia, 8%; and other, 30%. Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 37%; Mexico, 26%; United Kingdom, 9%; and other, 28%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Nickel ores and concentrates, nickel content	2604.00.0040	Free.
Ferronickel	7202.60.0000	Free.
Unwrought nickel, not alloyed	7502.10.0000	Free.
Nickel waste and scrap	7503.00.0000	Free.
Nickel powders	7504.00.0010	Free.
Nickel flakes	7504.00.0050	Free.

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NICKEL

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4] The U.S. Department of Energy is holding nickel ingot contaminated by low-level radioactivity at Paducah, KY, and shredded nickel scrap at Oak Ridge, TN. See Lithium for statistics on lithium-nickel-cobalt-aluminum oxide.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Nickel alloys, gross weight	790	—	—	—	—

Events, Trends, and Issues: On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

In 2021, the annual average LME cash price was estimated to have increased by 30% compared with that in 2020, which was attributed to expectations of increased use of nickel in electric vehicle batteries and continued strong demand for stainless steel.

Mine production in Indonesia increased by an estimated 30%, which was facilitated by the ongoing commissioning of integrated nickel pig iron and stainless-steel projects. The country's first hydrometallurgical plant began operation in May on Obi Island. It was among several similar projects in the country that were designed to produce intermediate nickel products to be used as feed material at battery-grade nickel sulfate plants.

World Mine Production and Reserves: Reserves for Australia, Canada, Russia, and the United States were revised based on new information from company and (or) Government reports.

	Mine production		Reserves[5]
	2020	2021[e]	
United States	16,700	18,000	[6]340,000
Australia	169,000	160,000	[7]21,000,000
Brazil	77,100	100,000	16,000,000
Canada	167,000	130,000	2,000,000
China	120,000	120,000	2,800,000
Indonesia	771,000	1,000,000	21,000,000
New Caledonia[8]	200,000	190,000	NA
Philippines	334,000	370,000	4,800,000
Russia	283,000	250,000	7,500,000
Other countries	373,000	410,000	20,000,000
World total (rounded)	2,510,000	2,700,000	>95,000,000

World Resources:[5] Identified land-based resources averaging approximately 0.5% nickel or greater contain at least 300 million tons of nickel, with about 60% in laterites and 40% in sulfide deposits. Extensive nickel resources also are found in manganese crusts and nodules on the ocean floor.

Substitutes: Low-nickel, duplex, or ultrahigh-chromium stainless steels have been substituted for austenitic grades in construction. Nickel-free specialty steels are sometimes used in place of stainless steel in the power-generating and petrochemical industries. Titanium alloys can substitute for nickel metal or nickel-base alloys in corrosive chemical environments.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as primary imports – primary exports + adjustments for industry stock changes, excluding secondary consumer stocks.

[2]Defined as apparent primary consumption + reported secondary consumption.

[3]Defined as imports – exports + adjustments for consumer stock changes.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Includes reserve data for three projects. An additional three domestic projects have defined resources but have not yet defined reserves.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 8.3 million tons.

[8]Overseas Territory of France.

NIOBIUM (COLUMBIUM)

(Data in metric tons of contained niobium unless otherwise noted)

Domestic Production and Use: Significant U.S. niobium mine production has not been reported since 1959. Companies in the United States produced niobium-containing materials from imported niobium concentrates, oxides, and ferroniobium. Niobium was consumed mostly in the form of ferroniobium by the steel industry and as niobium alloys and metal by the aerospace industry. In 2021, there was an increase in apparent consumption of niobium for high-strength low-alloy steel and superalloy applications. Major end-use distribution of domestic niobium consumption was estimated as follows: steels, about 80%, and superalloys, about 20%. The estimated value of niobium consumption was $340 million, as measured by the value of imports.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine	—	—	—	—	—
Imports for consumption[1]	9,330	11,200	10,100	7,200	8,000
Exports[1]	1,490	955	668	785	1,000
Shipments from Government stockpile[2]	−66	−76	−84	−88	−1
Consumption:[e]					
Apparent[3]	7,780	10,100	9,370	6,330	7,000
Reported[4]	7,640	6,850	6,680	5,120	5,700
Price, unit value, ferroniobium, dollars per kilogram[5]	20	21	23	21	20
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Niobium was recycled when niobium-bearing steels and superalloys were recycled; scrap recovery, specifically for niobium content, was negligible. The amount of niobium recycled is not available, but it may be as much as 20% of apparent consumption.

Import Sources (2017–20): Niobium and tantalum ores and concentrates: Australia, 36%; Rwanda, 34%; Congo (Kinshasa), 7%; Mozambique, 6%; and other, 17%. Niobium oxide: Brazil, 60%; Thailand, 15%; Russia, 11%; Estonia, 6%; and other, 8%. Ferroniobium and niobium metal: Brazil, 67%; Canada, 31%; Germany, 1%, and other, 1%. Total imports: Brazil, 65%; Canada, 27%; and other, 8%. Of the U.S. niobium material imports (by contained weight), 89% was ferroniobium, 10% was niobium oxide, 1% was niobium ores and concentrates, and <1% was niobium metal.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Niobium oxide	2825.90.1500	3.7% ad valorem.
Ferroniobium:		
Less than 0.02% P or S, or less than 0.4% Si	7202.93.4000	5% ad valorem.
Other	7202.93.8000	5% ad valorem.
Niobium:		
Waste and scrap[6]	8112.92.0600	Free.
Powders and unwrought metal	8112.92.4000	4.9% ad valorem.
Niobium, other[6]	8112.99.9000	4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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NIOBIUM (COLUMBIUM)

Government Stockpile:[7]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Ferroniobium (gross weight)	544	—	—	—	—
Niobium metal (gross weight)	10	—	—	—	—

Events, Trends, and Issues: In 2021, U.S. niobium apparent consumption (measured in niobium content) was estimated to be 7,000 tons, an 11% decrease from that in 2020. One domestic company developing its Elk Creek project in Nebraska announced that it acquired a key land parcel in April, affording ownership of 90% of the project's mineral reserves and resources. The project would be the only niobium mine and primary niobium-processing facility in the United States, with construction to begin after financing was obtained.

Brazil continued to be the world's leading niobium producer with approximately 88% of global production, followed by Canada with about 10%. Global niobium production and consumption were thought to have increased in 2021 as steel production in most countries began to recover from the global COVID-19 pandemic. According to international trade statistics under the Harmonized Tariff Code 7202.93 (ferroniobium), Brazil's total exports were 69,400 tons from January through September 2021, 31% greater than through the same period in 2020. Most of Brazil's exports were sent to China, followed by the Netherlands and the Republic of Korea.

A leading niobium producer in Brazil completed its most recent capacity upgrades which increased the original capacity by 50% to 150,000 tons per year of niobium products (approximately 98,000 tons per year of niobium content). Further, two additional producers in Brazil entered the funding stages for new capacity upgrades. The completion of those projects could provide a potential significant increase in production in Brazil over the next decade.

World Mine Production and Reserves:

	Mine production 2020	Mine production 2021[e]	Reserves[8]
United States	—	—	170,000
Brazil	59,800	66,000	16,000,000
Canada	6,500	7,400	1,600,000
Other countries	1,350	1,400	NA
World total (rounded)	67,700	75,000	>17,000,000

World Resources:[8] World resources of niobium are more than adequate to supply projected needs. Most of the world's identified resources of niobium occur as pyrochlore in carbonatite (igneous rocks that contain more than 50%-by-volume carbonate minerals) deposits and are outside the United States.

Substitutes: The following materials can be substituted for niobium, but a performance loss or higher cost may ensue: ceramic matrix composites, molybdenum, tantalum, and tungsten in high-temperature (superalloy) applications; molybdenum, tantalum, and titanium as alloying elements in stainless and high-strength steels; and molybdenum and vanadium as alloying elements in high-strength low-alloy steels.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated niobium content of ferroniobium, niobium and tantalum ores and concentrates, niobium oxide, and niobium powders and unwrought metal.

[2]Change in total inventory from prior yearend inventory. If negative, net increase in inventory.

[3]Defined as imports – exports + adjustments for Government stock changes.

[4]Only includes ferroniobium and nickel niobium.

[5]Unit value is weighted average unit value of gross weight of U.S. ferroniobium trade (imports plus exports.)

[6]This category includes niobium-containing material and other material.

[7]See Appendix B for definitions.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

NITROGEN (FIXED)—AMMONIA

(Data in thousand metric tons of contained nitrogen unless otherwise noted)

Domestic Production and Use: Ammonia was produced by 16 companies at 35 plants in 16 States in the United States during 2021; 2 additional plants were idle for the entire year. About 60% of total U.S. ammonia production capacity was in Louisiana, Oklahoma, and Texas because of their large reserves of natural gas, the dominant domestic feedstock for ammonia. In 2021, U.S. producers operated at about 84% of rated capacity. The United States was one of the world's leading producers and consumers of ammonia. Urea, ammonium nitrate, nitric acid, ammonium phosphates, and ammonium sulfate were, in descending order of quantity produced, the major derivatives of ammonia produced in the United States.

Approximately 88% of apparent domestic ammonia consumption was for fertilizer use, including anhydrous ammonia for direct application, urea, ammonium nitrates, ammonium phosphates, and other nitrogen compounds. Ammonia also was used to produce explosives, plastics, synthetic fibers and resins, and numerous other chemical compounds.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[1]	11,600	13,100	13,500	14,000	14,000
Imports for consumption	3,090	2,530	2,020	1,980	2,200
Exports	612	224	338	369	260
Consumption, apparent[2]	14,100	15,300	15,200	15,700	16,000
Stocks, producer, yearend	320	490	420	310	360
Price, average, free on board gulf coast,[3] dollars per short ton	247	281	232	223	510
Employment, plant, number[e]	1,500	1,600	1,600	1,600	1,600
Net import reliance[4] as a percentage of apparent consumption	18	14	11	11	12

Recycling: None.

Import Sources (2017–20): Trinidad and Tobago, 63%; Canada 34%; Venezuela, 2%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Ammonia, anhydrous	2814.10.0000	Free.
Urea	3102.10.0000	Free.
Ammonium sulfate	3102.21.0000	Free.
Ammonium nitrate	3102.30.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The Henry Hub spot natural gas price ranged between $2.36 and $6.23 per million British thermal units for most of the year, with an average of about $4.12 per million British thermal units. Natural gas prices in 2021 were higher than those in 2020—a result of below average storage levels of natural gas and strong demand for U.S. liquified natural gas. The U.S. Department of Energy, Energy Information Administration, projected that Henry Hub natural gas spot prices would average around $4.00 per million British thermal units in 2022.

The weekly average gulf coast ammonia price was $245 per short ton at the beginning of 2021 and increased to $603 per short ton in late October. The average ammonia price for 2021 was estimated to be $510 per short ton. In 2021, high natural gas prices resulted in higher ammonia prices.

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NITROGEN (FIXED)—AMMONIA

A long period of stable and low natural gas prices in the United States made it economical for companies to upgrade existing ammonia plants and construct new nitrogen facilities. The additional capacity has reduced ammonia imports. Expansion in the ammonia industry took place throughout the past 5 years; however, no additional U.S. ammonia capacity increases have been announced.

Global ammonia capacity is expected to increase by a total of 4% during the next 4 years. Capacity additions are expected in Africa, eastern Europe, and south Asia. As part of the capacity increase several decarbonized ammonia projects are being proposed. Demand for ammonia is expected to increase by 1% per year with the largest increases expected in Latin America and south Asia.

Large corn plantings maintain the continued demand for nitrogen fertilizers. According to the U.S. Department of Agriculture, U.S. corn growers planted 37.4 million hectares of corn in crop-year 2021 (July 1, 2020, through June 30, 2021), which was 3% greater than the area planted in crop-year 2020. Corn acreage in crop-year 2022 is expected to increase because of anticipated higher returns for corn compared with those of other crops.

World Ammonia Production and Reserves:

	Plant production		Reserves[5]
	2020	2021[e]	
United States	14,000	14,000	Available atmospheric nitrogen and sources of natural gas for production of ammonia are considered adequate for all listed countries.
Algeria	2,200	2,200	
Australia	1,600	1,600	
Canada	3,900	3,900	
China	39,000	39,000	
Egypt	4,200	4,200	
Germany	2,330	2,200	
India	12,200	12,000	
Indonesia	5,900	5,900	
Iran	3,600	3,600	
Malaysia	1,300	1,300	
Netherlands	2,100	2,000	
Oman	1,730	1,700	
Pakistan	3,300	3,300	
Poland	2,260	2,200	
Qatar	3,300	3,300	
Russia	16,100	16,000	
Saudi Arabia	4,300	4,300	
Trinidad and Tobago	4,170	4,200	
Ukraine	2,300	2,300	
Uzbekistan	1,100	1,100	
Vietnam	1,150	1,200	
Other countries	15,400	15,000	
World total (rounded)	147,000	150,000	

World Resources:[5] The availability of nitrogen from the atmosphere for fixed nitrogen production is unlimited. Mineralized occurrences of sodium and potassium nitrates, such as those found in the Atacama Desert of Chile, contribute minimally to the global nitrogen supply.

Substitutes: Nitrogen is an essential plant nutrient that has no substitute. No practical substitutes for nitrogen explosives and blasting agents are known.

[e]Estimated.

[1]Source: The Fertilizer Institute; data adjusted by the U.S. Geological Survey.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]Source: Green Markets.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

PEAT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The estimated free on board (f.o.b.) mine value of marketable peat sold by producers in the conterminous United States was $14 million in 2021. Peat was harvested and processed by 29 companies in 11 conterminous States. Florida, Illinois, Maine, Michigan, and Minnesota were the leading producing States and accounted for 98% of peat sold. Reed-sedge peat accounted for approximately 87% of the total volume produced, followed by sphagnum moss with 10%. Domestic peat applications included earthworm culture medium, golf course construction, mixed fertilizers, mushroom culture, nurseries, packing for flowers and plants, seed inoculants, and vegetable cultivation. In the industrial sector, peat was used as an oil absorbent and as an efficient filtration medium for the removal of waterborne contaminants in mine waste streams, municipal storm drainage, and septic systems.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	498	479	456	444	420
Sales by producers	515	545	556	524	540
Imports for consumption	1,150	1,200	1,160	1,390	1,700
Exports	30	37	46	46	38
Consumption, apparent[1]	1,520	1,670	1,480	1,780	2,000
Price, average value, f.o.b. mine, dollars per ton	27.55	25.88	24.59	24.74	25.00
Stocks, producer, yearend	222	196	280	288	290
Employment, mine and plant, number[e]	540	540	540	530	530
Net import reliance[2] as a percentage of apparent consumption	67	71	69	75	80

Recycling: None.

Import Sources (2017–20): Canada, 96%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Peat	2703.00.0000	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Peat is an important component of plant-growing media, and the demand for peat generally follows that of horticultural applications. In the United States, the short-term outlook is for production to average about 420,000 tons per year and imported peat from Canada is expected to continue to account for more than 80% of domestic consumption. Imports for 2021 were estimated to have increased to 1.7 million tons from 1.4 million tons in 2020, and exports were estimated to have decreased to about 38,000 tons from 46,000 tons in 2020. In 2021, peat stocks were estimated to have remained about the same as those in the previous year. Based on estimated world production for 2021, the world's leading peat producers were, in descending order of production, Finland, Sweden, Germany, Latvia, Belarus, and Canada.

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PEAT

In many parts of the world, concerns about climate change prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's ability to act as a carbon sink. Most of Ireland's peat production ended in 2021, as the country transitioned to alternative fuel sources. Ireland continued to produce peat briquettes but was expected to stop by 2024. The country's goal was to have at least 80% of its fossil-fuel sector employment transitioned to the renewable energy sector by 2025. In 2021, Finland continued to work toward its goal of becoming carbon neutral by 2035. To achieve this, peat production was to be phased out in favor of other forms of noncarbon energy. In 2021, about 35% of Finland's energy consumption was supplied by peat and other fossil fuels. Several European countries, including Belarus, Ireland, and Sweden, were planning or implementing peatland restoration projects to help combat greenhouse-gas emissions and restore wildlife habitats. These initiatives were expected to decrease peat production across Europe in the future.

World Mine Production and Reserves: Reserves for countries that reported by volume only and had insufficient data for conversion to tons were combined and included with "Other countries." Reserves for Estonia and Latvia were revised based on information from company reports.

	Mine production		Reserves[3]
	2020	2021[e]	
United States	444	420	150,000
Belarus	2,590	1,900	2,600,000
Canada	1,400	1,300	720,000
Estonia	1,060	1,100	570,000
Finland	12,000	12,000	6,000,000
Germany	2,300	2,300	([4])
Ireland	1,300	—	([4])
Latvia	2,000	2,100	150,000
Lithuania	460	460	210,000
Poland	900	900	([4])
Russia	1,000	1,000	1,000,000
Sweden	2,400	2,400	([4])
Ukraine	680	330	([4])
Other countries[e]	350	350	1,400,000
World total (rounded)	28,900	27,000	13,000,000

World Resources:[3] Peat is a renewable resource, continuing to accumulate on 60% of global peatlands. However, the volume of global peatlands has been decreasing at a rate of 0.05% annually owing to harvesting and land development. Many countries evaluate peat resources based on volume or area because the variations in densities and thickness of peat deposits make it difficult to estimate tonnage. Volume data have been converted using the average bulk density of peat produced in each of those countries. More than 50% of the U.S. peat resources are located in undisturbed areas of Alaska.

Substitutes: Natural organic materials, such as composted yard waste and coir (coconut fiber), compete with peat in horticultural applications. Shredded paper and straw are used to hold moisture for some grass-seeding applications. The superior water-holding capacity and physiochemical properties of peat limit substitution alternatives in most applications.

[e]Estimated. — Zero.

[1]Defined as production + imports – exports + adjustments for industry stock changes.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Included with "Other countries."

PERLITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, the quantity of domestic processed crude perlite sold and used was estimated to be 500,000 tons with a value of $31 million. Crude ore production was from eight mines operated by five companies in six Western States. One other mine was idle throughout the year. New Mexico and Oregon continued to be the leading producing States. Domestic apparent consumption of crude perlite was estimated to be 650,000 tons. Processed crude perlite was expanded at 55 plants in 28 States. The applications for expanded perlite were building construction products, 44%; horticultural aggregate, 21%; fillers, 14%; filter aid, 12%; and other, 9%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Mine production, crude ore	587	504	629	845	860
Sold and used, processed crude perlite	479	444	397	493	500
Imports for consumption[1]	171	204	183	158	180
Exports[1]	18	16	19	25	32
Consumption, apparent[2]	632	632	561	626	650
Price, average value, free on board mine, dollars per ton	71	69	64	61	63
Employment, mine and mill, number	139	130	140	140	145
Net import reliance[3] as a percentage of apparent consumption	24	30	29	21	23

Recycling: Not available.

Import Sources (2017–20): Greece, 90%; China, 7%; Mexico, 2%; and Turkey, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Vermiculite, perlite, and chlorites, unexpanded	2530.10.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Perlite is a siliceous volcanic glass that expands up to 20 times its original volume when rapidly heated. In horticultural uses, expanded perlite is used to provide moisture retention and aeration without compaction when added to soil. Horticultural perlite is useful to both commercial growers and hobby gardeners. Owing primarily to cost, some commercial greenhouse growers in the United States have recently switched to a wood fiber material over perlite. Perlite, however, remained a preferred soil amendment for segments of greenhouse growers because it does not degrade or compact over lengthy growing times and is inert. Construction applications for expanded perlite are numerous because it is fire resistant, an excellent insulator, and lightweight. Novel and small markets for perlite have increased during the past 10 years; cosmetics, environmental remediation, and personal care products have become increasing markets for perlite.

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PERLITE

A California company opened a second expanding plant in southern California and began shipping in April 2021. Project planning progressed at a perlite deposit in Nevada that could be developed as a potential supplier of crude perlite ore for household and industrial applications.

The value of total construction put in place in the United States increased by about 6% during the first 6 months of 2021 compared with that of the same period in 2020, indicating a similar change in consumption of perlite. Construction products remained the largest domestic market for perlite. Increased interest in commercial greenhouse and hobby gardening may also correspond to increased consumption of horticultural-grade perlite.

Based on estimated world production for 2021, the world's leading producers were, in descending order of production, China, Turkey, Greece, and the United States, with about 36%, 29%, 17%, and 12%, respectively, of world production. Although China was the leading producer, most of its perlite production was thought to be consumed internally. Greece and Turkey remained the leading exporters of perlite.

World Mine Production and Reserves:

	Production		Reserves[4]
	2020	2021[e]	
United States	[5]493	[5]500	50,000
Argentina[e]	18	20	NA
Armenia[e]	50	50	NA
China[e]	1,500	1,500	NA
Greece	710	710	120,000
Hungary[e]	80	80	49,000
Iran[e]	72	70	73,000
Mexico[e]	20	20	NA
New Zealand[e]	18	20	NA
Slovakia[e]	32	30	NA
Turkey[e]	1,200	1,200	57,000
Other countries[e]	30	30	NA
World total (rounded)	4,220	4,200	NA

World Resources:[4] Perlite occurrences in Arizona, California, Idaho, Nevada, New Mexico, and Oregon are thought to contain large resources. Significant deposits have been reported in China, Greece, Hungary, and Turkey, and a few other countries. Insufficient information was available to make reliable estimates of resources in many perlite-producing countries.

Substitutes: In construction applications, diatomite, expanded clay and shale, pumice, and slag can be substituted for perlite. For horticultural uses, coco coir, pumice, vermiculite, and wood pulp are alternative soil additives and are sometimes used in conjunction with perlite.

[e]Estimated. NA Not available.

[1]Exports and imports were estimated by the U.S. Geological Survey from U.S. Census Bureau combined data for vermiculite, perlite, and chlorites, unexpanded.

[2]Defined as sold or used processed perlite + imports – exports.

[3]Defined as imports − exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Processed ore sold and used by producers.

PHOSPHATE ROCK

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, phosphate rock ore was mined by five companies at 10 mines in four States and processed into an estimated 22 million tons of marketable product, valued at $1.7 billion, free on board (f.o.b.) mine. Florida and North Carolina accounted for more than 75% of total domestic output; the remainder was produced in Idaho and Utah. Marketable product refers to beneficiated phosphate rock with phosphorus pentoxide (P_2O_5) content suitable for phosphoric acid or elemental phosphorus production. More than 95% of the phosphate rock mined in the United States was used to manufacture wet-process phosphoric acid and superphosphoric acid, which were used as intermediate feedstocks in the manufacture of granular and liquid ammonium phosphate fertilizers and animal feed supplements. About 25% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium phosphate (DAP) and monoammonium phosphate (MAP) fertilizer and merchant-grade phosphoric acid. The balance of the phosphate rock mined was for the manufacture of elemental phosphorus, which was used to produce phosphorus compounds for industrial applications, primarily glyphosate herbicide.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, marketable	27,900	25,800	23,300	23,500	22,000
Sold or used by producers	26,300	23,300	23,400	22,600	23,000
Imports for consumption	2,470	2,770	2,140	2,520	2,400
Consumption, apparent[1]	28,800	26,000	25,500	25,100	25,000
Price, average value, f.o.b. mine,[2] dollars per ton	73.67	70.77	67.98	75.86	75.00
Stocks, producer, yearend	8,440	10,600	9,830	11,000	10,000
Employment, mine and beneficiation plant, number[e]	1,800	1,900	1,900	1,800	1,900
Net import reliance[3] as a percentage of apparent consumption	5	2	11	5	13

Recycling: None.

Import Sources (2017–20): Peru, 87%; Morocco, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Natural calcium phosphates:		
Unground	2510.10.0000	Free.
Ground	2510.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, domestic consumption of phosphate rock was estimated to be about the same as that in 2020. DAP and MAP production decreased as a result, in part, of technical problems at a phosphate plant in Florida and owing to the effects of Hurricane Ida in August, which damaged phosphate facilities in Louisiana. The affected facilities reopened in the fourth quarter.

World production was estimated to be about the same as that in 2020, with China, Morocco, and the United States remaining the leading producers. Production in Jordan, Morocco, and Saudi Arabia increased as expansions to capacity were being ramped up in 2021. Capacity expansion projects were ongoing in Brazil, Kazakhstan, Mexico, Russia, and South Africa; however, none of the projects were expected to be completed until after 2024.

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PHOSPHATE ROCK

One producer in Idaho submitted plans to shift production to a new phosphate rock mine when its existing mine is exhausted in about 5 years. The new mine would be located close to the current mine in Caribou County, and annual production capacity was expected to remain the same.

World consumption of P_2O_5 contained in fertilizer products was estimated to have increased by 7% in crop-year 2021 (July 1, 2020, to June 30, 2021) compared with that in crop-year 2020. The increases in world consumption and trade were driven by high crop prices, increased planted crop area, and increased crop exports. This was a continuation of the trend that began late in 2020, as markets rebounded from poor weather conditions in the growing season. South America and Asia were leading regions of growth in consumption of phosphate fertilizer, in terms of percentage increase over that in 2020.

World Mine Production and Reserves: Reserves for Israel, Jordan, and South Africa were updated with information from the producing companies in the respective countries. Turkey was listed separately from "Other countries."

	Mine production		Reserves[4]
	2020	2021[e]	
United States	23,500	22,000	1,000,000
Algeria	1,200	1,200	2,200,000
Australia	2,000	2,200	[5]1,100,000
Brazil	6,000	5,500	1,600,000
China[6]	88,000	85,000	3,200,000
Egypt	4,800	5,000	2,800,000
Finland	995	1,000	1,000,000
India	1,400	1,400	46,000
Israel	3,090	3,000	53,000
Jordan	8,940	9,200	1,000,000
Kazakhstan	1,300	1,500	260,000
Mexico	577	530	30,000
Morocco	37,400	38,000	50,000,000
Peru	3,300	3,800	210,000
Russia	14,000	14,000	600,000
Saudi Arabia	8,000	8,500	1,400,000
Senegal	1,600	2,200	50,000
South Africa	1,800	2,000	1,600,000
Togo	942	1,200	30,000
Tunisia	3,190	3,200	100,000
Turkey	600	600	50,000
Uzbekistan	900	900	100,000
Vietnam	4,500	4,700	30,000
Other countries	870	1,000	2,600,000
World total (rounded)	219,000	220,000	71,000,000

World Resources:[4] Some world reserves were reported only in terms of ore tonnage and grade. Phosphate rock resources occur principally as sedimentary marine phosphorites. The largest sedimentary deposits are found in northern Africa, the Middle East, China, and the United States. Significant igneous occurrences are found in Brazil, Canada, Finland, Russia, and South Africa. Large phosphate resources have been identified on the continental shelves and on seamounts in the Atlantic Ocean and the Pacific Ocean. World resources of phosphate rock are more than 300 billion tons. There are no imminent shortages of phosphate rock.

Substitutes: There are no substitutes for phosphorus in agriculture.

[e]Estimated.

[1]Defined as phosphate rock sold or used by producers + imports. U.S. producers stopped exporting phosphate rock in 2003.

[2]Marketable phosphate rock, weighted value, all grades.

[3]Defined as imports + adjustments for industry stock changes.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 110 million tons.

[6]Production data for large mines only, as reported by the National Bureau of Statistics of China.

PLATINUM-GROUP METALS

(Palladium, platinum, iridium, osmium, rhodium, and ruthenium)
[Data in kilograms of contained platinum-group metals (PGMs) unless otherwise noted]

Domestic Production and Use: One company in Montana produced approximately 18,000 kilograms of PGMs with an estimated value of about $1.4 billion. Small quantities of primary PGMs also were recovered as byproducts of copper-nickel mining in Michigan; however, this material was sold to foreign companies for refining. The leading domestic use for PGMs was in catalytic converters to decrease harmful emissions from automobiles. PGMs are also used in catalysts for bulk-chemical production and petroleum refining; dental and medical devices; electronic applications, such as in computer hard disks, hybridized integrated circuits, and multilayer ceramic capacitors; glass manufacturing; investment; jewelry; and laboratory equipment.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Mine production:[1]					
Palladium	14,000	14,300	14,300	14,600	14,000
Platinum	4,000	4,160	4,150	4,200	4,200
Imports for consumption:[2]					
Palladium	86,000	92,900	84,300	76,400	76,000
Platinum	53,200	58,500	42,300	64,800	56,000
PGM waste and scrap	354,000	40,700	35,200	188,000	210,000
Iridium	1,420	1,020	875	1,620	2,500
Osmium	856	25	([3])	1	1
Rhodium	11,600	14,500	15,000	20,700	17,000
Ruthenium	14,600	17,900	11,200	13,900	23,000
Exports:[4]					
Palladium	52,300	52,900	55,500	48,600	43,000
Platinum	16,700	18,900	17,400	28,900	30,000
PGM waste and scrap	37,200	31,700	20,800	33,200	42,000
Rhodium	844	2,010	1,210	1,470	1,300
Other PGMs	939	2,500	1,330	1,440	2,800
Consumption, apparent:[5, 6]					
Palladium	89,700	96,300	85,100	80,400	90,000
Platinum	51,600	53,700	37,000	47,200	37,000
Price, dollars per troy ounce:[7]					
Palladium	874.30	1,036.43	1,544.31	2,205.27	2,600.00
Platinum	951.23	882.66	866.94	886.02	1,200.00
Iridium	908.35	1,293.27	1,485.80	1,633.51	5,400.00
Rhodium	1,112.59	2,225.30	3,918.78	11,205.06	24,000.00
Ruthenium	76.86	244.41	262.59	271.83	510.00
Employment, mine, number	1,513	1,628	1,789	1,881	1,700
Net import reliance[6, 8] as a percentage of apparent consumption:					
Palladium	38	42	34	35	37
Platinum	71	74	67	77	70

Recycling: About 115,000 kilograms of palladium and platinum was recovered globally from new and old scrap in 2021, including about 53,000 kilograms recovered from automobile catalytic converters in the United States.

Import Sources (2017–20): Palladium: Russia, 35%; South Africa, 31%; Germany, 9%; and other, 25%. Platinum: South Africa, 38%; Germany, 20%; Switzerland, 12%; Italy, 6%; and other, 24%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free. See footnotes for specific Harmonized Tariff Schedule of the United States codes.

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PLATINUM-GROUP METALS

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[9]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Iridium	15	—	15	—	15
Platinum	261	—	261	—	261

Events, Trends, and Issues: Progress continued at a domestic mine expansion project, but full production was delayed to 2024 owing to disruptions from the COVID-19 pandemic and operational challenges associated with ventilation and ground conditions. Production of PGMs in South Africa, the world's leading supplier of mined material, increased by 13% compared with that in 2020 owing to increased mining in the UG2 orebody of the Bushveld Complex.

The estimated annual average prices of palladium, platinum, and ruthenium increased by 18%, 35%, and 88%, respectively, compared with those in 2020, and the estimated prices for rhodium doubled and iridium more than tripled. In addition, the prices of iridium, rhodium, and ruthenium all reached record highs in 2021.

Constrained automobile production owing to semiconductor chip shortages and a decline in diesel passenger vehicle production are expected to result in decreased demand for palladium, platinum, and rhodium used in catalytic converters.

World Mine Production and Reserves: Reserves for Russia were revised based on Government reports.

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2020	2021[e]	2020	2021[e]	
United States	14,600	14,000	4,200	4,200	900,000
Canada	20,000	17,000	7,000	6,000	310,000
Russia	93,000	74,000	23,000	19,000	4,500,000
South Africa	73,500	80,000	112,000	130,000	63,000,000
Zimbabwe	12,900	13,000	15,000	15,000	1,200,000
Other countries	2,670	2,800	4,320	4,300	NA
World total (rounded)	217,000	200,000	166,000	180,000	70,000,000

World Resources:[10] World resources of PGMs are estimated to total more than 100 million kilograms. The largest reserves are in the Bushveld Complex in South Africa.

Substitutes: Palladium has been substituted for platinum in most gasoline-engine catalytic converters because of the historically lower price for palladium relative to that of platinum. About 25% of palladium can routinely be substituted for platinum in diesel catalytic converters; the proportion can be as much as 50% in some applications. For some industrial end uses, one PGM can substitute for another, but with losses in efficiency.

[e]Estimated. NA Not available. — Zero.

[1]Estimated from published sources.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 7110.11.0010, 7110.11.0020, 7110.11.0050, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0010, 7110.41.0020, 7110.41.0030, 7110.49.0010, 7112.92.0000, and 7118.90.0020.

[3]Less than ½ unit.

[4]Includes data for the following Schedule B codes: 7110.11.0000, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0000, 7110.49.0000, and 7112.92.0000.

[5]Defined as primary production + secondary production + imports – exports.

[6]Excludes imports and (or) exports of waste and scrap.

[7]Engelhard Corp. unfabricated metal.

[8]Defined as imports – exports.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

POTASH

[Data in thousand metric tons of potassium oxide (K_2O) equivalent unless otherwise noted]

Domestic Production and Use: In 2021, the estimated sales value of marketable potash, free on board (f.o.b.) mine, was $520 million, which was 24% higher than that in 2020. Potash denotes a variety of mined and manufactured salts that contain the element potassium in water-soluble form. In agriculture, the term potash refers to potassic fertilizers, which are potassium chloride (KCl), potassium sulfate or sulfate of potash (SOP), and potassium magnesium sulfate (SOPM) or langbeinite. Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride for fertilizer use. The majority of U.S. production was from southeastern New Mexico, where two companies operated two underground mines and one deep-well solution mine. Sylvinite and langbeinite ores in New Mexico were beneficiated by flotation, dissolution-recrystallization, heavy-media separation, solar evaporation, and (or) combinations of these processes. In Utah, two companies operated three facilities. One company extracted underground sylvinite ore by deep-well solution mining. Solar evaporation crystallized the sylvinite ore from the brine solution, and a flotation process separated the MOP from byproduct sodium chloride. The firm also processed subsurface brines by solar evaporation and flotation to produce MOP at its other facility. Another company processed brine from the Great Salt Lake by solar evaporation to produce SOP and other byproducts.

The fertilizer industry used about 85% of U.S. potash sales, and the remainder was used for chemical and industrial applications. About 60% of the potash produced was SOPM and SOP, which are required to fertilize certain chloride-sensitive crops. The remainder of production was MOP and was used for agricultural and chemical applications.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, marketable[1]	480	520	510	460	480
Sales by producers, marketable[1]	490	520	480	500	530
Imports for consumption	5,860	5,710	5,150	5,370	7,000
Exports	128	105	145	147	100
Consumption, apparent[1, 2]	6,200	6,100	5,500	5,700	7,400
Price, average, all products,[3] f.o.b. mine, dollars per ton of K_2O	770	750	820	850	980
Price, average, muriate, f.o.b. mine, dollars per ton of K_2O	410	440	480	450	550
Employment, mine and mill, number	900	900	900	900	900
Net import reliance[4] as a percentage of apparent consumption	92	92	91	92	93

Recycling: None.

Import Sources (2017–20): Canada, 75%; Russia, 10%; Belarus, 8%; and other, 7%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Potassium nitrate	2834.21.0000	Free.
Potassium chloride	3104.20.0000	Free.
Potassium sulfate	3104.30.0000	Free.
Potassic fertilizers, other	3104.90.0100	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, U.S. potash consumption and trade reached record levels driven by high crop prices, increased planted crop area, and increased crop exports. This was a continuation of the trend that began late in 2020, as markets rebounded from poor weather conditions in the growing season and high potash stocks. The North American price of potash also increased substantially owing to increased consumption and tighter supplies. Industrial potash consumption continued to be lower, primarily for oil- and gas-well-drilling additives. The number of active oil- and gas-well-drilling rigs gradually increased throughout the year but was still well below the level before the COVID-19 pandemic.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

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POTASH

World potash consumption in 2021 for fertilizers was estimated to have increased to 45 million tons from 44 million tons in 2020, as demand peaked in the first half of the year in major consuming regions. Asia and South America continued to be the leading consuming regions. North America and South America and southeast Asia had the largest increases in consumption over that of 2020. World potash production increased, owing primarily to increased output in the major exporting countries of Belarus, Canada, and Russia to meet high demand in the first half of the year.

In August 2021, the United States imposed economic sanctions on Belarus for violations of international law, which included the state-run potash producer. The sanctions did not include the state-run exporting company for Belarus, and potash imports from Belarus continued, but at a lower volume because many buyers used other sources owing to uncertainty of future sanctions.

A new potash mine was in the development stage and pending operating permits in Osceola County, MI. The proposed solution mine would have an initial production capacity of 650,000 tons per year of MOP and was planned to increase to 1 million tons per year.

World annual potash capacity was projected to increase to near 69 million tons in 2025 from 62.3 million tons in 2021. Most of the increase would be MOP from new mines and expansion projects in Belarus, Canada, and Russia. New SOP mines were planned in Australia and Eritrea, and a polyhalite mine in the United Kingdom would also contribute to the capacity growth. New MOP mines in Brazil, Canada, Ethiopia, Morocco, Spain, and the United States were planned to begin operation past 2025 but could be delayed because of future unfavorable economic conditions or lack of funding.

World Mine Production and Reserves: Reserves for Russia were updated with the Australasian Joint Ore Reserves Committee (JORC)-compliant reserves reported by the producing companies.

	Mine production		Reserves[5]	
	2020	2021[e]	Recoverable ore	K_2O equivalent
United States[1]	460	480	970,000	220,000
Belarus	7,400	8,000	3,300,000	750,000
Brazil	254	210	10,000	2,300
Canada	13,800	14,000	4,500,000	1,100,000
Chile	900	900	NA	100,000
China	6,000	6,000	NA	350,000
Germany	2,200	2,300	NA	150,000
Israel	2,280	2,300	NA	[6]Large
Jordan	1,590	1,600	NA	[6]Large
Laos	270	300	500,000	75,000
Russia	8,110	9,000	NA	400,000
Spain	420	400	NA	68,000
Other countries	360	370	1,500,000	300,000
World total (rounded)	44,000	46,000	>11,000,000	>3,500,000

World Resources:[5] Estimated domestic potash resources total about 7 billion tons. Most of these lie at depths between 1,800 and 3,100 meters in a 3,110-square-kilometer area of Montana and North Dakota as an extension of the Williston Basin deposits in Manitoba and Saskatchewan, Canada. The Paradox Basin in Utah contains resources of about 2 billion tons, mostly at depths of more than 1,200 meters. The Holbrook Basin of Arizona contains resources of about 0.7 to 2.5 billion tons. A large potash resource lies about 2,100 meters under central Michigan and contains more than 75 million tons. Estimated world resources total about 250 billion tons.

Substitutes: No substitutes exist for potassium as an essential plant nutrient and as an essential nutritional requirement for animals and humans. Manure and glauconite (greensand) are low-potassium-content materials that can be profitably transported only short distances to crop fields. Glauconite is used as a potassium source for organic farming.

[e]Estimated. NA Not available.

[1]Data are rounded to no more than two significant digits to avoid disclosing company proprietary data.

[2]Defined as sales + imports – exports.

[3]Includes MOP, SOP, and SOPM. Does not include other chemical compounds that contain potassium.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Israel and Jordan recover potash from the Dead Sea, which contains nearly 2 billion tons of potassium chloride.

PUMICE AND PUMICITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 580,000 tons with an estimated processed value of about $18.6 million, free on board (f.o.b.) plant. That represented a slight increase in quantity and a 4% increase in value from the 2020 reported production of 578,000 tons valued at $17.9 million. Pumice and pumicite were mined in California, Idaho, Kansas, New Mexico, and Oregon. The porous, lightweight properties of pumice are well suited for its main uses. Mined pumice was used in the production of abrasives, concrete admixtures and aggregates, lightweight building blocks, horticultural purposes, and other uses, including absorbent, filtration, laundry stone washing, and road use.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine[1]	383	496	565	578	580
Imports for consumption	166	159	136	90	140
Exports[e]	12	11	11	8	11
Consumption, apparent[2]	537	644	690	660	710
Price, average value, f.o.b. mine or mill, dollars per ton	39	32	28	31	32
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	29	23	18	12	18

Recycling: Little to no known recycling.

Import Sources (2017–20): Greece, 92%; Iceland, 6%; and Mexico, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Pumice, crude or in irregular pieces, including crushed	2513.10.0010	Free.
Pumice, other	2513.10.0080	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced pumice and pumicite sold or used in 2021 was estimated to be slightly more than that in 2020. Imports and exports were estimated to have increased compared with those of 2020. Almost all imported pumice originated from Greece in 2021 and primarily supplied markets in the eastern and gulf coast regions of the United States.

Pumice and pumicite are plentiful in the Western United States, but legal challenges and public land designations could limit access to known deposits. Pumice and pumicite production are sensitive to mining and transportation costs. Although unlikely in the short term, an increase in fuel prices would likely lead to increases in production costs, making imports and competing materials attractive substitutes for domestic products.

All known domestic pumice and pumicite mining in 2021 was accomplished through open pit methods, generally in remote areas away from major population centers. Although the generation and disposal of reject fines in mining and milling may result in local dust issues at some operations, such environmental impacts are thought to be restricted to relatively small geographic areas.

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PUMICE AND PUMICITE

World production of pumice and related material was estimated to be 17 million tons in 2021, which was 10% more than that of 2020. Turkey, followed by Uganda, was the leading global producer of pumice and pumicite. Pumice is used more extensively as a building material outside the United States, which explained the large global production of pumice relative to that of the United States. In Europe, basic home construction uses stone and concrete as the preferred building materials. Prefabricated lightweight concrete walls, which may contain pumice as lightweight aggregate, are often produced and shipped to construction locations. Because of their cementitious properties, light weight, and strength, pumice and pumicite perform well in European-style construction.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States[1]	578	580	Large in the United States.
Algeria[5]	900	900	Quantitative estimates of reserves
Cameroon[5]	300	110	for most countries are not available.
Chile[5]	680	700	
Ecuador[5]	800	800	
Ethiopia	510	500	
France[5]	280	300	
Greece[5]	1,020	1,000	
Guadeloupe	200	200	
Guatemala	570	600	
Indonesia	200	200	
Jordan	900	900	
New Zealand	220	220	
Saudi Arabia[5]	560	560	
Spain	290	300	
Syria[5]	200	200	
Tanzania	260	160	
Turkey	5,400	7,000	
Uganda	960	1,100	
Other countries[5]	570	570	
World total (rounded)	15,400	17,000	

World Resources:[4] The identified U.S. resources of pumice and pumicite, estimated to be more than 25 million tons, are concentrated in the Western States. The estimated total resources (identified and undiscovered) in the Western and Great Plains States are at least 250 million tons and may total more than 1 billion tons. Large resources of pumice and pumicite have been identified on all continents.

Substitutes: The costs of transportation determine the maximum economic distance pumice and pumicite can be shipped and still remain competitive with alternative materials. Competitive materials that may be substituted for pumice and pumicite include crushed aggregates, diatomite, expanded shale and clay, and vermiculite.

[e]Estimated.

[1]Quantity sold and used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes pozzolan and (or) volcanic tuff.

QUARTZ CRYSTAL (INDUSTRIAL)

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Industrial cultured quartz crystal is electronic-grade quartz crystal that is manufactured, not mined. In the past, cultured quartz crystal was primarily produced using lascas[1] as raw quartz feed material. Lascas mining and processing in Arkansas ended in 1997. In 2021, two companies produced cultured quartz crystal in the United States. However, production data were withheld in order to avoid disclosing company proprietary data. In addition to lascas, these companies may use cultured quartz crystal that has been rejected during the manufacturing process, owing to crystallographic imperfections, as feed material. The companies likely use a mix of cultured quartz and imported lascas as feed material. In the past several years, cultured quartz crystal has been increasingly produced overseas, primarily in Asia. Electronic applications accounted for most industrial uses of quartz crystal; other uses included special optical applications.

Virtually all quartz crystal used for electronics was cultured, rather than natural, crystal. Electronic-grade quartz crystal is used to make frequency filters, frequency controls, and timers in electronic circuits employed for a wide range of products, such as communications equipment, computers, and many consumer goods, such as electronic games and television receivers.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine (lascas)	—	—	—	—	—
Cultured quartz crystal	W	W	W	W	W
Imports for consumption:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	6,760	16,100	54,800	114,000	84,000
Exports:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	55,300	43,400	40,900	37,100	37,000
Price, dollars per kilogram:					
As-grown cultured quartz	280	300	200	200	200
Lumbered quartz[2]	300	500	500	400	400
Net import reliance[3] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: An unspecified amount of rejected cultured quartz crystal was used as feed material for the production of cultured quartz crystal.

Import Sources (2017–20): Import statistics specific to lascas are not available because they are combined with other types of quartz. Cultured quartz crystal (piezoelectric quartz, unmounted): China,[4] 88%; Japan, 4%; Russia, 2%; and other, 6%.

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QUARTZ CRYSTAL (INDUSTRIAL)

Tariff: Item	Number	Normal Trade Relations 12–31–21
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5] The National Defense Stockpile contains 11 weight classes for natural quartz crystal that range from 0.2 kilogram to more than 10 kilograms. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Quartz crystal	7,140	—	7,148	—	7,148

Events, Trends, and Issues: Increased imports of piezoelectric quartz in the past several years are likely the result of increased demand for vibration sensors and frequency-control oscillators for aerospace, automotive, and telecommunication applications. Growth of the consumer electronics market (for example, personal computers, electronic games, and tablet computers) is also likely to remain a factor in sustaining global production of cultured quartz crystal.

World Mine Production and Reserves:[6] This information is unavailable, but the global reserves for lascas are thought to be large.

World Resources:[6] Limited resources of natural quartz crystal suitable for direct electronic or optical use are available throughout the world. World dependence on these resources will continue to decline because of the increased acceptance of cultured quartz crystal as an alternative material. Additionally, techniques using rejected cultured quartz crystal as feed material may result in decreased dependence on lascas for growing cultured quartz.

Substitutes: Silicon is increasingly being used as a substitute for quartz crystal for frequency-control oscillators in electronic circuits. Other materials, such as aluminum orthophosphate (the very rare mineral berlinite), langasite, lithium niobate, and lithium tantalate, which have larger piezoelectric coupling constants, have been studied and used. The cost competitiveness of these materials, as opposed to cultured quartz crystal, is dependent on the type of application that the material is used for and the processing required.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Lascas is a nonelectronic-grade quartz used as a feedstock for growing cultured quartz crystal and for production of fused quartz.

[2]As-grown cultured quartz that has been processed by sawing and grinding.

[3]Defined as imports – exports.

[4]Includes Hong Kong.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

RARE EARTHS[1]

[Data in metric tons of rare-earth-oxide (REO) equivalent unless otherwise noted]

Domestic Production and Use: Rare earths were mined domestically in 2021. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined as a primary product at a mine in Mountain Pass, CA. Monazite, a phosphate mineral, was produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates in the southeastern United States. The estimated value of rare-earth compounds and metals imported by the United States in 2021 was $160 million, a significant increase from $109 million in 2020. The estimated end-use distribution of rare earths was as follows: catalysts, 74%; ceramics and glass, 10%; metallurgical applications and alloys, 6%; polishing, 4%; and other, 6%.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:[e]					
Mineral concentrates	—	14,000	28,000	39,000	43,000
Compounds and metals	—	—	—	—	230
Imports:[e, 2]					
Compounds	11,000	10,800	12,200	6,510	7,700
Metals:					
Ferrocerium, alloys	309	298	330	274	320
Rare-earth metals, scandium, and yttrium	524	526	627	362	540
Exports:[e, 2]					
Ores and compounds	1,740	17,900	28,300	40,000	45,000
Metals:					
Ferrocerium, alloys	982	1,250	1,290	625	740
Rare-earth metals, scandium, and yttrium	55	28	83	25	29
Consumption, apparent, compounds and metals[3]	9,300	9,600	11,200	5,400	6,100
Price, average, dollars per kilogram:[4]					
Cerium oxide, 99.5% minimum	2	2	2	2	2
Dysprosium oxide, 99.5% minimum	187	179	239	261	400
Europium oxide, 99.99% minimum	77	53	35	31	31
Lanthanum oxide, 99.5% minimum	2	2	2	2	2
Mischmetal, 65% cerium, 35% lanthanum	6	6	6	5	6
Neodymium oxide, 99.5% minimum	50	50	45	49	49
Terbium oxide, 99.99% minimum	501	455	507	670	1,300
Employment, mine and mill, annual average, number	24	190	202	185	290
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	100	100	100	100	>90
Mineral concentrates	XX	E	E	E	E

Recycling: Limited quantities of rare earths are recovered from batteries, permanent magnets, and fluorescent lamps.

Import Sources (2017–20): Rare-earth compounds and metals: China, 78%; Estonia, 6%; Malaysia, 5%; Japan, 4%; and other, 7%. Compounds and metals imported from Estonia, Japan, and Malaysia were derived from mineral concentrates and chemical intermediates produced in Australia, China, and elsewhere.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Rare-earth metals	2805.30.0000	5.0% ad valorem.
Cerium compounds	2846.10.0000	5.5% ad valorem.
Other rare-earth compounds:		
Oxides or chlorides	2846.90.2000	Free.
Carbonates	2846.90.8000	3.7% ad valorem.
Ferrocerium and other pyrophoric alloys	3606.90.3000	5.9% ad valorem.

Depletion Allowance: Monazite, 22% on thorium content and 14% on rare-earth content (domestic), 14% (foreign); bastnäsite and xenotime, 14% (domestic and foreign).

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RARE EARTHS

Government Stockpile:[7] In the addition to the materials listed below, the FY 2021 and FY 2022 potential acquisitions include neodymium, 600 tons; praseodymium, 70 tons; and samarium-cobalt alloy, 50 tons.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cerium	—	500	—	550	—
Dysprosium	0.2	20	—	20	—
Europium	27.7	—	—	—	—
Ferrodysprosium	0.5	—	—	—	—
Lanthanum	—	1,300	—	1,300	—
Rare-earth-magnet block	—	100	—	100	—
Yttrium	25	600	—	25	—

Events, Trends, and Issues: Global mine production was estimated to have increased to 280,000 tons of REO equivalent. According to China's Ministry of Industry and Information Technology, the mine production quota for 2021 was 168,000 tons with 148,850 tons allocated to light rare earths and 19,150 tons to ion-adsorption clays.

World Mine Production and Reserves: Reserves for Australia, Russia, the United States, and "Other countries" were revised based on information from Government and industry reports.

	Mine production		Reserves[8]
	2020	2021[e]	
United States	39,000	43,000	1,800,000
Australia	21,000	22,000	[9]4,000,000
Brazil	600	500	21,000,000
Burma	31,000	26,000	NA
Burundi	300	100	NA
Canada	—	—	830,000
China	[10]140,000	[10]168,000	44,000,000
Greenland	—	—	1,500,000
India	2,900	2,900	6,900,000
Madagascar	2,800	3,200	NA
Russia	2,700	2,700	21,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	3,600	8,000	NA
Vietnam	700	400	22,000,000
Other countries	100	300	280,000
World total (rounded)	240,000	280,000	120,000,000

World Resources:[8] Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other mineral commodities. In North America, measured and indicated resources of rare earths were estimated to include 2.4 million tons in the United States and more than 15 million tons in Canada.

Substitutes: Substitutes are available for many applications but generally are less effective.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable. — Zero.

[1]Data include lanthanides and yttrium but exclude most scandium. See also Scandium and Yttrium.

[2]REO equivalent or content of various materials were estimated. Source: U.S. Census Bureau.

[3]Defined as production + imports – exports.

[4]Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports.

[6]In 2018–2020, all domestic production of mineral concentrates was exported or held in inventory, and all compounds and metals consumed were assumed to be imported material.

[7]Gross weight. See Appendix B for definitions.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 3.0 million tons.

[10]Production quota; does not include undocumented production.

RHENIUM

(Data in kilograms of contained rhenium unless otherwise noted)

Domestic Production and Use: During 2021, rhenium-containing products including ammonium perrhenate (APR), metal powder, and perrhenic acid were produced as byproducts from roasting molybdenum concentrates from porphyry copper-molybdenum deposits in Arizona and Montana. U.S. primary production was approximately 9,100 kilograms in 2021, a 4% increase from the previous year. The United States continued to be a leading producer of secondary rhenium, recovering rhenium from nickel-base superalloy scrap, spent oil-refining catalysts, and foundry revert. The major uses of rhenium were in superalloys used in high-temperature turbine engine components and in petroleum-reforming catalysts, representing an estimated 80% and 15%, respectively, of end uses. Bimetallic platinum-rhenium catalysts were used in petroleum reforming for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Rhenium improves the high-temperature (>1,000 degrees Celsius) strength properties of some nickel-base superalloys. Rhenium alloys were used in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and other applications. The value of rhenium consumed in 2021 was about $35 million as measured by the value of imports of rhenium metal and APR.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[1]	8,200	8,220	8,360	8,830	9,100
Imports for consumption[2]	34,500	39,400	44,300	25,200	23,000
Exports	NA	NA	NA	NA	NA
Consumption, apparent[3]	42,700	47,600	52,600	34,000	32,000
Price, average value, gross weight, dollars per kilogram:[4]					
Metal pellets, 99.99% pure	1,550	1,470	1,300	1,030	980
Ammonium perrhenate	1,530	1,410	1,280	1,130	1,000
Employment, number	Small	Small	Small	Small	Small
Net import reliance[5] as a percentage of apparent consumption	81	83	84	74	72

Recycling: Nickel-base superalloy scrap and scrapped turbine blades and vanes continued to be recycled hydrometallurgically to produce rhenium metal for use in new superalloy melts. The scrapped parts were also processed to generate engine revert—a high-quality, lower cost superalloy meltstock—by an increasing number of companies, mainly in the United States, Canada, Estonia, France, Germany, Japan, Poland, and Russia. Rhenium-containing catalysts were also recycled.

Import Sources (2017–20): Ammonium perrhenate: Kazakhstan, 21%; Canada, 18%; Germany, 16%; Poland, 16%; and other, 29%. Rhenium metal powder: Chile, 84%; Germany, 7%; Canada, 6%; and other, 3%. Total imports: Chile, 51%; Canada, 13%; Kazakhstan, 11%; Japan, 7%; and other, 18%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad valorem.
Rhenium (and other metals), waste and scrap	8112.92.0600	Free.
Rhenium, unwrought and powders	8112.92.5000	3% ad valorem.
Rhenium (and other metals), wrought	8112.99.9000	4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: For the 10th year in a row, rhenium metal and catalytic-grade APR prices decreased. In 2021, the price of catalytic-grade APR averaged $1,000 per kilogram, a 12% decrease from the annual average price in 2020. The rhenium metal pellet price averaged $980 per kilogram in 2021, a 5% decrease from the annual average price in 2020.

In 2021, apparent consumption in the United States decreased by 6% compared with that in 2020. During 2021, the United States continued to rely on imports for much of its supply of rhenium. Canada, Chile, Japan, and Kazakhstan supplied most of the imported rhenium. Imports of APR decreased by 32% in 2021 compared with those in the previous year. Imports of rhenium metal decreased by 6% in 2021 compared with those in the previous year. World rhenium production in 2021 was estimated to be essentially the same as that in 2020.

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RHENIUM

The United States and Germany continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Canada, Estonia, France, Japan, Poland, and Russia. Available information was insufficient to make U.S. secondary production estimates; however, industry sources estimated annual U.S. capacity between 18 and 20 tons of rhenium. Industry sources estimated approximately 25 tons of secondary rhenium was produced worldwide in 2021.

There were no primary rhenium projects in 2021 that were expected to significantly contribute to rhenium availability in the near future. Continued low prices of rhenium as well as the global COVID-19 pandemic continued to cause many rhenium recyclers as well as primary-rhenium production facilities to stop recycling or producing rhenium to focus on a more profitable market. The major aerospace companies were expected to continue testing superalloys that contain one-half the quantity of rhenium used in engine blades as currently designed, as well as testing rhenium-free alloys for other engine components.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

World Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2020	2021[e]	
United States	8,830	9,100	400,000
Armenia	260	260	95,000
Chile[8]	30,000	29,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	500	1,000	190,000
Korea, Republic of	2,800	2,800	NA
Poland	9,510	9,500	NA
Russia	NA	NA	310,000
Uzbekistan	4,900	4,900	NA
World total (rounded)	59,300	59,000	Large

World Resources:[7] Most rhenium occurs with molybdenum in porphyry copper deposits. Identified U.S. resources are estimated to be about 7 million kilograms. Rhenium also is associated with copper minerals in sedimentary deposits in Armenia, Kazakhstan, Poland, Russia, and Uzbekistan, where ore is processed for copper recovery and the rhenium-bearing residues are recovered at copper smelters.

Substitutes: Substitutes for rhenium in platinum-rhenium catalysts are continually being evaluated. Iridium and tin have achieved commercial success in one such application. Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium's share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects. Materials that can substitute for rhenium in various end uses are as follows: cobalt and tungsten for coatings on copper x-ray targets, rhodium and rhodium-iridium for high-temperature thermocouples, tungsten and platinum-ruthenium for coatings on electrical contacts, and tungsten and tantalum for electron emitters.

[e]Estimated. NA Not available.

[1]Based on 80% recovery of estimated rhenium contained in molybdenum disulfide concentrates. Secondary rhenium production is not included.

[2]Does not include wrought forms or waste and scrap. The rhenium content of ammonium perrhenate is 69.42%.

[3]Defined as production + imports – exports.

[4]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate. Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports.

[6]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Estimated rhenium recovered from roaster residues from Belgium, Chile, Mexico, and Peru.

RUBIDIUM

(Data in metric tons of rubidium oxide unless otherwise noted)

Domestic Production and Use: In 2021, no rubidium was mined in the United States; however, occurrences of rubidium-bearing minerals are known in Alaska, Arizona, Idaho, Maine, South Dakota, and Utah. Rubidium is also associated with some evaporate mineral occurrences in other States. Rubidium is not a major constituent of any mineral. Rubidium concentrate is produced as a byproduct of pollucite (cesium) and lepidolite (lithium) mining and is imported from other countries for processing in the United States.

Applications for rubidium and its compounds include biomedical research, electronics, specialty glass, and pyrotechnics. Specialty glasses are the leading market for rubidium; rubidium carbonate is used to reduce electrical conductivity, which improves stability and durability in fiber-optic telecommunications networks. Biomedical applications include rubidium salts used in antishock agents and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride, used as an antidepressant. Rubidium atoms are used in academic research, including the development of quantum-mechanics-based computing devices, a future application with potential for relatively high consumption of rubidium. Quantum computing research uses ultracold rubidium atoms in a variety of applications. Quantum computers, which have the ability to perform more complex computational tasks than traditional computers by calculating in two quantum states simultaneously, were expected to be in prototype phase within 10 years.

Rubidium's photoemissive properties make it useful for electrical-signal generators in motion-sensor devices, night-vision devices, photoelectric cells (solar panels), and photomultiplier tubes. Rubidium is used as an atomic resonance-frequency-reference oscillator for telecommunications network synchronization, playing a vital role in global positioning systems. Rubidium-rich feldspars are used in ceramic applications for spark plugs and electrical insulators because of their high dielectric constant. Rubidium hydroxide is used in fireworks to oxidize mixtures of other elements and produce violet hues. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 4 USNO rubidium fountain clocks.

Salient Statistics—United States: Consumption, export, and import data are not available. Some concentrate was imported to the United States for further processing. Industry information during the past decade suggests a domestic consumption rate of approximately 2,000 kilograms per year. The United States was 100% import reliant for rubidium minerals.

In 2021, one company offered 1-gram ampoules of 99.75%-grade rubidium (metal basis) for $93.40, a 5% increase from $89.00 in 2020, and 100-gram ampoules of the same material for $1,673.00, a 4% increase from $1,608.00 in 2020. The price for 10-gram ampoules of 99.8% rubidium formate hydrate (metal basis) was $262.00.

In 2021, the prices for 10 grams of 99.8% (metal basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $51.40, $71.20, $54.80, $62.70, and $48.50, respectively. The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $57.70 for 50 milliliters and $93.70 for 100 milliliters, a 17% and 16% increase, respectively, from those of 2020.

Recycling: None.

Import Sources (2017–20): No reliable data have been available to determine the source of rubidium ore imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of rubidium ore.

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RUBIDIUM

Tariff: Item	Number	Normal Trade Relations 12–31–21
Alkali metals, other	2805.19.9000	5.5% ad valorem.
Chlorides, other	2827.39.9000	3.7% ad valorem.
Bromides, other	2827.59.5100	3.6% ad valorem.
Iodides, other	2827.60.5100	4.2% ad valorem.
Sulfates, other	2833.29.5100	3.7% ad valorem.
Nitrates, other	2834.29.5100	3.5% ad valorem.
Carbonates, other	2836.99.5000	3.7% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic rubidium occurrences will remain uneconomic unless market conditions change, such as the development of new end uses or increased consumption for existing end uses, which in turn could lead to increased prices. No known human health issues are associated with exposure to naturally occurring rubidium, and its use has minimal environmental impact.

During 2021, no rubidium production was reported globally but rubidium was thought to have been produced in China. Production of rubidium from all countries, excluding China, ceased within the past two decades. Production in Namibia ceased in the early 2000s, followed by the Tanco Mine in Canada shutting down and later being sold after a mine collapse in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018, and the Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019. Recent reports indicate that with current processing rates, the world's stockpiles of rubidium ore, excluding those in China, will be depleted by 2022.

The primary processing plant of rubidium compounds globally, located in Germany, has reportedly operated far below capacity for the past few years. A company completed an updated mineral resource estimate for the Karibib project in Namibia, reporting 8.9 million metric tons of measured and indicated resources containing 0.23% rubidium and 303 parts per million cesium. The company also reported 6.72 million metric tons of proven and probable reserves containing 2.26% rubidium and 320 parts per million cesium. Located in the Karibib Pegmatite Belt, lithium would be the primary product, with cesium, potassium, and rubidium as potential byproducts.

World Mine Production and Reserves:[1] There were no official sources for rubidium production data in 2021. Lepidolite and pollucite, the principal rubidium-containing minerals in global rubidium reserves, can contain up to 3.5% and 1.5% rubidium oxide, respectively. Rubidium-bearing mineral resources are found in zoned pegmatites. Mineral resources exist globally, but extraction and concentration are mostly cost prohibitive. No reliable data are available to determine reserves for specific countries; however, Australia, Canada, China, and Namibia were thought to have reserves totaling less than 200,000 tons. Existing stockpiles at multiple former mine sites have continued feeding downstream refineries.

World Resources:[1] Significant rubidium-bearing pegmatite occurrences have been identified in Afghanistan, Australia, Canada, China, Denmark, Germany, Japan, Kazakhstan, Namibia, Peru, Russia, the United Kingdom, the United States, and Zambia. Minor quantities of rubidium are reported in brines in northern Chile and China and in evaporites in the United States (New Mexico and Utah), France, and Germany.

Substitutes: Rubidium and cesium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

SALT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Domestic production of salt was estimated to have decreased slightly in 2021 compared with that in 2020 to 40 million tons. The total value of salt sold or used was estimated to be about $2.5 billion. Twenty-six companies operated 63 plants in 16 States. The top producing States were Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 95% of the salt in the United States in 2021. The estimated percentage of salt sold or used was, by type, rock salt, 44%; salt in brine, 40%; vacuum pan salt, 10%; and solar salt, 6%.

Highway deicing accounted for about 42% of total salt consumed. The chemical industry accounted for about 39% of total salt sales, with salt in brine accounting for 90% of the salt used for chemical feedstock. Chlorine and caustic soda manufacturers were the main consumers within the chemical industry. The remaining markets for salt were distributors, 9%; food processing, 4%; agricultural, 2%; and general industrial and primary water treatment, 1% each. The remaining 2% was other uses combined with exports.

Salient Statistics—United States:[1]	2017	2018	2019	2020	2021[e]
Production	39,900	43,900	[e]42,000	[e]41,000	40,000
Sold or used by producers	38,700	44,200	[e]41,000	[e]40,000	39,000
Imports for consumption	12,600	17,900	18,600	15,800	16,000
Exports	1,130	986	1,020	1,250	1,000
Consumption:					
Apparent[2]	50,200	61,100	[e]58,000	[e]54,000	54,000
Reported	45,500	53,000	[e]50,000	[e]46,000	47,000
Price, average value of bulk, pellets and packaged salt, free on board (f.o.b.) mine and plant, dollars per ton:					
Vacuum and open pan salt	208.04	214.12	[e]215.00	[e]215.00	220.00
Solar salt	115.88	120.56	[e]125.00	[e]120.00	120.00
Rock salt	60.41	60.78	[e]59.00	[e]57.00	56.00
Salt in brine	9.49	8.30	[e]9.00	[e]9.00	9.00
Employment, mine and plant, number[e]	4,100	4,100	4,100	4,000	4,100
Net import reliance[3] as a percentage of apparent consumption	23	28	30	27	29

Recycling: None.

Import Sources (2017–20): Chile, 30%; Canada, 27%; Mexico, 12%; Egypt, 11%; and other, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global COVID-19 pandemic affected production and consumption of salt throughout the world in 2020 and 2021. The chloralkali industry was most affected because international trade declined, but the entire salt sector was negatively affected to varying degrees.

For much of the 2020–21 winter, temperatures were near or above average with lower or average precipitation throughout most of the traditional U.S. snowbelt. The number of winter weather events including freezing rain, sleet, and snow is a better predictor of demand for rock salt than total snowfall. Several low snowfall or icing events usually require more salt for highway deicing than a single large snowfall event. Rock salt production and imports in 2021 were expected to be near or slightly less than those in 2020 because demand from many local and State transportation departments decreased. Most local and State governments in regions that experienced a less intense winter season reportedly had remaining stockpiles and therefore less need to replenish supplies of rock salt for the 2021–22 winter.

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SALT

For the 2021–22 winter, the National Oceanic and Atmospheric Administration predicted a La Niña weather pattern for the second consecutive year. A strong La Niña historically favors an average to warmer temperature pattern, but a moderate La Niña favors a colder winter. Based on several factors, the forecasts slightly favor higher precipitation than a normal winter for the Midwest, interior Northeast, and Northwest areas of the United States. All these areas were predicted to be warmer than average except for the Northwest, which is expected to receive more precipitation than average. A warmer and drier pattern than average was predicted for the southern areas of the United States. These forecasts would indicate that demand for rock salt could decrease in the Midwest and northeastern United States.

Demand for salt brine used in the chloralkali industry was expected to increase in 2022 as demand for caustic soda and polyvinyl chloride increases globally, especially in Asia. Salt exports from Australia and especially India have increased in recent years to meet the increasing demand in China, but tensions between China and both countries could affect trade.

World Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States[1]	[e]41,000	40,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	[e]11,000	12,000	
Brazil	[e]7,400	7,400	
Canada	[e]10,000	10,000	
Chile	9,570	10,000	
China	[e]63,000	64,000	
Djibouti	3,100	3,200	
France	[e]5,400	5,400	
Germany	15,300	15,000	
India	[e]29,000	29,000	
Iran	[e]2,600	2,600	
Italy	1,540	2,000	
Mexico	[e]9,000	9,000	
Netherlands	[e]6,000	6,200	
Pakistan	3,750	4,000	
Poland	3,780	4,000	
Russia	[e]8,100	8,000	
Saudi Arabia	2,640	2,700	
Spain	[e]4,200	4,200	
Turkey	[e]6,900	6,900	
Ukraine	[e]2,000	2,000	
United Kingdom	[e]4,700	4,700	
Other countries	[e]30,000	33,000	
World total (rounded)	280,000	290,000	

World Resources:[4] World continental resources of salt are vast, and the salt content in the oceans is nearly unlimited. Domestic resources of rock salt and salt from brine are primarily in Kansas, Louisiana, Michigan, New York, Ohio, and Texas. Saline lakes and solar evaporation salt facilities are in Arizona, California, Nevada, New Mexico, Oklahoma, and Utah. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

Substitutes: No economic substitutes or alternatives for salt exist in most applications. Calcium chloride and calcium magnesium acetate, hydrochloric acid, and potassium chloride can be substituted for salt in deicing, certain chemical processes, and food flavoring, but at a higher cost.

[e]Estimated.

[1]Excludes production from Puerto Rico.

[2]Defined as sold or used by producers + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SAND AND GRAVEL (CONSTRUCTION)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2021, 1.0 billion tons of construction sand and gravel valued at $9.9 billion was produced by an estimated 3,870 companies operating 6,800 pits and 340 sales and (or) distribution yards in 50 States. Leading producing States were, in order of decreasing tonnage, California, Texas, Arizona, Minnesota, Utah, Michigan, Washington, Ohio, Colorado, and New York, which together accounted for about 53% of total output. It is estimated that about 46% of construction sand and gravel was used as portland cement concrete aggregates, 21% for road base and coverings and road stabilization, 13% for construction fill, 12% for asphaltic concrete aggregate and for other bituminous mixtures, and 4% for other miscellaneous uses. The remaining 4% was used for concrete products, filtration, golf course maintenance, plaster and gunite sands, railroad ballast, road stabilization, roofing granules, and snow and ice control.

The estimated output of construction sand and gravel in the United States shipped for consumption in the first 9 months of 2021 was 753 million tons, an increase of 7% compared with that in the same period of 2020. Third quarter shipments for consumption increased by 4% compared with those in the same period of 2020. Additional production information, by quarter, for each State, geographic division, and the United States is reported by the U.S. Geological Survey in its quarterly Mineral Industry Surveys for crushed stone and sand and gravel.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	888	912	935	942	1,000
Imports for consumption	7	6	5	5	4
Exports	(2)	(2)	(2)	(2)	(2)
Consumption, apparent[3]	895	918	940	947	1,000
Price, average value, dollars per metric ton	8.84	9.09	9.31	9.58	9.90
Employment, mine and mill, number[4]	36,500	38,600	39,600	37,900	36,000
Net import reliance[5] as a percentage of apparent consumption	1	1	1	1	(2)

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain sand and gravel aggregate, were recycled on a limited but increasing basis in most States. In 2021, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2017–20): Canada, 95%; Mexico, 3%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Sand, other	2505.90.0000	Free.
Pebbles and gravel	2517.10.0015	Free.

Depletion Allowance: Common varieties, 5% (domestic and foreign).

Government Stockpile: None.

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SAND AND GRAVEL (CONSTRUCTION)

Events, Trends, and Issues: Construction sand and gravel production was about 1.0 billion tons in 2021, an increase of 6% compared with that in 2020. Apparent consumption also increased by 6% to 1.0 billion tons. Consumption of construction sand and gravel increased in 2021 because of growth in the private and public construction markets. Usually, commercial and heavy-industrial construction activity, infrastructure funding, labor availability, new single-family housing unit starts, and weather affect growth in construction sand and gravel production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to infrastructure improvements around the Nation. The underlying factors that would support a rise in prices of construction sand and gravel are expected to be present in 2022, especially in and near metropolitan areas.

The construction sand and gravel industry continued to be concerned with environmental, health, permitting, safety, and zoning regulations. On November 15, 2021, the Infrastructure Investment and Jobs Act was signed into law. The legislation will reauthorize surface transportation programs for 5 years and invest $110 billion in additional funding to repair roads and bridges and support major, transformational projects. Movement of sand and gravel operations away from densely populated regions was expected to continue where zoning regulations and local sentiment discouraged them. Resultant regional shortages of construction sand and gravel and higher fuel costs could result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	942	1,000	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources:[6] Sand and gravel resources are plentiful throughout the world. However, because of environmental regulations, geographic distribution, and quality requirements for some uses, sand and gravel extraction is uneconomical in some cases. The most important commercial sources of sand and gravel have been glacial deposits, river channels, and river flood plains. Use of offshore deposits in the United States is mostly restricted to beach erosion control and replenishment. Other countries routinely mine offshore deposits of aggregates for onshore construction projects.

Substitutes: Crushed stone, the other major construction aggregate, is often substituted for natural sand and gravel, especially in more densely populated areas of the Eastern United States. Crushed stone remains the dominant choice for construction aggregate use. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2021.

[e]Estimated. NA Not available.

[1]See also Sand and Gravel (Industrial) and Stone (Crushed).

[2]Less than ½ unit.

[3]Defined as production + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their sand and gravel production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

SAND AND GRAVEL (INDUSTRIAL)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, industrial sand and gravel valued at an estimated $2.3 billion was produced by 167 companies from 248 operations in 33 States. The value of production of industrial sand and gravel in 2021 increased slightly compared with that in the previous year. The leading producing States were, in descending order of production, Texas, Wisconsin, Illinois, Missouri, Oklahoma, Louisiana, North Carolina, Alabama, California, Tennessee, New Jersey, and Minnesota. Combined production from these States accounted for about 86% of total domestic sales and use. Approximately 64% of the U.S. tonnage was used as hydraulic-fracturing sand and well-packing and cementing sand; 11% as other whole-grain silica; and 10% as glassmaking sand. Other uses were, in decreasing quantity of use, foundry sand, whole-grain fillers for building products, recreational sand, other ground silica sand, and silica gravel, which accounted for 12%, combined. Other minor uses were, in decreasing quantity of use, chemicals, abrasives, filtration sand, ceramics, roofing granules, fillers, traction, and metallurgic flux, combined, accounted for the remaining 3% of industrial sand and gravel end uses.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Sold or used	104,000	126,000	108,000	70,000	72,000
Imports for consumption	366	392	389	417	360
Exports	4,600	6,440	5,540	4,030	5,600
Consumption, apparent[2]	99,800	120,000	103,000	66,400	67,000
Price, average value, dollars per ton	52.10	56.10	46.10	30.70	33.00
Employment, quarry and mill, number[e]	4,000	4,000	3,500	2,000	2,500
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Some foundry sand is recycled, and recycled cullet (pieces of glass) represents a significant proportion of reused silica. About 33% of glass containers are recycled.

Import Sources (2017–20): Canada, 85%; Vietnam, 5%; Brazil and Taiwan, 2% each; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Sand containing 95% or more silica and not more than 0.6% iron oxide	2505.10.1000	Free.

Depletion Allowance: Industrial sand or pebbles, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of industrial sand and gravel was estimated to be 67 million tons in 2021, a slight increase from that of the previous year. The most important driving force in the industrial sand and gravel industry remained the production and sale of hydraulic-fracturing sand (frac sand). For several years, the consumption of frac sand increased as hydrocarbon exploration in the United States transitioned to natural gas and petroleum extracted from shale deposits. However, industrial sand and gravel consumption decreased in recent years, primarily as a result of decreased natural-gas- and petroleum-well drilling in North America and oil well completion activity. These decreases were exacerbated by restrictions imposed as the result of the global COVID-19 pandemic, which resulted in a significant decline in consumption of petroleum products, which in turn prompted a decrease in demand for hydraulic-fracturing sand. Imports of industrial sand and gravel in 2021 were an estimated 360,000 tons, a 14% decrease from those of the previous year. Imports of silica are generally of two types—small shipments of very high-purity silica or a few large shipments of lower grade silica shipped only under special circumstances (for example, very low freight rates). The United States remained a net exporter of industrial sand and gravel; U.S. exports of industrial sand and gravel increased by 39% in 2021 compared with those of the previous year.

The United States was the world's leading producer and consumer of industrial sand and gravel based on estimated world production figures. Collecting definitive data on industrial sand and gravel production in most nations is difficult because of the wide range of terminology and specifications used by different countries. The United States remained a major exporter of industrial sand and gravel, shipping it to almost every region of the world. High global demand for U.S. industrial sand and gravel can be attributed to the high quality and advanced processing techniques used in the United States for many grades of industrial sand and gravel, meeting specifications for virtually any use.

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SAND AND GRAVEL (INDUSTRIAL)

The duration and outcome of the global COVID-19 pandemic remains uncertain; however, measures previously instituted to mitigate the spread of the global COVID-19 pandemic are expected to continue to be eased or lifted in the United States and around the world. The pandemic is likely to have less of a negative effect on the economies of the United States and the world going forward, which could result in increased production and consumption of industrial sand and gravel.

Additionally, the industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2021, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration (OSHA) finalized regulations to further restrict exposure to crystalline silica at quarry sites and in other industries that use materials containing it. Phased implementation of the new regulations took effect through 2021, affecting various industries that use materials containing silica. Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations, and logistical issues, including ongoing development and permitting of operations producing hydraulic-fracturing sand. These factors may result in future sand and gravel operations being located farther from high-population centers.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States	70,000	72,000	Large. Industrial sand and gravel deposits are widespread.
Argentina	2,500	3,500	
Australia	3,000	3,500	
Austria	1,570	1,600	
Bulgaria	8,350	8,400	
Canada	4,700	5,000	
France	11,000	11,000	
Guatemala	1,900	1,900	
India	11,900	12,000	
Indonesia	2,640	2,600	
Italy	10,000	10,000	
Japan	1,920	1,900	
Malaysia	3,700	4,000	
Mexico	2,700	3,000	
Netherlands	54,000	54,000	
Poland	5,490	5,500	
South Africa	2,300	2,200	
Spain	5,700	5,700	
Turkey	10,300	12,000	
United Kingdom	4,400	4,400	
Other countries	16,900	18,000	
World total (rounded)	235,000	240,000	

World Resources:[4] Sand and gravel resources of the world are large. However, because of their geographic distribution, environmental restrictions, and quality requirements for some uses, extraction of these resources is sometimes uneconomical. Quartz-rich sand and sandstone, the main sources of industrial silica sand, occur throughout the world.

Substitutes: Alternative materials that can be used for glassmaking and for foundry and molding sands are chromite, olivine, staurolite, and zircon sands. Although costlier and mostly used in deeper wells, alternative materials that can be used as proppants are sintered bauxite and kaolin-based ceramic proppants.

[e]Estimated. E Net exporter.

[1]See also Sand and Gravel (Construction).

[2]Defined as production (sold or used) + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SCANDIUM[1]

(Data in metric tons of scandium oxide equivalent unless otherwise noted)

Domestic Production and Use: Domestically, scandium was neither mined nor recovered from process streams or mine tailings in 2021. Previously, scandium was produced domestically primarily from the scandium-yttrium silicate mineral thortveitite and from byproduct leach solutions from uranium operations. Limited capacity to produce ingot and distilled scandium metal existed at facilities in Ames, IA; Tolleson, AZ; and Urbana, IL. The principal uses for scandium in 2021 were in aluminum-scandium alloys and solid oxide fuel cells (SOFCs). Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Price, yearend:					
Compounds, dollars per gram:					
Acetate, 99.9% purity, 5-gram lot size[2]	44	44	45	45	43
Chloride, 99.9% purity, 5-gram lot size[2]	124	125	129	133	137
Fluoride, 99.9% purity, 1- to 5-gram lot size[3]	277	206	209	214	216
Iodide, 99.999% purity, 5-gram lot size[2]	183	165	157	161	161
Oxide, 99.99% purity, 5-kilogram lot size[4]	4.6	4.6	3.9	3.8	2.2
Metal:					
Scandium, distilled dendritic, 2-gram lot size,[2] dollars per gram	226	226	233	233	238
Scandium, ingot, 5-gram lot size,[2] dollars per gram	132	132	134	134	137
Scandium-aluminum alloy, 1-kilogram lot size,[4] dollars per kilogram	350	360	300	340	350
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Although no definitive data exist listing import sources, imported material was thought to be mostly from Europe, China, Japan, and Russia.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Rare-earth metals, unspecified	2805.30.0000	5.0% ad valorem.
Compounds of rare-earth metals:		
Mixtures of oxides of yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of chlorides of yttrium or scandium as the predominant metal	2846.90.2082	Free.
Mixtures of other rare-earth carbonates, including scandium	2846.90.8075	3.7% ad valorem.
Mixtures of other rare-earth compounds, including scandium	2846.90.8090	3.7% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global supply and consumption of scandium oxide was estimated to be about 15 to 25 tons per year. Scandium was recovered from titanium, zirconium, cobalt, and nickel process streams. China, the Philippines, and Russia were the leading producers. Prices quoted for scandium oxide in the United States in 2021 decreased significantly compared with those in 2020. Owing in part to low capacity utilization, China's ex-works prices for scandium oxide were significantly less than United States quoted prices.

In the United States, a new metallurgical testing program for production of scandium recently achieved success at the bench scale for the Nebraska polymetallic Elk Creek project where additional financing for construction was being sought. Probable reserves were estimated to be 36 million tons containing 65.7 parts per million (2,400 tons) scandium. Plans for the project included downstream production of ferroniobium, titanium dioxide, and scandium oxide. At the La Paz Scandium and Rare Earths project in Arizona, necessary permits and approvals were in place for the core drilling campaign to determine if a primary scandium mine could be established.

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The Bokan project in Alaska and the Round Top project in Texas also included scandium recovery in their process plans. In addition, research continued to develop methods for separating scandium from coal and coal byproducts. SOFC sourcing of scandium is expanding beyond China to include Japan and the Philippines.

A global mining and polymetallic metal producer announced the commissioning of a new scandium plant in Sorel-Tracy, Quebec, Canada, with a capacity of 3 tons per year of 99.99% scandium oxide. The company announced completion of the first sale of high-performance aluminum-scandium alloy for metal additive manufacturing. In Australia, several polymetallic projects were under development and seeking permitting, financing, and offtake agreements. Projects and prospects included the Nyngan, Owendale, and Sunrise projects in New South Wales along with others. The SCONI project commissioned the construction phase of its pilot P-CAM production plant in North Queensland.

In the Philippines, a 7.5-ton-per-year scandium oxide equivalent commercial plant designed to recover scandium at the Taganito high-pressure acid-leach nickel operation produced an estimated gross output of about 13 dry tons of scandium oxalate in 2020 with 2021 first quarter production of 3.6 tons. In Russia, feasibility studies for making scandium oxide as a byproduct of alumina refining at a smelter in the Ural Mountains were ongoing. The pilot plant was reported to have produced scandium oxide with purity greater than 99%. Based on pilot-plant test results, plans were in place for a 3-ton-per-year scandium oxide plant. In the Kurgan region of Russia, two mobile sorption plants were put into operation and two additional sorption columns were mounted directly at the plant site with extractive purification technology to obtain scandium oxide with a purity of 99.9%. Another technology made it possible for production aluminum-scandium alloys as byproduct of uranium production. In 2019 (the most recent year for which there were published data), commercial production at the scandium project was 230 kilograms of metal produced and shipped to customers. At Agios Nikolaos, Greece, a pilot plant successfully demonstrated recovery of scandium from bauxite residue in industrial waste at a vertically integrated aluminum and alumina plant through a patented selective ion recovery technology as part of the European Union's Horizon 2020 research and development program.

The Kiviniemi scandium project in eastern Finland features a resource of 13.4 million tons at a grade of 163 parts per million scandium where scandium is mainly incorporated into the lattice of clinopyroxene and amphibole.

In China, a large state-owned enterprise in Shanghai was producing 50 tons per year of scandium oxide raw material with a long-term expected capacity of 100 tons per year. Another company in Henan Province had a 10-ton-per-year scandium oxide capacity with plans to increase annual output to 20 tons.

World Mine Production and Reserves:[6] No scandium was recovered from mining operations in the United States. As a result of its low concentration, scandium is produced exclusively as a byproduct during processing of various ores or recovered from previously processed tailings or residues. Historically, scandium was produced as byproduct material in China (iron ore, rare earths, titanium, and zirconium), Kazakhstan (uranium), the Philippines (nickel), Russia (apatite and uranium), and Ukraine (uranium). Foreign mine production data for 2020 and 2021 were not available.

World Resources:[6] Resources of scandium are abundant. Scandium's crustal abundance is greater than that of lead. Scandium lacks affinity for the common ore-forming anions; therefore, it is widely dispersed in the lithosphere and forms solid solutions with low concentrations in more than 100 minerals. Scandium resources have been identified in Australia, Canada, China, Finland, Guinea, Kazakhstan, Madagascar, Norway, South Africa, the Philippines, Russia, Ukraine, and the United States.

Substitutes: Titanium and aluminum high-strength alloys as well as carbon-fiber materials may substitute in high-performance scandium-alloy applications. Under certain conditions, light-emitting diodes may displace mercury-vapor high-intensity lamps that contain scandium iodide. In some applications that rely on scandium's unique properties, substitution is not possible.

[e]Estimated.

[1]See also Rare Earths. Scandium is one of the 17 rare-earth elements.

[2]Source: Alfa Aesar, a part of Thermo Fisher Scientific Inc.

[3]Source: Sigma-Aldrich, a part of MilliporeSigma.

[4]Source: Stanford Materials Corp.

[5]Defined as imports – exports. Quantitative data are not available.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

SELENIUM

(Data in metric tons of contained selenium unless otherwise noted)

Domestic Production and Use: In 2021, the only domestic selenium-producing copper refinery halted production of refined selenium but produced selenium-bearing anode slime. The two other electrolytic copper refineries, operating in Arizona and Utah, did not recover selenium domestically, but did produce selenium-bearing anode slimes. U.S. selenium production in prior years and consumption and stock data were withheld to avoid disclosing company proprietary data. Estimates for end uses in global consumption were, in descending order, metallurgy (including manganese production), glass manufacturing, agriculture, chemicals and pigments, electronics, and other uses.

Selenium is used in blasting caps to control delays; in catalysts to enhance selective oxidation; in copper, lead, and steel alloys to improve machinability; in the electrolytic production of manganese to increase yields; in glass manufacturing to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass; in gun bluing to improve cosmetic appearance and provide corrosion resistance; in plating solutions to improve appearance and durability; in rubber compounding chemicals to act as a vulcanizing agent; and in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells.

Selenium is an essential micronutrient and is used as a human dietary supplement, a dietary supplement for livestock, and as a fertilizer additive to enrich selenium-poor soils. Selenium is also used as an active ingredient in antidandruff shampoos.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery	W	W	W	W	—
Imports for consumption:					
Selenium metal	450	445	496	366	360
Selenium dioxide	19	12	5	18	77
Exports,[1] metal	242	158	361	147	240
Consumption, apparent,[2] metal	W	W	W	W	W
Price, average,[3] dollars per pound	15.55	16.85	9.15	6.61	8.00
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption, metal	E	<25	<25	<50	>75

Recycling: Domestic production of secondary selenium was estimated to be very small because most scrap from older plain paper photocopiers and electronic materials was exported for recovery of the contained selenium.

Import Sources (2017–20): Selenium metal: Philippines, 18%; China,[5] 16%; Mexico, 14%; Germany, 13%; and other, 39%. Selenium dioxide: Republic of Korea, 29%; China, 24%; Germany, 18%; Canada, 14%; and other, 15%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Selenium metal	2804.90.0000	Free.
Selenium dioxide	2811.29.2000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The supply of selenium is directly affected by the supply of the materials from which it is a byproduct—copper and, to a lesser extent, nickel—and it is directly affected by the number of facilities that recover selenium. The estimated annual average price for selenium was $8.00 per pound in 2021, a 21% increase from that in 2020. Average weekly prices have risen steadily from the beginning of 2021. Copper producers in China had opted to stop sales from their inventories, reducing availability of selenium. Selenium prices increased owing to a rise in crude selenium feedstock costs.

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SELENIUM

In China, selenium suppliers and consumers both experienced difficulties acquiring adequate materials. Electrolytic manganese production was the main metallurgical end use for selenium in China, where selenium dioxide was used in the electrolytic process to increase current efficiency and the metal deposition rate. Manganese production decreased in 2021, owing to output reductions by major manganese producers in China. The reductions were put in place to reduce spot availability and raise prices. The manganese industry alliance had a commitment to shut down operations for 30 days every 4 months, with a total of 90 days in 2021.

World Refinery Production and Reserves:

	Refinery production[6]		Reserves[7]
	2020	2021[e]	
United States	W	—	10,000
Belgium	200	200	—
Canada	60	60	6,000
China	1,200	1,100	26,000
Finland	84	100	—
Germany	300	300	—
India	14	10	—
Japan	740	750	—
Peru	35	40	13,000
Poland	74	65	3,000
Russia	340	300	20,000
Sweden	10	20	—
Turkey	50	50	—
Other countries[8]	14	25	22,000
World total (rounded)	[9]3,120	3,000	100,000

World Resources:[7] Reserves for selenium are based on identified copper deposits and average selenium content. Coal generally contains between 0.5 and 12 parts per million selenium, or about 80 to 90 times the average for copper deposits. The recovery of selenium from coal fly ash, although technically feasible, does not appear likely to be economical in the foreseeable future.

Substitutes: Silicon is the major substitute for selenium in low- and medium-voltage rectifiers. Organic pigments have been developed as substitutes for cadmium sulfoselenide pigments. Other substitutes include cerium oxide as either a colorant or decolorant in glass; tellurium in pigments and rubber; bismuth, lead, and tellurium in free-machining alloys; and bismuth and tellurium in lead-free brasses. Sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal, but it is not as energy efficient.

The selenium-tellurium photoreceptors used in some plain paper copiers and laser printers have been replaced by organic photoreceptors in newer machines. Amorphous silicon and cadmium telluride are the two principal competitors with CIGS in thin-film photovoltaic solar cells.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]There was no exclusive Schedule B number for selenium dioxide exports.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]Selenium metal powder, free on board, U.S. warehouse, minimum 99.5% purity. Source: Argus Media group—Argus Metals International.

[4]Defined as imports – exports + adjustments for industry stock changes; export data are incomplete for common forms of selenium, which may be exported under unexpected or misidentified forms, such as copper slimes, copper selenide, or zinc selenide.

[5]Includes Hong Kong.

[6]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues but did not recover refined selenium from these materials indigenously were excluded to avoid double counting.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Australia, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan are known to produce refined selenium, but output was not reported, and information was inadequate to make reliable production estimates.

[9]Excludes U.S. production.

SILICON

(Data in thousand metric tons of contained silicon unless otherwise noted)

Domestic Production and Use: Six companies produced silicon materials in 2021, all east of the Mississippi River. Most ferrosilicon was consumed in the ferrous foundry and steel industries, predominantly in the Eastern United States, and was sourced primarily from domestic quartzite (silica). The main consumers of silicon metal were producers of aluminum alloys and the chemical industry, in particular for the manufacture of silicones. The semiconductor and solar energy industries, which manufacture chips for computers and photovoltaic cells from high-purity silicon, respectively, also consumed silicon metal.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, ferrosilicon[1] and silicon metal[2]	415	430	310	277	310
Imports for consumption:					
Ferrosilicon, all grades	147	140	127	140	120
Silicon metal	136	116	124	97	93
Exports:					
Ferrosilicon, all grades	11	12	8	4	7
Silicon metal	71	45	40	31	57
Consumption, apparent,[3] ferrosilicon[1] and silicon metal[2]	616	637	517	481	459
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% Si[4]	94.47	104.24	102.35	103.38	110.00
Ferrosilicon, 75% Si[5]	86.88	107.58	89.15	87.40	140.00
Silicon metal[2, 5]	116.56	134.15	105.70	96.84	140.00
Stocks, producer, ferrosilicon[1] and silicon metal,[2] yearend	26	19	15	12	11
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades	<50	<50	<50	>50	<50
Silicon metal[2]	<50	<50	<50	<50	<50
Total	33	32	40	42	32

Recycling: Insignificant.

Import Sources (2017–20): Ferrosilicon: Russia, 40%; Canada, 14%; Brazil, 10%; Iceland, 8%; and other, 28%. Silicon metal: Brazil, 30%; Canada, 21%; Norway, 13%; Australia, 8%; and other, 28%. Total: Russia, 21%; Brazil, 20%; Canada, 17%; Norway, 7%; and other, 35%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Silicon, more than 99.99% Si	2804.61.0000	Free.
Silicon, 99.00%–99.99% Si	2804.69.1000	5.3% ad valorem.
Silicon, other	2804.69.5000	5.5% ad valorem.
Ferrosilicon, 55%–80% Si:		
More than 3% Ca	7202.21.1000	1.1% ad valorem.
Other	7202.21.5000	1.5% ad valorem.
Ferrosilicon, 80%–90% Si	7202.21.7500	1.9% ad valorem.
Ferrosilicon, more than 90% Si	7202.21.9000	5.8% ad valorem.
Ferrosilicon, other:		
More than 2% Mg	7202.29.0010	Free.
Other	7202.29.0050	Free.

Depletion Allowance: Quartzite, 14% (domestic and foreign); gravel, 5% (domestic and foreign).

Government Stockpile: None.

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SILICON

Events, Trends, and Issues: Combined domestic ferrosilicon and silicon metal production in 2021, expressed in terms of contained silicon, increased from that in 2020. One producer reopened its ferrosilicon production facility in March 2021 owing to increased demand for ferrosilicon products and improved domestic pricing. The facility had closed in July 2020 owing to decreased demand and lower prices—in part because of the global COVID-19 pandemic, as well as competition from lower priced imported ferrosilicon. Domestic production during the first 8 months of 2021 was about 5% more, on a silicon-content basis, than that during the same period in 2020. By August 2021, average U.S. spot market prices increased by almost 9% for 50%-grade ferrosilicon and by almost 60% for 75%-grade ferrosilicon compared with the annual averages in 2020; the average silicon metal spot market price increased by almost 50% compared with the annual average spot price in 2020.

Excluding the United States, ferrosilicon accounted for almost 70% of world silicon production on a silicon-content basis in 2021. The leading countries for ferrosilicon production were, in descending order and on a silicon-content basis, China, Russia, and Norway. For silicon metal, the leading producers were China, Brazil, and Norway. China accounted for approximately 70% of total global estimated production of silicon materials in 2021. Global production of silicon materials, on a silicon-content basis, was estimated to be about 5% more than that in 2020. Global production of steel, the leading use of ferrosilicon, increased in 2021 compared with production in 2020 owing to increased demand following the negative effects of the global COVID-19 pandemic.

World Production and Reserves:

	Production[7]		Reserves[8]
	2020	2021[e]	
United States	277	310	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates are not available.
Australia	42	42	
Bhutan[9]	67	70	
Brazil	404	390	
Canada	47	50	
China	5,600	6,000	
France	112	120	
Iceland	103	110	
India[9]	59	60	
Kazakhstan	67	67	
Malaysia[9]	109	80	
Norway	345	350	
Poland	42	42	
Russia	576	580	
Spain	55	58	
Ukraine[9]	40	49	
Other countries	175	160	
World total (rounded)	8,120	8,500	

World Resources:[8] World and domestic resources for making silicon metal and alloys are abundant and, in most producing countries, adequate to supply world requirements for many decades. The source of the silicon is silica in various natural forms, such as quartzite.

Substitutes: Aluminum, silicon carbide, and silicomanganese can be substituted for ferrosilicon in some applications. Gallium arsenide and germanium are the principal substitutes for silicon in semiconductor and infrared applications.

[e]Estimated.

[1]Ferrosilicon grades include the two standard grades of ferrosilicon—50% silicon and 75% silicon—plus miscellaneous silicon alloys.

[2]Metallurgical-grade silicon metal.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Source: CRU Group, transaction prices based on weekly averages.

[5]Source: S&P Global Platts Metals Week, mean import prices based on monthly averages.

[6]Defined as imports – exports + adjustments for industry stock changes.

[7]Production quantities are the silicon content of combined totals for ferrosilicon and silicon metal, except as noted.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Silicon content of ferrosilicon only.

SILVER

(Data in metric tons[1] of contained silver unless otherwise noted)

Domestic Production and Use: In 2021, U.S. mines produced approximately 1,000 tons of silver with an estimated value of $830 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 33 domestic base- and precious-metal operations. Alaska continued as the country's leading silver-producing State, followed by Nevada. There were 24 U.S. refiners that reported production of commercial-grade silver with an estimated total output of 2,000 tons from domestic and foreign ores and concentrates and from new and old scrap. The physical properties of silver include high ductility, electrical conductivity, malleability, and reflectivity. In 2021, the estimated domestic uses for silver were physical investment, 26%; electrical and electronics, 21%; coins and medals, 11%; jewelry and silverware, 4%; and other, 38%. Other applications for silver include use in antimicrobial bandages, clothing, pharmaceuticals, and plastics; batteries; bearings; brazing and soldering; catalytic converters in automobiles; electroplating; inks; mirrors; photography; photovoltaic solar cells; water purification; and wood treatment. Mercury and silver, the main components of dental amalgam, are biocides, and their use in amalgam inhibits recurrent decay.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine	1,030	934	981	1,030	1,000
Refinery:					
Primary	1,420	1,420	1,420	1,420	1,400
Secondary (new and old scrap)	490	632	643	640	650
Imports for consumption[2]	5,040	4,840	4,770	6,740	6,500
Exports[2]	157	603	220	140	160
Consumption, apparent[3]	6,400	5,790	6,290	8,260	8,000
Price, bullion, average, dollars per troy ounce[4]	17.08	15.73	16.24	20.58	25.00
Stocks, yearend:					
Industry	150	170	52	60	60
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	7,570	9,150	9,860	12,330	11,000
Employment, mine and mill, number[6]	1,050	982	1,000	1,180	1,500
Net import reliance[7] as a percentage of apparent consumption	76	73	74	80	79

Recycling: In 2021, approximately 650 tons of silver was recovered from new and old scrap, about 8% of apparent consumption.

Import Sources (2017–20):[2] Mexico, 47%; Canada, 23%; Chile, 4%; Poland, 4%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Silver ores and concentrates	2616.10.0040	0.8 ¢/kg on lead content.
Bullion	7106.91.1010	Free.
Dore	7106.91.1020	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of silver (see salient statistics above).

Events, Trends, and Issues: The estimated average silver price in 2021 was $25.00 per troy ounce, 22% higher than the average price in 2020. The price began the year at $27.51 per troy ounce, increased to a high of $29.45 per troy ounce on February 1, then decreased to a low of $21.75 per troy ounce on September 30. The price of silver generally decreased throughout the year. The February 1 daily price was the highest since December 11, 2020. U.S. investment was a major contributing factor to the rise in silver prices. Increased investment was driven by novice buyers from nontraditional sources in late January and early February.

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SILVER

In 2021, global consumption of silver was estimated to have increased slightly from that in 2020. Coin and bar consumption increased in 2021 for the fifth year in a row, led by U.S. investments. In 2021, physical investment in the United States in silver reached an estimated 7,900 tons (250 million troy ounces) compared with 6,240 tons (201 million troy ounces) in 2020. This was partially offset by an 85% decrease in investments in India. Consumption for industrial uses was estimated to have increased in the first 6 months of 2021 owing to the reopening of economies. Consumption of silver in jewelry and silverware was estimated to have increased by 24% and 32%, respectively. Despite decreased investment in India, global physical holdings of silver reached a reported 36,600 tons (1.18 billion troy ounces) compared with 33,200 tons (1.07 billion troy ounces) in 2020.[8]

World silver mine production increased slightly in 2021 to an estimated 24,000 tons, principally as a result of increased production from mines in Argentina, India, Mexico, and Peru following shutdowns in 2020 in response to the global COVID-19 pandemic. Domestic silver mine production was estimated to have decreased by 3% in 2021 to 1,000 tons compared with the 1,030 tons produced in 2020.

World Mine Production and Reserves: Reserves for Australia, Peru, and Poland were revised based on information from Government sources.

	Mine production		Reserves[9]
	2020	2021[e]	
United States	1,030	1,000	26,000
Argentina	710	800	NA
Australia	1,340	1,300	[10]90,000
Bolivia	930	1,000	22,000
Chile	1,580	1,600	26,000
China	3,380	3,400	41,000
Kazakhstan	435	450	NA
Mexico	5,540	5,600	37,000
Peru	2,770	3,000	120,000
Poland	1,250	1,300	67,000
Russia	1,320	1,300	45,000
Other countries	3,230	3,100	57,000
World total (rounded)	23,500	24,000	530,000

World Resources:[9] Although silver was a principal product at several mines, silver was primarily obtained as a byproduct from lead-zinc, copper, and gold mines, in descending order of production. The polymetallic ore deposits from which silver was recovered account for more than two-thirds of U.S. and world resources of silver. Most recent silver discoveries have been associated with gold occurrences; however, copper and lead-zinc occurrences that contain byproduct silver will continue to account for a significant share of reserves and resources in the future.

Substitutes: Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for traditional photographic applications for silver. Surgical pins and plates may be made with stainless steel, tantalum, and titanium in place of silver. Stainless steel may be substituted for silver flatware. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles.

[e]Estimated. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Silver content of base metal ores and concentrates, ash and residues, refined bullion, and dore; excludes coinage, and waste and scrap material.

[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.

[4]Engelhard's industrial bullion quotations. Source: S&P Global Platts Metals Week.

[5]Source: U.S. Mint. Balance in U.S. Mint only; includes deep storage and working stocks.

[6]Source: U.S. Department of Labor, Mine Safety and Health Administration (MSHA). Only includes mines where silver is the primary product. In 2021, MSHA changed the Mine Employment values in their publicly available database.

[7]Defined as imports – exports + adjustments for Government and industry stock changes.

[8]DiRienzo, Michael, and Newman, Philip, 2020, Key components of silver market affected by pandemic in 2020—Global demand and mine supply impacted, while physical silver investment expected to surge to a 5-year high: Silver Institute and Metal Focus, November 19, 2 p.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 25,000 tons.

SODA ASH

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The total value of domestic natural soda ash (sodium carbonate) produced in 2021 was estimated to be about $1.8 billion[1], and the quantity produced was 12 million tons, about 20% more than that of the previous year. The U.S. soda ash industry comprised four companies in Wyoming operating five plants and one company in California operating one plant. The five producing companies have a combined annual nameplate capacity of 13.9 million tons (15.3 million short tons). Borax, salt, and sodium sulfate were produced as coproducts of sodium carbonate production in California. Chemical caustic soda, sodium bicarbonate, and sodium sulfite were manufactured as coproducts at several of the Wyoming soda ash plants. Sodium bicarbonate was produced at an operation in Colorado using soda ash feedstock shipped from the company's Wyoming facility.

Based on 2021 quarterly reports, the estimated distribution of soda ash by end use was glass, 49%; chemicals, 28%; miscellaneous uses, 8%; distributors, 5%; soap and detergents, 5%; flue gas desulfurization, 3%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production[2]	12,000	11,900	11,700	9,990	12,000
Imports for consumption	19	51	115	98	80
Exports	6,990	6,960	7,020	5,590	6,500
Consumption:					
Apparent[3]	5,040	4,980	4,830	4,480	5,400
Reported	4,910	4,850	4,720	4,440	5,300
Price, average sales value (natural source), free on board (f.o.b.) mine or plant:					
Dollars per metric ton	146.26	148.69	153.24	145.67	155
Dollars per short ton	132.68	134.89	139.02	132.15	141
Stocks, producer, yearend	293	297	289	305	290
Employment, mine and plant, number[e]	2,600	2,600	2,600	2,400	2,400
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: No soda ash was recycled by producers; however, glass container producers use cullet glass, thereby reducing soda ash consumption.

Import Sources (2017–20): Turkey, 81%; Bulgaria and Mexico, 4% each; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Disodium carbonate	2836.20.0000	1.2% ad valorem.

Depletion Allowance: Natural, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Production, exports, and consumption in 2021 nearly returned to levels seen before the global COVID-19 pandemic. More than one-half of U.S. production of soda ash was exported, and exports were estimated to have increased by 16% compared with those in 2020. Domestic consumption reported by producers increased by about 19% in 2021 compared with that in 2020, and apparent consumption in 2021 increased by about 21% compared with that in 2020.

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SODA ASH

Relatively low production costs and lower environmental impacts provide natural soda ash producers some advantage over producers of synthetic soda ash. The production of synthetic soda ash normally consumes more energy and releases more carbon dioxide than that of natural soda ash. In recent years, U.S. producers of natural soda ash were able to expand their markets when several synthetic soda ash plants were closed or idled in other parts of the world.

After increasing capacity during the past 4 years, total production capacity in Turkey was estimated to be between 4 million and 5 million tons per year, and soda ash shipments in Turkey, especially for export, were expected to increase during the next few years. Total United States imports, mostly from Turkey, have recently been about 100,000 tons per year, which was more than double the average quantity of annual imports during the past decade.

World Mine Production and Reserves: Reserves for Turkey were revised based on Government and industry reports.

	Mine production		Reserves[5, 6]
	2020	2021[e]	
Natural:			
United States	9,990	12,000	[7]23,000,000
Botswana	250	260	400,000
Ethiopia	18	20	400,000
Kenya	220	250	7,000
Turkey	4,200	4,400	880,000
Other countries	NA	NA	280,000
World total, natural (rounded)	14,700	17,000	25,000,000
World total, synthetic (rounded)	40,400	42,000	XX
World total (rounded)	55,100	59,000	XX

World Resources:[6] Natural soda ash is obtained from trona and sodium carbonate-rich brines. The world's largest deposit of trona is in the Green River Basin of Wyoming. About 47 billion tons of identified soda ash resources could be recovered from the 56 billion tons of bedded trona and the 47 billion tons of interbedded or intermixed trona and halite, which are in beds more than 1.2 meters thick. Underground room-and-pillar mining, using conventional and continuous mining, is the primary method of mining Wyoming trona ore. This method has an average 45% mining recovery, whereas average recovery from solution mining is 30%. Improved solution-mining techniques, such as horizontal drilling to establish communication between well pairs, could increase this extraction rate and enable companies to develop some of the deeper trona beds. Wyoming trona resources are being depleted at the rate of about 15 million tons per year (8.3 million tons of soda ash). Searles Lake and Owens Lake in California contain an estimated 815 million tons of soda ash reserves. At least 95 natural sodium carbonate deposits have been identified in the world, the resources of only some of which have been quantified. Although soda ash can be manufactured from salt and limestone, both of which are practically inexhaustible, synthetic soda ash is costlier to produce and generates environmental wastes.

Substitutes: Caustic soda can be substituted for soda ash in certain uses, particularly in the pulp and paper, water treatment, and certain chemical sectors. Soda ash, soda liquors, or trona can be used as feedstock to manufacture chemical caustic soda, which is an alternative to electrolytic caustic soda.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable.

[1]Does not include values for soda liquors and mine waters.

[2]Natural only.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]The reported quantities are sodium carbonate only. About 1.8 tons of trona yield 1 ton of sodium carbonate.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]From trona, nahcolite, and dawsonite deposits.

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2021, 1.5 billion tons of crushed stone valued at more than $19 billion was produced by an estimated 1,410 companies operating 3,440 quarries and 180 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Missouri, Florida, Pennsylvania, Ohio, Georgia, North Carolina, Virginia, California, and Tennessee, which together accounted for about 54% of total crushed stone output. Of the total domestic crushed stone produced in 2021, about 70% was limestone and dolomite; 15%, granite; 6%, traprock; 5%, miscellaneous stone; 3%, sandstone and quartzite; and the remaining 1% was divided, in descending order of tonnage, among marble, volcanic cinder and scoria, calcareous marl, slate, and shell. It is estimated that about 72% of crushed stone was used as a construction aggregate, mostly for road construction and maintenance; 16% for cement manufacturing; 8% for lime manufacturing; 2% for agricultural uses; and the remaining 2% for other chemical, special, and miscellaneous uses and products.

The estimated output of crushed stone in the United States shipped for consumption in the first 9 months of 2021 was 1.14 billion tons, an increase of 3% compared with that in the same period of 2020. Third quarter shipments for consumption increased by 4% compared with those in the same period of 2020. Additional production information, by quarter, for each State, geographic division, and the United States is reported by the U.S. Geological Survey in its quarterly Mineral Industry Surveys for crushed stone and sand and gravel.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	1,370	1,390	1,490	1,470	1,500
Recycled material	43	38	38	38	38
Imports for consumption	19	21	24	20	18
Exports	1	(2)	(2)	(2)	(2)
Consumption, apparent[3]	1,430	1,450	1,550	1,530	1,600
Price, average value, dollars per metric ton	11.36	11.64	11.96	12.22	13.00
Employment, quarry and mill, number[4]	68,600	68,500	69,000	67,000	67,000
Net import reliance[5] as a percentage of apparent consumption	1	1	2	1	1

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain crushed stone aggregate, were recycled on a limited but increasing basis in most States. In 2021, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2017–20): Mexico, 54%; Canada, 28%; The Bahamas, 12%; Honduras, 5%; and other, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Chalk:		
Crude	2509.00.1000	Free.
Other	2509.00.2000	Free.
Limestone, except pebbles and gravel	2517.10.0020	Free.
Crushed or broken stone	2517.10.0055	Free.
Marble granules, chippings and powder	2517.41.0000	Free.
Stone granules, chippings and powders	2517.49.0000	Free.
Limestone flux; limestone and other calcareous stone	2521.00.0000	Free.

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STONE (CRUSHED)

Depletion Allowance: For some special uses, 14% (domestic and foreign); if used as ballast, concrete aggregate, riprap, road material, and similar purposes, 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Crushed stone production was about 1.5 billion tons in 2021, an increase of 3% compared with 1.47 billion tons in 2020. Apparent consumption also increased to 1.6 billion tons. Consumption of crushed stone increased in 2021 because of growth in the private and public construction markets. Usually, commercial and heavy-industrial construction activity, infrastructure funding, labor availability, new single-family housing unit starts, and weather affect growth in crushed stone production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to infrastructure improvements around the Nation. The underlying factors that would support a rise in prices of crushed stone are expected to be present in 2022, especially in and near metropolitan areas.

The crushed stone industry continued to be concerned with environmental, health, safety, and zoning regulations. On November 15, 2021, the Infrastructure Investment and Jobs Act was signed into law. The legislation will reauthorize surface transportation programs for 5 years and invest $110 billion in additional funding to repair roads and bridges and support major, transformational projects. Shortages in some urban and industrialized areas are expected to continue to increase owing to local zoning regulations and land-development alternatives. These issues are expected to continue and to cause new crushed stone quarries to be located away from large population centers. Resultant regional shortages of crushed stone and higher fuel costs could result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	1,470	1,500	Adequate, except where special types are needed or where local shortages exist.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources:[6] Stone resources are plentiful throughout the world. The supply of high-purity limestone and dolomite suitable for specialty uses is limited in many geographic areas. The largest resources of high-purity limestone and dolomite in the United States are in the central and eastern parts of the country.

Substitutes: Crushed stone substitutes for roadbuilding include sand and gravel, and iron and steel slag. Substitutes for crushed stone used as construction aggregates include construction sand and gravel, iron and steel slag, sintered or expanded clay or shale, perlite, or vermiculite. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2021.

[e]Estimated. NA Not available.

[1]See also Sand and Gravel (Construction) and Stone (Dimension).

[2]Less than ½ unit.

[3]Defined as production + recycled material + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their crushed stone production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

STONE (DIMENSION)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Approximately 2.3 million tons of dimension stone, valued at $430 million, was sold or used by U.S. producers in 2021. Dimension stone was produced by approximately 200 companies operating 236 quarries in 34 States. Leading producing States were, in descending order by tonnage, Texas, Wisconsin, Indiana, Georgia, and Vermont. These five States accounted for about 67% of the production quantity and contributed about 56% of the value of domestic production. Approximately 47%, by tonnage, of dimension stone sold or used was limestone, followed by sandstone (20%), granite (18%), dolomite and slate (4% each), and the remaining 7% was divided, in descending order of tonnage, among quartzite, miscellaneous stone, marble, and traprock. By value, the leading sales or uses were for limestone (43%), followed by granite (28%), sandstone (11%), slate (7%), dolomite (4%), and the remaining 7% was divided, in descending order of total value, among marble, quartzite, traprock and miscellaneous stone. Rough stone represented 59% of the tonnage and 54% of the value of all the dimension stone sold or used by domestic producers, including exports. The leading uses and distribution of rough stone, by tonnage, were in building and construction (52%) and in irregular-shaped stone (34%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (45%), flagging (11%), slabs and blocks for building and construction (10%), and curbing (9%).

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Sold or used by producers:[2]					
Quantity	2,880	2,660	2,520	2,350	2,300
Value, million dollars	453	437	415	424	430
Imports for consumption, value, million dollars	2,120	2,090	1,900	1,750	2,300
Exports, value, million dollars	69	70	59	47	48
Consumption, apparent, value, million dollars[3]	2,510	2,460	2,250	2,130	2,700
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	3,900	3,900	3,900	3,800	3,700
Net import reliance[5] as a percentage of apparent consumption (based on value)	82	82	82	80	84
Granite only, sold or used by producers:					
Quantity	526	484	430	436	420
Value, million dollars	115	108	105	110	120
Imports, value, million dollars	1,020	915	863	794	890
Exports, value, million dollars	22	19	17	13	11
Consumption, apparent, value, million dollars[3]	1,110	1,000	950	892	1,000
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	800	800	800	800	800
Net import reliance[5] as a percentage of apparent consumption (based on value)	90	89	89	88	88

Recycling: Small amounts of dimension stone were recycled, principally by restorers of old stone work.

Import Sources (2017–20, by value): All dimension stone: China,[6] 24%; Brazil, 23%; Italy, 19%; India, 13%; and other, 21%. Granite only: Brazil, 44%; China,[6] 22%; India, 19%; Italy, 6%; and other, 9%.

Tariff: Dimension stone tariffs ranged from free to 6.5% ad valorem, according to type, degree of preparation, shape, and size, for countries with normal trade relations in 2021. Most crude or roughly trimmed stone was imported at 3.7% ad valorem or less.

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STONE (DIMENSION)

Depletion Allowance: All dimension stone, 14% (domestic and foreign); slate used or sold as sintered or burned lightweight aggregate, 7.5% (domestic and foreign); dimension stone used for rubble and other nonbuilding purposes, 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The United States remained one of the world's leading markets for dimension stone. In 2021, total imports of dimension stone increased in value by about 33% compared with the value in 2020. In 2021, increased demand for dimension stone for construction and refurbishment used in residential markets helped offset decreased demand in commercial markets. Both markets were affected by the measures instituted to mitigate the spread of the global COVID-19 pandemic. These measures also affected the home remodeling sector, which increased by 7.6% in the third quarter of 2021 compared with that in 2020, according to the Joint Center for Housing Studies of Harvard University. Dimension stone exports increased slightly to about $48 million. Apparent consumption, by value, was estimated to be $2.7 billion in 2021—a 28% increase compared with that in 2020.

In November 2021, a $1.2 trillion infrastructure bill, the Infrastructure Investment and Jobs Act, was signed into law, which included $110 billion for construction and repair of bridges and roads and transportation research and other projects. Additional funding included $17 billion and $25 billion to upgrade and repair ports and airports, respectively. The leading uses of rough blocks of stone are in building and construction. Dressed stone, such as slabs, ashlars, and flagging are often used in airport interiors and exteriors.

The dimension stone industry continued to be concerned with safety and health regulations and environmental restrictions in 2021, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration finalized new regulations to further restrict exposure to crystalline silica at quarry sites and other industrial operations that use materials containing it. Final implementation of the new regulations took effect in 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2020	2021[e]	
United States	2,350	2,300	Adequate, except for certain special types and local shortages.
Other countries	NA	NA	
World total	NA	NA	

World Resources:[7] Dimension stone resources of the world are sufficient. Resources can be limited on a local level or occasionally on a regional level by the lack of a particular kind of stone that is suitable for dimension purposes.

Substitutes: Substitutes for dimension stone include aluminum, brick, ceramic tile, concrete, glass, plastics, resin-agglomerated stone, and steel.

[e]Estimated. NA Not available.

[1]See also Stone (Crushed).

[2]Includes granite, limestone, and other types of dimension stone.

[3]Defined as sold or used + imports – exports.

[4]Excludes office staff.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

STRONTIUM

(Data in metric tons of contained strontium unless otherwise noted)

Domestic Production and Use: Although deposits of strontium minerals occur widely throughout the United States, none have been mined in the United States since 1959. Domestic production of strontium carbonate, the principal strontium compound, ceased in 2006. Virtually all the strontium mineral celestite consumed in the United States since 2006 is thought to have been used as an additive in drilling fluids for oil and natural gas wells. A few domestic companies produced small quantities of downstream strontium chemicals from imported strontium carbonate.

Based on import data, the estimated end-use distribution in the United States for strontium, including celestite and strontium compounds, was ceramic ferrite magnets and pyrotechnics and signals, 40% each; and other uses, including drilling fluids, electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass accounted for the remaining 20%.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	11,300	16,900	7,960	1,060	—
Strontium compounds[2]	6,660	6,350	5,560	4,440	4,800
Exports, strontium compounds	36	32	20	32	12
Consumption, apparent:[3]					
Celestite	11,300	16,900	7,960	1,060	—
Strontium compounds	6,620	6,320	5,540	4,410	4,800
Total	17,900	23,200	13,500	5,470	4,800
Price, average value of celestite imports at port of exportation, dollars per ton	74	78	82	90	XX
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Celestite: Mexico, 100%. Strontium compounds: Mexico, 47%; Germany, 43%; China, 5%; and other, 5%. Total imports: Mexico, 80%; Germany, 16%; China, 2%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Celestite	2530.90.8010	Free.
Strontium compounds:		
Strontium metal	2805.19.1000	3.7% ad valorem.
Strontium oxide, hydroxide, peroxide	2816.40.1000	4.2% ad valorem.
Strontium nitrate	2834.29.2000	4.2% ad valorem.
Strontium carbonate	2836.92.0000	4.2% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Apparent consumption of total strontium declined by 12% in 2021. Apparent consumption of strontium compounds increased by 9%, but apparent consumption of celestite decreased by 100% to zero. Following a 59% decrease of apparent consumption of all forms of strontium in 2020 because of the economic downturn caused by restrictions imposed worldwide as the result of the global COVID-19 pandemic, consumption of strontium compounds increased as the economy began to recover in 2021. World celestite production was estimated to have increased slightly from that of 2020.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

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STRONTIUM

No imports of celestite, the most commonly used strontium mineral, were reported in 2021, likely the result of decreased use of celestite in natural-gas- and oil-well-drilling fluids. Although drilling activity increased in 2021, it remained very low compared with that seen in the few years before the pandemic. In recent years, nearly all celestite imports were from Mexico and were thought to be used as additives in drilling fluids for oil and natural gas exploration and production. For these applications, celestite is ground but undergoes no chemical processing. A small quantity of high-value celestite imports were reported; these were most likely mineral specimens. Although no strontium carbonate was produced in the United States, celestite is the raw material from which strontium carbonate and other strontium compounds are produced.

Strontium carbonate is the most commonly traded strontium compound and is used as the raw material from which other strontium compounds are derived. Strontium carbonate is sintered with iron oxide to produce permanent ceramic ferrite magnets, and strontium nitrate contributes a brilliant red color to fireworks and signal flares. Smaller quantities of these and other strontium compounds were consumed in several other applications, including electrolytic production of zinc, glass production, master alloys, and pigments and fillers. Imports of strontium compounds were estimated to have increased by 8% in 2021.

World Mine Production and Reserves:[4]

	Mine production		Reserves[5]
	2020	2021[e]	
United States	—	—	Quantitative estimates of reserves for most countries were not available.
Argentina	[e]700	700	
China	[e]80,000	80,000	
Iran	[e]90,000	90,000	
Mexico	33,500	35,000	
Spain	[e]150,000	150,000	
World total (rounded)	[e]350,000	360,000	

World Resources:[5] World resources of strontium are thought to exceed 1 billion tons.

Substitutes: Barium can be substituted for strontium in ferrite ceramic magnets; however, the resulting barium composite will have a reduced maximum operating temperature when compared with that of strontium composites. Substituting for strontium in pyrotechnics is hindered by difficulty in obtaining the desired brilliance and visibility imparted by strontium and its compounds. In drilling mud, barite is the preferred material, but celestite may substitute for some barite, especially when barite prices are high.

[e]Estimated. XX Not applicable. — Zero.

[1]The strontium content of celestite is 43.88%, assuming an ore grade of 92%, which was used to convert units of celestite to strontium content.

[2]Strontium compounds, with their respective strontium contents, in descending order, include metal (100.00%); oxide, hydroxide, and peroxide (70.00%); carbonate (59.35%); and nitrate (41.40%). These factors were used to convert gross weight of strontium compounds to strontium content.

[3]Defined as imports − exports.

[4]Gross weight of celestite in tons.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

SULFUR

(Data in thousand metric tons of contained sulfur unless otherwise noted)

Domestic Production and Use: In 2021, recovered elemental sulfur and byproduct sulfuric acid were produced at 95 operations in 27 States. Total shipments were valued at about $740 million. Elemental sulfur production was estimated to be 7.5 million tons; Louisiana and Texas accounted for about 55% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 35 companies at 90 plants in 26 States. Byproduct sulfuric acid, representing about 7% of production of sulfur in all forms, was recovered at five nonferrous-metal smelters in four States by four companies. Domestic elemental sulfur provided 59% of domestic consumption, and byproduct sulfuric acid accounted for about 5%. The remaining 36% of sulfur consumed was provided by imported sulfur and sulfuric acid. About 90% of sulfur consumed was in the form of sulfuric acid.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Recovered elemental	9,070	9,000	8,110	7,310	7,500
Other forms	560	672	596	581	600
Total (rounded)	9,630	9,670	8,710	7,890	8,100
Shipments, all forms	9,680	9,690	8,700	7,900	8,200
Imports for consumption:					
Recovered elemental[e]	1,850	2,230	1,850	2,230	2,500
Sulfuric acid	954	997	971	1,200	1,100
Exports:					
Recovered elemental	2,340	2,390	2,200	1,310	1,700
Sulfuric acid	80	112	72	64	140
Consumption, apparent, all forms[1]	10,100	10,400	9,250	9,960	10,000
Price, reported average value, free on board, mine and (or) plant, dollars per ton of elemental sulfur	46.40	81.20	51.10	24.40	90
Stocks, producer, yearend	124	118	124	109	120
Employment, mine and (or) plant, number	2,400	2,400	2,400	2,400	2,400
Net import reliance[2] as a percentage of apparent consumption	4	7	6	21	18

Recycling: Typically, between 2.5 million and 5 million tons of spent sulfuric acid is reclaimed from petroleum refining and chemical processes during any given year.

Import Sources (2017–20): Elemental: Canada, 73%; Russia, 17%; Kazakhstan, 5%; and other, 5%. Sulfuric acid: Canada, 61%; Mexico, 18%; Spain, 7%; Germany, 5%; and other, 9%. Total sulfur imports: Canada, 69%; Russia, 11%; Mexico, 6%; Kazakhstan, 4%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Sulfur, crude or unrefined	2503.00.0010	Free.
Sulfur, all kinds, other	2503.00.0090	Free.
Sulfur, sublimed or precipitated	2802.00.0000	Free.
Sulfuric acid	2807.00.0000	Free.

Depletion Allowance: 22% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Total U.S. sulfur production in 2021 was estimated to have increased by 3% from that of 2020, and shipments also increased by 4% from those of 2020. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations increased by 3%. However, in the first 6 months of 2021, U.S. sulfur production was lower than 2020 because of the cold weather that affected the central United States in mid-February, leading to the largest reduction in Gulf Coast refining operations over the past several years. In addition, Hurricanes Ida and Nicholas brought Gulf Coast refining to a standstill. Domestically, refinery sulfur production is expected to increase as refining utilization increases. Domestic byproduct sulfuric acid is expected to remain relatively constant, unless one or more of the remaining nonferrous-metal smelters close.

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SULFUR

Domestic phosphate rock consumption in 2021 was estimated to have remained the same as that in 2020, which resulted in the same consumption of sulfur to process the phosphate rock into phosphate fertilizers.

World sulfur production was slightly more than it was in 2020 as a result of increased demand and is likely to steadily increase for the foreseeable future. New sulfur demand associated with phosphate fertilizer projects is expected mostly in Africa, and sulfur demand likely will also increase in Asia and Eastern Europe.

Contract sulfur prices in Tampa, FL, began 2021 at around $69 per long ton. The sulfur price decreased to $195 per long ton in mid-July, and then decreased to $183 per long ton by the end of September. Fourth-quarter 2021 prices remained at $183 per long ton. In the past few years, sulfur prices have been variable, a result of the volatility in the demand for sulfur. High sulfur prices in 2021 were a result of supply issues.

World Production and Reserves:

	Production, all forms		Reserves[3]
	2020	2021[e]	
United States	7,890	8,100	Reserves of sulfur in crude oil, natural gas, and sulfide ores are large. Because most sulfur production is a result of the processing of fossil fuels, supplies are expected to be adequate for the foreseeable future. Because petroleum and sulfide ores can be processed long distances from where they are produced, sulfur production may not be in the country to which the reserves were attributed. For instance, sulfur from Saudi Arabian oil may be recovered at refineries in the United States.
Australia	900	900	
Brazil	500	500	
Canada	4,900	4,900	
Chile	1,300	1,300	
China[4]	17,300	17,000	
Finland	717	720	
Germany	633	630	
Greece	500	500	
India	3,460	3,500	
Iran	2,200	2,200	
Japan	3,040	3,000	
Kazakhstan	4,480	4,500	
Korea, Republic of	3,080	3,100	
Kuwait	620	600	
Poland	992	1,000	
Qatar	2,000	2,000	
Russia	7,530	7,500	
Saudi Arabia	6,500	6,500	
South Africa	900	900	
Turkmenistan	700	700	
United Arab Emirates	6,000	6,000	
Other countries	3,600	3,600	
World total (rounded)	79,800	80,000	

World Resources:[3] Resources of elemental sulfur in evaporite and volcanic deposits, and sulfur associated with natural gas, petroleum, tar sands, and metal sulfides, total about 5 billion tons. The sulfur in gypsum and anhydrite is almost limitless, and 600 billion tons of sulfur is contained in coal, oil shale, and shale that is rich in organic matter. Production from these sources would require development of low-cost methods of extraction. The domestic sulfur resource is about one-fifth of the world total.

Substitutes: Substitutes for sulfur at present or anticipated price levels are not satisfactory; some acids, in certain applications, may be substituted for sulfuric acid, but usually at a higher cost.

[e]Estimated.

[1]Defined as shipments + imports – exports.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Sulfur production in China includes byproduct elemental sulfur recovered from natural gas and petroleum, the estimated sulfur content of byproduct sulfuric acid from metallurgy, and the sulfur content of sulfuric acid from pyrite.

TALC AND PYROPHYLLITE[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Three companies operated five talc producing mines in three States during 2021, and domestic production of crude talc was estimated to be nearly unchanged at 490,000 tons valued at $22 million. Talc was mined in Montana, Texas, and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 490,000 tons valued at about $130 million, a 9% increase from the value in 2020. Talc produced and sold in the United States was used in ceramics (including automotive catalytic converters) (23%), paper (18%), paint (17%), plastics (11%), rubber (6%), roofing (4%), and cosmetics (1%). The remaining 20% was for agriculture, export, insecticides, and other miscellaneous uses.

One company in North Carolina mined and processed pyrophyllite in 2020. Domestic production was withheld to avoid disclosing company proprietary data and was estimated to have increased from that in 2020. Pyrophyllite was sold for refractory, paint, and ceramic products.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, mine	610	648	578	[e]490	490
Sold by producers	528	537	515	[e]460	490
Imports for consumption	336	313	281	189	280
Exports	220	273	234	188	240
Consumption, apparent[2]	644	577	562	[e]460	530
Price, average, milled, dollars per metric ton[3]	214	227	240	265	270
Employment, mine and mill, number:[4]					
Talc	206	208	202	187	190
Pyrophyllite	31	30	31	31	30
Net import reliance[5] as a percentage of apparent consumption	18	7	8	<1	8

Recycling: Insignificant.

Import Sources (2017–20): Pakistan, 46%; Canada, 28%; China,[6] 11%; and other, 15%. Large quantities of crude talc were thought to have been mined in Afghanistan before being milled in and exported from Pakistan.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Natural steatite and talc:		
Not crushed, not powdered	2526.10.0000	Free.
Crushed or powdered	2520.26.0000	Free.
Talc, steatite, and soapstone; cut or sawed	6815.99.2000	Free.

Depletion Allowance: Block steatite talc: 22% (domestic), 14% (foreign). other talc and pyrophyllite: 14% (domestic and foreign).

Government Stockpile: None.

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TALC AND PYROPHYLLITE

Events, Trends, and Issues: Canada, China, and Pakistan were the principal sources for United States talc imports in recent years. Imports from Pakistan have increased in recent years and accounted for nearly one-half of total imports. Imports from Canada have supplied nearly one-third of the total, whereas imports from China have decreased recently to about 10% of total imports. Canada and Mexico continued to be the primary destinations for United States talc exports, collectively receiving about one-half of exports. Imports and exports of talc and related materials were estimated to have increased by at least 35% in 2021 compared with those of 2020. Primarily owing to the global COVID-19 pandemic, U.S. talc consumption, exports, imports, production, and sales were unusually low in 2020. Production and sales of domestically sourced talc remained at near 2020 levels in 2021, but apparent consumption increased as trade rebounded in 2021, returning to near 2019 levels.

The amount of talc used in rubber production increased in 2020 and 2021 in response to greater demand for rubber stoppers as the medical industry shipped large quantities of COVID-19 vaccines. Ceramic tile and sanitaryware formulations and the technology for firing ceramic tile changed over recent decades, reducing the amount of talc required for the manufacture of some ceramic products. For paint, the industry shifted its focus to production of water-based paint (a product for which talc is not well suited because it is hydrophobic) from oil-based paint in order to reduce volatile emissions. The amount of talc used for paper manufacturing began to decrease beginning in the 1990s, and some talc used for pitch control was replaced by chemical agents. For cosmetics, manufacturers of body dusting powders shifted some of their production from talc-based to corn-starch-based products.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2020	2021[e]	
United States (crude)	[e,8]490	[8]490	140,000
Brazil (crude and beneficiated)[9]	650	650	45,000
Canada (unspecified minerals)	230	240	NA
China (unspecified minerals)	1,300	1,400	82,000
Finland	278	300	Large
France (crude)	450	450	Large
India[9]	1,670	1,700	110,000
Italy (includes steatite)	165	170	NA
Japan[9]	160	160	100,000
Korea, Republic of[9]	476	450	81,000
Pakistan	126	120	NA
South Africa[9]	126	130	NA
Other countries (includes crude)[9]	600	700	Large
World total (rounded)	[8]6,720	[8]7,000	Large

World Resources:[7] The United States is self-sufficient in most grades of talc and related minerals, but lower priced imports have replaced domestic minerals for some uses. Talc occurs in the United States from New England to Alabama in the Appalachian Mountains and the Piedmont region, as well as in California, Montana, Nevada, Texas, and Washington. Domestic and world identified resources are estimated to be approximately five times the quantity of reserves.

Substitutes: Substitutes for talc include bentonite, chlorite, feldspar, kaolin, and pyrophyllite in ceramics; chlorite, kaolin, and mica in paint; calcium carbonate and kaolin in paper; bentonite, kaolin, mica, and wollastonite in plastics; and kaolin and mica in rubber.

[e]Estimated. NA Not available.

[1]All statistics exclude pyrophyllite unless otherwise noted.

[2]Defined as sold by producers + imports – exports.

[3]Average ex-works unit value of milled talc sold by U.S. producers, based on data reported by companies.

[4]Includes only companies that mine talc or pyrophyllite. Excludes office workers and mills that process imported or domestically purchased material.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Excludes U.S. production of pyrophyllite.

[9]Includes pyrophyllite.

TANTALUM

(Data in metric tons of contained tantalum unless otherwise noted)

Domestic Production and Use: Significant U.S. tantalum mine production has not been reported since 1959. Domestic tantalum resources are of low grade, some are mineralogically complex, and most are not commercially recoverable. Companies in the United States produced tantalum alloys, capacitors, carbides, compounds, and tantalum metal from imported tantalum ores and concentrates and tantalum-containing materials. Tantalum metal and alloys were recovered from foreign and domestic scrap. Domestic tantalum consumption was not reported by consumers. Major end uses for tantalum included alloys for gas turbines used in the aerospace and oil and gas industries; tantalum capacitors for automotive electronics, mobile phones, and personal computers; tantalum carbides for cutting and boring tools; and tantalum oxide (Ta_2O_5) was used in glass lenses to make lighter weight camera lenses that produce a brighter image. The value of tantalum consumed in 2021 was estimated to exceed $220 million as measured by the value of imports.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,460	1,660	1,380	1,230	1,300
Exports[1]	549	681	423	417	580
Shipments from Government stockpile[2]	—	—	—	−16	−10
Consumption, apparent[3]	907	975	956	797	710
Price, tantalite, dollars per kilogram of Ta_2O_5 content[4]	193	214	161	158	158
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-containing electronic components and from tantalum-containing cemented carbide and superalloy scrap. The amount of tantalum recycled was not available, but it may be as much as 30% of apparent consumption.

Import Sources (2017–20): Tantalum ores and concentrates: Australia, 36%; Rwanda, 34%; Congo (Kinshasa), 7%; Mozambique, 6%; and other, 17%. Tantalum metal and powder: China,[6] 39%; Germany, 22%; Kazakhstan, 12%; Thailand, 12%; and other, 15%. Tantalum waste and scrap: Indonesia, 20%; China,[6] 17%; Japan, 16%; and other, 47%. Total: China,[6] 23%; Germany, 11%; Australia, 8%; Indonesia, 8%; and other, 50%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Tantalum ores and concentrates	2615.90.6060	Free.
Tantalum oxide[7]	2825.90.9000	3.7% ad valorem.
Potassium fluorotantalate[7]	2826.90.9000	3.1% ad valorem.
Tantalum, unwrought:		
Powders	8103.20.0030	2.5% ad valorem.
Alloys and metal	8103.20.0090	2.5% ad valorem.
Tantalum, waste and scrap	8103.30.0000	Free.
Tantalum, other	8103.90.0000	4.4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[8]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Tantalum carbide powder	—	—	1.71	—	1.71
Tantalum niobium concentrate (gross weight)	92	—	—	—	—
Tantalum metal[9] (gross weight)	0.085	15.4	0.09	—	0.09
Tantalum alloy (gross weight)	0.0015	—	—	—	—

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TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption (measured in contained tantalum) was estimated to have decreased by 11% from that in 2020. In 2021, estimated U.S. imports for consumption increased by 6%. Most of the tantalum imported was in the form of metal and powder (45%), followed by ores and concentrates (30%), and waste and scrap (24%). Waste and scrap imports saw the most significant variation by declining 37% from that in 2020. Estimated U.S. exports increased by 39% in 2021. In 2021, the average monthly price of tantalum ore remained constant at about $158 per kilogram of Ta_2O_5 content between both years.

Global tantalum production and consumption were thought to have increased in 2021 as steel production in most countries began to recover from the global COVID-19 pandemic. Production in Rwanda was estimated to have increased based on reported ore production through August 2021. China remained the leading export destination through the same period, accounting for approximately 30% of tantalum ores and concentrates, waste and scrap, and metals consumption. Brazil, Congo (Kinshasa), Nigeria, and Rwanda accounted for about 80% of estimated global tantalum production in 2021.

World Mine Production and Reserves: Reserves for Australia were revised based on Government information.

	Mine production		Reserves[10]
	2020	2021[e]	
United States	—	—	—
Australia	34	62	[11]94,000
Bolivia	7	7	NA
Brazil	470	470	40,000
Burundi	24	32	NA
China	74	76	NA
Congo (Kinshasa)	780	700	NA
Ethiopia	69	52	NA
Mozambique	43	43	NA
Nigeria	260	260	NA
Russia	49	39	NA
Rwanda	254	270	NA
Uganda	38	40	NA
World total (rounded)	2,100	2,100	NA

World Resources:[10] Identified world resources of tantalum, most of which are in Australia, Brazil, and Canada, are considered adequate to supply projected needs. The United States has about 55,000 tons of tantalum resources in identified deposits, most of which were considered uneconomical at 2021 prices for tantalum.

Substitutes: The following materials can be substituted for tantalum, but a performance loss or higher costs may ensue: niobium and tungsten in carbides; aluminum, ceramics, and niobium in electronic capacitors; glass, molybdenum, nickel, niobium, platinum, stainless steel, titanium, and zirconium in corrosion-resistant applications; and hafnium, iridium, molybdenum, niobium, rhenium, and tungsten in high-temperature applications.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated tantalum content of synthetic tantalum-niobium concentrates, niobium and tantalum ores and concentrates, tantalum waste and scrap, unwrought tantalum alloys and powder, and other tantalum articles. Synthetic concentrates and niobium ores and concentrates were assumed to contain 32% Ta_2O_5. Tantalum ores and concentrates were assumed to contain 37% Ta_2O_5. Ta_2O_5 is 81.897% tantalum.

[2]Change in total inventory from prior yearend inventory. If negative, increase in inventory.

[3]Defined as production + imports – exports + adjustments for Government stock changes.

[4]Price is annual average price reported by CRU Group. The estimate for 2021 includes data available through October 2021.

[5]Defined as imports – exports + adjustments for Government stock changes.

[6]Includes Hong Kong.

[7]This category includes tantalum-containing material and other material.

[8]See Appendix B for definitions.

[9]Potential acquisitions are for unspecified tantalum materials; potential disposals are for tantalum scrap in the Government stockpile.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 39,000 tons.

TELLURIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, tellurium was recovered in copper slimes in the United States. One company in Texas was thought to export copper anode slimes to Mexico for recovery of commercial-grade tellurium. One company in Utah announced the development of a tellurium plant with a capacity of 20 tons per year which was expected to begin production in the fourth quarter of 2021. Downstream companies further refined imported commercial-grade metal to produce tellurium dioxide, high-purity tellurium, and tellurium compounds for specialty applications.

Tellurium was predominantly used in the production of cadmium telluride (CdTe) for thin-film solar cells. Another important end use was for the production of bismuth telluride (BiTe), which is used in thermoelectric devices for both cooling and energy generation. Other uses were as an alloying additive in steel to improve machining characteristics, as a minor additive in copper alloys to improve machinability without reducing conductivity, in lead alloys to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. It was used in the chemical industry as a vulcanizing agent and accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production. Other uses included those in photoreceptor and thermoelectric devices, blasting caps, and as a pigment to produce various colors in glass and ceramics.

Global consumption estimates of tellurium by end use are solar, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery	W	W	W	W	W
Imports for consumption	163	192	59	12	22
Exports	2	4	1	([1])	2
Consumption, apparent[2]	W	W	W	W	W
Price,[3] dollars per kilogram	38	74	60	56	68
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	>95	>95	>95	>95	>95

Recycling: For traditional metallurgical and chemical uses, there was little or no old scrap from which to extract secondary tellurium because these uses of tellurium are highly dispersive or dissipative. A very small amount of tellurium was recovered from scrapped selenium-tellurium photoreceptors employed in older plain-paper copiers in Europe. A plant in the United States recycled tellurium from CdTe solar cells; however, the amount recycled was limited because most CdTe solar cells were relatively new and had not reached the end of their useful life.

Import Sources (2017–20): Canada, 57%; Germany, 19%; China,[5] 17%; the Philippines, 4%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, domestic tellurium content in anode slimes was estimated to have remained essentially unchanged from that in 2020. One domestic producer of anode slimes shipped at least a portion of its anode slimes to Mexico for treatment and refining. In 2021, the domestic average monthly price of tellurium generally increased throughout the year, continuing a trend from December 2020. The price increased from around $60 per kilogram in January to $71 per kilogram in October.

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TELLURIUM

Domestic imports of tellurium were estimated to have increased by about 83% in 2021 from those of 2020, mostly as a result of a significant increase in imports from the Philippines. During the first 8 months of 2021, the United States imported 9.5 tons of tellurium from the Philippines, an increase of 82% with respect to the total imports from the Philippines in 2020, and an increase of 325% with respect to the same time period in 2020. Imports from Japan also increased in the first 8 months of 2021, by 161% compared with the same time period in 2020.

World production of tellurium was estimated to be about 580 tons in 2021. China was the leading producer of refined tellurium, recovering tellurium from copper anode slimes and from residues generated during the lead, nickel, precious metals, and zinc smelting processes. In early 2021, a Chinese producer of tellurium metal announced an increase of tellurium production following the Lunar New Year holiday, rising from 3 to 4 tons per month to 6 tons per month, or 72 tons per year. In Canada, one producer announced further investment in their new ultrahigh-purity tellurium line. The line is expected to produce up to 7N purity (99.99999%) tellurium for digital and solid-state radiation detectors, as well as other applications. Solid-state radiation detectors produce highly accurate images, and are used in healthcare, security, and military systems.

World Refinery Production and Reserves: The values shown for reserves include only tellurium contained in copper reserves. These estimates assume that more than one-half of the tellurium contained in unrefined copper anodes is recoverable.

	Refinery production		Reserves[6]
	2020	2021[e]	
United States	W	W	3,500
Bulgaria	[e]3	5	NA
Canada	[e]44	45	800
China	[e]330	340	6,600
Japan	[e]70	75	—
Russia	71	70	NA
South Africa	[e]2	3	—
Sweden	42	40	670
Other countries[7]	NA	NA	19,000
World total (rounded)	[8]562	[8]580	31,000

World Resources:[6] Data on tellurium resources were not available. More than 90% of tellurium has been produced from anode slimes collected from electrolytic copper refining, and the remainder was derived from skimmings at lead refineries and from flue dusts and gases generated during the smelting of bismuth, copper, and lead-zinc ores. Potential sources of tellurium include bismuth telluride and gold telluride ores.

Substitutes: Several materials can replace tellurium in most of its uses, but usually with losses in efficiency or product characteristics. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and (or) selenium can act as vulcanization agents in place of tellurium. The selenides and sulfides of niobium and tantalum can serve as electrical-conducting solid lubricants in place of tellurides of those metals.

The selenium-tellurium photoreceptors used in some plain paper photocopiers and laser printers have been replaced by organic photoreceptors in newer devices. Amorphous silicon and copper-indium-gallium selenide were the two principal competitors of CdTe in thin-film photovoltaic solar cells. Bismuth selenide and organic polymers can be used to substitute for some BiTe thermal devices.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Less than ½ unit. U.S. Census Bureau export data were adjusted by U.S. Geological Survey.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]Average annual price for 99.95% tellurium, in warehouse, Rotterdam. Source: Argus Media group—Argus Metals International.

[4]Defined as imports – exports + adjustments for industry stock changes. For 2020, exports were not included in the calculation.

[5]Includes Hong Kong.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]In addition to the countries listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland produced refined tellurium, but output was not reported and available information was inadequate to make reliable production estimates.

[8]Excludes U.S. production.

THALLIUM

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Small quantities of thallium are consumed annually, but variations in pricing and value data make it difficult to estimate the value of consumption. The primary end uses included the following: radioisotope thallium-201 used for medical purposes in cardiovascular imaging; thallium used as an activator (sodium iodide crystal doped with thallium) in gamma radiation detection equipment; thallium-barium-calcium-copper-oxide high-temperature superconductors used in filters for wireless communications; thallium used in lenses, prisms, and windows for infrared detection and transmission equipment; thallium-arsenic-selenium crystal filters used for light diffraction in acousto-optical measuring devices; and thallium used in mercury alloys for low-temperature measurements. Other uses include as an additive in glass to increase its refractive index and density, a catalyst for organic compound synthesis, and a component in high-density liquids for gravity separation of minerals.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	—	—	—	57	—
Waste and scrap	—	23	27	—	—
Other articles	—	41	38	—	10
Exports:					
Unwrought metal and powders	34	100	290	300	300
Waste and scrap	364	853	133	359	100
Other articles	1,560	[1]31,400	[1]79,100	580	600
Consumption, estimated[2]	—	64	65	57	10
Price, metal,[e, 3] dollars per kilogram	NA	NA	7,600	8,200	8,400
Net import reliance[4] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2017–2020): China, 41%; Russia 31%, Norway, 15%; and the United Kingdom, 13%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Unwrought and powders	8112.51.0000	4.0% ad valorem.
Waste and scrap	8112.52.0000	Free.
Other	8112.59.0000	4.0% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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THALLIUM

Events, Trends, and Issues: As of August 2021, no imports of unwrought thallium metal and powder or thallium waste and scrap were reported. All exports of unwrought thallium and powders left the New Orleans, LA, customs district and went to Taiwan. No exports of thallium waste and scrap were reported through August 2021, but 100 kilograms was estimated for the year based on prior year data. Most exports of other thallium articles (Schedule B number 8112.59.0000) were exported from Washington, DC, to Hungary, and a small quantity was sent to Hungary from Buffalo, NY. In 2018 and 2019, reported exports of thallium articles were unusually high in quantity; these exports likely were misclassified material.

Demand for thallium for use in cardiovascular-imaging applications has declined owing to superior performance and availability of alternatives, such as the medical isotope technetium-99. A global shortage of technetium-99 from 2009 to 2011 had contributed to an increase in thallium consumption during that period. Since 2011, consumption of thallium has declined significantly. Small quantities of thallium are used for research.

The leading global uses for thallium were gamma radiation detection equipment, high-temperature superconductors, infrared optical materials, low-melting glasses, photoelectric cells, and radioisotopes. Producers of these products were in China, Japan, the Republic of Korea, and the United States.

Thallium metal and its compounds are highly toxic materials and are strictly controlled to prevent harm to humans and the environment. Thallium and its compounds can be absorbed into the human body by skin contact, ingestion, or inhalation of dust or fumes. Under its national primary drinking water regulations for public water supplies, the U.S. Environmental Protection Agency has set an enforceable Maximum Contaminant Level of 2 parts per billion thallium in drinking water.

World Refinery Production and Reserves:[5] Thallium is produced commercially in only a few countries as a byproduct in the roasting of copper, lead, and zinc ores and is recovered from flue dust. Because most producers withhold thallium production data, global production data are limited. In 2021, global production of thallium was estimated to be about 10,000 kilograms. China, Kazakhstan, and Russia were thought to be leading producers of primary thallium. Since 2005, substantial thallium-rich deposits have been identified in Brazil, China, North Macedonia, and Russia. Quantitative estimates of reserves are not available, owing to the difficulty in identifying deposits where thallium can be extracted economically. Previous estimates of reserves were based on the thallium content of zinc ores.

World Resources:[5] Although thallium is reasonably abundant in the Earth's crust, estimated at about 0.7 part per million, it exists mostly in association with potassium minerals in clays, granites, and soils, and it is not generally considered to be commercially recoverable from those materials. The major source of recoverable thallium is trace amounts found in sulfide ores of copper, lead, zinc, and other metallic elements. World resources of thallium contained in identified zinc resources could be as much as 17,000,000 kilograms; most are in Canada, Europe, and the United States. World identified resources of coal contain an estimated 630,000,000 kilograms of thallium.

Substitutes: Although other materials and formulations can substitute for thallium in gamma radiation detection equipment and optics used for infrared detection and transmission, thallium materials are presently superior and more cost effective for these very specialized uses. The medical isotope technetium-99 can be used in cardiovascular-imaging applications instead of thallium. Nonpoisonous substitutes, such as tungsten compounds, are being marketed as substitutes for thallium in high-density liquids for gravity separation of minerals.

[e]Estimated. NA Not available. — Zero.

[1]Includes material that may have been misclassified.

[2]Estimated to be equal to imports.

[3]Estimated price of 99.99%-pure granules in 100-gram lots.

[4]Defined as imports – exports. Consumption and exports of unwrought thallium were from imported material or from a drawdown in unreported inventories.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

THORIUM

(Data in kilograms, gross weight, unless otherwise noted)

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2021, monazite may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Essentially, all thorium compounds and alloys consumed by the domestic industry were derived from imports. The number of companies that processed or fabricated various forms of thorium for commercial use was not available. Thorium's use in most products was generally limited because of concerns over its naturally occurring radioactivity. Imports of thorium compounds are sporadic owing to changes in consumption and fluctuations in consumer inventory levels. The estimated value of thorium compounds imported for consumption by the domestic industry in 2021 was $427,000 (through August 2021), compared with $55,400 in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine[1]	—	[2]500,000	[2]1,700,000	[2]960,000	W
Imports for consumption:					
Ore and concentrates (monazite)	—	1,000	—	3,000	—
Compounds (oxide, nitrate, and so forth)	8,510	9,000	3,970	1,920	8,000
Exports:					
Ore and concentrates (monazite)	—	520,000	1,700,000	960,000	—
Compounds (oxide, nitrate, and so forth)[3]	2,060	3,260	1,660	213	2,500
Consumption, apparent:[4]					
Ore and concentrates (monazite)	—	1,000	—	3,000	—
Compounds (oxide, nitrate, and so forth)	6,450	5,740	2,310	1,710	5,500
Price, average value, compounds, India,[5] dollars per kilogram	73	72	72	NA	NA
Net import reliance[6] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2017–20): Monazite: United Kingdom, 75%; and Canada, 25%. Thorium compounds: India, 74%; and France, 26%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Thorium ore and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad valorem.

Depletion Allowance: Monazite, 22% on thorium content, and 14% on rare-earth and yttrium content (domestic); 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic demand for thorium alloys, compounds, and metals was limited. In addition to research purposes, various commercial uses of thorium included catalysts, high-temperature ceramics, magnetrons in microwave ovens, metal-halide lamps, nuclear medicine, optical coatings, tungsten filaments, and welding electrodes.

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THORIUM

Exports of unspecified thorium compounds were estimated to be 2,500 kilograms in 2021. More than 90% of the exports have a unit value of less than $50 per kilogram, so it is likely that they were misclassified. Only the quantity of compounds with unit values more than $50 per kilogram were included in the total export estimate. Owing to potentially misclassified material and variations in the type and purity of thorium compounds, the unit value of exports varied widely by month and by exporting customs district.

Globally, monazite was produced primarily for its rare-earth-element content, and only a small fraction of the byproduct thorium produced was consumed. Madagascar was the leading producer of monazite. Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. In international trade, China was the leading importer of monazite; Brazil, Madagascar, Thailand, and Vietnam were China's leading import sources. The United States exported monazite to China, including Hong Kong. China's exports became more regulated and were optimized to add value.

The Eneabba mineral sands project (Australia) was exporting monazite but had upgraded its processing facilities and was studying the feasibility of an integrated rare-earths refinery. Monazite from the Moma Mine (Mozambique) was being exported. The status of the Kvanefjeld project (Greenland) was in flux because of environmental concerns. The Steenkrampskraal Mine (South Africa) made several improvements to its plant and was working with an energy company in Norway to develop fuel pellets for use in nuclear powerplants.

Several companies and countries were active in the pursuit of commercializing thorium as a fuel material for a new generation of nuclear reactors. Thorium-based nuclear research and development programs have been or were underway in Australia, Belgium, Brazil, Canada, China, Czechia, Denmark, Finland, France, Germany, India, Israel, Italy, Japan, the Republic of Korea, the Netherlands, Norway, Russia, the United Kingdom, and the United States.

World Mine Production and Reserves:[7] Production and reserves are associated with the recovery of monazite in heavy-mineral-sand deposits. Without demand for the rare earths, monazite likely would not be recovered for its thorium content under current market conditions.

World Resources:[7] The world's leading thorium resources are found in placer, carbonatite, and vein-type deposits. Thorium is found in several minerals, including monazite, thorite, and thorianite. According to the World Nuclear Association,[8] worldwide identified thorium resources were estimated to total 6.4 million tons of thorium. Thorium resources are found throughout the world, most notably in Australia, Brazil, India, and the United States. India has the largest resources (850,000 tons), followed by Brazil (630,000 tons) and Australia and the United States (600,000 tons each).

Substitutes: Nonradioactive substitutes have been developed for many applications of thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, yttrium, and zirconium can substitute for magnesium-thorium alloys in aerospace applications. Cerium, lanthanum, yttrium, and zirconium oxides can substitute for thorium in welding electrodes. Several replacement materials (such as yttrium fluoride and proprietary materials) are in use as optical coatings instead of thorium fluoride.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Monazite may have been produced as a separate concentrate or included as an accessory mineral in heavy-mineral concentrates.

[2]Estimates based on exports.

[3]Excludes estimates of material that may have been misclassified.

[4]Defined as production + imports – exports. Shown separately for ore and concentrates and for compounds. Production is only for ore and concentrates.

[5]Calculated from U.S. Census Bureau import data.

[6]Defined as imports – exports; however, a meaningful net import reliance could not be calculated owing to uncertainties in the classification of material being imported and exported.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]World Nuclear Association, 2017, Thorium: London, United Kingdom, World Nuclear Association, February.

TIN

(Data in metric tons of contained tin unless otherwise noted)

Domestic Production and Use: Tin has not been mined or smelted in the United States since 1993 and 1989, respectively. Twenty-five firms accounted for over 90% of the primary tin consumed domestically in 2021. The major uses for tin in the United States were chemicals, 25%; tinplate, 22%; alloys, 12%; solder, 9%; babbitt, brass and bronze, and tinning, 8%; bar tin, 2%; and other, 22%. Based on the average S&P Global Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin in 2021 was $1.2 billion, and the estimated value of tin recovered from old scrap domestically in 2021 was $342 million.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, secondary:[e]					
Old scrap	10,000	9,890	10,500	9,550	10,000
New scrap	8,100	8,100	8,100	8,000	8,100
Imports for consumption:					
Refined	34,300	36,800	34,100	31,600	35,000
Tin alloys, gross weight	1,550	1,430	1,020	843	1,300
Tin waste and scrap, gross weight	52,100	47,700	30,400	20,700	17,000
Exports:					
Refined	1,560	941	1,300	519	1,600
Tin alloys, gross weight	966	885	1,200	1,130	680
Tin waste and scrap, gross weight	3,460	5,980	2,470	1,200	2,500
Shipments from Government stockpile, gross weight	2	13	1	—	410
Consumption, apparent, refined[1]	42,500	42,300	43,100	41,300	45,000
Price, average, cents per pound:[2]					
New York dealer	937	936	868	799	1,600
London Metal Exchange (LME), cash	911	914	846	777	1,500
Stocks, consumer and dealer, yearend	6,660	10,100	10,300	9,590	8,400
Net import reliance[3] as a percentage of apparent consumption, refined	76	77	76	77	78

Recycling: About 18,000 tons of tin from old and new scrap was estimated to have been recycled in 2021. Of this, about 10,000 tons was recovered from old scrap at 1 detinning plant and about 75 secondary nonferrous metal-processing plants, accounting for 23% of apparent consumption.

Import Sources (2017–20): Refined tin: Indonesia, 25%; Peru, 22%; Malaysia, 19%; Bolivia, 17%; and other, 17%. Waste and scrap: Canada, 99%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Unwrought tin:		
Tin, not alloyed	8001.10.0000	Free.
Tin alloys, containing, by weight:		
5% or less lead	8001.20.0010	Free.
More than 5% but not more than 25% lead	8001.20.0050	Free.
More than 25% lead	8001.20.0090	Free.
Tin waste and scrap	8002.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Tin (gross weight)	3,617	—	4,034	—	4,000

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TIN

Events, Trends, and Issues: The estimated amount of tin recycled domestically in 2021 increased by 3% compared with that in 2020. The estimated annual average New York dealer price for refined tin in 2021 was 1,600 cents per pound, double that in 2020. The estimated annual average LME cash price for refined tin in 2021 was 1,500 cents per pound, a 93% increase from that in 2020. In 2021, the monthly average New York dealer tin price increased for 8 consecutive months from January through August. Supply constraints owing to shipping bottlenecks, reimposed COVID-19 pandemic shutdowns, and an increased demand for electronic and consumer goods, were largely responsible for the almost doubling of refined tin prices during 2021. In March, the United States Defense Logistics Agency began offering stockpiled tin for sale.

Throughout the year, global production struggled to maintain an adequate supply of refined tin to meet rebounding consumer demand. Pandemic-related measures, including shutdowns and border restrictions, affected refined tin production in Burma, Indonesia, Malaysia, and Rwanda. Smelters were temporarily closed for repair and annual maintenance in China and Malaysia. Shipping container shortages and bottlenecks at shipping terminals exacerbated supply constraints. Globally, consumption increased in 2021 for alloys, chemicals, solder, and tinplate while demand for lead-acid batteries remained steady.

World Mine Production and Reserves: Reserves for Australia, Burma, Congo (Kinshasa), Malaysia, Peru, Russia, and "Other countries" were revised based on information from company and Government reports.

	Mine production		Reserves[5]
	2020	2021[e]	
United States	—	—	—
Australia	8,120	8,300	[6]560,000
Bolivia	14,700	18,000	400,000
Brazil	16,900	22,000	420,000
Burma[e]	29,000	28,000	700,000
China[e]	84,000	91,000	1,100,000
Congo (Kinshasa)[e]	17,300	16,000	130,000
Indonesia[e]	53,000	71,000	800,000
Laos[e]	1,400	1,600	NA
Malaysia	2,960	3,100	81,000
Nigeria[e]	5,000	1,200	NA
Peru	20,600	30,000	150,000
Russia	2,500	3,500	200,000
Rwanda[e]	1,800	2,200	NA
Vietnam[e]	5,400	6,100	11,000
Other countries	782	930	310,000
World total (rounded)	264,000	300,000	4,900,000

World Resources:[5] Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those of the rest of the world. World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

Substitutes: Aluminum, glass, paper, plastic, or tin-free steel substitute for tin in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, alternative copper-base alloys, and plastics for bronze; plastics for bearing metals that contain tin; and compounds of lead and sodium for some tin chemicals.

[e]Estimated. NA Not available. — Zero.

[1]Defined as production from old scrap + refined tin imports – refined tin exports + adjustments for Government and industry stock changes.

[2]Source: S&P Global Platts Metals Week.

[3]Defined as refined imports – refined exports + adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 261,000 tons.

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Titanium sponge metal was produced by one operation in Utah. Production data were withheld to avoid disclosing company proprietary data. The facility in Salt Lake City, UT, with an estimated capacity of 500 tons per year, produced titanium that was further refined for use in electronics. A second sponge facility in Henderson, NV, with an estimated capacity of 12,600 tons per year, was idled since 2020 owing to market conditions. A third facility, in Rowley, UT, with an estimated capacity of 10,900 tons per year, has remained on care-and-maintenance status since 2016.

Although detailed 2021 consumption data were withheld to avoid disclosing proprietary data, the majority of titanium metal was used in aerospace applications, and the remainder was used in armor, chemical processing, marine hardware, medical implants, power generation, consumer, and other applications. The value of imported sponge was about $140 million, a significant decrease compared with $173 million in 2020.

In 2021, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3.2 billion. The estimated end-use distribution of TiO_2 pigment consumption was paints (including lacquers and varnishes), 60%; plastics, 20%; paper, 5%; and other, 15%. Other uses of TiO_2 included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption[e]	23,300	23,700	30,000	19,200	14,000
Exports	3,090	533	869	711	120
Consumption, reported	37,400	35,200	W	W	W
Price, dollars per kilogram[2]	10.40	10.70	11.80	11.70	11.70
Stocks, industry, yearend[e]	13,200	10,700	W	W	W
Employment, number[e]	150	150	150	150	20
Net import reliance[3] as a percentage of reported consumption	88	73	>50	>50	>90
Titanium dioxide pigment:					
Production	1,260,000	1,150,000	1,100,000	[e]890,000	1,100,000
Imports for consumption	240,000	268,000	226,000	263,000	260,000
Exports	634,000	528,000	401,000	386,000	520,000
Consumption, apparent[4]	870,000	893,000	930,000	770,000	840,000
Price, dollars per metric ton[2]	2,570	2,730	2,750	2,710	2,900
Producer price index (1982=100), yearend[5]	205	205	NA	NA	NA
Employment, number[e]	3,110	3,050	3,050	3,100	3,100
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Owing to limited responses from voluntary surveys, consumption of titanium scrap metal was withheld for the titanium metal industry. Consumption data for the steel, superalloy, other industries were not available.

Import Sources (2017–20): Sponge metal: Japan, 88%; Kazakhstan, 8%; Ukraine, 3%; and other, 1%. Titanium dioxide pigment: Canada, 40%; China, 19%; Germany, 9%; Belgium, 5%; and other, 27%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Titanium oxides (unfinished TiO_2 pigments)	2823.00.0000	5.5% ad valorem.
TiO_2 pigments, 80% or more TiO_2	3206.11.0000	6.0% ad valorem.
TiO_2 pigments, other	3206.19.0000	6.0% ad valorem.
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3.7% ad valorem.
Unwrought titanium metal	8108.20.0010	15.0% ad valorem.
Titanium waste and scrap metal	8108.30.0000	Free.
Other titanium metal articles	8108.90.3000	5.5% ad valorem.
Wrought titanium metal	8108.90.6000	15.0% ad valorem.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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TITANIUM AND TITANIUM DIOXIDE

Events, Trends, and Issues: The 500-ton-per-year Salt Lake City, UT, plant was the only active domestic producer of titanium sponge, and the Salt Lake City operations primarily supported the production of electronic-grade materials. Consequently, U.S. producers of titanium ingot and downstream products were reliant on imports of titanium sponge and scrap. Reduced demand from the aerospace and other industries resulted in a 27% decrease in imports of titanium sponge compared with those in 2020. Japan (92%) and Kazakhstan (6%) were the leading import sources for titanium sponge in 2021. U.S. imports of titanium waste and scrap were about 11,000 tons. Germany (20%), the United Kingdom (15%), Canada (13%), France (10%), and Japan (8%) were the leading import sources for titanium waste and scrap in 2021. The duty-paid unit value of scrap imports was about $4.70 per kilogram. The U.S. Department of Commerce (DOC) led investigations under section 232 of the Trade Expansion Act of 1962 that determined titanium sponge imports into the United States threatened to impair national security. The investigation concluded that the United States was at risk of losing the remaining industrial capacity and technical knowledge related to titanium sponge production that is essential to meet national defense and critical infrastructure requirements. In October, the DOC published its findings and recommendations from the investigation in the Federal Register (86 FR 59115). Changes to existing tariff rates for titanium sponge were not recommended.

Domestic production of TiO_2 pigment in 2021 was estimated to be about 1.1 million tons. Although heavily reliant on imports of titanium mineral concentrates, the United States was a net exporter of TiO_2 pigments. After a multiyear low in 2020, exports of titanium pigments increased significantly in 2021. China's TiO_2 pigment production was estimated to be 3.7 million tons.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production[e]		Capacity, 2021[6]	
	2020	2021	Sponge	Pigment
United States	W	W	500	1,370,000
Australia	—	—	—	260,000
Canada	—	—	—	104,000
China	123,000	120,000	177,000	4,000,000
Germany	—	—	—	472,000
India	250	250	500	108,000
Japan	49,200	35,000	68,800	314,000
Kazakhstan	15,000	16,000	26,000	1,000
Mexico	—	—	—	300,000
Russia	31,000	27,000	46,500	55,000
Saudi Arabia	2,800	3,700	15,600	210,000
Ukraine	5,000	5,400	12,000	120,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	784,000
World total (rounded)	[7]230,000	[7]210,000	350,000	8,400,000

World Resources:[8] Reserves and resources of titanium minerals are discussed in the Titanium Mineral Concentrates chapter.

Substitutes: Few materials possess titanium metal's strength-to-weight ratio and corrosion resistance. In high-strength applications, titanium competes with aluminum, composites, intermetallics, steel, and superalloys. Aluminum, nickel, specialty steels, and zirconium alloys may be substituted for titanium for applications that require corrosion resistance. Ground calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide as a white pigment.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also Titanium Mineral Concentrates.

[2]Landed duty-paid value based on U.S. imports for consumption.

[3]Defined as imports – exports.

[4]Defined as production + imports – exports.

[5]U.S. Department of Labor, Bureau of Labor Statistics.

[6]Yearend operating capacity.

[7]Excludes U.S. production.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

TITANIUM MINERAL CONCENTRATES[1]

[Data in thousand metric tons of contained titanium dioxide (TiO_2) unless otherwise noted]

Domestic Production and Use: In 2021, one company recovered ilmenite and rutile concentrates from its surface-mining operations near Nahunta, GA, and Starke, FL. A second company processed existing mine tailings to recover a mixed heavy-mineral concentrate in South Carolina. Based on reported data through September, the estimated value of titanium mineral and synthetic concentrates imported into the United States in 2021 was $690 million. Abrasive sands, monazite, and zircon were coproducts of domestic titanium minerals mining operations. An estimated 95% of titanium mineral concentrates were consumed by domestic TiO_2 pigment producers. The remaining 5% was used in welding-rod coatings and for manufacturing carbides, chemicals, and titanium metal.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production[2]	100	100	100	[e]100	100
Imports for consumption	1,170	1,100	1,160	807	1,000
Exports, all forms[e]	6	32	8	18	6
Consumption, apparent[3]	1,300	1,200	1,300	[e]900	1,100
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, free on board (f.o.b.) Australia[4]	740	1,025	1,125	1,175	1,500
Ilmenite and leucoxene, bulk, f.o.b. Australia[5]	393	420	504	460	640
Ilmenite, average value of imports[6]	173	219	186	215	240
Slag, 80%–95% TiO_2, average value of imports[6]	664	738	792	757	750
Employment, mine and mill, number	286	299	310	216	250
Net import reliance[7] as a percentage of apparent consumption	92	91	92	88	90

Recycling: None.

Import Sources (2017–20): South Africa, 41%; Australia, 17%; Madagascar, 12%; Mozambique, 8%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Synthetic rutile	2614.00.3000	Free.
Ilmenite and ilmenite sand	2614.00.6020	Free.
Rutile concentrate	2614.00.6040	Free.
Titanium slag	2620.99.5000	Free.

Depletion Allowance: Ilmenite and rutile, 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of titanium mineral concentrates is tied to production of TiO_2 pigments that are primarily used in paint, paper, and plastics. Demand for these primary uses is related to changes in the gross domestic product. Domestic apparent consumption of titanium mineral concentrates in 2021 was estimated to have increased significantly from that in 2020 when apparent consumption was affected by a downturn in economic activity owing to the global COVID-19 pandemic. Inventory changes were not included in the apparent consumption calculation. Exports of titanium mineral concentrates were small compared with apparent consumption. As of September, South Africa (27%), Madagascar (18%), Australia (15%), and Mozambique (15%) were the leading sources of titanium mineral concentrates imports to the United States. Mining and heavy-mineral-processing operations were expanded near Starke, FL, and prefeasibility studies were underway at the Titan heavy-mineral-sands project near Camden, TN.

In 2021, China continued to be the leading producer and consumer of titanium mineral concentrates, accounting for 37% of global production of ilmenite. Mozambique and South Africa also were leading producers of titanium mineral concentrates. China's imports of titanium mineral concentrates were about 3.6 million tons in gross weight, an increase of 21% compared with those in 2020. As of October, Mozambique (32%), Australia (14%), Vietnam (13%), and Kenya (9%) were the leading sources of titanium mineral concentrates to China. In Saudi Arabia, commissioning of a project to produce up to 500,000 tons per year of titanium slag was delayed by technical problems and supply constraints resulting from COVID-19 restrictions. Other projects were being developed in Australia, China, Malawi, Mozambique, Norway, Senegal, and Tanzania.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for Australia, Kenya, Madagascar, and South Africa were revised based on Government or industry reports.

	Mine production		Reserves[8]
	2020	2021[e]	
Ilmenite:			
United States[2, 9]	100	100	2,000
Australia	480	480	[10]160,000
Brazil	34	66	43,000
Canada[11]	595	600	31,000
China	2,800	3,000	230,000
India	174	180	85,000
Kenya	201	190	390
Madagascar[11]	254	310	22,000
Mozambique	965	970	26,000
Norway	444	440	37,000
Senegal	300	360	NA
South Africa[11]	1,020	1,000	30,000
Ukraine	464	430	5,900
Vietnam	138	220	1,600
Other countries	67	67	26,000
World total (ilmenite, rounded)[9]	8,000	8,400	700,000
Rutile:			
United States	([9])	([9])	([9])
Australia	190	200	[10]31,000
India	11	11	7,400
Kenya	73	71	170
Madagascar	8	10	400
Mozambique	6	9	890
Senegal	9	10	NA
Sierra Leone	114	120	490
South Africa	86	90	6,500
Ukraine	95	95	2,500
Other countries	13	13	NA
World total (rutile, rounded)[9]	605	630	49,000
World total (ilmenite and rutile, rounded)	8,600	9,000	750,000

World Resources:[8] Ilmenite accounts for about 90% of the world's consumption of titanium minerals. World resources of anatase, ilmenite, and rutile total more than 2 billion tons.

Substitutes: Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings.

[e]Estimated. NA Not available.

[1]See also Titanium and Titanium Dioxide.

[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.

[3]Defined as production + imports – exports. Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.

[4]Source: Fast Markets IM; average of yearend price.

[5]Zen Innovations AG, Global Trade Tracker.

[6]Landed duty-paid unit value based on U.S. imports for consumption. Source: U.S. Census Bureau.

[7]Defined as imports – exports.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]U.S. rutile production and reserves data are included with ilmenite.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves for ilmenite and rutile were estimated to be 38 million and 9.4 million tons, respectively.

[11]Mine production is primarily used to produce titaniferous slag.

TUNGSTEN

(Data in metric tons of contained tungsten unless otherwise noted)

Domestic Production and Use: No domestic production of commercial tungsten concentrates has been reported since 2015. Approximately six U.S. companies had the capability to convert tungsten concentrates, ammonium paratungstate (APT), tungsten oxide, and (or) scrap to tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals. Nearly 60% of the tungsten consumed in the United States was used in cemented carbide parts for cutting and wear-resistant applications, primarily in the construction, metalworking, mining, and oil and gas drilling industries. The remainder was used to make various alloys and specialty steels; electrodes, filaments, wires, and other components for electrical, electronic, heating, lighting, and welding applications; and chemicals for various applications. The estimated value of apparent consumption in 2021 was approximately $600 million.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Concentrate	3,920	4,050	2,760	2,020	1,400
Other forms[1]	9,780	10,400	11,100	8,650	10,000
Exports:					
Concentrate	531	284	583	480	390
Other forms[2]	3,010	3,210	2,780	2,460	2,500
Shipments from Government stockpile:					
Concentrate	1,460	1,180	663	728	800
Other forms	—	—	—	34	93
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent,[3] all forms	W	W	W	W	W
Price,[4] concentrate, average U.S. spot market, dollars per metric ton unit of tungsten trioxide[5]	245	326	270	270	270
Stocks, industry, concentrate and other forms, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>50	>50	>50	>50	>50

Recycling: The estimated quantity of secondary tungsten produced and the amount consumed from secondary sources by processors and end users in 2021 were withheld to avoid disclosing company proprietary data.

Import Sources (2017–20): Tungsten contained in ores and concentrates, intermediate and primary products, wrought and unwrought tungsten, and waste and scrap: China, 32%; Bolivia, 9%; Germany, 9%; Canada, 5%; and other, 45%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Ores	2611.00.3000	Free.
Concentrates	2611.00.6000	37.5¢/kg tungsten content.
Tungsten oxides	2825.90.3000	5.5% ad valorem.
Ammonium tungstates	2841.80.0010	5.5% ad valorem.
Tungsten carbides	2849.90.3000	5.5% ad valorem.
Ferrotungsten	7202.80.0000	5.6% ad valorem.
Tungsten powders	8101.10.0000	7.0% ad valorem.
Tungsten waste and scrap	8101.97.0000	2.8% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Metal powder	—	—	125	—	125
Ores and concentrates	6,850	—	1,360	—	1,360
Tungsten alloys, gross weight[8]	5	5	—	—	—

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TUNGSTEN

Events, Trends, and Issues: World tungsten supply was dominated by production in China and exports from China. China's Government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate production, and placing constraints on mining and processing. In 2021, reduced production during or after environmental and safety inspections at Chinese mining operations contributed to periods when supplies of tungsten concentrates were constrained in China. Production of tungsten concentrate outside China was expected to increase in 2021 but to remain at less than 20% of world production. Scrap continued to be an important source of raw material for the tungsten industry worldwide. Beginning in 2020 and into 2021, the tungsten scrap supply was constrained because less scrap is generated during periods of low industrial activity.

China was the world's leading tungsten consumer. Analysts forecast global tungsten consumption in 2021 will be higher than that in 2020 as the global economy and industrial production continued to improve following declines in 2020 resulting from the global COVID-19 pandemic. In 2021, most prices of tungsten concentrates, scrap, and downstream tungsten materials trended upward in response to strong demand, constrained spot supplies of ammonium paratungstate and concentrates, reduced scrap availability, and low inventory levels. Transportation delays and increased freight costs contributed to supply constraints and price increases.

World Mine Production and Reserves: Reserves for Portugal, Spain, Vietnam, and "Other countries" were revised based on updated company data and (or) information from the Governments of those countries.

	Mine production		Reserves[9]
	2020	2021[e]	
United States	—	—	NA
Austria	890	900	10,000
Bolivia	1,350	1,400	NA
China	66,000	66,000	1,900,000
Korea, North	410	400	29,000
Portugal	550	620	5,100
Russia	2,400	2,400	400,000
Rwanda	860	950	NA
Spain	500	900	52,000
Vietnam	4,500	4,500	100,000
Other countries	960	1,200	1,200,000
World total (rounded)	78,400	79,000	3,700,000

World Resources:[9] World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits. Canada, Kazakhstan, Russia, and the United States also have significant tungsten resources.

Substitutes: Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide, niobium carbide, or titanium carbide; ceramics; ceramic-metallic composites (cermets); and tool steels. Most of these options reduce, rather than replace, the amount of tungsten used. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels, although most molybdenum steels still contain tungsten; lighting based on carbon nanotube filaments, induction technology, and light-emitting diodes for lighting based on tungsten electrodes or filaments; depleted uranium or lead for tungsten or tungsten alloys in applications requiring high density or the ability to shield radiation; and depleted uranium alloys or hardened steel for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles. In some applications, substitution would result in increased cost or a loss in product performance.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Includes ammonium and other tungstates; ferrotungsten; tungsten carbides; tungsten metal powders; tungsten oxides, chlorides, and other tungsten compounds; unwrought tungsten; wrought tungsten forms; and tungsten waste and scrap.

[2]Includes ammonium and other tungstates, ferrotungsten, tungsten carbides, tungsten metal powders, unwrought tungsten, wrought tungsten forms, and tungsten waste and scrap.

[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.

[4]Source: Platts Metals Week.

[5]A metric ton unit of tungsten trioxide contains 7.93 kilograms of tungsten.

[6]Defined as imports – exports + adjustments for Government and industry stock changes.

[7]See Appendix B for definitions.

[8]Tungsten-rhenium metal.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

VANADIUM

(Data in metric tons of contained vanadium unless otherwise noted)

Domestic Production and Use: Byproduct vanadium production in Utah from the mining of uraniferous sandstones on the Colorado Plateau ceased in early 2020 and was not restarted in 2021. Secondary vanadium production continued in Arkansas and Ohio where processed waste materials (petroleum residues, spent catalysts, and utility ash) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, and vanadium pentoxide. Two additional secondary producers in Pennsylvania and Texas remained idle. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2021. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine, mill	—	—	460	17	—
Imports for consumption:					
Aluminum-vanadium master alloy	288	281	222	101	40
Ash and residues	4,530	5,020	3,780	60	100
Ferrovanadium	2,810	2,970	2,280	1,350	2,000
Oxides and hydroxides, other	148	98	105	67	25
Vanadium chemicals[1]	607	515	201	211	360
Vanadium metal[2]	54	28	45	([3])	1
Vanadium ores and concentrates	2	590	192	4	4
Vanadium pentoxide	3,400	4,600	3,620	1,670	2,000
Exports:					
Aluminum-vanadium master alloy	132	90	29	13	100
Ash and residues	322	287	354	159	260
Ferrovanadium	229	575	295	165	120
Oxides and hydroxides, other	148	53	750	51	270
Vanadium metal[2]	59	39	27	1	2
Vanadium ores and concentrates	37	29	170	164	200
Vanadium pentoxide	126	563	423	50	14
Consumption:					
Apparent[4]	10,800	12,400	8,850	2,860	3,600
Reported	4,670	5,640	4,840	5,010	4,500
Price, average, vanadium pentoxide,[5] dollars per pound	7.61	16.4	12.2	6.7	8.2
Stocks, yearend[6]	227	250	257	269	260
Net import reliance[7] as a percentage of apparent consumption	100	100	95	99	100

Recycling: The quantity of vanadium recycled from spent chemical process catalysts was significant and may compose as much as 40% of total vanadium catalysts.

Import Sources (2017–20): Ferrovanadium: Austria, 44%; Canada, 33%; Russia, 12%; Japan, 4%; and other, 7%. Vanadium pentoxide: Brazil, 47%; South Africa, 35%; China, 8%; Taiwan, 5%; and other, 5%. Total: Canada, 26%; China, 14%; Brazil, 10%; South Africa, 9%; and other, 41%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Vanadium ores and concentrates	2615.90.6090	Free.
Vanadium bearing ash and residues	2620.40.0030	Free.
Vanadium bearing ash and residues, other	2620.99.1000	Free.
Chemical compounds:		
Vanadium pentoxide, anhydride	2825.30.0010	5.5% ad valorem.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad valorem.
Vanadium sulfates	2833.29.3000	5.5% ad valorem.
Vanadates	2841.90.1000	5.5% ad valorem.
Hydrides and nitrides of vanadium	2850.00.2000	5.5% ad valorem.
Ferrovanadium	7202.92.0000	4.2% ad valorem.
Vanadium metal	8112.92.7000	2.0% ad valorem.
Vanadium and articles thereof[8]	8112.99.2000	2.0% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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VANADIUM

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of vanadium in 2021 increased by 25% from that in 2020. The estimated average Chinese vanadium pentoxide price in 2021 increased by 22% compared with the 2020 price, and the estimated United States ferrovanadium price increased by 51% to $16.30 per pound in 2021 compared with that in 2020. Governments globally announced different measures to revive their economies after they were negatively affected by the global COVID-19 pandemic.

China continued to be the world's top vanadium producer, producing the majority of its vanadium from vanadiferous iron ore processed for steel production. In response to the global pandemic, China's Government implemented stimulus measures which led to record steel production in China. As a result, Chinese steel mills used more domestic titaniferous magnetite ore and resulted in Chinese producers operating at near capacity. Despite the significant increase in vanadium slag production in China, several environmental restrictions by China's Government to cut pollution may impose further constraints on vanadium slag production at steel plants. The limited capacity of vanadium-producing steel plants was expected to continue to cause vanadium prices to fluctuate.

In the third quarter of 2021, a producer in Brazil announced the commissioning of a vanadium trioxide processing plant at its Maracas Menchen Mine. The company emphasized that its decision to include production of high purity vanadium would be key to supporting its vanadium redox flow battery technology business. A vanadium producer in South Africa announced that it was completing an expanded prefeasibility study of its facility to determine the most-capital-efficient manner to increase vanadium production. It aimed to increase its facility's capacity by approximately 50% by yearend 2022 and more than double capacity in the long term if market conditions continued to improve.

World Mine Production and Reserves:

	Mine production		Reserves[9]
	2020	2021[e]	(thousand metric tons)
United States	17	—	45
Australia	—	—	[10]6,000
Brazil	6,620	6,700	120
China	70,000	73,000	9,500
Russia	19,500	19,000	5,000
South Africa	8,580	9,100	3,500
World total (rounded)	105,000	110,000	24,000

World Resources:[9] World resources of vanadium exceed 63 million tons. Vanadium occurs in deposits of phosphate rock, titaniferous magnetite, and uraniferous sandstone and siltstone, in which it constitutes less than 2% of the host rock. Significant quantities are also present in bauxite and carboniferous materials, such as coal, crude oil, oil shale, and tar sands. Because vanadium is typically recovered as a byproduct or coproduct, demonstrated world resources of the element are not fully indicative of available supplies. Although domestic resources and secondary recovery are adequate to supply a large portion of domestic needs, almost all of U.S. demand is currently met by foreign sources.

Substitutes: Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. Currently, no acceptable substitute for vanadium is available for use in aerospace titanium alloys.

[e]Estimated. — Zero.

[1]Includes vanadium chlorides, hydrides, nitrides, and sulfates, as well as vanadates of vanadium.

[2]Includes waste and scrap.

[3]Less than ½ unit.

[4]Defined as production + imports – exports + adjustments for industry stock changes.

[5]The 2017 annual average vanadium pentoxide price includes U.S. monthly averages for January to June 2017 and China monthly average prices for July to December 2017. The prices for 2018–2021 are the China annual average vanadium pentoxide prices. Source: CRU Group.

[6]Includes chlorides, ferrovanadium, vanadates, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.

[7]Defined as imports – exports + adjustments for industry stock changes.

[8]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 1.1 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies with mining and processing facilities in South Carolina and Virginia produced approximately 100,000 tons of vermiculite concentrate; data have been rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data. Flakes of raw vermiculite concentrate are micaceous in appearance and contain interlayer water in their structure. When the flakes are heated rapidly to a temperature above 870 degrees Celsius, the water flashes into steam, and the flakes expand into accordionlike particles. This process is called exfoliation or expansion, and the resulting ultralightweight material is chemically inert, fire resistant, and odorless. Most vermiculite concentrate produced in the United States was shipped to 15 exfoliating plants in nine States. The end uses for exfoliated vermiculite were estimated to be agriculture and horticulture, 32%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 24%; insulation, 9%; and other, 35%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[1, 2]	100	100	100	100	100
Imports for consumption[e]	28	37	39	40	38
Exports[e]	15	13	8	8	12
Consumption:					
Apparent, concentrate[e, 3]	110	120	130	130	130
Reported, exfoliated	77	79	79	81	78
Price, range of value, concentrate, ex-plant, dollars per ton	140–575	140–575	NA	NA	NA
Employment, number[e]	63	66	73	73	68
Net import reliance[4] as a percentage of apparent consumption[e, 5]	10	20	20	20	20

Recycling: Insignificant.

Import Sources (2017–20): South Africa, 70%; Brazil, 28%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Vermiculite, perlite, and chlorites, unexpanded	2530.10.0000	Free.
Exfoliated vermiculite, expanded clays, foamed slag, and similar expanded materials	6806.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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VERMICULITE

Events, Trends, and Issues: U.S. exports and imports of vermiculite are not collected as a separate category by the U.S. Census Bureau. U.S. imports were estimated to be about 38,000 tons in 2021, a decrease which could be related to disruptions in the global supply chain. Most imports came from South Africa and Brazil in 2021. One U.S. company announced a packaging surcharge in 2021 owing to the rising costs it was incurring from its suppliers. In 2020, a U.S. exfoliating plant in Florida closed, while another in New Mexico ceased producing exfoliated vermiculite.

Exploration and development of vermiculite deposits containing medium, large, and premium (coarser) grades (greater than 5-millimeter particle size) are likely to continue (mostly in China and South Africa) because of the higher demand for those grades. Finer grade production has exceeded consumption for several years, with Brazil and the United States continuing to be the leading producers. Producers will continue to investigate ways to increase the use of the finer grades in existing products and as a substitute for coarser vermiculite while continuing to develop new and innovative applications.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	[1, 2]100	[1, 2]100	25,000
Brazil	50	60	6,600
Bulgaria	10	10	NA
China	NA	NA	NA
India	2	2	1,600
Mexico	([7])	([7])	NA
Russia	29	30	NA
South Africa	150	140	14,000
Turkey	1	1	NA
Uganda	9	10	NA
Uzbekistan	2	2	NA
Zimbabwe	29	30	NA
World total (rounded)[8]	380	390	NA

World Resources:[6] In addition to the producing mines in South Carolina and Virginia, there are vermiculite occurrences in Colorado, Nevada, North Carolina, Texas, and Wyoming that contain estimated resources of 2 million to 3 million tons. Significant deposits have been reported in Australia, China, Russia, Uganda, and some other countries, but reserve and resource information comes from many sources and, in most cases, it is not clear whether the numbers refer to vermiculite alone or vermiculite plus other minerals and host rock and overburden.

Substitutes: Expanded perlite is a substitute for exfoliated vermiculite in lightweight concrete and plaster. Other denser but less costly alternatives in these applications include expanded clay, shale, slag, and slate. Alternate materials for loose-fill fireproofing insulation include fiberglass, perlite, and slag wool. In agriculture, substitutes include bark and other plant materials, peat, perlite, sawdust, and synthetic soil conditioners.

[e]Estimated. NA Not available.

[1]Concentrate sold or used by producers.

[2]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.

[3]Defined as concentrate sold or used by producers + imports – exports.

[4]Defined as imports – exports.

[5]Data are rounded to one significant digit to avoid disclosing company proprietary data.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Less than ½ unit.

[8]Does not include China's production.

WOLLASTONITE

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2021. U.S. production of wollastonite (sold or used by producers) was withheld to avoid disclosing company proprietary data but was estimated to have increased from that of 2020. Economic resources of wollastonite typically form as a result of thermal metamorphism of siliceous limestone during regional deformation or chemical alteration of limestone by siliceous hydrothermal fluids along faults or contacts with magmatic intrusions. Deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah; however, New York is the only State where long-term continuous mining has taken place.

The U.S. Geological Survey does not collect consumption statistics for wollastonite, but consumption was estimated to have increased in 2021 compared with that of 2020. Ceramics (frits, sanitaryware, and tile), friction products (primarily brake linings), metallurgical applications (flux and conditioner), paint (architectural and industrial paints), plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds), and miscellaneous uses (including adhesives, concrete, glass, and sealants) accounted for wollastonite sales in the United States.

In ceramics, wollastonite decreases shrinkage and gas evolution during firing; increases green and fired strength; maintains brightness during firing; permits fast firing; and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding, a source for calcium oxide, a slag conditioner, and protects the surface of molten metal during the continuous casting of steel. As an additive in paint, it improves the durability of the paint film, acts as a pH buffer, improves resistance to weathering, reduces gloss and pigment consumption, and acts as a flatting and suspending agent. In plastics, wollastonite improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, stable at high temperatures, and improves flexural and tensile strength.

Salient Statistics—United States: The United States was thought to be a net exporter of wollastonite in 2021. Comprehensive trade data were not available for wollastonite because it is imported and exported under generic Harmonized Tariff Schedule of the United States and Schedule B codes, respectively, that include multiple mineral commodities. Prices for domestically produced wollastonite were estimated to be between $330 to $360 per metric ton. Price data for globally produced wollastonite were unavailable. Products with finer grain sizes and acicular (highly elongated) particles sold for higher prices. Surface treatment, when necessary, also increased the selling price. Approximately 55 people were employed at wollastonite mines and mills in 2021 (excluding office workers) in the United States.

Recycling: None.

Import Sources (2017–20): Comprehensive trade data were not available, but wollastonite was primarily imported from Canada and Mexico.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

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WOLLASTONITE

Events, Trends, and Issues: Construction starts of new housing units through July 2021 increased by 21.8% compared with those during the same period in 2020 with the largest increase in starts being in single unit, privately owned houses. Sales of wollastonite to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, were thought to have increased as well as sales of wollastonite for primary iron and steel production, which increased by 18% compared with those during the same period of 2020. Supply-chain issues as well as the continuing impact of the global COVID-19 pandemic limited consumption in two major markets. The production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, decreased slightly in the first 7 months of 2021 and was 35% lower than production in 2019. Plastics production was expected to be 3% lower in 2021 than that in 2020.

Globally, ceramics, paint, and polymers (such as plastics and rubber) accounted for most wollastonite sales. Lesser global uses for wollastonite included miscellaneous construction products, friction materials, metallurgical applications, and paper. Several research projects continued in Canada, India, and the United States to evaluate the efficacy of wollastonite in carbon dioxide sequestration. Studies were being conducted to evaluate wollastonite's ability to capture atmospheric carbon dioxide when added to crop fields and its ability to enhance crop productivity. Wollastonite's ability to reduce carbon dioxide emissions in cement production by lowering kiln temperatures needed to produce cement and absorbing carbon dioxide in the process was being evaluated. Global sales of wollastonite were estimated to be in the range of 850,000 to 950,000 tons, higher than those in 2020.

World Mine Production and Reserves: More countries than those listed may produce wollastonite; however, many countries do not publish wollastonite production data.

	Mine production[e]		Reserves[1]
	2020	2021	
United States	W	W	World resources of wollastonite are
Canada	20,000	20,000	thought to exceed 100 million tons.
China	890,000	900,000	Many deposits have been identified
India	170,000	180,000	but have not been surveyed
Mexico	77,700	100,000	sufficiently to quantify their reserves.
Other countries	17,000	20,000	
World total (rounded)[2]	1,200,000	1,200,000	

World Resources:[1] Reliable estimates of wollastonite resources do not exist for most countries. Large deposits of wollastonite have been identified in China, Finland, India, Mexico, and the United States. Smaller, but significant, deposits have been identified in Canada, Chile, Kenya, Namibia, South Africa, Spain, Sudan, Tajikistan, Turkey, and Uzbekistan.

Substitutes: The acicular nature of many wollastonite products allows wollastonite to compete with other acicular materials, such as ceramic fiber, glass fiber, steel fiber, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene, in products where improvements in dimensional stability, flexural modulus, and heat deflection are sought. Wollastonite also competes with several nonfibrous minerals or rocks, such as kaolin, mica, and talc, which are added to plastics to increase flexural strength, and such minerals as barite, calcium carbonate, gypsum, and talc, which impart dimensional stability to plastics. In ceramics, wollastonite competes with carbonates, feldspar, lime, and silica as a source of calcium and silica. Its use in ceramics depends on the formulation of the ceramic body and the firing method.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

[2]Excludes U.S. production.

YTTRIUM[1]

[Data in metric tons of yttrium oxide (Y_2O_3) equivalent unless otherwise noted]

Domestic Production and Use: Yttrium is one of the rare-earth elements. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined in 2020 as a primary product at the Mountain Pass Mine in California, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Yttrium was estimated to represent about 0.12% of the rare-earth elements in the Mountain Pass bastnaesite ore. Insufficient information was available to determine the yttrium content of mine production. Monazite, a rare-earth phosphate mineral, was produced as a separated concentrate that includes yttrium-rich xenotime. Both are accessory minerals in heavy-mineral-sand concentrates.

The leading end uses of yttrium were in catalysts, ceramics, electronics, lasers, metallurgy, and phosphors. In ceramic applications, yttrium compounds were used in abrasives, bearings and seals, high-temperature refractories for continuous-casting nozzles, jet-engine coatings, oxygen sensors in automobile engines, and wear-resistant and corrosion-resistant cutting tools. In electronics, yttrium-iron garnets were components in microwave radar to control high-frequency signals. Yttrium was an important component in yttrium-aluminum-garnet laser crystals used in dental and medical surgical procedures, digital communications, distance and temperature sensing, industrial cutting and welding, nonlinear optics, photochemistry, and photoluminescence. In metallurgical applications, yttrium was used as a grain-refining additive and as a deoxidizer. Yttrium was used in heating-element alloys, high-temperature superconductors, and superalloys. Yttrium was used in phosphor compounds for flat-panel displays and various lighting applications.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine	—	NA	NA	NA	NA
Imports for consumption, yttrium, alloys, compounds, and metal[e, 2]	380	450	360	650	670
Exports, compounds[e, 3]	2	14	6	1	9
Consumption, apparent[e, 4]	400	400	400	600	700
Price, average, dollars per kilogram:[5]					
Y_2O_3, minimum 99.999% purity	3	3	3	3	5
Yttrium metal, minimum 99.9% purity	35	36	34	34	38
Net import reliance[6, 7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Insignificant.

Import Sources (2017–20):[8] Yttrium compounds: China,[9] 97%; the Republic of Korea, 1%; Japan, 1%; and other, 1%. Nearly all imports of yttrium metal and compounds are derived from mineral concentrates processed in China. Import sources do not include yttrium contained in value-added intermediates and finished products.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Rare-earth metals, unspecified, whether or not intermixed or interalloyed	2805.30.0090	5.0% ad valorem.
Mixtures of rare-earth oxides containing yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of rare-earth chlorides containing yttrium or scandium as the predominant metal	2846.90.2082	Free.
Yttrium-bearing materials and compounds containing by weight >19% to <85% Y_2O_3	2846.90.4000	Free.
Other rare-earth compounds, including yttrium and other compounds	2846.90.8000	3.7% ad valorem.

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YTTRIUM

Depletion Allowance: Monazite, thorium content, 22% (domestic), 14% (foreign); yttrium, rare-earth content, 14% (domestic and foreign); and xenotime, 14% (domestic and foreign).

Government Stockpile:[10]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Yttrium	25	600	—	25	—

Events, Trends, and Issues: China produced most of the world's supply of yttrium from its weathered clay ion-adsorption ore deposits in the southern Provinces—primarily Fujian, Guangdong, and Jiangxi—and from a lesser number of deposits in Guangxi and Hunan. Yttrium also was produced from similar clay deposits in Burma.

Globally, yttrium was mainly consumed in the form of oxide compounds for ceramics and phosphors. Lesser amounts were consumed in electronic devices, lasers, optical glass, and metallurgical applications. The average prices for yttrium metal and Y_2O_3 both increased compared with those in 2020. China's Ministry of Industry and Information Technology raised quotas for rare-earth mining and separation to 168,000 tons and 162,000 tons of rare-earth-oxide equivalent, respectively. The yttrium content of the production quota was not specified. Mine production was allocated to 148,850 tons of light rare earths and 19,150 tons of ion-adsorption clays.

In 2020, China's exports of yttrium compounds and metal were estimated to be 3,300 tons of Y_2O_3 equivalent, and the leading export destinations were, in descending order, Japan, the United States, the Republic of Korea, Germany, and France.

World Mine Production and Reserves:[11] World mine production of yttrium contained in rare-earth mineral concentrates was estimated to be 8,000 to 12,000 tons. Most of this production took place in China and Burma. Global reserves of Y_2O_3 equivalent were estimated to be more than 500,000 tons. The leading countries for these reserves included Australia, Brazil, Canada, China, and India. Although mine production in Burma was significant, information on reserves in Burma was not available. Global reserves may be adequate to satisfy near-term demand at current rates of production; however, recent high demand of ion-adsorption clay rare earths in Burma and China as well as changes in economic conditions, environmental issues, or permitting and trade restrictions could affect the availability and pricing of many of the rare-earth elements, including yttrium.

World Resources:[11] Large resources of yttrium in monazite and xenotime are available worldwide in placer deposits, carbonatites, uranium ores, and weathered clay deposits (ion-adsorption ore). Additional resources of yttrium occur in apatite-magnetite-bearing rocks, deposits of niobium-tantalum minerals, non-placer monazite-bearing deposits, sedimentary phosphate deposits, and uranium ores.

Substitutes: Substitutes for yttrium are available for some applications but generally are much less effective. In most uses, especially in electronics, lasers, and phosphors, yttrium is generally not subject to direct substitution by other elements. As a stabilizer in zirconia ceramics, Y_2O_3 may be substituted with calcium oxide or magnesium oxide, but the substitutes generally impart lower toughness.

[e]Estimated. NA Not available. — Zero.

[1]See also Rare Earths; trade data for yttrium are included in the data shown for rare earths.

[2]Estimated from Trade Mining LLC and IHS Markit Ltd. shipping records.

[3]Includes data for the following Schedule B code: 2846.90.2015.

[4]Defined as imports – exports. Rounded to one significant digit. Yttrium consumed domestically was imported or refined from imported materials.

[5]Free on board China. Source: Argus Media group—Argus Metals International.

[6]Defined as imports – exports.

[7]In 2018, 2019, 2020, and 2021, domestic production of mineral concentrates was stockpiled or exported. Consumers of compounds and metals were reliant on imports and stockpiled inventory of compounds and metals.

[8]Includes estimated Y_2O_3 equivalent from the following Harmonized Tariff Schedule of the United States codes: 2846.90.2015, 2846.90.2082, 2846.90.4000, 2846.90.8050, and 2846.90.8060.

[9]Includes Hong Kong.

[10]See Appendix B for definitions.

[11]See Appendix C for resource and reserve definitions and information concerning data sources.

ZEOLITES (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, six companies in the United States operated nine zeolite mines and produced an estimated 87,000 tons of natural zeolites, slightly more than that of 2020. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. Minor quantities of erionite, ferrierite, mordenite, and (or) phillipsite also likely were produced. New Mexico was estimated to be the leading natural zeolite-producing State in 2021. The top three companies accounted for approximately 75% of total domestic production.

An estimated 76,000 tons of natural zeolites was sold in the United States during 2021, slightly more compared with that of 2020. Domestic uses were, in descending order of estimated quantity, animal feed, odor control, unspecified end uses (such as ice melt, soil amendment, and synthetic turf), water purification, pet litter, wastewater treatment, fungicide or pesticide carrier, oil and grease absorbent, air filtration and gas absorbent, fertilizer carrier, desiccant, and aquaculture. Animal feed, odor control, and water purification applications likely accounted for about 60% of the domestic sales tonnage.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine	82,400	86,100	87,800	86,700	87,000
Sales, mill	81,300	80,500	77,100	75,300	76,000
Imports for consumption[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Exports[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Consumption, apparent[1]	81,300	80,500	77,100	75,300	76,000
Price, range of value, dollars per ton[2]	100–300	[e]50–300	[e]50–300	[e]50–300	50–300
Employment, mine and mill, number[e, 3]	110	110	120	120	120
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Zeolites used for desiccation, gas absorbance, wastewater cleanup, and water purification may be reused after reprocessing of the spent zeolites. Information about the quantity of recycled natural zeolites was unavailable.

Import Sources (2017–20): Comprehensive trade data were not available for natural zeolite minerals because they were imported and exported under generic Harmonized Tariff Schedule of the United States and Schedule B codes, respectively, that include multiple mineral commodities or under codes for finished products. Nearly all imports and exports were thought to be synthetic zeolites.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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ZEOLITES (NATURAL)

Events, Trends, and Issues: Prior to the 1990s, annual output of natural zeolites in the United States was less than 15,000 tons. Production rose more than sixfold from 1990 through 2021 owing predominantly to increases in sales for animal feed applications, although sales for odor control and water purification also increased significantly. In contrast, sales for pet litter declined substantially during this period as a result of competition from other products.

World Mine Production and Reserves: Many countries either do not report production of natural zeolites or production is reported with a 2- to 3-year lag time. End uses for natural zeolites in countries that mine large tonnages of zeolite minerals typically include low-value, high-volume construction applications, such as dimension stone, lightweight aggregate, and pozzolanic cement. As a result, production data for some countries may not accurately indicate the quantities of natural zeolites used in the high-value applications that are reflected in the U.S. data.

World reserves of natural zeolites have not been estimated. Deposits occur in many countries, but companies rarely publish reserves data. Further complicating estimates of reserves is the fact that much of the reported world production includes altered volcanic tuffs with low to moderate concentrations of zeolites that are typically used in high-volume construction applications. Some deposits should, therefore, be excluded from reserves estimates because it is the rock itself and not its zeolite content that makes the deposit valuable.

	Mine production		Reserves[5]
	2020	2021[e]	
United States	86,700	87,000	Two of the leading companies in the United States reported combined reserves of 80 million tons in 2021; total U.S. reserves likely are substantially larger. World data are unavailable, but reserves are estimated to be large.
China	[e]52,000	52,000	
Cuba	[e]53,000	53,000	
Georgia	135,000	140,000	
Hungary	[e]29,000	29,000	
Indonesia	[e]130,000	130,000	
Jordan	12,000	12,000	
Korea, Republic of	131,000	130,000	
New Zealand	[e]100,000	100,000	
Russia	[e]35,000	35,000	
Slovakia	[e]117,000	120,000	
Turkey	[e]73,000	50,000	
Other countries	5,450	5,500	
World total (rounded)	959,000	944,000	

World Resources:[5] Recent estimates for domestic and global resources of natural zeolites are not available. Resources of chabazite and clinoptilolite in the United States are sufficient to satisfy foreseeable domestic demand.

Substitutes: For pet litter, zeolites compete with other mineral-based litters, such as those manufactured using bentonite, diatomite, fuller's earth, and sepiolite; organic litters made from shredded corn stalks and paper, straw, and wood shavings; and litters made using silica gel. Diatomite, perlite, pumice, vermiculite, and volcanic tuff compete with natural zeolites as lightweight aggregate. Zeolite desiccants compete against such products as magnesium perchlorate and silica gel. Zeolites compete with bentonite, gypsum, montmorillonite, peat, perlite, silica sand, and vermiculite in various soil amendment applications. Activated carbon, diatomite, or silica sand may substitute for zeolites in water-purification applications. As an oil absorbent, zeolites compete mainly with bentonite, diatomite, fuller's earth, sepiolite, and a variety of polymer and natural organic products. In animal feed, zeolites compete with bentonite, diatomite, fuller's earth, kaolin, silica, and talc as anticaking and flow-control agents.

[e]Estimated. E Net exporter.

[1]Defined as mill sales + imports – exports. Information about industry stocks was unavailable.

[2]Range of ex-works mine and mill unit values for individual natural zeolite operations, based on data reported by U.S. producers and U.S. Geological Survey estimates. Average unit values per ton for the past 5 years were $140 in 2017, and an estimated $125 in 2018, 2019, 2020, and 2021. Prices vary with the percentage of zeolite present in the product, the chemical and physical properties of the zeolite mineral(s), particle size, surface modification and (or) activation, and end use.

[3]Excludes administration and office staff. Estimates based on data from the Mine Safety and Health Administration.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

ZINC

(Data in thousand metric tons of contained zinc unless otherwise noted)

Domestic Production and Use: The value of zinc mined in 2021, based on zinc contained in concentrate, was about $2.4 billion. Zinc was mined in five States at seven mining operations by five companies. Three smelter facilities, one primary and two secondary, operated by three companies, produced commercial-grade zinc metal. Of the total reported zinc consumed, most was used in galvanizing, followed by brass and bronze, zinc-based alloys, and other uses.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Zinc in ores and concentrates	774	824	753	718	740
Refined zinc[1]	132	116	115	180	220
Imports for consumption:					
Zinc in ores and concentrates	7	(2)	(2)	3	8
Refined zinc	729	775	830	700	700
Exports:					
Zinc in ores and concentrates	682	806	792	546	580
Refined zinc	33	23	5	2	5
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent, refined zinc[3]	829	868	939	878	920
Price, average, cents per pound:					
North American[4]	139.3	141.0	124.1	110.8	145
London Metal Exchange (LME), cash	131.2	132.7	115.6	102.7	136
Stocks, reported producer and consumer, refined zinc, yearend	114	119	116	120	110
Employment, number:					
Mine and mill[5]	2,420	2,630	2,470	2,360	2,400
Smelter, primary	240	250	250	220	220
Net import reliance[6] as a percentage of apparent consumption					
Ores and concentrates	E	E	E	E	E
Refined zinc	84	87	88	79	76

Recycling: In 2021, an estimated 60% of the refined zinc produced in the United States was recovered from secondary materials at both primary and secondary smelters. Secondary materials included galvanizing residues and crude zinc oxide recovered from electric arc furnace dust.

Import Sources (2017–20): Ores and concentrates: Peru, 89%; China, 11%; other, <1%. Refined metal: Canada, 63%; Mexico, 15%; Peru, 7%; Spain, 7%; and other, 8%. Waste and scrap (gross weight): Canada, 64%; Mexico, 34%; and other, 2%. Combined total (includes gross weight of waste and scrap): Canada, 63%; Mexico, 15%; Peru, 7%; Spain, 7%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Zinc ores and concentrates, zinc content	2608.00.0030	Free.
Zinc oxide; zinc peroxide	2817.00.0000	Free.
Unwrought zinc, not alloyed:		
Containing 99.99% or more zinc	7901.11.0000	1.5% ad valorem.
Containing less than 99.99% zinc:		
Casting-grade	7901.12.1000	3% ad valorem.
Other	7901.12.5000	1.5% ad valorem.
Zinc alloys	7901.20.0000	3% ad valorem.
Zinc waste and scrap	7902.00.0000	Free.

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ZINC

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Zinc	7.25	—	7.25	—	7.25

Events, Trends, and Issues: Estimated global zinc mine production in 2021 increased from that in 2020, when mine production was constrained in some countries because of Government-mandated lockdowns and a decrease in zinc prices following the onset of the global COVID-19 pandemic. According to the International Lead and Zinc Study Group,[8] estimated global refined zinc production in 2021 was forecast to increase slightly to 14.13 million tons and estimated metal consumption to increase by 6% to 14.09 million tons, resulting in a production-to-consumption surplus.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

World Mine Production and Reserves: Reserves for Australia, Canada, India, Mexico, Peru, Sweden, and the United States were revised based on Government or company reports.

	Mine production[9] 2020	Mine production[9] 2021[e]	Reserves[10]
United States	718	740	9,000
Australia	1,310	1,300	[11]69,000
Bolivia	360	490	4,800
Canada	211	260	5,400
China	4,060	4,200	44,000
India	720	810	9,100
Kazakhstan	222	220	12,000
Mexico	638	720	19,000
Peru	1,330	1,600	19,000
Russia	280	280	22,000
Sweden	232	230	3,700
Other countries	1,950	2,000	34,000
World total (rounded)	12,000	13,000	250,000

World Resources:[10] Identified zinc resources of the world are about 1.9 billion tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; aluminum alloys, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-base alloys are major competitors for zinc-base diecasting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. E Net exporter. — Zero.

[1]Includes primary and secondary zinc metal production.

[2]Less than ½ unit.

[3]Defined as refined production + refined imports – refined exports + adjustments for Government stock changes.

[4]Source: S&P Global Platts Metals Week, North American Special High Grade (SHG) zinc; based on the LME cash price plus premium.

[5]Includes mine and mill employment at all zinc-producing mines. Excludes office workers. Source: Mine Safety and Health Administration.

[6]Defined as imports – exports + adjustments for Government stock changes.

[7]See Appendix B for definitions.

[8]International Lead and Zinc Study Group, 2021, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 12, [5] p.

[9]Zinc content of concentrates and direct shipping ores.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 24 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, one company recovered zircon (zirconium silicate) from surface-mining operations in Florida and Georgia as a coproduct from the mining of heavy-mineral sands and the processing of titanium and zirconium mineral concentrates, and a second company processed existing mineral sands tailings in Florida. Zirconium metal and hafnium metal were produced from zirconium chemical intermediates by one producer in Oregon and one in Utah. Zirconium and hafnium are typically contained in zircon at a ratio of about 36 to 1. Zirconium chemicals were produced by the metal producer in Oregon and by at least 10 other companies. Ceramics, foundry sand, opacifiers, and refractories are the leading end uses for zircon. Other end uses of zircon include abrasives, chemicals (predominantly, zirconium basic sulfate and zirconium oxychloride octohydrate as intermediate chemicals), metal alloys, and welding rod coatings. The leading consumers of zirconium metal are the chemical process and nuclear energy industries. The leading use of hafnium metal is in superalloys.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, zirconium ores and concentrates (ZrO_2 content)[1]	[2]50,000	[3]100,000	[2]20,000	[2]20,000	[2]20,000
Imports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	24,300	26,400	22,600	15,600	18,000
Zirconium, unwrought, powder, and waste and scrap	899	1,880	1,820	2,030	560
Zirconium, wrought	282	282	289	302	250
Hafnium, unwrought, powder, and waste and scrap	113	42	32	16	16
Exports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	31,500	77,500	40,500	12,200	12,000
Zirconium, unwrought, powder, and waste and scrap	627	556	897	664	550
Zirconium, wrought	972	1,150	816	830	770
Consumption, apparent,[4] zirconium ores and concentrates (ZrO_2 content)[1]	[2]50,000	[3]100,000	[2]10,000	[2]30,000	[2]30,000
Price:					
Zircon, dollars per metric ton (gross weight):					
Australia, free on board[5]	975	NA	NA	NA	NA
China, cost, insurance, and freight[6]	1,295	1,625	1,585	1,415	1,780
Imported[7]	916	1,290	1,490	1,380	1,340
Zirconium, unwrought, imports, China,[8] dollars per kilogram	12	13	14	6	8
Hafnium, unwrought,[6] dollars per kilogram	900	840	780	750	830
Net import reliance[9] as a percentage of apparent consumption:					
Zirconium ores and concentrates	E	E	E	<25	<25
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and (or) from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled. Hafnium metal recycling was insignificant.

Import Sources (2017–20): Zirconium ores and concentrates: South Africa, 54%; Senegal, 25%; Australia, 19%; Russia, 2%; and other, <1%. Zirconium, unwrought, including powder: China, 89%; Germany, 8%; and other, 3%. Zirconium, wrought: France, 64%; Germany, 18%; Belgium, 5%; and other, 13%. Hafnium, unwrought: Germany, 42%; France, 29%; China, 24%; the United Kingdom, 2%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Zirconium ores and concentrates	2615.10.0000	Free.
Ferrozirconium	7202.99.1000	4.2% ad valorem.
Zirconium, unwrought and powder	8109.20.0000	4.2% ad valorem.
Zirconium waste and scrap	8109.30.0000	Free.
Other zirconium articles	8109.90.0000	3.7% ad valorem.
Hafnium, unwrought, powder, and waste and scrap	8112.92.2000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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ZIRCONIUM AND HAFNIUM

Events, Trends, and Issues: Global production of zirconium mineral concentrates was essentially unchanged in 2021 compared with that in 2020. Advanced exploration and development projects with planned production of zircon concentrates were ongoing in Australia, Madagascar, Mozambique, Senegal, Tanzania, and elsewhere. In the United States, mining and heavy-mineral-processing operations were expanded near Starke, FL, and prefeasibility studies were underway at the Titan heavy-mineral-sands project near Camden, TN. U.S. exports of zirconium ores and concentrates were essentially unchanged, whereas imports increased by 15% from those in 2020 but remained lower than those in previous years. Australia, Senegal, and South Africa continued to be the leading import sources of zirconium ores and concentrates. The leading global exporters of zirconium mineral concentrates were Australia, Senegal, and South Africa. The leading global importers were China, India, and Spain.

Global producers of zirconium sponge included China, France, India, Russia, and the United States. The leading global exporters of unwrought zirconium metal under Harmonized System Code 8109.20 were China, Germany, and the United States. France and Russia led the global importers of unwrought zirconium.

World Mine Production and Reserves: World primary hafnium production data were not available, and quantitative estimates of hafnium reserves are not available. Zirconium reserves for Australia were revised on the basis of Government reports. Zirconium reserves for Kenya and South Africa were revised on the basis of company reports.

	Zirconium ores and zircon concentrates, mine production (thousand metric tons, gross weight)		Zirconium reserves[10] (thousand metric tons, ZrO_2 content)[1]
	2020	2021[e]	
United States	[2]30	[2]30	500
Australia	400	400	[11]50,000
China	140	140	500
Indonesia	64	55	NA
Kenya	29	30	50
Mozambique	110	110	1,800
Senegal	60	70	NA
South Africa	280	270	5,900
Other countries	117	110	11,000
World total (rounded)	1,200	1,200	70,000

World Resources:[10] Resources of zircon in the United States included about 14 million tons associated with titanium resources in heavy-mineral-sand deposits. Phosphate rock and sand and gravel deposits could potentially yield substantial amounts of zircon as a byproduct. World resources of hafnium are associated with those of zircon and baddeleyite. Quantitative estimates of hafnium resources were not available.

Substitutes: Chromite and olivine can be used instead of zircon for some foundry applications. Dolomite and spinel refractories can also substitute for zircon in certain high-temperature applications. Niobium (columbium), stainless steel, and tantalum provide limited substitution in nuclear applications, and titanium and synthetic materials may substitute in some chemical processing plant applications. Silver-cadmium-indium control rods are used in lieu of hafnium at numerous nuclear powerplants. Zirconium can be used interchangeably with hafnium in certain superalloys.

[e]Estimated. E Net exporter. NA Not available.

[1]Calculated ZrO_2 content as 65% of gross production.

[2]Data are rounded to one significant digit to avoid disclosing company proprietary data.

[3]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.

[4]Defined as production + imports – exports.

[5]Source: Industrial Minerals, average of yearend price. Prices of zircon from Australia were discontinued at yearend 2017.

[6]Source: Argus Media group—Argus Metals International, average of yearend price.

[7]Unit value based on annual United States imports for consumption from Australia, Senegal, and South Africa.

[8]Unit value based on annual United States imports for consumption from China.

[9]Defined as imports – exports.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 22.1 million tons, gross weight.

APPENDIX A

Abbreviations and Units of Measure

1 carat (metric) (diamond)	= 200 milligrams
1 flask (fl)	= 76 pounds, avoirdupois, or 33.47 kilograms
1 karat (gold)	= one twenty-fourth part
1 kilogram (kg)	= 2.2046 pounds, avoirdupois
1 long ton (lt)	= 2,240 pounds, avoirdupois
1 long ton unit (ltu)	= 1% of 1 long ton, or 22.4 pounds, avoirdupois
long calcined ton (lct)	= excludes water of hydration
long dry ton (ldt)	= excludes excess free moisture
Mcf	= 1,000 cubic feet
1 metric ton (t)	= 2,204.6 pounds, avoirdupois, or 1,000 kilograms
1 metric ton (t)	= 1.1023 short ton
1 metric ton unit (mtu)	= 1% of 1 metric ton, or 10 kilograms
metric dry ton (mdt)	= excludes excess free moisture
1 pound (lb)	= 453.6 grams
psia	= pounds per square inch absolute
1 short ton (st)	= 2,000 pounds, avoirdupois
1 short ton unit (stu)	= 1% of 1 short ton, or 20 pounds, avoirdupois
short dry ton (sdt)	= excludes excess free moisture
1 troy ounce (tr oz)	= 1.09714 avoirdupois ounces, or 31.103 grams
1 troy pound	= 12 troy ounces

APPENDIX B

Definitions of Selected Terms Used in This Report

Terms Used for Materials in the National Defense Stockpile and Federal Helium Reserve

Fiscal year for the U.S. Government is the period from October 1 through September 30. Fiscal year (FY) 2021 is from October 1, 2020, through September 30, 2021. FY 2022 is from October 1, 2021, through September 30, 2022.

Inventory refers to the quantity of mineral materials held in the National Defense Stockpile or in the Federal Helium Reserve. Nonstockpile-grade materials may be included in the table; where significant, the quantities of these stockpiled materials are specified in the text accompanying the table.

Potential disposals indicate the total amount of a material in the National Defense Stockpile that the U.S. Department of Defense is permitted to dispose of under the Annual Materials Plan approved by Congress for the fiscal year. Congress has authorized disposal over the long term at rates designed to maximize revenue but avoid undue disruption to the usual markets and financial loss to the United States. Disposals are defined as any disposal or sale of National Defense Stockpile stock. For mineral commodities that have a disposal plan greater than the inventory, the actual quantity will be limited to the remaining disposal authority or inventory. Note that, unlike the National Defense Stockpile, helium stockpile sales by the Bureau of Land Management under the Helium Privatization Act of 1996 are permitted to exceed disposal plans.

Potential acquisitions indicate the maximum amount of a material that may be acquired by the U.S. Department of Defense for the National Defense Stockpile under the Annual Materials Plan approved by Congress for the fiscal year.

Depletion Allowance

The depletion allowance is a business tax deduction analogous to depreciation, but which applies to an ore reserve rather than equipment or production facilities. Federal tax law allows this deduction from taxable corporate income, recognizing that an ore deposit is a depletable asset that must eventually be replaced.

APPENDIX C

Reserves and Resources

Reserves data are dynamic. They may be reduced as ore is mined and (or) the feasibility of extraction diminishes, or more commonly, they may continue to increase as additional deposits (known or recently discovered) are developed, or currently exploited deposits are more thoroughly explored and (or) new technology or economic variables improve their economic feasibility. Reserves may be considered a working inventory of mining companies' supplies of an economically extractable mineral commodity. As such, the magnitude of that inventory is necessarily limited by many considerations, including cost of drilling, taxes, price of the mineral commodity being mined, and the demand for it. Reserves will be developed to the point of business needs and geologic limitations of economic ore grade and tonnage. For example, in 1970, identified and undiscovered world copper resources were estimated to contain 1.6 billion metric tons of copper, with reserves of about 280 million tons of copper. Since then, about 600 million tons of copper have been produced worldwide, but world copper reserves in 2021 were estimated to be 880 million tons of copper, more than triple those in 1970, despite the depletion by mining of much more than the 1970 estimated reserves.

Future supplies of minerals will come from reserves and other identified resources, currently undiscovered resources in deposits that will be discovered in the future, and material that will be recycled from current in-use stocks of minerals or from minerals in waste disposal sites. Undiscovered deposits of minerals constitute an important consideration in assessing future supplies. Mineral-resource assessments have been carried out for small parcels of land being evaluated for land reclassification, for the Nation, and for the world.

Part A—Resource and Reserve Classification for Minerals[1]

Introduction

Through the years, geologists, mining engineers, and others operating in the minerals field have used various terms to describe and classify mineral resources, which as defined herein include energy materials. Some of these terms have gained wide use and acceptance, although they are not always used with precisely the same meaning.

The U.S. Geological Survey (USGS) collects information about the quantity and quality of all mineral resources. In 1976, the USGS and the U.S. Bureau of Mines developed a common classification and nomenclature, which was published as USGS Bulletin 1450–A—"Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey." Experience with this resource classification system showed that some changes were necessary in order to make it more workable in practice and more useful in long-term planning. Therefore, representatives of the USGS and the U.S. Bureau of Mines collaborated to revise Bulletin 1450–A. Their work was published in 1980 as USGS Circular 831—"Principles of a Resource/Reserve Classification for Minerals."

Long-term public and commercial planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. Thus, resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions. To best serve these planning needs, known resources should be classified from two standpoints: (1) purely geologic or physical and chemical characteristics—such as grade, quality, tonnage, thickness, and depth—of the material in place; and (2) profitability analyses based on costs of extracting and marketing the material in a given economy at a given time. The former constitutes important objective scientific information of the resource and a relatively unchanging foundation upon which the latter more valuable economic delineation can be based.

The revised classification system, designed generally for all mineral materials, is shown graphically in figures C1and C2; its components and their usage are described in the text. The classification of mineral and energy resources is necessarily arbitrary because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy-fuel resources for the Nation or for specific areas.[1]

Resource and Reserve Definitions

A dictionary definition of resource, "something in reserve or ready if needed," has been adapted for mineral and energy resources to comprise all materials, including those only surmised to exist, that have present or anticipated future value.

Resource.—A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Original Resource.—The amount of a resource before production.

Identified Resources.—Resources for which location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified resources include economic, marginally economic, and subeconomic components. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into measured, indicated, and inferred.

[1]Based on U.S. Geological Survey Circular 831, 1980.

Demonstrated.—A term for the sum of measured plus indicated resources.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.—Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurements are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred.—Estimates are based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Reserve Base.—That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term “geologic reserve” has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.

Inferred Reserve Base.—The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit and for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence.

Reserves.—That part of the reserve base that could be economically extracted or produced at the time of determination. The term “reserves” need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as “extractable reserves” and “recoverable reserves” are redundant and are not a part of this classification system.

Marginal Reserves.—That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technological factors.

Economic.—This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Subeconomic Resources.—The part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Undiscovered Resources.—Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, undiscovered resources may be divided into two parts, as follows:

Hypothetical Resources.—Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources.—Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Restricted Resources or Reserves.—That part of any resource or reserve category that is restricted from extraction by laws or regulations. For example, restricted reserves meet all the requirements of reserves except that they are restricted from extraction by laws or regulations.

Other Occurrences.—Materials that are too low grade or for other reasons are not considered potentially economic, in the same sense as the defined resource, may be recognized and their magnitude estimated, but they are not classified as resources. A separate category, labeled “other occurrences,” is included in figures C1 and C2. In figure C1, the boundary between subeconomic and other occurrences is limited by the concept of current or potential feasibility of economic production, which is required by the definition of a resource. The boundary is obviously uncertain, but limits may be specified in terms of grade, quality, thickness, depth, extractable percentage, or other economic-feasibility variables.

Cumulative Production.—The amount of past cumulative production is not, by definition, a part of the resource. Nevertheless, a knowledge of what has been produced is important in order to understand current resources, in terms of both the amount of past production and the amount of residual or remaining in-place resource. A separate space for cumulative production is shown in figures C1 and C2. Residual material left in the ground during current or future extraction should be recorded in the resource category appropriate to its economic-recovery potential.

Figure C1.—Major Elements of Mineral-Resource Classification, Excluding *Reserve Base* and *Inferred Reserve Base*

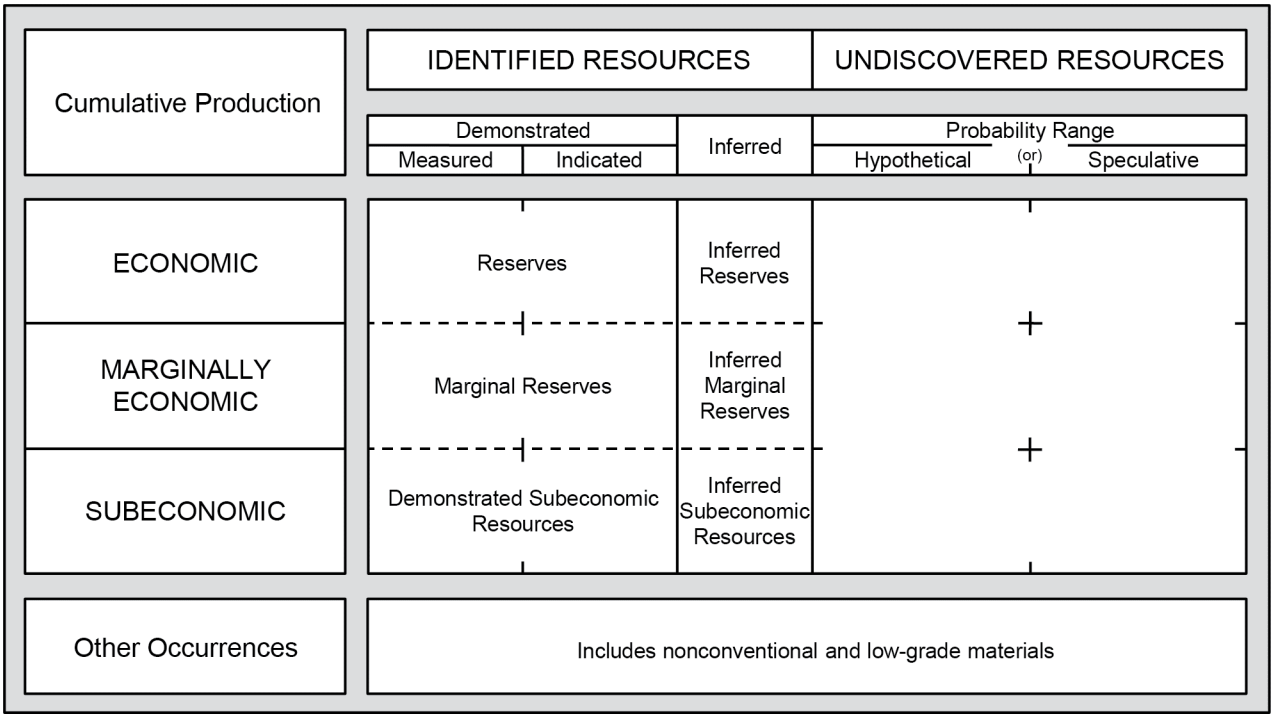
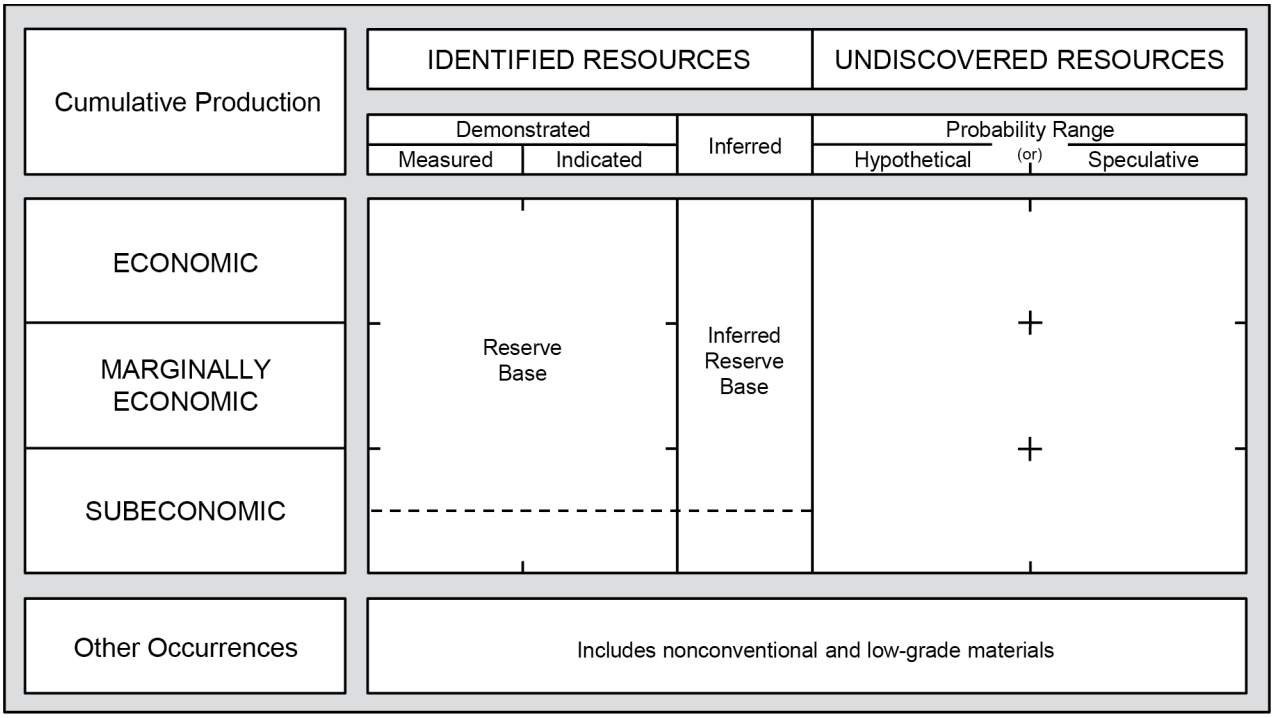


Figure C2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



Part B—Sources of Reserves Data

National information on reserves for most mineral commodities found in this report, including those for the United States, is derived from a variety of sources. The ideal source of such information would be comprehensive evaluations that apply the same criteria to deposits in different geographic areas and report the results by country. In the absence of such evaluations, national reserves estimates compiled by countries for selected mineral commodities are a primary source of national reserves information. Lacking national assessment information by governments, sources such as academic articles, company reports, presentations by company representatives, and trade journal articles, or a combination of these, serve as the basis for national information on reserves reported in the mineral commodity sections of this publication.

A national estimate may be assembled from the following: historically reported reserves information carried for years without alteration because no new information is available, historically reported reserves reduced by the amount of historical production, and company-reported reserves. International minerals availability studies conducted by the U.S. Bureau of Mines before 1996 and estimates of identified resources by an international collaborative effort (the International Strategic Minerals Inventory) are the bases for some reserves estimates. The USGS collects some qualitative information about the quantity and quality of mineral resources but does not directly measure reserves or resources, and companies or governments do not directly report information about reserves or resources to the USGS. Reassessment of reserves is a continuing process, and the intensity of this process differs by mineral commodity, country, and time period.

Some countries have specific definitions for reserves data, and reserves for each country are assessed separately, based on reported data and definitions. An attempt is made to make reserves consistent among countries for a mineral commodity and its byproducts. For example, the Australasian Joint Ore Reserves Committee (JORC) established the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code) that sets out minimum standards, recommendations, and guidelines for public reporting in Australasia of exploration results, mineral resources, and ore reserves. Companies listed on the Australian Securities Exchange and the New Zealand Stock Exchange are required to report publicly on ore reserves and mineral resources under their control, using the JORC Code.

Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources. Because of its specific use in the JORC Code, the term "reserves" is not used in the national inventory, where the highest category is "Economic Demonstrated Resources" (EDR). In essence, EDR combines the JORC Code categories "proved reserves" and "probable reserves," plus measured resources and indicated resources. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term. Accessible Economic Demonstrated Resources represent the resources within the EDR category that are accessible for mining. Reserves for Australia in the Mineral Commodity Summaries 2022 are Accessible EDR. For more information, see table 3 in "Australia's Identified Mineral Resources 2020" (https://doi.org/10.11636/1327-1466.2020).

In Canada, the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) provides definition standards for the classification of mineral resources and mineral reserves estimates into various categories. The category to which a resource or reserves estimate is assigned depends on the level of confidence in the geologic information available on the mineral deposit, the quality and quantity of data available on the deposit, the level of detail of the technical and economic information that has been generated about the deposit, and the interpretation of the data and information. For more information on the CIM definition standards, see https://mrmr.cim.org/en/standards/canadian-mineral-resource-and-mineral-reserve-definitions/.

In Russia, reserves for most minerals can appear in a number of sources, although no comprehensive list of reserves is published. Reserves data for a limited set of mineral commodities are available in the annual report "Gosudarstvennyi Doklad o Sostoyanii i Ispol'zovanii Mineral'no-Syryevyh Resursov Rossiyskoy Federatsii" (State Report on the State and Use of Mineral and Raw Materials Resources of the Russian Federation), which is published by Russia's Ministry of Natural Resources and Environment. Reserves data for various minerals appear at times in journal articles, such as those in the journal "Mineral'nyye Resursy Rossii. Ekonomika i Upravleniye" (Mineral Resources of Russia. Economics and Management), which is published by the "OOO RG-Inform," a subsidiary of Rosgeologiya Holding. It is sometimes not clear if the reserves are being reported in ore or mineral content. It is also in many cases not clear which definition of reserves is being used, because the system inherited from the former Soviet Union has a number of ways in which the term "reserves" is defined, and these definitions qualify the percentage of resources that are included in a specific category. For example, the Soviet reserves classification system, besides the categories A, B, C1, and C2, which represent progressively detailed knowledge of a mineral deposit based on exploration data, has other subcategories cross imposed upon the system. Under the broad category reserves (zapasy), there are subcategories that include balance reserves (balansovyye zapasy, or economic reserves) and outside-the-balance reserves (zabalansovye zapasy, or subeconomic reserves), as well as categories that include explored, industrial, and proven reserves, and the reserves totals can vary significantly, depending on the specific definition of reserves being reported.

APPENDIX D

Country Specialists Directory

Minerals information country specialists at the U.S. Geological Survey collect and analyze information on the mineral industries of more than 170 nations throughout the world. The specialists are available to answer minerals-related questions concerning individual countries.

Africa and the Middle East

Algeria	Mowafa Taib
Angola	Meralis Plaza-Toledo
Bahrain	Philip A. Szczesniak
Benin	Meralis Plaza-Toledo
Botswana	Thomas R. Yager
Burkina Faso	Alberto A. Perez
Burundi	Thomas R. Yager
Cabo Verde	Meralis Plaza-Toledo
Cameroon	Philip A. Szczesniak
Central African Republic	Philip A. Szczesniak
Chad	Philip A. Szczesniak
Comoros	Philip A. Szczesniak
Congo (Brazzaville)	Philip A. Szczesniak
Congo (Kinshasa)	Thomas R. Yager
Côte d'Ivoire	Alberto A. Perez
Djibouti	Thomas R. Yager
Egypt	Mowafa Taib
Equatorial Guinea	Meralis Plaza-Toledo
Eritrea	Thomas R. Yager
Eswatini	Philip A. Szczesniak
Ethiopia	Meralis Plaza-Toledo
Gabon	Alberto A. Perez
The Gambia	Meralis Plaza-Toledo
Ghana	Meralis Plaza-Toledo
Guinea	Alberto A. Perez
Guinea-Bissau	Meralis Plaza-Toledo
Iran	Philip A. Szczesniak
Iraq	Philip A. Szczesniak
Israel	Philip A. Szczesniak
Jordan	Mowafa Taib
Kenya	Thomas R. Yager
Kuwait	Philip A. Szczesniak
Lebanon	Mowafa Taib
Lesotho	Philip A. Szczesniak
Liberia	Meralis Plaza-Toledo
Libya	Mowafa Taib
Madagascar	Thomas R. Yager
Malawi	Thomas R. Yager
Mali	Alberto A. Perez
Mauritania	Mowafa Taib
Mauritius	Philip A. Szczesniak
Morocco and Western Sahara	Mowafa Taib
Mozambique	Meralis Plaza-Toledo
Namibia	Philip A. Szczesniak
Niger	Alberto A. Perez
Nigeria	Thomas R. Yager
Oman	Philip A. Szczesniak
Qatar	Philip A. Szczesniak
Reunion	Philip A. Szczesniak
Rwanda	Thomas R. Yager
São Tomé & Principe	Meralis Plaza-Toledo

Africa and the Middle East—Continued

Saudi Arabia	Mowafa Taib
Senegal	Alberto A. Perez
Seychelles	Philip A. Szczesniak
Sierra Leone	Alberto A. Perez
Somalia	Philip A. Szczesniak
South Africa	Thomas R. Yager
South Sudan	Alberto A. Perez
Sudan	Mowafa Taib
Syria	Mowafa Taib
Tanzania	Thomas R. Yager
Togo	Alberto A. Perez
Tunisia	Mowafa Taib
Uganda	Thomas R. Yager
United Arab Emirates	Philip A. Szczesniak
Yemen	Mowafa Taib
Zambia	Philip A. Szczesniak
Zimbabwe	Philip A. Szczesniak

Asia and the Pacific

Afghanistan	Karine M. Renaud
Australia	Spencer D. Buteyn
Bangladesh	Keita F. DeCarlo
Bhutan	Keita F. DeCarlo
Brunei	Spencer D. Buteyn
Burma (Myanmar)	Ji Won Moon
Cambodia	Ji Won Moon
China	Ji Won Moon
Fiji	Spencer D. Buteyn
India	Karine M. Renaud
Indonesia	Jaewon Chung
Japan	Keita F. DeCarlo
Korea, North	Jaewon Chung
Korea, Republic of	Jaewon Chung
Laos	Ji Won Moon
Malaysia	Spencer D. Buteyn
Mongolia	Jaewon Chung
Nauru	Spencer D. Buteyn
Nepal	Keita F. DeCarlo
New Caledonia	Spencer D. Buteyn
New Zealand	Spencer D. Buteyn
Pakistan	Keita F. DeCarlo
Papua New Guinea	Spencer D. Buteyn
Philippines	Ji Won Moon
Singapore	Spencer D. Buteyn
Solomon Islands	Jaewon Chung
Sri Lanka	Keita F. DeCarlo
Taiwan	Jaewon Chung
Thailand	Ji Won Moon
Timor-Leste	Jaewon Chung
Vietnam	Ji Won Moon

Europe and Central Eurasia

Albania	Jaewon Chung
Armenia	Elena Safirova
Austria	Sinan Hastorun
Azerbaijan	Elena Safirova
Belarus	Elena Safirova
Belgium	Loyd M. Trimmer III
Bosnia and Herzegovina	Karine M. Renaud
Bulgaria	Karine M. Renaud
Croatia	Karine M. Renaud
Cyprus	Sinan Hastorun
Czechia	Loyd M. Trimmer III
Denmark, Faroe Islands, and Greenland	Joanna Goclawska
Estonia	Sinan Hastorun
Finland	Joanna Goclawska
France	Keita F. DeCarlo
Georgia	Elena Safirova
Germany	Elena Safirova
Greece	Sinan Hastorun
Hungary	Loyd M. Trimmer III
Iceland	Joanna Goclawska
Ireland	Joanna Goclawska
Italy	Loyd M. Trimmer III
Kazakhstan	Elena Safirova
Kosovo	Sinan Hastorun
Kyrgyzstan	Karine M. Renaud
Latvia	Sinan Hastorun
Lithuania	Sinan Hastorun
Luxembourg	Keita F. DeCarlo
Malta	Jaewon Chung
Moldova	Elena Safirova
Montenegro	Jaewon Chung
Netherlands	Loyd M. Trimmer III
North Macedonia	Karine M. Renaud
Norway	Joanna Goclawska
Poland	Joanna Goclawska
Portugal	Joanna Goclawska
Romania	Keita F. DeCarlo
Russia	Elena Safirova
Serbia	Karine M. Renaud
Slovakia	Keita F. DeCarlo
Slovenia	Loyd M. Trimmer III
Spain	Loyd M. Trimmer III
Sweden	Joanna Goclawska
Switzerland	Keita F. DeCarlo
Tajikistan	Karine M. Renaud
Turkey	Sinan Hastorun
Turkmenistan	Karine M. Renaud
Ukraine	Elena Safirova
United Kingdom	Jaewon Chung
Uzbekistan	Elena Safirova

North America, Central America, and the Caribbean

Aruba	Yadira Soto-Viruet
The Bahamas	Yadira Soto-Viruet
Belize	Jesse J. Inestroza
Canada	Jesse J. Inestroza
Costa Rica	Jesse J. Inestroza
Cuba	Yadira Soto-Viruet
Dominican Republic	Yadira Soto-Viruet
El Salvador	Jesse J. Inestroza
Guatemala	Jesse J. Inestroza
Haiti	Yadira Soto-Viruet
Honduras	Jesse J. Inestroza
Jamaica	Yadira Soto-Viruet
Mexico	Alberto A. Perez
Nicaragua	Jesse J. Inestroza
Panama	Jesse J. Inestroza
Trinidad and Tobago	Yadira Soto-Viruet

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Bolivia	Yolanda Fong-Sam
Brazil	Yolanda Fong-Sam
Chile	Yadira Soto-Viruet
Colombia	Jesse J. Inestroza
Ecuador	Jesse J. Inestroza
French Guiana	Yolanda Fong-Sam
Guyana	Yolanda Fong-Sam
Paraguay	Yadira Soto-Viruet
Peru	Yadira Soto-Viruet
Suriname	Yolanda Fong-Sam
Uruguay	Yadira Soto-Viruet
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Thomas R. Yager	(703) 648–7739	tyager@usgs.gov

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MINERAL COMMODITY SUMMARIES 2023

Abrasives
Aluminum
Antimony
Arsenic
Asbestos
Barite
Bauxite
Beryllium
Bismuth
Boron
Bromine
Cadmium
Cement
Cesium
Chromium
Clays
Cobalt
Copper
Diamond
Diatomite
Feldspar
Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

USGS
science for a changing world

Cover. Cross section of a superconducting electromagnet used in the Large Hadron Collider (LHC), the world's largest and most powerful particle accelerator, at the European Organization for Nuclear Research (CERN)'s accelerator complex. The superconducting properties of the magnet are achieved using copper-clad niobium-titanium (NbTi) coils, which surround the particle beam pipes. The particle beams travel in an ultrahigh vacuum at close to the speed of light, and huge forces are needed to guide them around the 27-kilometer-long ring of the LHC. NbTi magnets are used to bend, flatten, and focus the particle beams along the way. Photograph by Abraham J. Padilla, U.S. Geological Survey.

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MINERAL COMMODITY SUMMARIES 2023

Abrasives
Aluminum
Antimony
Arsenic
Asbestos
Barite
Bauxite
Beryllium
Bismuth
Boron
Bromine
Cadmium
Cement
Cesium
Chromium
Clays
Cobalt
Copper
Diamond
Diatomite
Feldspar
Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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KEY PUBLICATIONS

Minerals Yearbook—These annual publications review the mineral industries of the United States and of more than 180 other countries. They contain statistical data on minerals and materials and include information on economic and technical trends and developments and are available at https://www.usgs.gov/centers/national-minerals-information-center/publications. The three volumes that make up the Minerals Yearbook are volume I, Metals and Minerals; volume II, Area Reports—Domestic; and volume III, Area Reports—International.

Mineral Commodity Summaries—Published on an annual basis, this report is the earliest Government publication to furnish estimates covering nonfuel mineral industry data and is available at https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries. Data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for more than 90 individual minerals and materials.

Mineral Industry Surveys—These periodic statistical and economic reports are designed to provide timely statistical data on production, shipments, stocks, and consumption of significant mineral commodities and are available at https://www.usgs.gov/centers/national-minerals-information-center/mineral-industry-surveys. The surveys are issued monthly, quarterly, or at other regular intervals.

Materials Flow Studies—These publications describe the flow of minerals and materials from extraction to ultimate disposition to help better understand the economy, manage the use of natural resources, and protect the environment and are available at https://www.usgs.gov/centers/national-minerals-information-center/materials-flow.

Recycling Reports—These studies illustrate the recycling of metal commodities and identify recycling trends and are available at https://www.usgs.gov/centers/national-minerals-information-center/recycling-statistics-and-information.

Historical Statistics for Mineral and Material Commodities in the United States (Data Series 140)—This report provides a compilation of statistics on production, trade, and use of approximately 90 mineral commodities since as far back as 1900 and is available at https://www.usgs.gov/centers/national-minerals-information-center/historical-statistics-mineral-and-material-commodities.

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- All current and many past publications are available as downloadable Portable Document Format (PDF) files through https://www.usgs.gov/centers/national-minerals-information-center.

INTRODUCTION

Each mineral commodity chapter of the 2023 edition of the U.S. Geological Survey (USGS) Mineral Commodity Summaries (MCS) includes information on events, trends, and issues for each mineral commodity as well as discussions and tabular presentations on domestic industry structure, Government programs, tariffs, 5-year salient statistics, and world production, reserves, and resources. The MCS is the earliest comprehensive source of 2022 mineral production data for the world. More than 90 individual minerals and materials are covered by 2-page synopses.

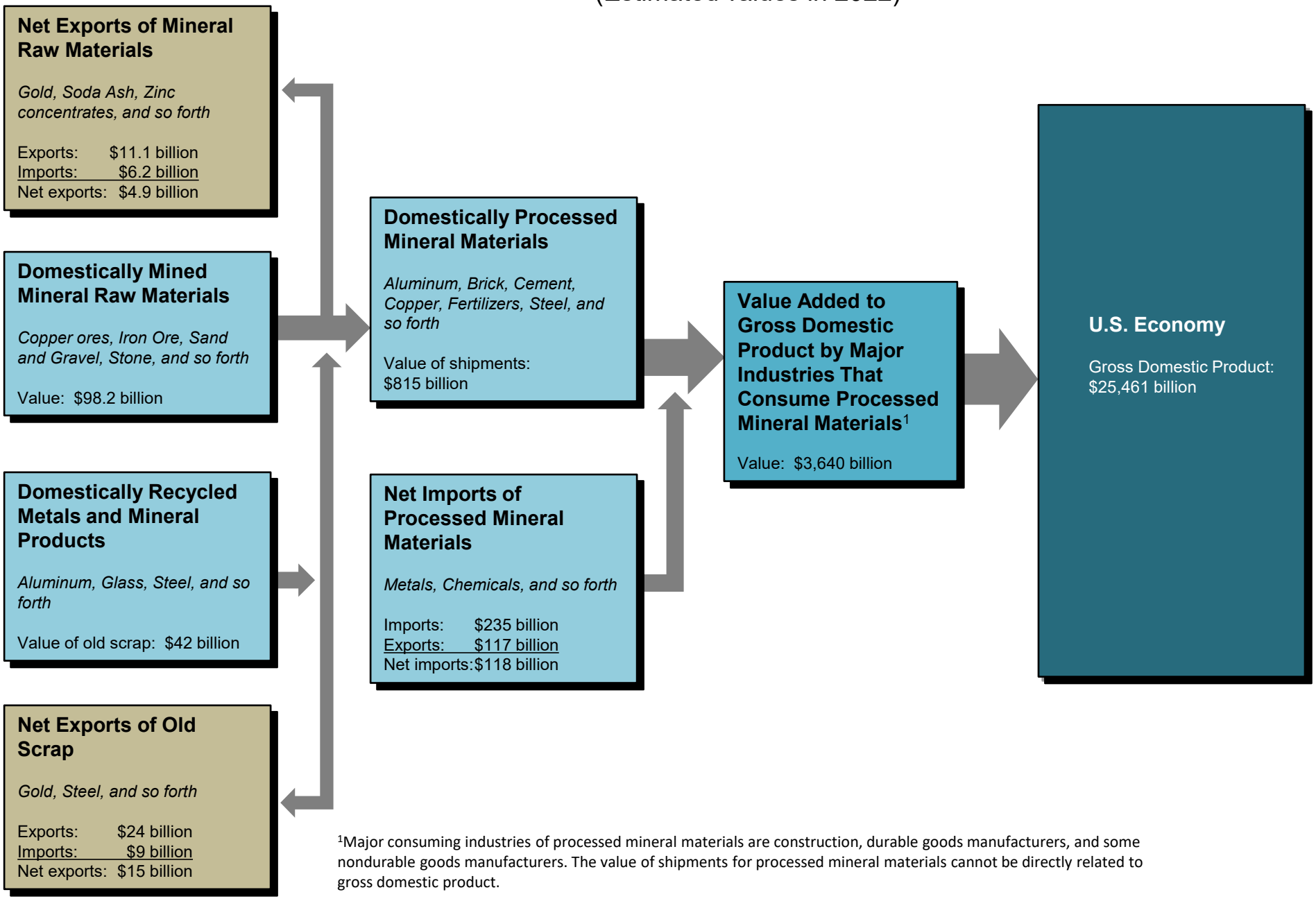
For mineral commodities for which there is a Government stockpile, detailed information concerning the stockpile status is included in the 2-page synopsis.

Abbreviations and units of measure and definitions of selected terms used in the report are in Appendix A and Appendix B, respectively. Reserves and resources information is in Appendix C, which includes “Part A—Resource and Reserve Classification for Minerals” and “Part B—Sources of Reserves Data.” A directory of USGS minerals information country specialists and their responsibilities is in Appendix D.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the MCS 2023 are welcomed.

Figure 1.—The Role of Nonfuel Mineral Commodities in the U.S. Economy

(Estimated values in 2022)



[1]Major consuming industries of processed mineral materials are construction, durable goods manufacturers, and some nondurable goods manufacturers. The value of shipments for processed mineral materials cannot be directly related to gross domestic product.

Sources: U.S. Geological Survey and U.S. Department of Commerce.

SIGNIFICANT EVENTS, TRENDS, AND ISSUES

In 2022, the estimated total value of nonfuel mineral production in the United States was $98.2 billion, an increase of 4% from the revised total of $94.6 billion in 2021. The estimated value of metals production decreased by 6% to $34.7 billion from a revised total of $36.9 billion in 2021. The total value of industrial minerals production was $63.5 billion, a 10% increase from that in 2021 (table 1). Of this total, $31.4 billion was construction aggregates production (construction sand and gravel and crushed stone). Crushed stone was the leading nonfuel mineral commodity in 2022 with a production value of $21 billion and accounted for 21% of the total value of U.S. nonfuel mineral production.

Increases in production of nonfuel mineral commodities and increases in prices of some industrial minerals and minerals used to make batteries contributed to the total value of nonfuel mineral production increasing in 2022. For the metals sector, there was reduced production for several metals owing to reduced ore grades and weather-related issues. Gold, iron ore, magnesium metal, palladium, platinum, silver, and titanium had some of the largest percentage decreases in production value. For the industrial minerals sector, increased construction and materials for energy and infrastructure projects as well as other manufacturing sectors led to increased production value. The largest percentage increases in production value were in barite, bromine, feldspar, helium, iodine, lithium, potash, pumice, and sand and gravel (industrial).

The U.S. Geological Survey (USGS) published the “2022 Final List of Critical Minerals” in the Federal Register (87 FR 10381). The 2022 list of critical minerals, which revised the U.S. critical minerals list (CML) published in 2018 (83 FR 23295), included 50 mineral commodities instead of 35 mineral commodities or mineral groups. There were also many initiatives, projects, and legislation passed that focused on securing American supply chains and supporting domestic production projects. Please refer to the “U.S. Critical Minerals Update” section for more details.

Foreign Trade

Presidential Proclamation 10328 of December 27, 2021, established a tariff rate quota for member countries of the European Union (EU) and provided for quarterly limits on imports of certain steel commodities that could be imported without being subject to the 25% ad valorem tariffs imposed in 2018 under section 232 of the Trade Expansion Act of 1962. Additionally, the proclamation authorized the U.S. Department of Commerce to renew all EU exclusions utilized in fiscal year 2021 for a period of 2 years from the date of the proclamation.

In February 2022, it was announced that the United States and Japan had reached an agreement for the quota of steel that could be imported without being subject to the 25% ad valorem tariffs under section 232 of the Trade Expansion Act of 1962 that were put in place in 2018. The additional 10% ad valorem tariff on aluminum remained in place.

In March 2022, it was announced that the United States and the United Kingdom reached an agreement on import quotas of steel and aluminum products that would not be subject to the ad valorem tariffs. However, certain requirements had to be met including a certificate of analysis and the imported items could not contain primary material from Belarus, China, or Russia.

In February 2022, Executive Order 14065 ”Blocking Property of Certain Persons and Prohibiting Certain Transactions With Respect to Continued Russian Efforts to Undermine the Sovereignty and Territorial Integrity of Ukraine” was issued outlining certain prohibitions on investments; exportation and importation of goods, services, or technology to or from covered regions; and financing.

In September 2022, the Office of the United States Trade Representative (USTR) published a Federal Register notice (87 FR 55073) that announced that the USTR was keeping the additional tariffs placed on imports from China while the USTR was conducting its 4-year review of the actions imposed under section 301(b) of the Trade Act of 1974, (19 U.S.C. 2411, as amended): China’s acts, policies, and practices related to technology transfer, intellectual property, and innovation. The decision incorporated public comments that had been received from a prior notice published in May soliciting input on whether to retain or terminate the additional 25% ad valorem duty for products imported from China (Lists 1, 2, and 3) and an additional tariff for List 4 items that had been put in place in July and August 2018. In October, the USTR issued a Federal Register notice (87 FR 62914) seeking public comment on the effectiveness of the actions taken under section 301 in achieving the objectives and any other actions that could be taken.

U.S. Production and Consumption

As shown in figure 1, minerals remained fundamental to the U.S. economy, contributing to the real gross domestic product at several levels, including mining, processing, and manufacturing finished products. The estimated value of nonfuel minerals produced at mines in the United States in 2022 was $98.2 billion. The value of net exports of mineral raw materials decreased by 4% to $4.9 billion from a revised $5.1 billion in 2021. The value of net exports of old scrap decreased to $15 billion. The value of domestically recycled products totaled $42 billion, and iron and steel scrap contributed $18 billion to that total. Domestic raw materials and domestically recycled materials were used to produce mineral materials worth $810 billion. These mineral materials as well as $118 billion of imports of processed mineral materials were, in turn, consumed by downstream industries creating an estimated value of $3.64 trillion in 2022, a 9% increase from that in 2021.

Figure 2 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2022, imports made up more than one-half of the U.S. apparent consumption for 51 nonfuel mineral commodities, and the United States was 100% net import reliant for 15 of those. Of the 50 mineral commodities identified in the “2022 Final List of Critical Minerals,” the United States was 100% net import reliant for 12, and an additional 31 critical mineral commodities (including 14 lanthanides, which are listed under rare earths) had a net import reliance greater than 50% of apparent consumption. Additional information regarding critical minerals in the United States can be found in the “U.S. Critical Minerals Update” section.

Figure 3 shows the countries that were sources of nonfuel mineral commodities for which the United States was greater than 50% net import reliant in 2022 and the number of mineral commodities for which each highlighted country was a leading supplier. China and Canada supplied the largest number of these nonfuel mineral commodities. The countries that were the leading sources of imported mineral commodities with greater than 50% net import reliance were: China, 26 mineral commodities; Canada, 20 mineral commodities; Germany, 14 mineral commodities; Brazil, 11 mineral commodities; South Africa, 10 mineral commodities; and Mexico, 9 mineral commodities.

The estimated value of U.S. metal mine production in 2022 was $34.7 billion, 6% lower than the revised value in 2021 (table 1). In 2022, the capacity utilization for the metals mining industry was 61%, less than the 63% capacity utilization in 2021 (table 2). Principal contributors to the total value of metal mine production in 2022 were copper, 33%; gold, 28%; iron ore, 15%; zinc, 9%; and molybdenum, 5%.

The estimated value of U.S. industrial minerals production in 2022, including construction aggregates, was $63.5 billion, about 10% more than the revised value of 2021 (table 1). In 2022, the capacity utilization for the nonmetallic minerals mining industry was 88%, slightly more than the 87% capacity utilization in 2021 (table 2). The value of industrial minerals production in 2022 was dominated by crushed stone, 33%; cement (masonry and portland), 18%; construction sand and gravel, 16%; and industrial sand and gravel, 9%.

In 2022, U.S. production of 13 mineral commodities was valued at more than $1 billion each. These commodities were, in decreasing order of value, crushed stone, cement, copper, construction sand and gravel, gold, industrial sand and gravel, iron ore, zinc, salt, lime, phosphate rock, molybdenum, and soda ash.

In 2022, 9 States had more than $3 billion worth of publishable nonfuel mineral commodities production value and another 12 States had more than $1.5 billion (fig. 4).

The top 10 ranked States (based on total value including withheld values) were, in descending order of production value, Arizona, Nevada, Texas, California, Minnesota, Alaska, Florida, Utah, Michigan, and Missouri (table 3).

The West region was the leading region in the production of the metals and metallic minerals with an estimated value of $27 billion in 2022 (fig. 5).

The South region was the leading region in the production of other industrial minerals (excludes construction sand and gravel and crushed stone production) with an estimated value of $13.2 billion in 2022 (fig. 6).

In 2022, there were seven States that produced more than $1 billion worth of crushed stone. These States were, in descending order of production value, Texas, Florida, Pennsylvania, North Carolina, Georgia, Virginia, and Tennessee. There were another nine States with more than $500 million worth of crushed stone production (fig. 7).

Construction sand and gravel was produced in every State. California was the only State that produced more than $1 billion worth of construction sand and gravel in 2022 but three other States, in descending order of production value, Texas, Arizona, and Washington, produced more than $500 million. Florida, Colorado, New York, Ohio, Utah, and Michigan, in descending order of production value, were the other top 10 producing States (fig. 8).

The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) is responsible for the operational oversight of the National Defense Stockpile (NDS) of strategic and critical materials. Managing the security, environmentally sound stewardship, and ensuring the readiness of all NDS stocks is the mission of the DLA Strategic Materials. The NDS currently contains 47 unique commodities stored at nine locations within the continental United States. In fiscal year 2022, the NDS added one material along with additional quantities of eight other materials and approximately $103 million of excess materials were sold. Revenue from the Stockpile Sales Program fund the operation of the NDS and the acquisition of new stocks. For reporting purposes, NDS stocks are categorized as held in reserve or available for sale. The majority of stocks are held in reserve. Additional detailed information can be found in the “Government Stockpile” sections in the mineral commodity chapters that follow. Under the authority of the Defense Production Act of 1950 (Public Law 81–774), the USGS advises the DLA Strategic Materials on acquisitions and disposals of NDS mineral materials.

Figure 2.—2022 U.S. Net Import Reliance[1]

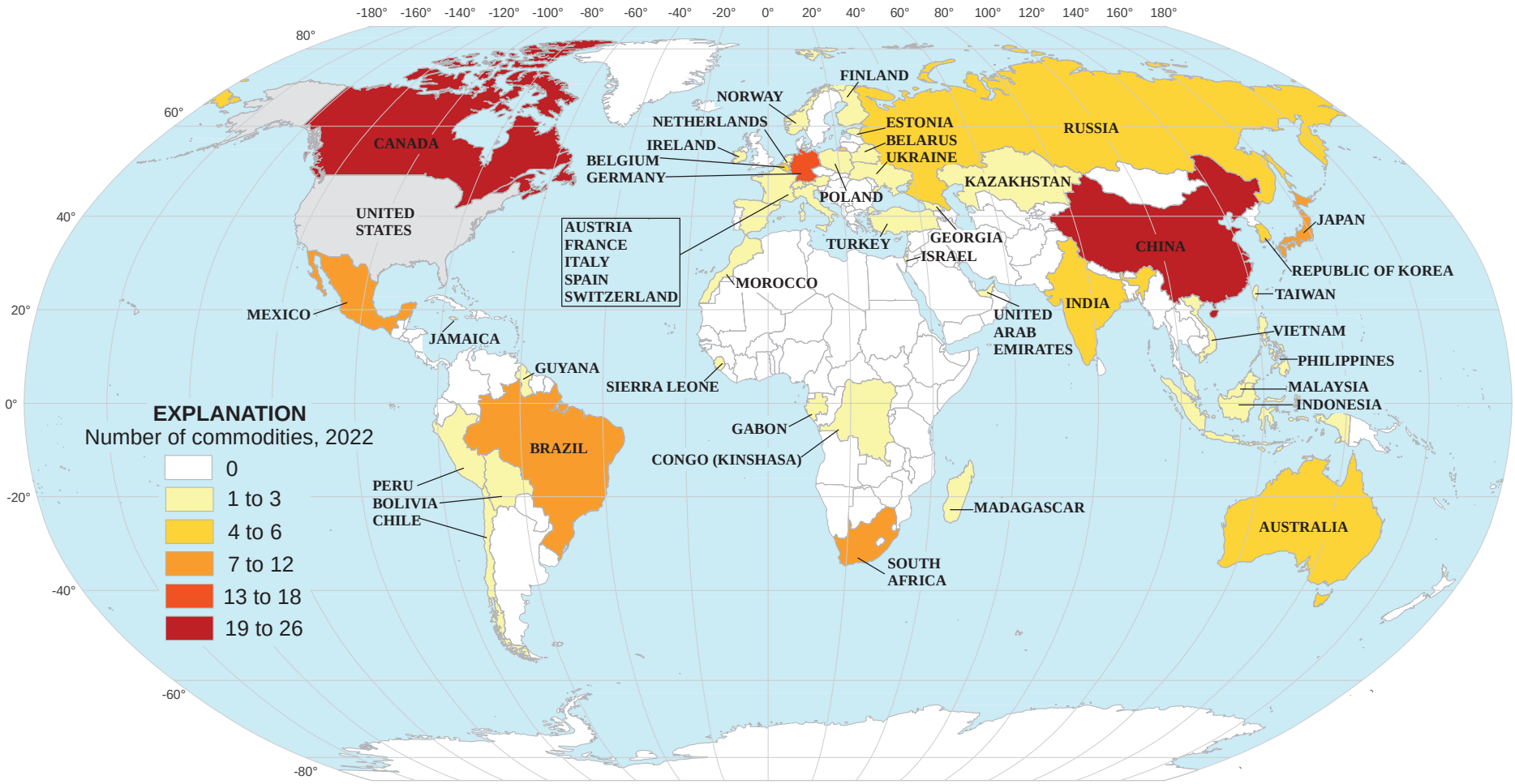
Commodity	Net import reliance as a percentage of apparent consumption	Major import sources (2018–21)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany
FLUORSPAR	100	Mexico, Vietnam, South Africa, Canada
GALLIUM	100	China, Germany, Japan, Ukraine
GRAPHITE (NATURAL)	100	China, Mexico, Canada, Madagascar
INDIUM	100	Republic of Korea, Canada, China, France
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, Austria
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	Germany
SCANDIUM	100	Europe, China, Japan, Philippines
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
YTTRIUM	100	China, Germany, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
BISMUTH	96	China, Republic of Korea, Mexico, Belgium
NEPHELINE SYENITE	>95	Canada
RARE EARTHS,[3] compounds and metals	>95	China, Malaysia, Estonia, Japan
TITANIUM, sponge metal	>95	Japan, Kazakhstan, Ukraine
POTASH	94	Canada, Russia, Belarus
DIAMOND (INDUSTRIAL), stones	89	South Africa, Congo (Kinshasa), India, Sierra Leone
IRON OXIDE PIGMENTS, natural and synthetic	87	China, Germany, Brazil, Canada
ANTIMONY, metal and oxide	83	China, Belgium, India
CHROMIUM, all forms	83	South Africa, Kazakhstan, Russia, Germany
STONE (DIMENSION)	82	Brazil, China, Italy, India
PEAT	81	Canada
TITANIUM MINERAL CONCENTRATES	81	South Africa, Australia, Madagascar, Canada
ABRASIVES, silicon carbide	79	China, Brazil, Netherlands, South Africa
TIN, refined	77	Peru, Indonesia, Bolivia, Malaysia
COBALT	76	Norway, Canada, Finland, Japan
ZINC, refined	76	Canada, Mexico, Peru, Spain
ABRASIVES, fused aluminum oxide	>75	China, Canada, Brazil, Austria
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Brazil, Guyana, Turkey
TELLURIUM	>75	Canada, Germany, China, Philippines
GARNET (INDUSTRIAL)	69	South Africa, China, India, Australia
RHENIUM	69	Chile, Canada, Germany, Kazakhstan
SILVER	69	Mexico, Canada, Poland, Chile
PLATINUM	66	South Africa, Germany, Switzerland, Italy
DIAMOND (INDUSTRIAL), bort, grit, dust, and powder	62	China, Republic of Korea, Ireland, Russia
ALUMINA	59	Brazil, Australia, Jamaica, Canada
NICKEL	56	Canada, Norway, Australia, Finland
ALUMINUM	54	Canada, United Arab Emirates, Russia, China
VANADIUM	54	Canada, China, Brazil, South Africa
MAGNESIUM COMPOUNDS	53	China, Israel, Canada, Brazil
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
MAGNESIUM METAL	>50	Canada, Israel, Mexico, Taiwan
SELENIUM	>50	Philippines, Mexico, Germany, China
TUNGSTEN	>50	China, Germany, Bolivia, Vietnam
ZIRCONIUM, ores and concentrates	<50	South Africa, Senegal, Australia, Russia
SILICON, metal and ferrosilicon	45	Russia, Brazil, Canada, Norway
LEAD, refined	42	Canada, Mexico, Republic of Korea
COPPER, refined	41	Chile, Canada, Mexico
FELDSPAR	39	Turkey, Mexico
SALT	29	Chile, Canada, Mexico, Egypt
PERLITE	28	Greece, China, Mexico
PALLADIUM	26	Russia, South Africa, Italy, Germany
LITHIUM	>25	Argentina, Chile, China, Russia
BROMINE	<25	Israel, Jordan, China
CADMIUM, unwrought	<25	Australia, Germany, China, Peru
MICA (NATURAL), scrap and flake	24	Canada, China, India, Finland
CEMENT	21	Canada, Turkey, Greece, Mexico
VERMICULITE	20	South Africa, Brazil

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (abrasives, metallic; boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum; rare earths, mineral concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zinc, ores and concentrates) or less than 20% net import reliant (beryllium; gypsum; iron and steel; iron and steel slag; lime; nitrogen (fixed)—ammonia; phosphate rock; pumice and pumicite; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]Listed in descending order of import share.

[3]Data include lanthanides.

Figure 3.—Major Import Sources of Nonfuel Mineral Commodities for Which the United States was Greater Than 50% Net Import Reliant in 2022



Source: U.S. Geological Survey

Table 1.—U.S. Mineral Industry Trends

	2018	2019	2020	2021	2022[e]
Total mine production (million dollars):					
Metals	28,000	26,900	27,700	36,900	34,700
Industrial minerals	56,000	56,000	53,000	57,700	63,500
Coal	27,200	25,500	16,800	21,000	21,300
Employment (thousands of workers):					
Coal mining, all employees	52	51	40	37	38
Nonfuel mineral mining, all employees	140	140	136	138	140
Chemicals and allied products, production workers	546	558	537	540	570
Stone, clay, and glass products, production workers	311	312	296	298	310
Primary metal industries, production workers	295	301	272	269	280
Average weekly earnings of workers (dollars):					
Coal mining, all employees	1,546	1,617	1,518	1,619	1,800
Chemicals and allied products, production workers	1,071	1,065	1,065	1,104	1,100
Stone, clay, and glass products, production workers	945	968	981	1,017	1,100
Primary metal industries, production workers	1,038	1,026	1,008	1,074	1,200

[e]Estimated.

Sources: U.S. Geological Survey, U.S. Department of Energy, and U.S. Department of Labor.

Table 2.—U.S. Mineral-Related Economic Trends

	2018	2019	2020	2021	2022[e]
Gross domestic product (billion dollars)	20,533	21,381	21,061	23,315	25,461
Industrial production (2017=100):					
Total index:	103	102	95	100	100
Manufacturing:	101	100	93	99	100
Nonmetallic mineral products	100	101	97	98	100
Primary metals:	103	97	86	97	97
Iron and steel	103	95	86	102	96
Aluminum	106	102	90	104	110
Nonferrous metals (except aluminum)	102	102	94	95	110
Chemicals	99	97	95	100	100
Mining:	113	121	103	106	110
Coal	98	92	69	75	78
Oil and gas extraction	116	130	122	122	130
Metals	98	96	92	91	88
Nonmetallic minerals	104	106	100	105	110
Capacity utilization (percent):					
Total industry:	79	78	73	77	80
Mining:	87	87	72	81	87
Metals	70	68	66	63	61
Nonmetallic minerals	89	90	83	87	88
Housing starts (thousands)	1,247	1,291	1,395	1,605	1,570
Light vehicle sales (thousands)	17,225	16,961	14,472	14,947	13,800
Highway construction, value, put in place (billion dollars)	91	99	103	101	110

[e]Estimated.

Sources: U.S. Department of Commerce and Federal Reserve Board.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Mineral Commodities Produced in 2022[p, 1, 2]

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Alabama	$1,920	17	1.96	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Alaska	4,510	6	4.59	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	10,100	1	10.31	Cement, copper, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Arkansas	1,100	29	1.12	Bromine, cement, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California[6]	5,610	4	5.71	Boron minerals, cement, rare earths, sand and gravel (construction), stone (crushed).
Colorado	1,870	19	1.91	Cement, gold, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Connecticut	194	43	0.20	Sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[7]	25	50	0.03	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida[6, 7]	2,810	7	2.86	Cement, clay (attapulgite and kaolin), phosphate rock, sand and gravel (construction), stone (crushed).
Georgia[6]	2,320	12	2.37	Cement, clay (kaolin and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Hawaii	156	44	0.16	Sand and gravel (construction), stone (crushed).
Idaho	371	33	0.38	Lead, phosphate rock, sand and gravel (construction), silver, zinc.
Illinois[7]	1,250	25	1.27	Cement, magnesium compounds, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Indiana	1,380	26	1.40	Cement, lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa	846	34	0.86	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[7]	1,170	27	1.19	Cement, helium (Grade-A), salt, sand and gravel (construction), stone (crushed).
Kentucky[7]	806	28	0.82	Cement, clay (common clay), lime, sand and gravel (construction), stone (crushed).
Louisiana	1,030	31	1.05	Clay (common clay), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[7]	100	47	0.10	Cement, peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[7]	414	35	0.42	Cement, sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[7]	206	41	0.21	Clay (common clay), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	3,360	9	3.42	Cement, iron ore, magnesium compounds, nickel sulfide concentrates, salt.
Minnesota[7]	4,780	5	4.86	Iron ore, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Mississippi	225	42	0.23	Clay (ball clay, bentonite, common clay, montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	3,150	10	3.21	Cement, lead, lime, sand and gravel (industrial), stone (crushed).
Montana	1,600	21	1.63	Copper, molybdenum mineral concentrates, palladium, platinum, sand and gravel (construction).

See footnotes at end of table.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Mineral Commodities Produced in 2022[p, 1, 2]—Continued

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Nebraska[7]	$256	39	0.26	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	8,930	2	9.09	Copper, diatomite, gold, and sand gravel (construction), stone (crushed).
New Hampshire[7]	135	45	0.14	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	425	38	0.43	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	1,470	24	1.49	Cement, copper, potash, sand and gravel (construction), stone (crushed).
New York	1,950	15	1.98	Cement, salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina	1,900	18	1.93	Clay (common clay and fire clay), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[7]	105	48	0.11	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Ohio[7]	1,490	14	1.52	Cement, lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	1,030	30	1.05	Cement, iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon	693	36	0.70	Cement, diatomite, pumice and pumicite, sand and gravel (construction), stone (crushed).
Pennsylvania[7]	2,060	13	2.09	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Rhode Island[7]	88	49	0.09	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina[7]	1,160	23	1.18	Cement, gold, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Dakota	475	37	0.48	Cement, gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,940	16	1.97	Cement, sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	8,030	3	8.17	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	3,600	8	3.66	Copper, gold, potash, salt, sand and gravel (construction).
Vermont[7]	136	46	0.14	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,530	22	1.56	Cement, kyanite, lime, sand and gravel (construction), stone (crushed).
Washington	901	32	0.92	Cement, diatomite, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
West Virginia[7]	204	40	0.21	Cement, lime, salt, sand and gravel (industrial), stone (crushed).
Wisconsin[7]	1,720	20	1.75	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	2,480	11	2.53	Cement, clay (bentonite and common clay), helium (Grade-A), sand and gravel (construction), soda ash.
Undistributed	4,210	XX	4.29	XX
Total	98,200	XX	100.00	

[p]Preliminary. XX Not applicable.

[1]Includes data available through December 14, 2022.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Rank based on total, unadjusted State values.

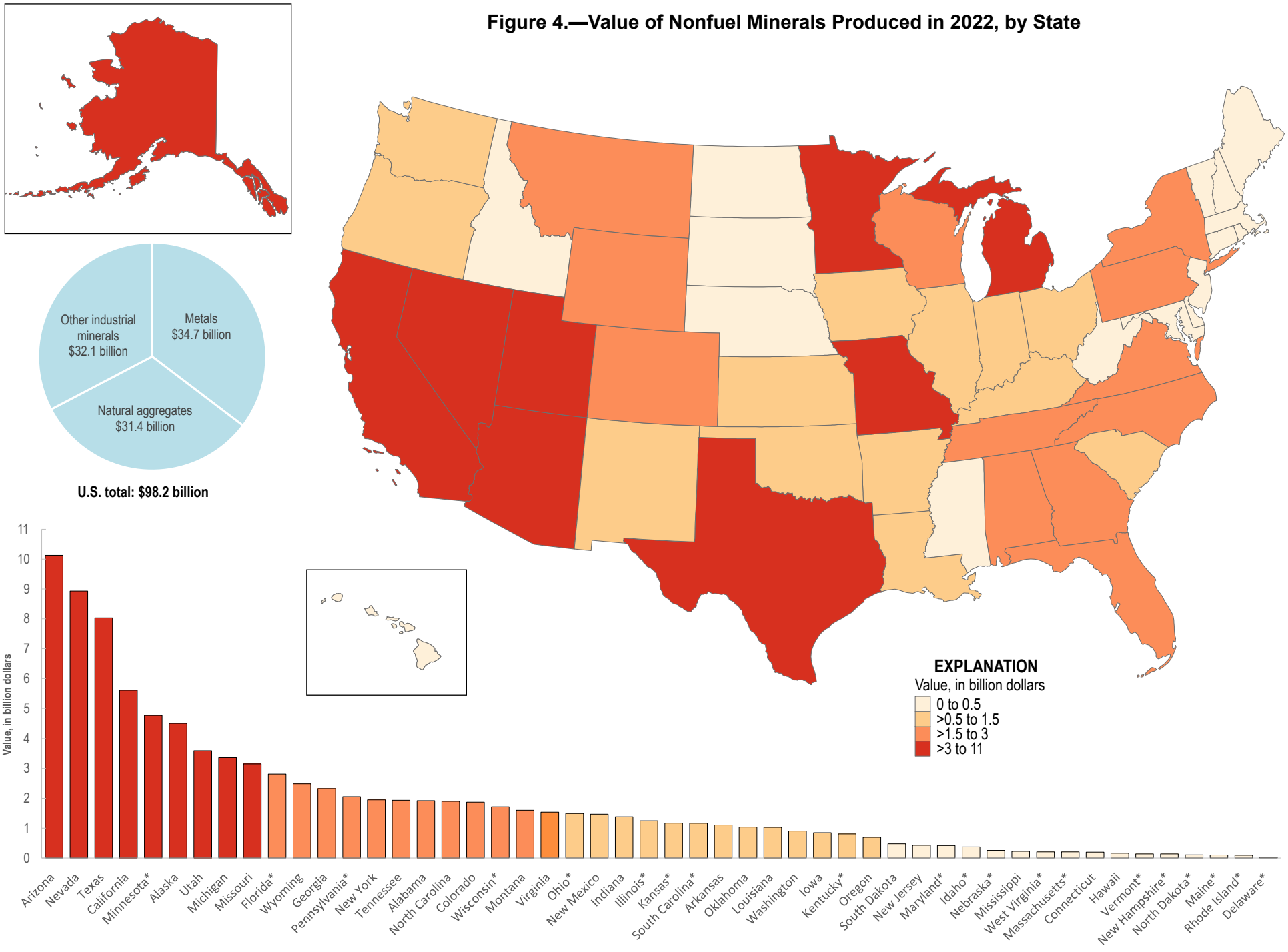
[4]"Percent of U.S. total" calculated to two decimal places.

[5]Listed in alphabetical order.

[6]California also produces significant quantities of titanium mineral concentrates and Florida and Georgia produce significant quantities of rare earths and titanium and zirconium mineral concentrates. Breakdown by State is not included in State total to avoid disclosure of company proprietary data.

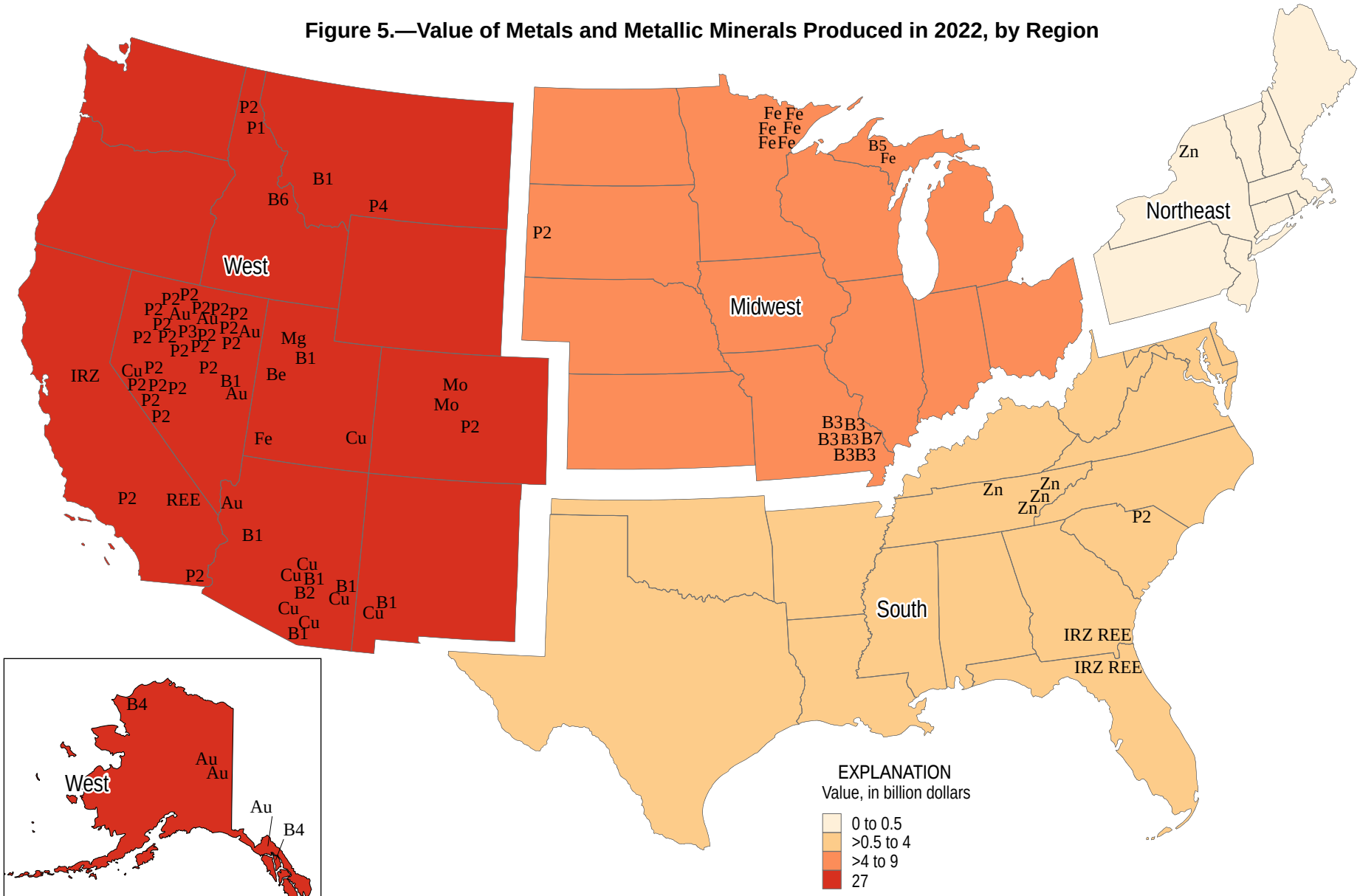
[7]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed."

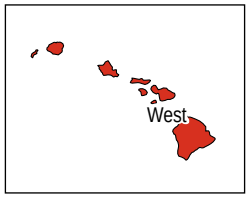
Figure 4.—Value of Nonfuel Minerals Produced in 2022, by State



*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

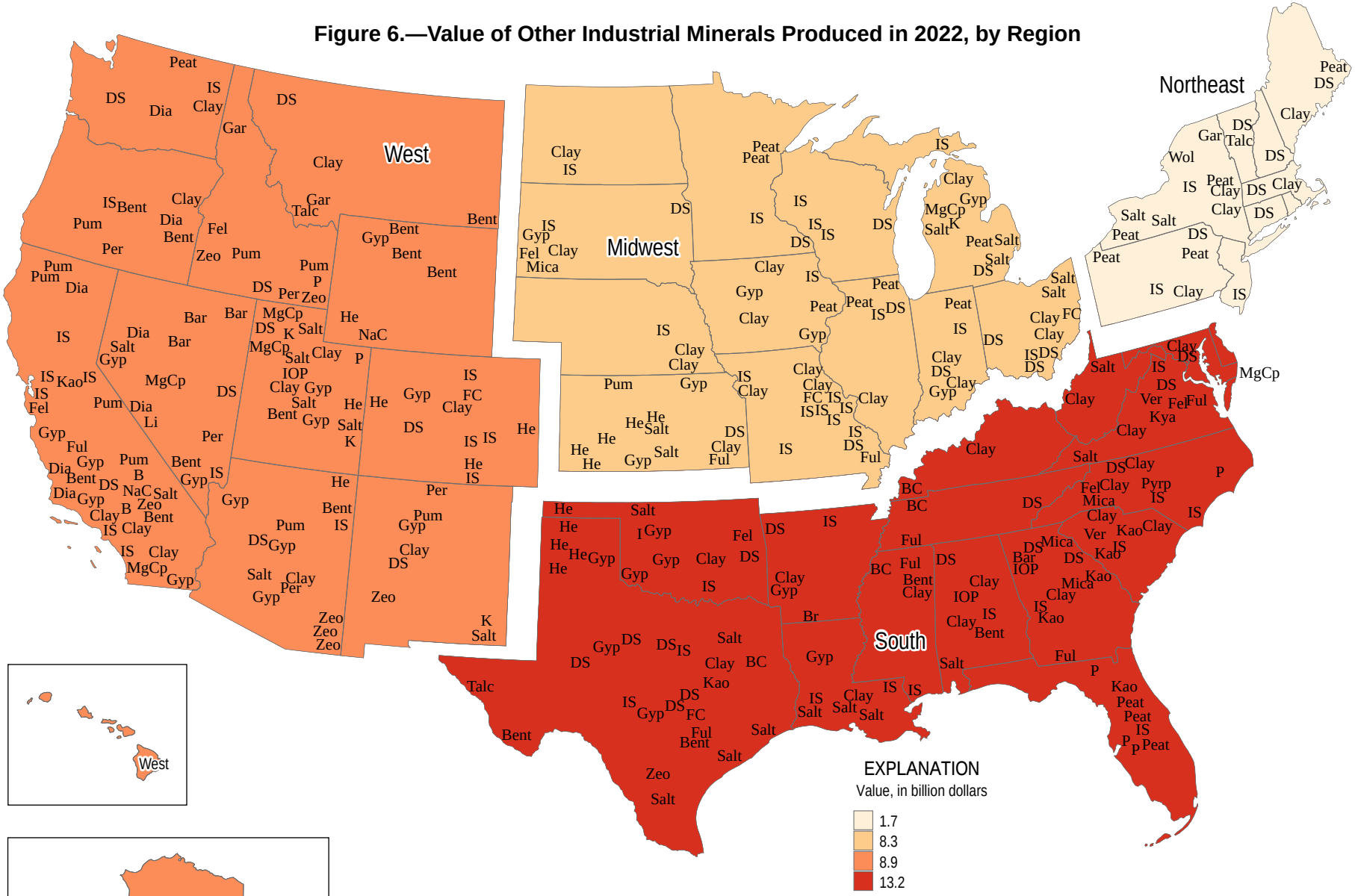
Figure 5.—Value of Metals and Metallic Minerals Produced in 2022, by Region





Au	Gold	B6	Cobalt, copper, gold	Mg	Magnesium	REE	Rare-earth elements
B1	Copper ± molybdenum ± gold and silver ± rhenium	B7	Cobalt, copper, nickel	Mo	Molybdenum	Zn	Zinc
B2	Copper ± silver	Be	Beryllium	P1	Silver ± base metals ± gold		
B3	Lead and zinc ± copper ± silver	Cu	Copper	P2	Gold and silver		
B4	Silver ± zinc ± lead and gold	Fe	Iron Ore	P3	Gold and silver ± base metals		
B5	Nickel, copper, cobalt ± gold ± platinum ± palladium	IRZ	Ilmenite, rutile, and zircon	P4	Platinum and palladium ± gold ± silver ± nickel		

Figure 6.—Value of Other Industrial Minerals Produced in 2022, by Region



B	Borates	DS	Dimension stone	I	Iodine	MgCp	Magnesium Compounds	Pyrp	Pyrophyllite
Bar	Barite	FC	Fire clay	IOP	Iron oxide pigments	Mica	Mica	Salt	Salt
BC	Ball clay	Fel	Feldspar	IS	Industrial sand	NaC	Soda ash	Talc	Talc
Bent	Bentonite	Ful	Fuller's earth	K	Potash	P	Phosphate rock	Ver	Vermiculite
Br	Bromine	Gar	Garnet	Kao	Kaolin	Peat	Peat	Wol	Wollastonite
Clay	Common clay	Gyp	Gypsum	Kya	Kyanite	Per	Perlite	Zeo	Zeolites
Dia	Diatomite	He	Helium	Li	Lithium	Pum	Pumice		

Figure 7.—Value of Crushed Stone Produced in 2022, by State

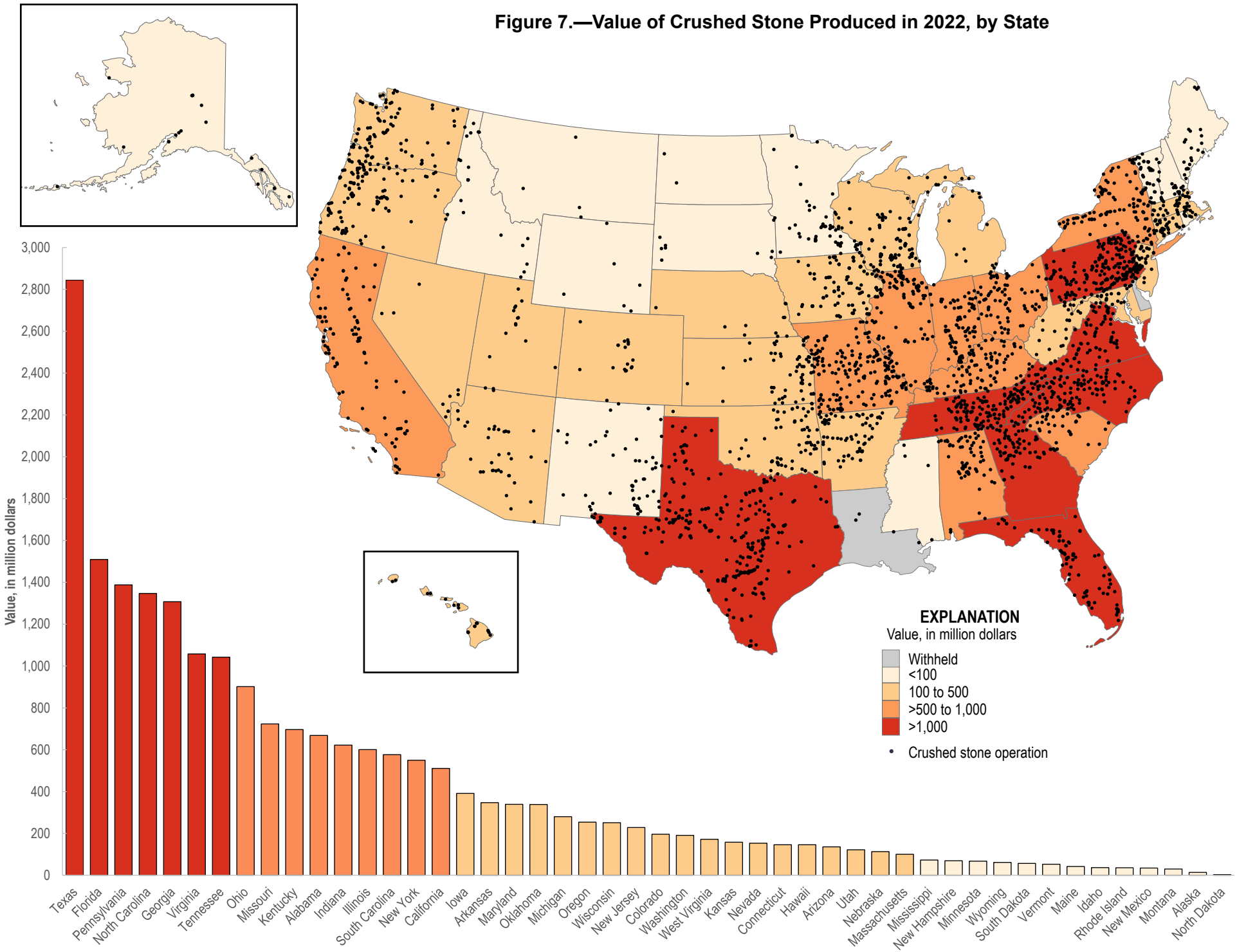


Figure 8.—Value of Construction Sand and Gravel Produced in 2022, by State

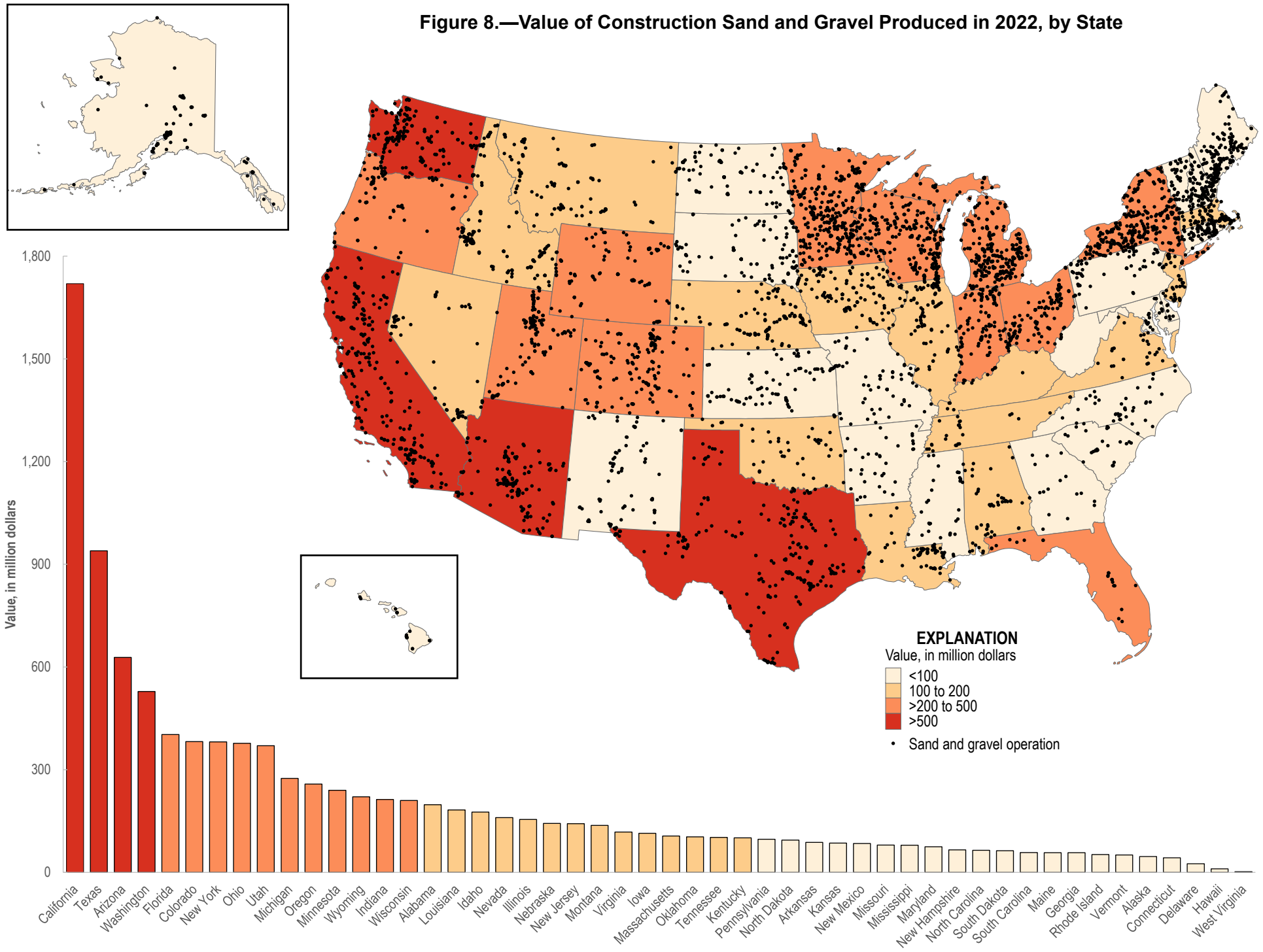


Table 4.—The 2022 U.S. Critical Minerals List[1]

Critical mineral	Applications
Aluminum	Metallurgy and many sectors of the economy.
Antimony	Flame retardants and lead-acid batteries.
Arsenic	Semiconductors.
Barite	Hydrocarbon production.
Beryllium	Aerospace and defense.
Bismuth	Medical, metallurgy, and atomic research.
Cerium[2]	Catalytic converters, ceramics, glass, metallurgy, and polishing compounds.
Cesium	Research and development.
Chromium	Metallurgy.
Cobalt	Batteries and metallurgy.
Dysprosium[2]	Data storage devices, lasers, and permanent magnets.
Erbium[2]	Fiber optics, glass colorant, lasers, and optical amplifiers.
Europium[2]	Nuclear control rods and phosphors.
Fluorspar	Cement, industrial chemical, and metallurgy.
Gadolinium[2]	Medical imaging, metallurgy, and permanent magnets.
Gallium	Integrated circuits and optical devices.
Germanium	Defense and fiber optics.
Graphite	Batteries, fuel cells, and lubricants.
Hafnium	Ceramics, nuclear control rods, and metallurgy.
Holmium[2]	Lasers, nuclear control rods, and permanent magnets.
Indium	Liquid crystal displays.
Iridium[3]	Anode coatings for electrochemical processes and chemical catalyts.
Lanthanum[2]	Batteries, catalysts, ceramics, glass, and metallurgy.
Lithium	Batteries.
Lutetium[2]	Cancer therapies, electronics, and medical imaging.
Magnesium	Metallurgy.
Manganese	Batteries and metallurgy.
Neodymium[2]	Catalysts, lasers, and permanent magnets.
Nickel	Batteries and metallurgy.
Niobium	Metallurgy.
Palladium[3]	Catalytic converters and catalysts.
Platinum[3]	Catalytic converters and catalysts.
Praseodymium[2]	Aerospace alloys, batteries, ceramics, colorants, and permanent magnets.
Rhodium[3]	Catalytic converters, catalysts, and electrical components.
Rubidium	Research and development.
Ruthenium[3]	Catalysts, electronic components, and computer chips.
Samarium[2]	Cancer treatments, nuclear, and permanent magnets.
Scandium	Ceramics, fuel cells, and metallurgy.
Tantalum	Capacitors and metallurgy.
Tellurium	Metallurgy, solar cells, and thermoelectric devices.
Terbium[2]	Fiber optics, lasers, permanent magnets, and solid state devices.
Thulium[2]	Lasers and metallurgy.
Tin	Metallurgy.
Titanium	Metallurgy and pigments.
Tungsten	Metallurgy.
Vanadium	Batteries, catalysts, and metallurgy.
Ytterbium[2]	Catalysts, lasers, metallurgy, and scintillators.
Yttrium	Catalysts, ceramics, lasers, metallurgy, and phosphors.
Zinc	Metallurgy.
Zirconium	Metallurgy and nuclear.

[1]The 2022 Final List of Critical Minerals published February 24, 2022 by U.S. Geological Survey (87 FR 10381).

[2]Included in the Rare Earths chapter.

[3]Included in the Platinum-Group Metals chapter.

U.S. CRITICAL MINERALS UPDATE

The U.S. Critical Minerals List

On February 24, 2022, pursuant to section 7002 of the Energy Act of 2020 (Public Law 116–260) and using the definition of "critical mineral" and the criteria specified therein, the U.S. Geological Survey (USGS) published the "2022 Final List of Critical Minerals" in the Federal Register (87 FR 10381). The 2022 list of critical minerals, which revised the U.S. critical minerals list (CML) published in 2018 (83 FR 23295), included 50 mineral commodities instead of 35 mineral commodities or mineral groups (table 4). The changes in the 2022 CML from the prior 2018 CML were the addition of nickel and zinc, listing out individual platinum-group metals and rare-earth elements, and the removal of helium, potash, rhenium, strontium, and uranium. The CML is to be updated at least every 3 years and revised as necessary consistent with available data.

On May 7, 2021, Open-File Report 2021–1045, "Methodology and Technical Input for the 2021 Review and Revision of the U.S. Critical Minerals List" was published by the USGS as required by section 7002 of title VII of the Energy Act of 2020. The report documented the updated evaluation methodology and the resultant updated draft list of minerals recommended for inclusion in the CML. Uranium was excluded by its definition as mineral fuels in the Mining and Minerals Policy Act of 1970 [30 U.S.C. 21(a)].

On November 9, 2021, a proposed revised U.S. CML was published in the Federal Register (86 FR 62199). Following adjudication of public comments, the new CML was published in February 2022 (87 FR 10381).

Background

A series of actions by the Government in recent years have addressed domestic supply chain vulnerabilities, beginning with Executive Order 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," which was issued on December 26, 2017, and initiated a whole-of-government call to action to identify critical minerals and develop a strategy to address U.S. supply-chain vulnerabilities. Subsequently, there have been additional actions including: (1) the 2018 CML was published by the USGS; (2) the 2019 Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals was published by the Department of Commerce with interagency input; (3) several Presidential determinations were issued directing the use of Defense Production Act (DPA) Title III authorities to strengthen the U.S. industrial base for rare-earth magnets; (4) Executive Order 13953, Addressing the Threat to the Domestic Supply Chain Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries was issued; and (5) the Energy Act of 2020 was passed by Congress and signed into law.

Most recently, actions were taken to accomplish the objectives outlined in Executive Order 14017, "America's Supply Chains," issued in February 2021, that directed the Executive Branch agencies to launch an immediate 100-day review and strategy development process to identify and address vulnerabilities in the supply chains of four key product sectors: semiconductors manufacturing and advanced packaging, high-capacity batteries, including electric-vehicle batteries, critical and strategic minerals and materials, and pharmaceuticals and active pharmaceutical ingredients. The reports outlining strategies for the four sectors were released in June 2021.

In November 2021, Congress passed and the President signed the $1.2 trillion Bipartisan infrastructure Law (Infrastructure Investment and Jobs Act, H.R. 3684, Public Law 117–58) (BIL). The law outlined investments for bridges, roads, telecommunications broadband networks, water, energy systems, and ports and rail improvements for efficient transport of goods and produce across the country. It also provided funding for research and development of clean energy projects, domestic production of batteries, critical mineral recycling, reclamation and domestic critical minerals production and supply-chain projects including $320 million over 5 years for the USGS Earth Mapping Resources Initiative (Earth MRI).

Supply Chain Security and U.S. Government Critical Minerals Initiatives in 2022

In 2022, many Executive Branch and Congressional actions were taken to support and enhance America's supply chains in the areas of focus identified in Executive Order 14017.

On March 31, 2022, a Presidential determination was signed requiring the use of DPA title III authorities to strengthen the U.S. industrial base for large-capacity batteries and specifically increasing domestic mining and processing of critical materials for the large-capacity battery supply chain such as cobalt, graphite, lithium, and nickel. The determination directed the Secretary of Defense to support (1) feasibility studies for "mature mining, beneficiation, and value-added processing projects" for such critical materials; (2) byproduct and coproduct production at existing mining and other industrial facilities; and (3) improvements to increase productivity, workforce safety, and sustainability in critical minerals mining, beneficiation, and processing.

On May 21, 2022, the Ukraine Supplemental Appropriations Act of 2022 provided $600 million for DPA title III funds for missiles and munitions in support of Ukraine and strategic and critical materials to expand domestic capacity. The areas of interest for funding for critical materials included feasibility studies, byproduct and coproduct extraction, modernization and productivity

improvements, recycling and reclamation, and industrial resources.

On August 9, 2022, the CHIPS and Science Act of 2022 (Public Law 117–167) was signed into law; it provided $280 billion in funding over the next 10 years for domestic research, commercialization, and manufacturing of semiconductors as well next generation technology and workforce development. The goals of the law are to enhance domestic capability in several areas: reduce the likelihood that shocks abroad might disrupt the supply of semiconductor chips; create domestic jobs; improve international competitiveness; and ensure a secure supply of semiconductors to limit manufacturing vulnerabilities.

On August 16, 2022, the Inflation Reduction Act of 2022 (Public Law 117–169) was signed into law with the aim to reduce inflation. Specifically related to critical minerals, it authorized $391 billion in funding for climate change and domestic energy production. The legislation included targeted tax incentives aimed at manufacturing U.S.-sourced materials such as batteries, electric vehicles, solar, and wind parts and technologies like carbon capture systems. The legislation also includes key requirements around domestic sourcing—for example, for use of domestic steel in wind projects.

In October 2022, the "American Battery Materials Initiative" was launched, which will be led by a White House steering committee and coordinated by the U.S. Department of Energy (DOE) with support from the U.S. Department of the Interior. The initiative will work through the Partnership for Global Infrastructure and Investment and leverage ongoing work by the U.S. Department of State, to work with partners and allies to strengthen critical mineral supply chains globally, and it will leverage and maximize ongoing efforts throughout the U.S. government to meet resource requirements and bolster energy security.

In December 2022, the $858 billion National Defense Authorization Act was signed into law, which included a provision requiring a Federal strategy be developed to recycle and recover critical minerals from batteries used in the Federal electric vehicle fleet.

Critical Minerals Investments in 2022

On February 22, 2022, the U.S. Department of Defense (DOD) awarded a $35 million contract to a company to design and build a facility to process heavy rare-earth elements (HREEs) in California. The project would establish the first processing and separation facility for HREEs in the United States. Including this project, the DOD had invested over $100 million in enhancing America's rare-earth supply-chain resiliency and expanding domestic rare-earth magnet processing capabilities and capacity.

In July 2022, the USGS Earth MRI, a collaborative project between the USGS and State geological surveys to collect and modernize the Nation's geologic mapping and data resources, released two reports. Open-File Report 2019–1023–D, "Focus Areas for Data Acquisition for Potential Domestic Resources of 13 Critical Minerals in the Conterminous United States and Puerto Rico—Antimony, Barite, Beryllium, Chromium, Fluorspar, Hafnium, Helium, Magnesium, Manganese, Potash, Uranium, Vanadium, and Zirconium," defined focus areas for future data collection for resources for the 13 critical minerals evaluated in the conterminous United States and Puerto Rico during phase 3 of the study. Phases 1 and 2 of the Earth MRI addressed aluminum, cobalt, graphite, lithium, niobium, platinum-group elements (PGEs), rare-earth elements (REEs), tantalum, tin, titanium, and tungsten. The second report, Open-File Report 2019–1023–E, "Alaska Focus Area Definition for Data Acquisition for Potential Domestic Sources of Critical Minerals in Alaska for Antimony, Barite, Beryllium, Chromium, Fluorspar, Hafnium, Magnesium, Manganese, Uranium, Vanadium, and Zirconium," similarly defined focus areas for further investigation into critical mineral resources in Alaska.

In August 2022, the Defense Advanced Research Projects Agency (DARPA) partnered with the USGS to launch the Artificial Intelligence for Critical Mineral Assessment Competition. The goal of the competition was to develop methods to reduce the time required to complete parts of the resource assessment using artificial intelligence and machine learning to automate key processes. The partnership will help the USGS conduct assessments for more than 50 critical mineral resources to aid in economic planning and land-use decision making. The USGS has over a century of accumulated data, contained mostly within 100,000 geologic maps and many reports that provide the fundamental basis for these resource assessments. Only about 5% of the materials were fully digitized vector files which are needed for analysis and the rest were scanned images of paper maps. In December 2022, winners of the competition were announced: a Canadian company received top prize for automated georeferencing and a United States university partnership received top prize for legend-based feature extraction.

On October 19, 2022, the DOE announced the first set of projects funded by the Bipartisan Infrastructure Law to expand domestic manufacturing of batteries for electric vehicles (EVs) and the electrical grid including $2.8 billion for 20 manufacturing and processing companies in 12 States—Alabama, Georgia, Kentucky, Louisiana, Missouri, Nevada, New York, North Carolina, North Dakota, Ohio, Tennessee, and Washington. When matched by recipients, the funding will leverage a total of more than $9 billion to boost American production of EV batteries.

In October 2022, the USGS announced a $3.2 million project to collect geophysical data to improve mapping of critical mineral resources in parts of Iowa, Minnesota, Nebraska, and South Dakota. Substantial funding for the project came from the USGS Earth MRI using supplemental appropriation from the BIL.

In November 2022, the USGS announced a $1.45 million project to conduct geologic mapping, airborne geophysical surveying and geochemical sampling in support of critical mineral resource studies in Nevada and Oregon. Substantial funding for the project came from the USGS Earth MRI using supplemental appropriation from the BIL.

In December 2022, the DOD announced its first critical minerals award using Ukraine Supplemental Appropriations funds to a stibnite-gold project in Idaho for completing environmental and engineering studies.

Other information regarding individual projects and new production facilities can be found within each critical mineral chapter in this publication (p. 28–203).

U.S. Production and Consumption of Critical Minerals in 2022

In 2022, the value of domestic primary mine production of critical minerals was $5.4 billion. A total of 14 individual mineral commodities and the rare-earths group of minerals (without specification of the specific lanthanides) were produced in the United States.

The United States was 100% net import reliant for 12 of the 50 individually listed critical minerals and was more than 50% net import reliant for an additional 31 critical mineral commodities (including 14 lanthanides, which are listed under rare earths (fig. 2, tables 4, 5). The United States had secondary production for 14 critical minerals which resulted in net import reliance being less than 100%. Recycling provided the only source of domestic supply for antimony, bismuth, chromium, germanium, tin, tungsten, and vanadium (table 5).

China was the leading producing nation for 30 of the 50 critical minerals (including 14 lanthanides, which are listed under rare earths). The other leading producers of critical minerals were Australia and South Africa with three critical minerals each and Congo (Kinshasa) with two critical minerals (table 5). For 30 critical minerals, production was highly concentrated (50% or more) in a single country, of which 5 critical minerals had 80% or more of global production dominated by one country, 17 (including 14 lanthanides, which are listed under rare earths) with 70% to less than 80% of global production dominated by one country, 4 with 60% to less than 70% of global production dominated by one country, and 4 with 50% to less than 60% of global production dominated by one country.

Figure 9 shows the trends in net import reliance for critical minerals over the past 20 years. For most critical minerals, the United States is heavily reliant on foreign sources for its consumption requirements; exceptions include beryllium, magnesium, and zirconium.

Figure 10 shows both the 1-year percent change in prices of critical minerals between 2021 and 2022 and the 5-year compound annual growth rate (CAGR) in the prices of critical minerals from 2018 to 2022. In 2022, the 1-year percent change in the prices of lithium, neodymium, and yttrium were all above 100% (double) compared with their respective prices in 2021. The CAGR for most critical minerals has been positive over the past 5 years, reflecting a trend of increasing prices for these commodities.

All supply chains, from mine to final distribution and retail, were affected when the coronavirus disease 2019 (COVID-19) emerged and became a global pandemic. For the United States, the 2020 consumption of most nonfuel mineral commodities decreased relative to that in 2019. Of the critical mineral commodities, 16 experienced decreases in consumption during that time period, whereas 6 experienced increases. The markets for mineral commodities vary such that the trends can differ significantly for the different commodities depending on their unique market situations. For example, gold, platinum, and silver, precious metals perceived as investment metals, experienced large increases in consumption between 2019 and 2020 (fig. 11).

Mineral commodity markets can be quite volatile, but the nonfuel mineral commodity mining and refining sectors did experience significant disruptions, especially in the first half of 2020. However, the second half of 2020 and 2021 were characterized by a rebound in demand and prices, so the overall effect of the disruptions between 2020 and 2021 were dampened (fig. 12). In 2022, consumption for many mineral commodities continued to increase and began to approach or exceed pre-pandemic levels, and consumption of most commodities in 2022 increased from that in 2021 (fig. 13).

Figure 14 shows the relationship between primary metals and byproduct or companion metals. As discussed in Open-File Report 2021–1045, “Methodology and Technical Input for the 2021 Review and Revision of the U.S. Critical Minerals List,” the degree to which a metal is obtained largely or entirely as a byproduct of one or more host metals from geologic ores may complicate the supply of these commodities. Of the 50 critical minerals, only aluminum, nickel, platinum, tin, titanium, and zinc are primary metals.

Table 5.—Estimated Salient Critical Minerals Statistics in 2022[1]

(Metric tons, mine production, unless otherwise specified)

Critical mineral	United States					World			
	Primary production	Secondary production	Apparent consumption	Net import reliance as a percentage of apparent consumption	Primary import source (2018–21)	Leading producing country	Production in leading country	Percentage of world total	World production total
Aluminum (bauxite)	W	—	[2]2,900,000	>75	Jamaica	Australia	100,000,000	26	[3]380,000,000
Antimony	—	4,200	[4]27,000	83	China[5]	China	60,000	55	110,000
Arsenic	—	NA	[6]5,300	100	China[5]	Peru	[7]28,000	46	[7]61,000
Barite	W	—	W	>75	China[5]	India	2,600,000	33	[3]7,900,000
Beryllium	180	NA	180	1	Kazakhstan	United States	180	64	280
Bismuth[8]	—	80	2,000	96	China[5]	China	16,000	80	20,000
Chromium	—	100,000	590,000	83	South Africa	South Africa	18,000,000	44	41,000,000
Cobalt	800	1,900	7,800	76	Norway	Congo (Kinshasa)	130,000	68	190,000
Fluorspar	NA	—	500,000	100	Mexico	China	5,700,000	69	8,300,000
Gallium	NA	NA	[2]18	100	China	China	540	98	550
Germanium[8]	NA	W	[6]30	>50	China	China	NA	NA	NA
Graphite (natural)	—	NA	72,000	100	China[5]	China	850,000	65	1,300,000
Indium[8]	—	NA	[6]160	100	Republic of Korea	China	530	59	900
Lithium	W	NA	[6]3,000	>25	Argentina	Australia	61,000	47	[3]130,000
Magnesium[8]	W	37,000	[2]50,000	>50	Israel	China	900,000	90	[3]1,000,000
Manganese	—	—	890,000	100	Gabon	South Africa	7,200,000	36	20,000,000
Nickel	18,000	W	[9]220,000	56	Canada	Indonesia	1,600,000	48	3,300,000
Niobium	—	NA	7,600	100	Brazil	Brazil	71,000	90	79,000
Palladium	11	40	68	26	Russia	Russia	88	42	210
Platinum	3	11	42	66	South Africa	South Africa	140	74	190
Rare Earths (compounds and metals)[10]	250	NA	9,300	>95	China[5]	China	210,000	70	300,000
Scandium	—	—	NA	100	Europe	China	NA	NA	NA
Tantalum	—	NA	1,200	100	China[5]	Congo (Kinshasa)	860	43	2,000
Tellurium[8]	W	—	W	>75	Canada	China	340	53	[3]640
Tin	—	18,000	43,000	77	Peru	China	95,000	31	310,000
Titanium (metal)[8]	W	W	[3]28,000	>95	Japan	China	150,000	58	[3]260,000
Tungsten	—	W	W	>50	China[5]	China	71,000	85	84,000
Vanadium	—	4,400	9,500	54	Canada	China	70,000	70	100,000
Yttrium	NA	—	1,000	100	China[5]	China	NA	NA	NA
Zinc[8]	[11]220,000	([11])	910,000	76	Canada	NA	NA	NA	NA
Zirconium (ores and concentrates)	<100,000	NA	<100,000	<50	South Africa	Australia	500,000	36	[3]1,400,000

NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Critical minerals as published in the Federal Register on February 24, 2022 (87 FR 10381). Not all critical minerals are listed here. Cesium, hafnium,iridium, rhodium, rubidium, and ruthenium are not shown because available information is insufficient to make estimates of U.S. or world production.

[2]Reported consumption.

[3]Excludes U.S. production.

[4]Antimony in oxide and unwrought metal, powder.

[5]Includes Hong Kong.

[6]Estimated consumption.

[7]Arsenic trioxide.

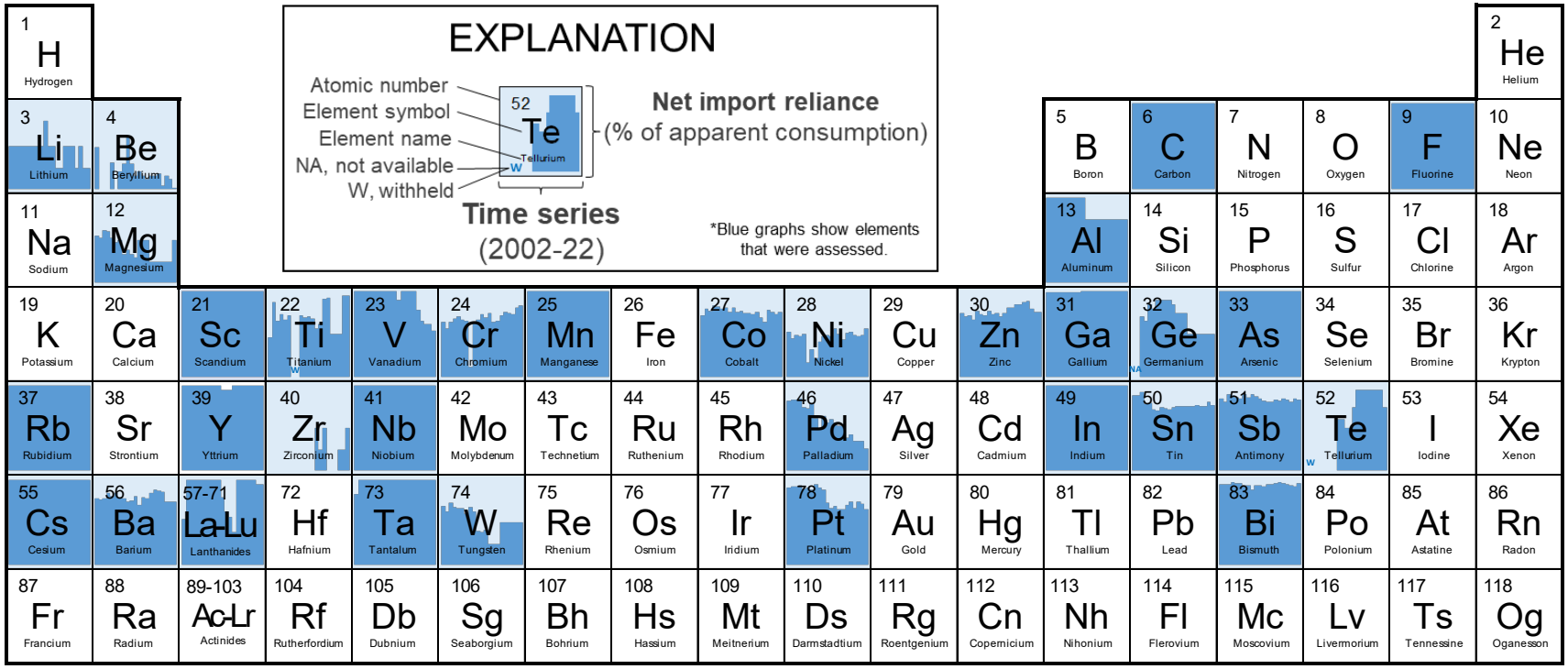
[8]Refinery production.

[9]Nickel in primary metal and secondary scrap.

[10]Data include lanthanides.

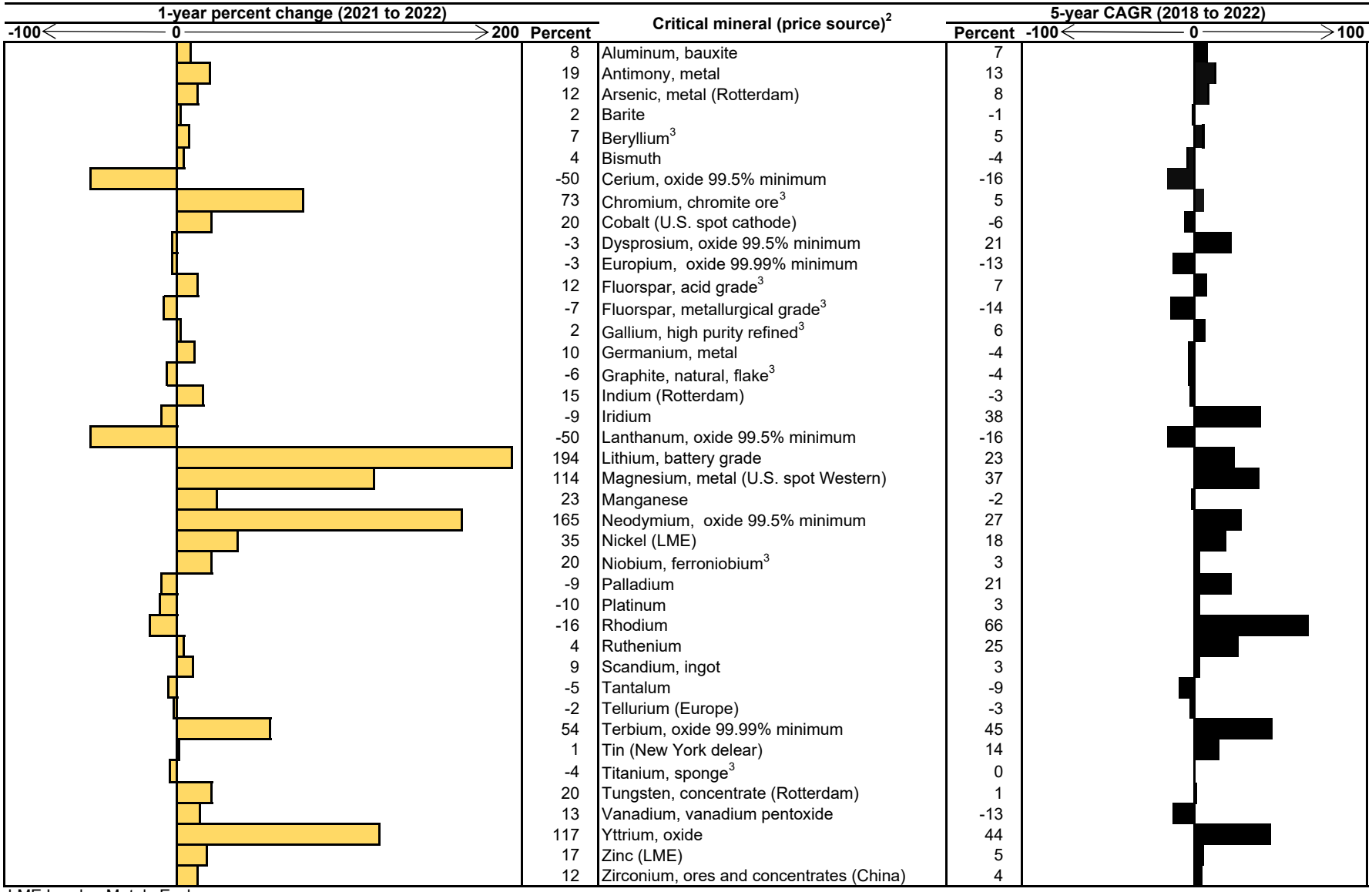
[11]Primary production includes both primary and secondary metal production.

Figure 9.—20-Year Trend of U.S. Net Import Reliance for Critical Minerals



For elements of the periodic table associated with mineral commodities identified as critical in 2022 (87 FR 10381), the figure displays the U.S. net import reliance (NIR) as a percent of apparent consumption from 2002 through 2022. Barite is listed under barium (Ba). Bauxite is listed under aluminum (Al). Fluorspar is listed under fluorine (F). Graphite (natural) is listed under carbon (C). Rare earths are listed under lanthanides (La–Lu). Net import reliance data are not available for hafnium, iridium, and rhodium for 2002 through 2022 and for germanium prior to 2004; data were withheld for tellurium prior to 2010 and titanium for 2008 and 2009. For some years, the NIR for antimony, barite, bauxite, germanium, lithium, magnesium, rare earths, tellurium, titanium, tungsten, yttrium, and zirconium are rounded to avoid disclosing company proprietary data.

Figure 10.—Estimated 1-Year Percent Change and 5-Year Compound Annual Growth Rate (CAGR) in Prices of Critical Minerals[1]



1-year percent change (2021 to 2022) Percent	Critical mineral (price source)[2]	5-year CAGR (2018 to 2022) Percent
8	Aluminum, bauxite	7
19	Antimony, metal	13
12	Arsenic, metal (Rotterdam)	8
2	Barite	-1
7	Beryllium[3]	5
4	Bismuth	-4
-50	Cerium, oxide 99.5% minimum	-16
73	Chromium, chromite ore[3]	5
20	Cobalt (U.S. spot cathode)	-6
-3	Dysprosium, oxide 99.5% minimum	21
-3	Europium, oxide 99.99% minimum	-13
12	Fluorspar, acid grade[3]	7
-7	Fluorspar, metallurgical grade[3]	-14
2	Gallium, high purity refined[3]	6
10	Germanium, metal	-4
-6	Graphite, natural, flake[3]	-4
15	Indium (Rotterdam)	-3
-9	Iridium	38
-50	Lanthanum, oxide 99.5% minimum	-16
194	Lithium, battery grade	23
114	Magnesium, metal (U.S. spot Western)	37
23	Manganese	-2
165	Neodymium, oxide 99.5% minimum	27
35	Nickel (LME)	18
20	Niobium, ferroniobium[3]	3
-9	Palladium	21
-10	Platinum	3
-16	Rhodium	66
4	Ruthenium	25
9	Scandium, ingot	3
-5	Tantalum	-9
-2	Tellurium (Europe)	-3
54	Terbium, oxide 99.99% minimum	45
1	Tin (New York delear)	14
-4	Titanium, sponge[3]	0
20	Tungsten, concentrate (Rotterdam)	1
13	Vanadium, vanadium pentoxide	-13
117	Yttrium, oxide	44
17	Zinc (LME)	5
12	Zirconium, ores and concentrates (China)	4

LME London Metals Exchange.

[1]Critical minerals as published in the Federal Register on February 24, 2022 (87 FR 10381). Not all critical minerals are listed here. Cesium, erbium, gadolinium, hafnium, holmium, lutetium, praseodymium, rubidium, samarium, thulium, and ytterbium are not shown because there was not enough information available regarding prices.

[2]Price source is only included for those commodities that have multiple price sources in their Salient table. For those commodities with a single price source, please refer to that commodity chapter's Salient table.

[3]Average annual unit value of imports.

Figure 11.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2019 to 2020

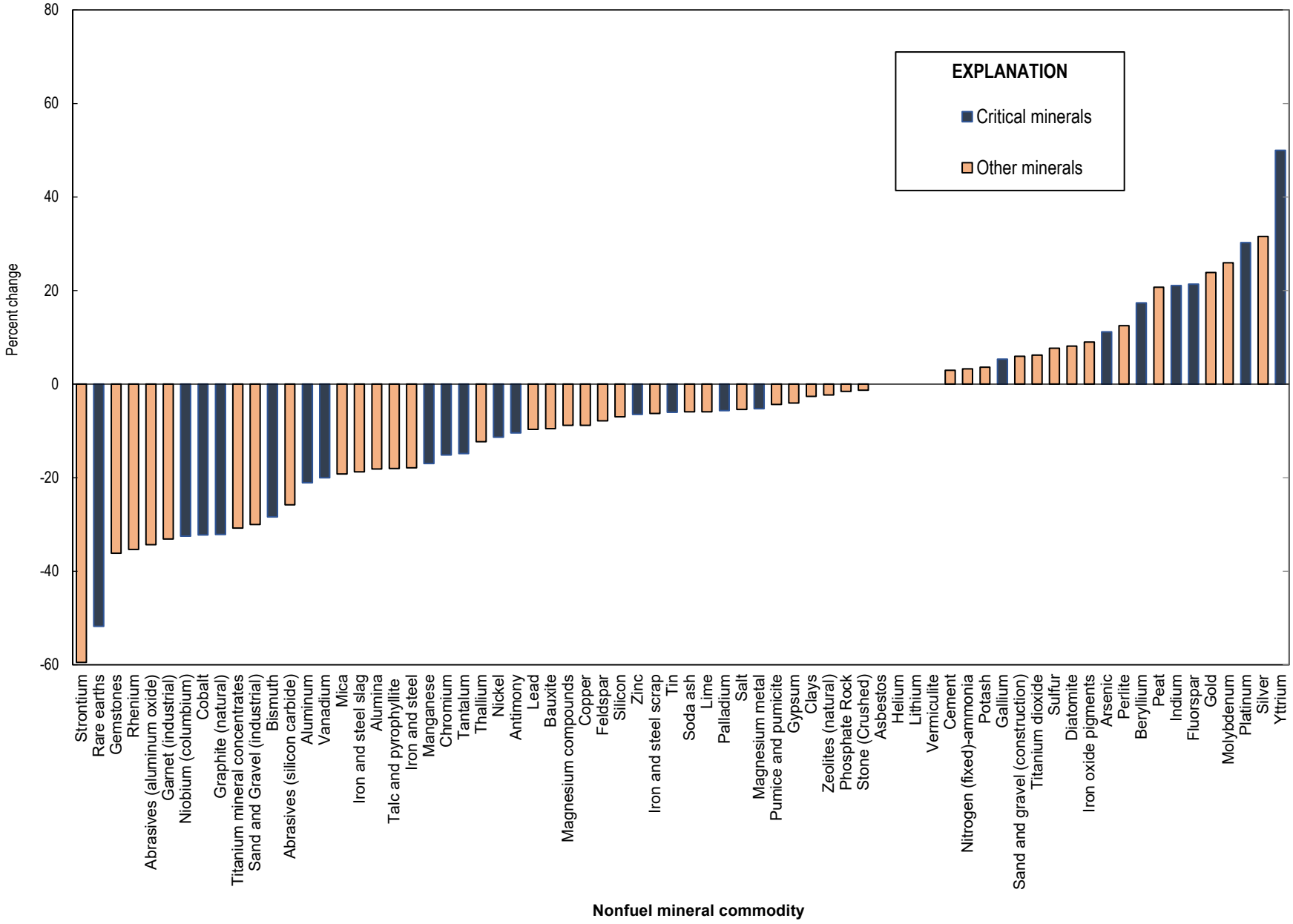


Figure 12.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2020 to 2021

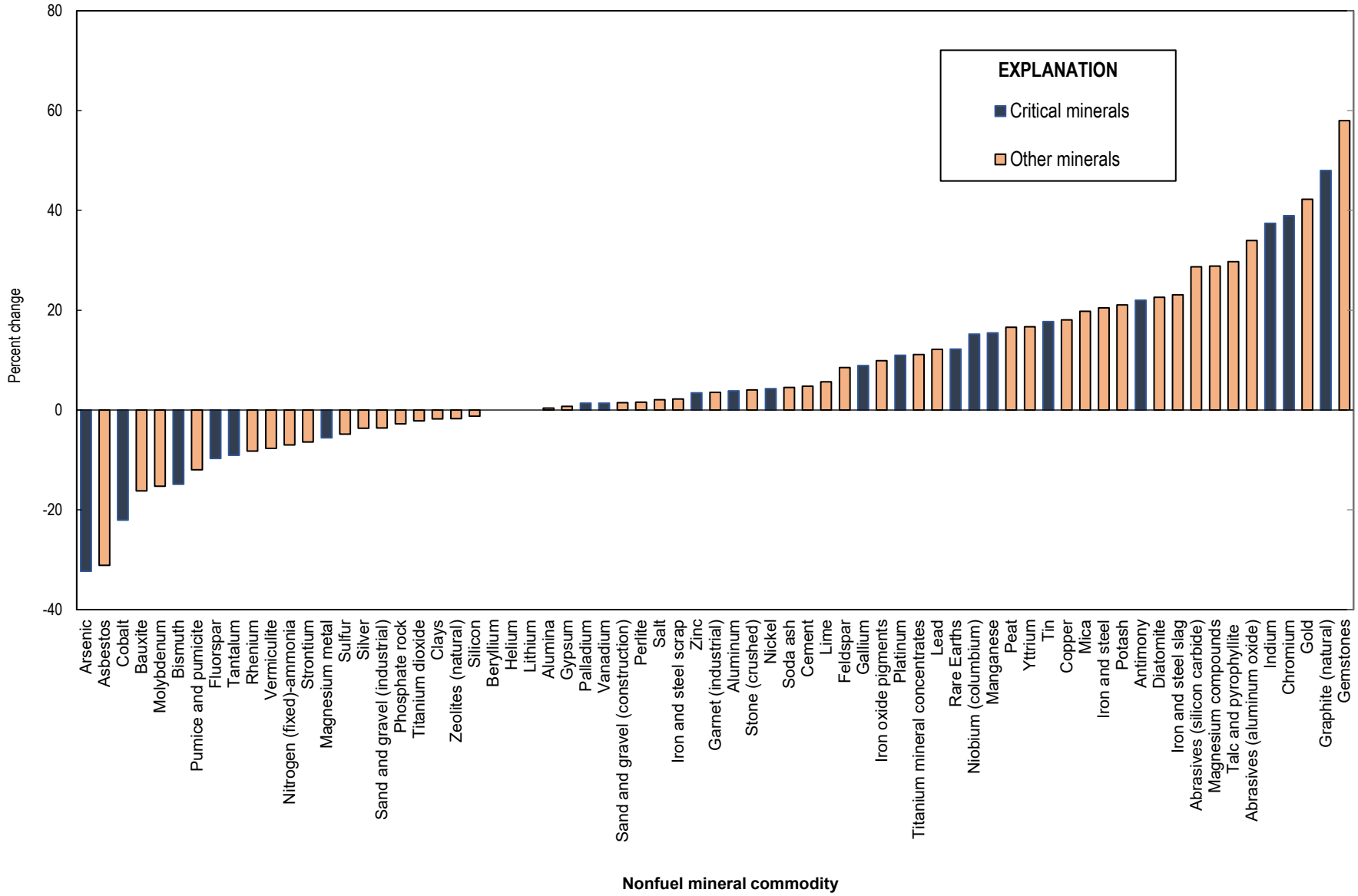


Figure 13.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2021 to 2022

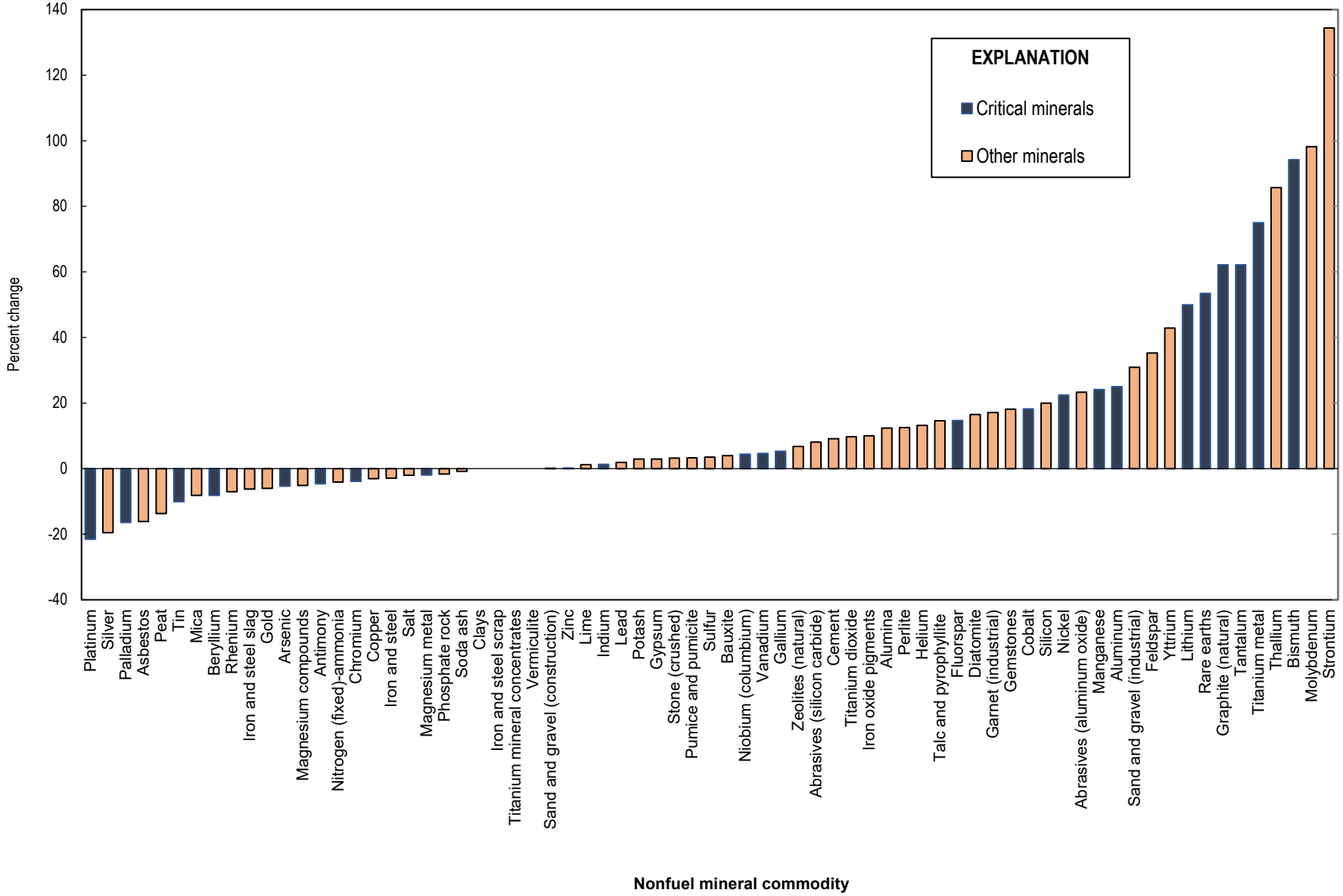
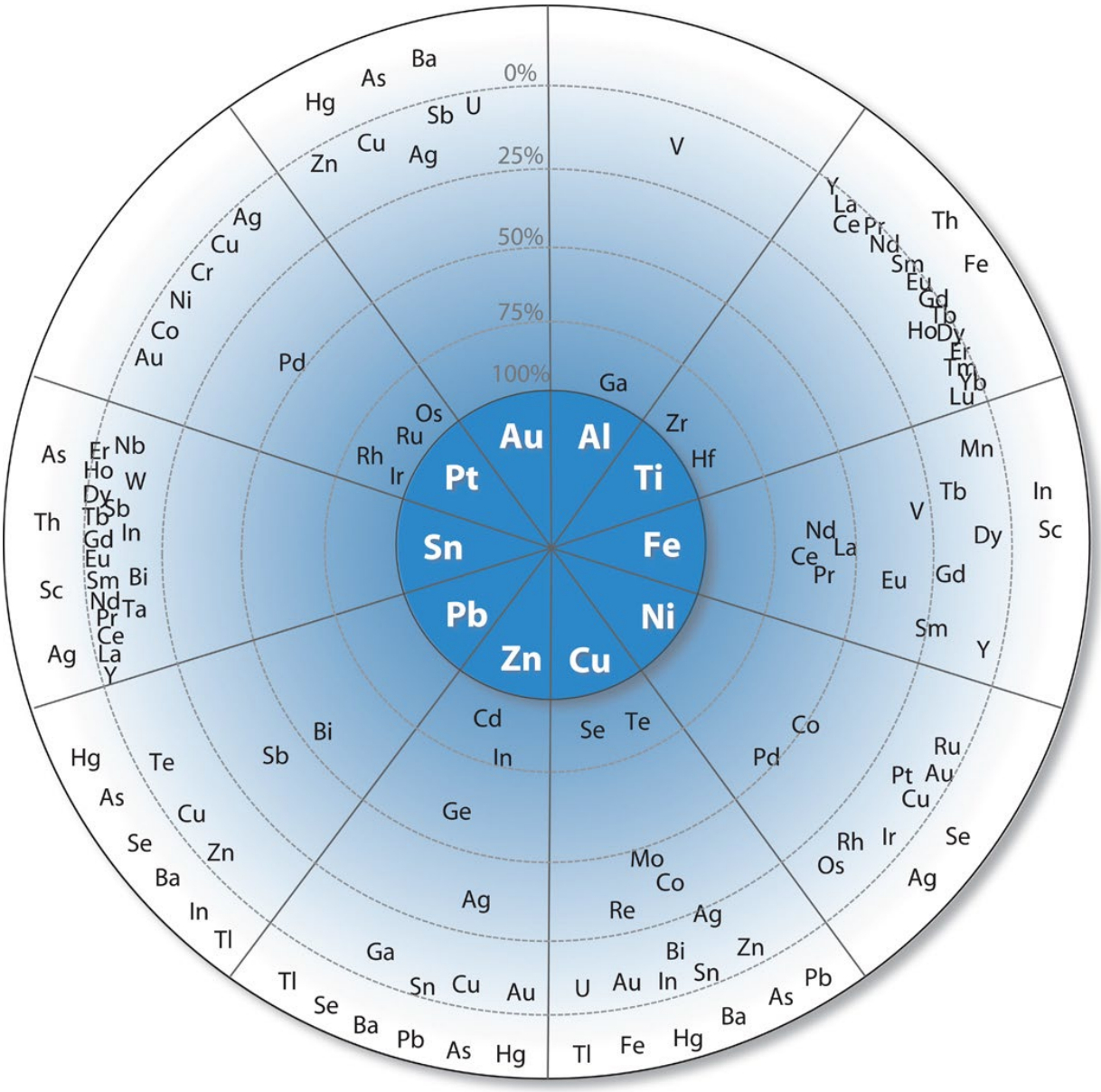


Figure 14.—Relation Between Byproduct Elements and Host Metals



The principal host metals form the inner circle. Byproduct elements are in the outer circle at distances proportional to the percentage of their primary production (from 100% to 0%) that originates with the host metal indicated. Source: Nassar, N.T., Graedel, T.E., and Harper, E.M., 2015, By-product metals are technologically essential but have problematic supply: ScienceAdvances, v. 1, no. 3, article E1400180. (Accessed January 19, 2023, at https://doi.org/10.1126/sciadv.1400180.)

ABRASIVES (MANUFACTURED)

(Fused aluminum oxide, silicon carbide, and metallic abrasives)
(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2022, fused aluminum oxide was produced by two companies at three plants in the United States and Canada. Production of crude fused aluminum oxide had an estimated value of $3.0 million. Silicon carbide was produced by two companies at two plants in the United States. Production of crude silicon carbide had an estimated value of about $30 million. Metallic abrasives were produced by 11 companies in eight States. Production of metallic abrasives had an estimated value of about $160 million, and metallic abrasive shipments were valued at $190 million. Bonded and coated abrasive products accounted for most abrasive uses of fused aluminum oxide and silicon carbide. Metallic abrasives are used primarily for steel shot and grit and cut wire shot, which are used for sandblasting, peening, and stonecutting applications.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	10,000	10,000
Silicon carbide[2]	35,000	35,000	35,000	35,000	35,000
Metallic abrasives	180,000	177,000	176,000	176,000	180,000
Shipments, metallic abrasives	196,000	195,000	194,000	193,000	190,000
Imports for consumption:					
Fused aluminum oxide	192,000	184,000	120,000	159,000	200,000
Silicon carbide	146,000	131,000	88,400	125,000	140,000
Metallic abrasives	29,900	27,900	25,800	26,400	21,000
Exports:					
Fused aluminum oxide	20,100	18,400	11,400	13,500	17,000
Silicon carbide	10,100	11,500	8,310	12,000	12,000
Metallic abrasives	33,600	31,200	18,100	20,200	22,000
Consumption, apparent:					
Fused aluminum oxide[3]	172,000	166,000	109,000	146,000	180,000
Silicon carbide[4]	171,000	155,000	115,000	148,000	160,000
Metallic abrasives[5]	192,000	192,000	202,000	199,000	190,000
Price, average unit value of imports, dollars per ton:					
Fused aluminum oxide, crude	681	716	666	674	800
Fused aluminum oxide, ground and refined	1,290	1,250	1,180	1,290	1,500
Silicon carbide, crude	670	701	628	587	1,000
Metallic abrasives	1,180	1,310	1,130	1,510	2,100
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>75	>75	>75	>75	>75
Silicon carbide	80	77	70	76	79
Metallic abrasives	E	E	4	3	E

Recycling: Up to 30% of fused aluminum oxide may be recycled, and about 5% of silicon carbide is recycled.

Import Sources (2018–21): Fused aluminum oxide, crude: China,[7] 93%; Bahrain, 3%; Russia, 2%; Canada, 1%; and other, 1%. Fused aluminum oxide, ground and refined: Canada, 25%; Brazil, 19%; Austria, 15%; China,[7] 13%; and other, 28%. Total fused aluminum oxide: China,[7] 63%; Canada, 10%; Brazil, 7%; Austria, 5%; and other, 15%. Silicon carbide, crude: China,[7] 90%; Netherlands and South Africa, 3% each; Luxembourg, 1%; and other 3%. Silicon carbide, ground and refined: China,[7] 48%; Brazil, 21%; Canada, 9%; Russia, 7%; and other, 15%. Total silicon carbide: China,[7] 79%; Brazil, 6%; Netherlands and South Africa, 3%, each; and other, 9%. Metallic abrasives: Canada, 33%; Turkey, 16%; China,[7] 12%; Thailand, 9%; and other, 30%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
Artificial corundum, crude	2818.10.1000	Free.
White, pink, ruby artificial corundum, greater than 97.5% aluminum oxide, grain	2818.10.2010	1.3% ad valorem.
Artificial corundum, not elsewhere specified or included, fused aluminum oxide, grain	2818.10.2090	1.3% ad valorem.
Silicon carbide, crude	2849.20.1000	Free.
Silicon carbide, grain	2849.20.2000	0.5% ad valorem.
Iron, pig iron, or steel granules	7205.10.0000	Free.

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ABRASIVES (MANUFACTURED)

Depletion Allowance: None.

Government Stockpile: None.

Events, Trends, and Issues: In 2022, China was the world's leading manufacturer of abrasive fused aluminum oxide and abrasive silicon carbide. Imports from China, where production costs were lower, continued to challenge abrasives manufacturers in the United States and Canada. China accounted for 93% of United States imports of crude fused aluminum oxide, 13% of ground and refined fused aluminum oxide imports, 90% of crude silicon carbide imports, and 48% of ground and refined silicon carbide imports. Foreign competition is expected to persist and continue to limit production in North America. The import quantity and value of abrasive fused aluminum oxide (crude and ground and refined) in 2022 were 26% and 44% higher, respectively, than those in 2021. The import quantity and value of abrasive silicon carbide (crude and ground and refined) in 2022 were 9% and 76% higher, respectively, than those in 2021.

The United States returned to being a net exporter of metallic abrasives in 2022 as compared with being a net importer in 2020 and 2021. Canada was the leading supplier of metallic abrasive imports.

The consumption of abrasives in the United States is influenced by activity in the manufacturing sectors that use them, particularly the aerospace, automotive, furniture, housing, and steel industries. The U.S. abrasive markets also are influenced by technological trends. Imports and exports continued to recover from the negative effects from the global coronavirus disease 2019 (COVID-19) pandemic, and they have returned to pre-pandemic levels.

World Production Capacity:

	Fused aluminum oxide[e]		Silicon carbide[e]	
	2021	2022	2021	2022
United States	—	—	40,000	40,000
United States and Canada	60,000	60,000	—	—
Australia	50,000	50,000	—	—
Austria	60,000	60,000	—	—
Brazil	50,000	50,000	40,000	40,000
China	800,000	800,000	450,000	450,000
France	40,000	40,000	20,000	20,000
Germany	80,000	80,000	35,000	35,000
India	40,000	40,000	5,000	5,000
Japan	15,000	15,000	60,000	60,000
Mexico	—	—	45,000	45,000
Norway	—	—	80,000	80,000
Venezuela	—	—	30,000	30,000
Other countries	80,000	80,000	200,000	200,000
World total (rounded)	1,300,000	1,300,000	1,000,000	1,000,000

World Resources:[8] Although domestic resources of raw materials for fused aluminum oxide production are limited, adequate resources are available in the Western Hemisphere. Domestic resources are more than adequate for silicon carbide production.

Substitutes: Natural and manufactured abrasives, such as garnet, emery, metallic abrasives, or staurolite, can be substituted for fused aluminum oxide and silicon carbide in various applications.

[e]Estimated. E Net exporter. — Zero.

[1]Production data for fused aluminum oxide are combined data from the United States and Canada to avoid disclosing company proprietary data.

[2]Rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.

[3]Defined as imports – exports because production includes data from Canada; actual consumption is higher than that shown.

[4]Defined as production + imports – exports.

[5]Defined as shipments + imports – exports.

[6]Defined as imports – exports.

[7]Includes Hong Kong.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

ALUMINUM[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, three companies operated six primary aluminum smelters in five States. Two of these six smelters operated at full capacity throughout the year. The other four smelters operated at reduced capacity and one of these four smelters began a temporary shutdown in June. A seventh smelter remained on standby throughout the year. Domestic smelters were operating at about 52% of capacity of 1.64 million tons per year at yearend 2022. Estimated primary production decreased by 3% compared with that in 2021 but estimated secondary production from new and old scrap increased by 3% compared with that in 2021. Based on published prices, the value of primary aluminum production was about $2.90 billion, 7% more than the $2.71 billion in 2021. The average annual U.S. market price increased by about 8% from that in 2021. Transportation applications accounted for 35% of domestic consumption; the remainder was used in packaging, 23%; building, 16%; electrical, 10%; machinery, 7%; consumer durables, 6%; and other, 3%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Primary	891	1,093	1,012	889	860
Secondary (from old scrap)	1,570	1,540	1,420	1,520	1,500
Secondary (from new scrap)	2,140	1,920	1,630	1,780	1,900
Imports for consumption:					
Crude and semimanufactures	5,550	5,280	4,260	4,830	5,900
Scrap	695	596	542	680	640
Exports:					
Crude and semimanufactures	1,310	1,110	906	851	1,000
Scrap	1,760	1,860	1,840	2,100	2,100
Consumption, apparent[2]	4,900	4,980	3,930	4,080	5,100
Supply, apparent[3]	7,040	6,910	5,560	5,860	7,000
Price, ingot, average U.S. market (spot), cents per pound[4]	114.7	99.5	89.7	138.5	150
Stocks, yearend:					
Aluminum industry	1,570	1,600	1,490	1,870	2,000
London Metal Exchange (LME), U.S. warehouses[5]	186	120	235	69	17
Employment, number[6]	31,600	32,900	30,100	28,900	28,000
Net import reliance[7] as a percentage of apparent consumption	50	47	38	41	54

Recycling: In 2022, aluminum recovered from purchased scrap in the United States was about 3.4 million tons, of which about 56% came from new (manufacturing) scrap and 44% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 29% of apparent consumption.

Import Sources (2018–21): Canada, 50%; United Arab Emirates, 9%; Russia, 5%; China,[8] 4%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Aluminum, not alloyed:		
Unwrought (in coils)	7601.10.3000	2.6% ad valorem.
Unwrought (other than aluminum alloys)	7601.10.6000	Free.
Aluminum alloys, unwrought (billet)	7601.20.9045	Free.
Aluminum scrap:		
Used beverage container scrap	7602.00.0030	Free.
Industrial process scrap	7602.00.0091	Free.

Depletion Allowance: Not applicable.[1]

Government Stockpile: None.

Events, Trends, and Issues: In June, a 250,000-ton-per-year primary aluminum smelter in Hawesville, KY, idled its full production for an estimated 9 to 12 months owing to high energy costs. In July, a 161,000-ton-per-year primary aluminum smelter in Newburgh, IN, curtailed one of three operating aluminum smelting lines, citing operational challenges. In July, force majeure was declared at a rolling mill and aluminum packaging products manufacturer in Newburgh, IN, that produced approximately 310,000 tons per year of rolled aluminum. A shortage of magnesium, an essential component of aluminum packaging products, was cited for the declaration. Production at the plant was reduced by up to 50% before the declaration was lifted in September. In August, low local demand led to the permanent closure of aluminum beverage can manufacturing facilities in Phoenix, AZ, and St. Paul, MN.

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ALUMINUM

In October, construction began on a $2.5 billion aluminum recycling and rolling plant in Bay Minette, AL. When completed in 2025, the plant was expected to produce 600,000 tons per year of finished products, including beverage cans. Prices for aluminum increased through March, then generally trended downward throughout 2022 in the United States and in world markets.

In June, a tariff-rate quota system began that exempted certain aluminum imports from the United Kingdom from the 10% tariff imposed since 2018 under the authority of section 232 of the Trade Expansion Act of 1962. The quota system consisted of quantity limits during two periods in 2022 and the requirement that imports of aluminum articles be accompanied by a certificate of analysis for the smelted primary aluminum contained within in the articles. To be eligible for the tariff exemption, imports could not contain primary aluminum from Belarus, China, or Russia.

In April, a 447,000-ton-per-year primary aluminum smelter in Sao Luis, Brazil, restarted operations with full production expected by yearend. Several European aluminum producers announced production curtailments owing to high energy costs. In August, a 175,000-ton-per-year primary aluminum smelter in Slovakia ceased production, and a 94,000-ton-per-year primary aluminum smelter in Norway curtailed operation of a single potline. In September, a 70,000-ton-per-year primary aluminum smelter in Germany reduced production by 50%, and a 290,000-ton-per-year primary aluminum smelter in France reduced production by 22%. By yearend, a Norwegian primary aluminum smelter reduced production across two facilities by 110,000 to 130,000 tons per year. These facilities have annual capacities of 197,000 tons per year and 270,000 tons per year of primary aluminum.

World Smelter Production and Capacity: Capacity data for China were revised based on company and Government reports.

	Smelter production		Yearend capacity	
	2021	2022[e]	2021	2022[e]
United States	889	860	1,640	1,600
Australia	1,570	1,500	1,720	1,700
Bahrain	1,560	1,600	1,550	1,600
Canada	3,140	3,000	3,270	3,300
China	38,900	40,000	42,300	44,000
Iceland	[e]750	750	890	900
India	3,970	4,000	4,060	4,100
Norway	[e]1,400	1,400	1,430	1,400
Russia	3,640	3,700	4,020	4,000
United Arab Emirates	2,540	2,700	2,780	2,800
Other countries	9,140	9,100	12,300	12,000
World total (rounded)	67,500	69,000	76,000	77,000

World Resources:[9] Global resources of bauxite are estimated to be between 55 billion and 75 billion tons and are sufficient to meet world demand for metal well into the future.

Substitutes: Composites can substitute for aluminum in aircraft fuselages and wings. Glass, paper, plastics, and steel can substitute for aluminum in packaging. Composites, magnesium, steel, and titanium can substitute for aluminum in ground transportation uses. Composites, steel, vinyl, and wood can substitute for aluminum in construction. Copper can replace aluminum in electrical and heat-exchange applications.

[e]Estimated.

[1]See also the Bauxite and Alumina chapter.

[2]Defined as primary production + secondary production from old scrap + imports – exports ± adjustments for stock changes; excludes imported scrap.

[3]Defined as primary production + secondary production + imports – exports ± adjustments for stock changes; excludes imported scrap.

[4]Source: S&P Global Platts Metals Week.

[5]Includes aluminum alloy. Starting with 2019, also includes off-warrant stocks of primary and alloyed aluminum; estimated for 2019.

[6]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.

[7]Defined as imports – exports ± adjustments for industry stock changes; excludes imported scrap.

[8]Includes Hong Kong.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

ANTIMONY

(Data in metric tons of contained antimony unless otherwise noted)

Domestic Production and Use: In 2022, no marketable antimony was mined in the United States. A mine in Nevada that had extracted about 800 tons of stibnite ore from 2013 through 2014 was placed on care-and-maintenance status in 2015 and had no reported production in 2022. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced in 2022 was about $60 million. Recycling supplied about 15% of estimated domestic consumption, and the remainder came mostly from imports. In the United States, the leading uses of antimony were as follows: flame retardants, 40%; metal products, including antimonial lead and ammunition, 36%; and nonmetal products, including ceramics and glass and rubber products, 24%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	331	377	254	379	400
Secondary	4,090	4,140	[e]4,250	[e]4,250	4,200
Imports for consumption:					
Ore and concentrates	96	121	105	31	30
Oxide	19,200	17,200	15,000	19,100	19,000
Unwrought, powder	5,760	6,030	5,200	6,970	6,500
Waste and scrap[1]	202	17	6	13	60
Exports:					
Ore and concentrates[1]	38	9	10	9	67
Oxide	1,750	1,570	1,230	1,530	2,100
Unwrought, powder	313	296	296	824	1,300
Waste and scrap[1]	9	14	11	136	35
Consumption, apparent[2]	27,300	25,900	23,200	28,300	27,000
Price, metal, average, dollars per pound[3]	3.81	3.04	2.67	5.31	6.30
Net import reliance[4] as a percentage of apparent consumption	84	83	81	84	83

Recycling: The bulk of secondary antimony is recovered at secondary lead smelters as antimonial lead, most of which was generated by, and then consumed by, the lead-acid battery industry.

Import Sources (2018–21): Ore and concentrates: China, 46%; Italy, 34%; India, 12%; Belgium, 5%; and other, 3%. Oxide: China,[5] 74%; Belgium, 10%; Bolivia, 5%; Thailand, 3%; and other, 8%. Unwrought metal and powder: China,[5] 30%; India, 28%; Vietnam, 13%; Burma, 12%; and other, 17%. Total metal and oxide: China,[5] 63%; Belgium, 8%; India, 7%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Ore and concentrates	2617.10.0000	Free.
Antimony oxide	2825.80.0000	Free.
Antimony and articles thereof:		
Unwrought antimony; powder	8110.10.0000	Free.
Waste and scrap	8110.20.0000	Free.
Other	8110.90.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[6]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Antimony	90.16	1,100	—	1,100	—

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ANTIMONY

Events, Trends, and Issues: China continued to be the leading global antimony producer in 2022 and accounted for 55% of global mine production. The supply of antimony raw materials and downstream production of antimony products was constrained in 2022 as a result of various temporary mine shutdowns to mitigate the spread of the coronavirus disease 2019 (COVID-19). The antimony price reached a high of $7.03 per pound in March 2022 and the estimated average price was $6.30 per pound in 2022 compared with the annual average price of $5.31 per pound in 2021.

World Mine Production and Reserves: Reserves for Australia and China were revised based on Government reports.

	Mine production		Reserves[7]
	2021	2022[e]	
United States	—	—	[8]60,000
Australia	4,000	4,000	[9]120,000
Bolivia	2,600	2,500	310,000
Burma	4,600	4,000	140,000
Canada	2	2	78,000
China	61,000	60,000	350,000
Guatemala	80	80	NA
Iran	400	400	NA
Kazakhstan	100	100	NA
Kyrgyzstan	—	—	260,000
Mexico	750	800	18,000
Pakistan	66	70	26,000
Russia (recoverable)	20,000	20,000	350,000
Tajikistan	16,800	17,000	50,000
Turkey	1,300	1,300	100,000
Vietnam	310	300	NA
World total (rounded)[10]	112,000	110,000	>1,800,000

World Resources:[7] U.S. resources of antimony are mainly in Alaska, Idaho, Montana, and Nevada. Principal identified world resources are in Australia, Bolivia, Burma, China, Mexico, Russia, South Africa, and Tajikistan. Additional antimony resources may occur in Mississippi Valley-type lead deposits in the Eastern United States.

Substitutes: Selected organic compounds and hydrated aluminum oxide are substitutes as flame retardants. Chromium, tin, titanium, zinc, and zirconium compounds substitute for antimony chemicals in enamels, paint, and pigments. Combinations of calcium, copper, selenium, sulfur, and tin are substitutes for alloys in lead-acid batteries.

[e]Estimated. NA Not available. — Zero.

[1]Gross weight.

[2]Defined as primary production + secondary production from old scrap + imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder ± adjustments for Government stock changes.

[3]Antimony minimum 99.65%, cost, insurance, and freight. Source: Argus Media group, Argus Metals International.

[4]Defined as imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder ± adjustments for Government stock changes.

[5]Includes Hong Kong.

[6]See Appendix B for definitions.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Company-reported probable reserves for the Stibnite Gold Project in Idaho.

[9]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 22,000 tons.

[10]In addition to the countries listed, antimony may have been produced in other countries, but available information was inadequate to make reliable estimates of output.

ARSENIC

(Data in metric tons of contained arsenic[1] unless otherwise noted)

Domestic Production and Use: Arsenic trioxide and primary arsenic metal have not been produced in the United States since 1985. The principal use for arsenic compounds was in herbicides and insecticides. Arsenic trioxide was predominantly used for the production of arsenic acid, which is a key ingredient in the production of chromated copper arsenate (CCA) preservatives. CCA preservatives are used for the pressure treating of lumber for primarily nonresidential applications such as light poles, marine applications, and retaining walls. Seven companies produced CCA-treated wood in the United States in 2022. High-purity (99.9999%) arsenic metal was used to produce gallium-arsenide (GaAs) semiconductors for solar cells, space research, and telecommunications. High-purity arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide (InGaAs) was used for short-wave infrared technology. The grids in lead-acid storage batteries were strengthened by the addition of arsenic metal. Arsenic metal also was used as an antifriction additive for bearings, to harden lead shot, and in clip-on wheel weights. The value of arsenic compounds and metal imported domestically in 2022 was estimated to be about $8 million. Given that arsenic metal has not been produced domestically since 1985, it is likely that only a small portion of the material reported by the U.S. Census Bureau as arsenic exports was pure arsenic metal, and most of the material that was reported under this category reflects the gross weight of alloys, compounds, residues, scrap, and waste containing arsenic. Therefore, the estimated consumption reported under U.S. salient statistics reflects only imports of arsenic products. Globally, the leading uses of arsenic were as follows: herbicides and insecticides, 45%; wood preservatives, 29%; electronics, 8%; and other, 18%.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Imports for consumption:[2]					
Arsenic metal	929	391	522	835	790
Compounds	5,540	7,050	7,750	4,760	4,600
Total	6,470	7,440	8,270	5,600	5,400
Exports, all forms of arsenic (gross weight)	107	56	29	31	100
Consumption, estimated, all forms of arsenic[3]	6,470	7,440	8,270	5,600	5,300
Price, metal, annual average,[4] dollars per pound:					
Rotterdam	1.10	1.03	0.94	1.34	1.5
U.S. warehouse	0.97	1.01	1.08	1.11	1.8
Net import reliance[5] as a percentage of estimated consumption, all forms of arsenic	100	100	100	100	100

Recycling: Arsenic metal was contained in new scrap recycled during GaAs semiconductor manufacturing. Arsenic-containing process water was internally recycled at wood treatment plants where CCA was used. Although scrap electronic circuit boards, relays, and switches may contain arsenic, no arsenic was known to have been recovered during the recycling process to recover other contained metals. No arsenic was recovered domestically from arsenic-containing residues and dusts generated at nonferrous smelters in the United States.

Import Sources (2018–21):[2] Arsenic acid: Malaysia, 82%; Hungary, 11%; and China, 7%. Arsenic metal: China,[6] 94%; Japan, 5%; and Germany, 1%. Arsenic trioxide: China, 54%; Morocco, 39%; Belgium, 5%; Germany, 1%; and other, 1%. All forms of arsenic: China,[6] 57%; Morocco, 35%; Belgium, 4%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Arsenic metal	2804.80.0000	Free.
Arsenic acid	2811.19.1000	2.3% ad valorem.
Arsenic trioxide	2811.29.1000	Free.
Arsenic sulfide	2813.90.1000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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ARSENIC

Events, Trends, and Issues: Peru, China, and Morocco, in descending order, continued to be the leading global producers of arsenic trioxide, accounting for about 93% of estimated world production in 2022. China and Morocco continued to supply about 93% of United States imports of arsenic trioxide in 2022. China was the leading world producer of arsenic metal and supplied about 97% of United States arsenic metal imports in 2022.

High-purity arsenic metal was used to produce GaAs, indium-arsenide, and InGaAs semiconductors that were used in biomedical, communications, computer, electronics, and photovoltaic applications. Total revenues from GaAs devices increased in 2022 because of fifth-generation (5G) technology that became standard for broadband cellular 5G networks and consumer devices. A variety of GaAs wafer manufacturers ranging from large, multinational corporations to small, privately owned companies competed in this industry, but the top six producers accounted for more than 75% of the market.

World Production and Reserves:

	Production[e, 7] (arsenic trioxide, gross weight)		Reserves[8]
	2021	2022	
United States	—	—	World reserves data are unavailable but are estimated to be more than 20 times world production.
Belgium	1,000	1,000	
Bolivia	120	140	
China	24,000	24,000	
Japan	40	45	
Morocco	[9]6,880	6,900	
Peru	27,000	28,000	
Russia	1,000	1,000	
World total (rounded)	60,000	61,000	

World Resources:[8] Arsenic may be obtained from copper, gold, and lead smelter flue dust, as well as from roasting arsenopyrite, the most abundant ore mineral of arsenic. Arsenic has been recovered from orpiment and realgar in China, Peru, and the Philippines and from copper-gold ores in Chile, and arsenic is associated with gold occurrences in Canada. Orpiment and realgar from gold mines in Sichuan Province, China, were stockpiled for later recovery of arsenic. Arsenic also may be recovered from enargite, a copper mineral. Arsenic trioxide was produced at the hydrometallurgical complex of Guemassa, near Marrakech, Morocco, from cobalt-arsenide ore from the Bou Azzer Mine.

Substitutes: Substitutes for CCA in wood treatment include alkaline copper quaternary, ammoniacal copper quaternary, ammoniacal copper zinc arsenate, alkaline copper quaternary boron-based preservatives, copper azole, copper citrate, and copper naphthenate. Treated wood substitutes include concrete, plastic composite material, plasticized wood scrap, or steel. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third-generation cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based integrated circuits are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. — Zero.

[1]Arsenic content of arsenic metal is 100%; arsenic content of arsenic compounds is 77.7% for arsenic acids, 60.7% for arsenic sulfides, and 75.71% for arsenic trioxide.

[2]Arsenic content estimated from the reported gross weight of imports.

[3]Estimated to be the same as total imports.

[4]Minimum 99% arsenic. Source Argus Media group, Argus Metals International.

[5]Defined as imports.

[6]Includes Hong Kong.

[7]Includes calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide; inclusion of such materials would not duplicate reported arsenic trioxide production. Chile and Mexico were thought to be significant producers of commercial-grade arsenic trioxide but have reported no production in recent years.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Reported.

ASBESTOS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: The last U.S. producer of asbestos ceased operations in 2002 as a result of the decline in domestic and international asbestos markets associated with health and liability issues. The United States has since been wholly dependent on imports to meet manufacturing needs. All of the unmanufactured asbestos fiber imported into and used within the United States has consisted of chrysotile since no later than 1999. In 2022, U.S. consumption of chrysotile was estimated to be 260 tons, and all imports originated from Brazil, based on data available through July. The chloralkali industry, which uses chrysotile to manufacture nonreactive semipermeable diaphragms that prevent chlorine generated at the anode of an electrolytic cell from reacting with sodium hydroxide generated at the cathode, has accounted for 100% of domestic asbestos fiber consumption since 2015. In addition to unmanufactured asbestos fiber, a small, but unknown, quantity of asbestos is imported annually within manufactured products. According to the U.S. Environmental Protection Agency (EPA), the only imported items known to contain asbestos as of 2020 were brake blocks for use in the oil industry, preformed gaskets used in the exhaust system of a specific type of utility vehicle, rubber sheets for gasket fabrication (primarily used to create a chemical containment seal in the production of titanium dioxide), and some vehicle friction products.[1]

Salient Statistics—United States:[2]	2018	2019	2020	2021	2022[e]
Imports for consumption[3]	681	172	305	41	[4]100
Exports[5]	—	—	—	—	—
Consumption, estimated[6]	500	450	450	310	260
Price, average U.S. customs unit value of imports, dollars per ton	1,670	1,570	2,110	1,880	1,900
Net import reliance[7] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Brazil, 75%; and Russia, 25%. The U.S. Census Bureau reported imports from China in 2021, but bill of lading information and data reported by the Government of China suggest that shipments from China were misclassified.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Crocidolite	2524.10.0000	Free.
Amosite	2524.90.0010	Free.
Chrysotile:		
Crudes	2524.90.0030	Free.
Milled fibers, group 3 grades	2524.90.0040	Free.
Milled fibers, group 4 and 5 grades	2524.90.0045	Free.
Other	2524.90.0055	Free.
Other, asbestos	2524.90.0060	Free.

Depletion Allowance: 22% (domestic), 10% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of unmanufactured asbestos fiber in the United States has decreased during the past several decades, falling from a record high of 803,000 tons in 1973 to 500 tons or less in each year since 2018. This decline has taken place as a result of health and liability issues associated with asbestos use, leading to the displacement of asbestos from traditional domestic markets by substitutes, alternative materials, and new technology. The chloralkali industry is the only remaining domestic consumer of asbestos in mineral form. As of yearend 2022, asbestos diaphragms were used in nine chloralkali plants in the United States and accounted for about one-third of U.S. chlorine production.

In April 2022, the EPA proposed a rule that would ban the commercial use, distribution in commerce, import, manufacturing, and processing of chrysotile for all chrysotile-containing products that are still used in the United States: aftermarket automotive brakes and linings and other vehicle friction products, diaphragms used in the chloralkali industry, oilfield brake blocks, and sheet and other gaskets. The prohibitions on asbestos diaphragms and sheet gaskets would take effect 2 years after the effective date of the final rule, and the prohibitions on other items would take effect 180 days after finalization. The EPA had not issued the final rule as of the end of September 2022. In 2019, the EPA banned all discontinued uses of asbestos from restarting without the EPA having an opportunity to evaluate each intended use and take any necessary regulatory action. If finalized, the rule proposed in April 2022 would effectively prohibit all uses of asbestos in the United States.

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ASBESTOS

Estimated worldwide consumption of unmanufactured asbestos fiber ranged from 1.1 to 1.3 million tons per year from 2015 through 2021, a significant decrease from approximately 2 million tons in 2000. Global demand for asbestos will likely continue for the foreseeable future, particularly for use in cement pipe, roofing sheets, and other construction materials in Asia.

The Supreme Federal Court of Brazil enacted a national ban on asbestos in November 2017. With the exception of an approximately 2-week pause because of a legal challenge in 2021, the only asbestos producer in the country has operated its mine continuously since November 2020 under the authority of a State law that permits the extraction and processing of asbestos in the State of Goias for export purposes only.

One company in Zimbabwe began producing asbestos in 2019 from tailings of its former mines, with an average monthly output of 500 tons as of August 2019. In 2020, the company was attempting to acquire funds to potentially restart operations at the King Mine (part of the Gaths mining complex) in Mashava and the Shabanie Mine in Zvishavane. Information on the status of asbestos production from tailings was unavailable in 2022, but local media reports suggested that the company lacked the capital required to return the mines to production. In addition to the financial challenges, critical areas of the mines were inaccessible because of flooding and rockfalls.

World Mine Production and Reserves: Reserves for China were revised based on Government reports.

	Mine production		
	2021	2022[e]	Reserves[8]
United States	—	—	Small
Brazil	[9]154,000	190,000	11,000,000
China	[e]130,000	130,000	15,000,000
Kazakhstan	250,000	230,000	Large
Russia	699,000	700,000	110,000,000
Zimbabwe	[e]10,000	—	Large
World total (rounded)	1,240,000	1,300,000	Large

World Resources:[8] Reliable evaluations of global asbestos resources have not been published recently, and available information was insufficient to make accurate estimates for many countries. However, world resources are large and more than adequate to meet anticipated demand in the foreseeable future. Resources in the United States are composed mostly of short-fiber asbestos for which use in asbestos-based products is more limited than long-fiber asbestos.

Substitutes: Numerous materials substitute for asbestos, including calcium silicate, carbon fiber, cellulose fiber, ceramic fiber, glass fiber, steel fiber, wollastonite, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene. Several nonfibrous minerals or rocks, such as perlite, serpentine, silica, and talc, are also considered to be possible asbestos substitutes for products in which the reinforcement properties of fibers are not required. Membrane cells and mercury cells are alternatives to asbestos diaphragms used in the chloralkali industry.

[e]Estimated. — Zero.

[1]Source: U.S. Environmental Protection Agency, 2020, Risk evaluation for asbestos part I—Chrysotile asbestos: Washington, DC, EPA Document no. EPA-740-R1-8012, December, 352 p.

[2]Includes unmanufactured asbestos fiber (chrysotile) only; excludes asbestos contained in manufactured products.

[3]Modified from reported U.S. Census Bureau data. Small quantities of additional chrysotile imports from Italy and Japan were reported in 2018, but existing asbestos bans suggest that these shipments were misclassified. Significant additional imports from China were reported in 2021 and 2022, but bill of lading information and data reported by the Government of China suggest that these shipments were also misclassified.

[4]According to the U.S. Census Bureau, chrysotile imports from Brazil totaled 50 tons through July. Final 2022 imports may differ significantly from the provided estimate because chrysotile imports typically do not follow a predictable pattern throughout the year.

[5]Exports of unmanufactured asbestos fiber reported by the U.S. Census Bureau were 235 tons in 2018, 2 tons in 2019, 1 ton in 2020, 461 tons in 2021, and 134 tons through July 2022. These shipments likely consisted of materials misclassified as asbestos, reexports, and (or) waste products because asbestos has not been mined in the United States since 2002.

[6]To account for year-to-year fluctuations in chrysotile imports owing to cycles of companies replenishing and drawing down stockpiles, consumption is estimated as a 5-year rolling average of imports for consumption. Information regarding the quantity of industry stocks was unavailable. [7]Defined as imports – exports. The United States has been 100% import reliant since 2002. All domestic consumption of unmanufactured asbestos fiber was from imports and unreported inventories.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Asbestos production in Brazil is permitted for export purposes only. The value shown represents reported country exports of asbestos.

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, three companies mined barite in Nevada. Two mines resumed production after having been idle for years, one since 2016 and one since 2020. Mine production increased, but data were withheld to avoid disclosing company proprietary data. The barite assets (two mines and one grinding plant) of a fourth company in Nevada were acquired by a gold-mining company that bought the properties for water and rail access but did not intend to resume barite production. An estimated 2.1 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in nine States. A company based in Turkey invested $10 million to construct a new grinding plant in Moundsville, WV.

Typically, more than 90% of the barite sold in the United States is used as a weighting agent in fluids used in the drilling of oil and natural gas wells. The majority of Nevada crude barite was ground in Nevada and then sold to companies drilling in the Central and Western United States. Because of the higher cost of rail and truck transportation compared to ocean freight, offshore drilling operations in the Gulf of Mexico and onshore drilling operations in other regions primarily used imported barite.

Barite also is used as a filler, extender, or weighting agent in products such as paints, plastics, and rubber. Some specific applications include use in automobile brake and clutch pads, in automobile paint primer for metal protection and gloss, as a weighting agent in rubber, and in the cement jacket around underwater petroleum pipelines. In the metal-casting industry, barite is part of the mold-release compounds. Because barite significantly blocks X-ray and gamma-ray emissions, it is used as aggregate in high-density concrete for radiation shielding around X-ray units in hospitals, nuclear powerplants, and university nuclear research facilities. Ultrapure barite is used as a contrast medium in X-ray and computed tomography examinations of the gastrointestinal tract.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Sold or used, mine	366	414	W	W	W
Ground and crushed[1]	2,420	2,350	1,410	1,670	2,100
Imports for consumption[2]	2,460	2,500	1,480	1,660	2,300
Exports[3]	67	38	48	62	89
Consumption, apparent (crude and ground)[4]	2,760	2,880	W	W	W
Price, average unit value, ground, ex-works, dollars per metric ton	176	179	183	167	170
Employment, mine and mill, number[e]	520	480	350	330	360
Net import reliance[5] as a percentage of apparent consumption	87	86	>75	>75	>75

Recycling: None.

Import Sources (2018–21): China,[6] 38%; India, 29%; Morocco, 16%; Mexico, 13%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Ground barite	2511.10.1000	Free.
Crude barite	2511.10.5000	$1.25 per metric ton.
Barium compounds:		
Barium oxide, hydroxide, and peroxide	2816.40.2000	2% ad valorem.
Barium chloride	2827.39.4500	4.2% ad valorem.
Barium sulfate, precipitated	2833.27.0000	0.6% ad valorem.
Barium carbonate, precipitated	2836.60.0000	2.3% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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BARITE

Events, Trends, and Issues: Historically, rig counts have been a good barometer of barite consumption. In 2022, the monthly average rig count in all regions except for Europe generally increased throughout the year. Through October, the world annual average rig count excluding the United States was 1,050, an increase of 15% compared with that in 2021. In all regions except for Canada, the average annual rig count remained below averages in 2019, before the coronavirus disease 2019 (COVID-19) pandemic. Increases in worldwide rig counts contributed to an estimated 17% increase in world barite production. In the United States, the annual average rig count increased by nearly 50% in 2022. This trend was reflected in domestic sales of ground barite, which were estimated to have increased by 26%. In addition to increased rig counts, barite consumption in the United States was likely supported by a decrease in the number of drilled-but-uncompleted (DUC) wells, which the U.S. Energy Information Administration began tracking in 2014. The number of DUC wells reached its highest level in June 2020, but by September 2022 had reached its lowest level since the inception of the count.

In April, the leading barite mining company in India completed its barite tender that is held every 3 years. Buyers compete for the company's barite production, which is offered in several grades—A-grade with a minimum specific gravity of 4.2, B-grade with a minimum specific gravity of 4.1, and C-, D-, and W-grades, with no guarantee as to specific gravity, but which typically exceeded 3.9. Prices for A- and B-grades increased by about 30% to 45%, or approximately $25 per metric ton. Three U.S. companies reportedly signed agreements to purchase a total of 1.6 million tons of barite.

World Mine Production and Reserves: In response to concerns about dwindling global reserves of 4.2-specific-gravity barite used by the oil- and gas-drilling industry, the American Petroleum Institute issued an alternate specification for 4.1-specific-gravity weighting agents in 2010. Estimated reserves data were included only if developed since the adoption of the 4.1-specific-gravity standard. Reserves for China were revised based on information from Government reports.

	Mine production		Reserves[7]
	2021	2022[e]	
United States	W	W	NA
China	2,100	1,900	37,000
India	1,600	2,600	51,000
Iran	224	220	100,000
Kazakhstan	450	500	85,000
Mexico	321	320	NA
Morocco	1,100	1,300	NA
Russia	150	150	12,000
Turkey	258	300	35,000
Other countries	528	580	70,000
World total (rounded)	[8]6,730	[8]7,900	NA

World Resources:[7] In the United States, identified resources of barite are estimated to be 150 million tons, and undiscovered resources contribute an additional 150 million tons. The world's barite resources in all categories are about 2 billion tons, but only about 740 million tons are identified resources.

Substitutes: In the oil- and gas-well-drilling industry, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. However, substitutes have been used in relatively small amounts, and barite remains the preferred choice for drilling applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Imported and domestic barite, crushed and ground, sold or used by domestic grinding establishments.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2511.10.1000, 2511.10.5000, and 2833.27.0000.

[3]Includes data for the following Schedule B codes: 2511.10.1000 and 2833.27.0000.

[4]Defined as mine production (sold or used) + imports – exports.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Excludes U.S. production.

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise noted)

Domestic Production and Use: In 2022, a limited amount of bauxite and bauxitic clay was produced for nonmetallurgical use in Alabama, Arkansas, and Georgia. Production statistics for bauxite were withheld to avoid disclosing company proprietary data. In 2022, the reported quantity of bauxite consumed was estimated to be 2.9 million tons, 4% more than that reported in 2021, with an estimated value of about $87 million. About 76% of the bauxite was refined by the Bayer process for alumina or aluminum hydroxide, and the remainder went to products such as abrasives, cement, chemicals, proppants, and refractories, and as a slag adjuster in steel mills. Alumina production was estimated to be 1.2 million tons, slightly more than that in 2021. About 63% of the alumina produced went to primary aluminum smelters, and the remainder went to nonmetallurgical products, such as abrasives, ceramics, chemicals, and refractories.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	3,980	4,620	3,760	3,880	3,600
Exports[2]	16	15	15	12	12
Stocks, industry, yearend[e, 2]	600	300	250	200	200
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	4,460	3,680	3,330	2,790	2,900
Price, average unit value of imports, free alongside ship (f.a.s.), dollars per metric ton	31	32	30	31	30
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[5]	1,570	1,410	1,340	1,180	1,200
Imports for consumption[5]	1,530	1,930	1,340	1,550	2,000
Exports[5]	288	200	153	180	160
Stocks, industry, yearend[5]	275	275	234	202	300
Consumption, apparent[3]	2,800	3,140	2,570	2,580	2,900
Price, average unit value of imports, f.a.s., dollars per metric ton	592	472	394	462	550
Net import reliance[4] as a percentage of apparent consumption	44	55	48	54	59

Recycling: None.

Import Sources (2018–21): Bauxite:[2] Jamaica, 63%; Brazil, 9%; Guyana and Turkey, 8% each; and other, 12%. Alumina:[5] Brazil, 59%; Australia and Jamaica, 14% each; Canada, 5%; and other, 8%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
Bauxite, calcined (refractory grade)	2606.00.0030	Free.
Bauxite, calcined (other)	2606.00.0060	Free.
Bauxite, crude dry (metallurgical grade)	2606.00.0090	Free.
Aluminum oxide (alumina)	2818.20.0000	Free.
Aluminum hydroxide	2818.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, one domestic alumina refinery produced alumina from imported bauxite. A 1.2-million-ton-per-year alumina refinery in Gramercy, LA, produced alumina for aluminum smelting and specialty-grade alumina. A 500,000-ton-per-year alumina refinery in Burnside, LA, was temporarily shut down in August 2020 and remains idle. No plans were announced regarding its reopening. The average prices, f.a.s., for U.S. imports for consumption of crude dry bauxite and metallurgical-grade alumina during the first 9 months of 2022 were $30 per ton and $553 per ton, a slight decrease and 25% more than those in the same period of 2021, respectively.

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BAUXITE AND ALUMINA[1]

The conflict between Russia and Ukraine led to the closure of a 1.7-million-ton-per-year alumina refinery in Ukraine. High energy costs in Europe caused a 600,000-ton-per-year alumina refinery in Romania to temporarily shutter and a 1.7-million-ton-per-year alumina refinery in Spain to curtail production by up to 60%. Additionally, several primary aluminum smelters and aluminum product manufacturers throughout Europe announced shutdowns or partial curtailments. In August, a 1.4-million-ton-per-year alumina refinery in Jamaica resumed operations after a fire in 2021 caused a year-long production stoppage. Operations at a 650,000-ton-per-year alumina refinery in Jamaica were suspended by the National Environment and Planning Agency for polluting a nearby river. A United States-based mining company that mines nonmetallurgical bauxite in Guyana acquired a United States proppant manufacturer with two manufacturing facilities located in Georgia.

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves: Reserves for Australia, China, and Indonesia were revised based company and Government reports.

	Alumina production[5]		Bauxite production		Bauxite reserves[6]
	2021	2022[e]	2021	2022[e]	
United States	1,180	1,200	W	W	20,000
Australia	20,400	20,000	103,000	100,000	[7]5,100,000
Brazil	[e]12,000	11,000	[e]33,000	33,000	2,700,000
Canada	1,360	1,300	—	—	—
China	75,200	76,000	[e]90,000	90,000	710,000
Germany	[e]900	750	—	—	—
Guinea	414	440	[e]86,000	86,000	7,400,000
India	[e]7,000	7,400	[e]17,400	17,000	660,000
Indonesia	[e]1,000	1,100	[e]21,000	21,000	1,000,000
Ireland	1,880	1,800	—	—	—
Jamaica	1,160	480	5,950	3,900	2,000,000
Kazakhstan	[e]1,400	1,400	4,370	4,400	160,000
Russia	3,050	3,100	5,680	5,000	500,000
Saudi Arabia	1,920	2,000	4,780	4,800	180,000
Spain	1,540	1,700	—	—	—
Ukraine	1,770	740	—	—	—
United Arab Emirates	2,300	2,300	—	—	—
Vietnam	1,456	1,500	[e]3,830	3,800	5,800,000
Other countries	2,620	2,200	9,330	8,900	5,100,000
World total (rounded)	139,000	140,000	[8]384,000	[8]380,000	31,000,000

World Resources:[6] Bauxite resources are estimated to be between 55 billion and 75 billion tons, distributed in Africa (32%), Oceania (23%), South America and the Caribbean (21%), Asia (18%), and elsewhere (6%). Domestic resources of bauxite are inadequate to meet long-term U.S. demand, but the United States and most other major aluminum-producing countries have essentially inexhaustible subeconomic resources of aluminum in materials other than bauxite.

Substitutes: Bauxite is the only raw material used in the production of alumina on a commercial scale in the United States. Although currently not economically competitive with bauxite, vast resources of clay are technically feasible sources of alumina. Other raw materials, such as alunite, anorthosite, coal wastes, and oil shales, offer additional potential alumina sources. Synthetic mullite, produced from kaolin, bauxitic kaolin, kyanite, and sillimanite, substitutes for bauxite-based refractories. Silicon carbide and alumina zirconia can substitute for alumina and bauxite in abrasives but cost more.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also the Aluminum chapter. As a general rule, 4 tons of dried bauxite is required to produce 2 tons of alumina, which, in turn, can be used to produce 1 ton of aluminum.

[2]Includes all forms of bauxite, expressed as dry equivalent weights.

[3]Defined as production + imports – exports ± adjustments for industry stock changes.

[4]Defined as imports – exports ± adjustments for industry stock changes.

[5]Calcined equivalent weights.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 1.7 billion tons.

[8]Excludes U.S. production.

BERYLLIUM

(Data in metric tons of contained beryllium unless otherwise noted)

Domestic Production and Use: One company in Utah mined bertrandite ore and converted it, along with imported beryl, into beryllium hydroxide. Some of the beryllium hydroxide was shipped to the company's plant in Ohio, where it was converted into metal, oxide, and downstream beryllium-copper master alloy, and some was sold. Estimated beryllium apparent consumption in 2022 was 180 tons and was valued at about $130 million based on the most recent beryllium price estimate. Based on sales revenues, approximately 24% of beryllium products were used in industrial components, 21% in automotive electronics, 17% in aerospace and defense applications, 10% in telecommunications infrastructure, 8% in consumer electronics, 5% in energy applications, 2% in semiconductor applications, and 13% in other applications. Beryllium alloy strip and bulk products, the most common forms of processed beryllium, were used in all application areas. Most unalloyed beryllium metal and beryllium composite products were used in defense and scientific applications. To ensure current and future availability of high-quality domestic beryllium to meet critical defense needs, the U.S. Department of Defense, under the Defense Production Act, Title III, invested in a public-private partnership with the leading U.S. beryllium producer to build a primary beryllium facility in Ohio. Construction of the facility was completed in 2011.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine shipments	165	160	165	175	180
Imports for consumption[1]	67	49	48	49	41
Exports[2]	30	37	25	30	47
Shipments from Government stockpile[3]	—	—	3	7	7
Consumption:					
Apparent[4]	202	167	196	196	180
Reported, ore	170	160	170	170	180
Price, annual average unit value, beryllium-copper master alloy,[5] dollars per kilogram of contained beryllium	590	620	620	680	730
Stocks, ore, consumer, yearend	30	35	30	35	35
Net import reliance[6] as a percentage of apparent consumption	18	4	16	11	1

Recycling: Beryllium was recovered from new scrap generated during the manufacture of beryllium products and from old scrap. Detailed data on the quantities of beryllium recycled are not available but may account for as much as 20% to 25% of total beryllium consumption. The leading U.S. beryllium producer established a comprehensive recycling program for all of its beryllium products, recovering approximately 40% of the beryllium content of the new and old beryllium alloy scrap.

Import Sources (2018–21):[1] Kazakhstan, 43%; Japan, 15%; Latvia, 15%; Brazil, 10%; and other, 17%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Beryllium ores and concentrates	2617.90.0030	Free.
Beryllium oxide and hydroxide	2825.90.1000	3.7% ad valorem.
Beryllium-copper master alloy	7405.00.6030	Free.
Beryllium-copper plates, sheets, and strip:		
Thickness of 5 millimeters (mm) or more	7409.90.1030	3% ad valorem.
Thickness of less than 5 mm:		
Width of 500 mm or more	7409.90.5030	1.7% ad valorem.
Width of less than 500 mm	7409.90.9030	3% ad valorem.
Beryllium:		
Unwrought, including powders	8112.12.0000	8.5% ad valorem.
Waste and scrap	8112.13.0000	Free.
Other	8112.19.0000	5.5% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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BERYLLIUM

Government Stockpile:[7] The Defense Logistics Agency Strategic Materials had a goal of retaining 47 tons of beryllium metal in the National Defense Stockpile.

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Beryl ore (gross weight)	1	—	—	—	—
Metal (all types)	50	—	7	—	7
Structured powder	7	—	—	—	—

Events, Trends, and Issues: Apparent consumption in 2022 decreased by 8% from that in 2021 owing primarily to a 16% decrease in estimated beryllium imports and a 57% increase estimated exports. During the first 6 months of 2022, the leading U.S. beryllium producer reported that net sales of its beryllium alloy strip and bulk products and beryllium metal and composite products were 27% higher than those during the first 6 months of 2021. Net sales of beryllium products increased primarily in the aerospace and defense, energy, and industrial components markets.

Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium in air, water, and other media. Industry is required to carefully control the quantity of beryllium dust, fumes, and mists in the workplace.

World Mine Production and Reserves:

	Mine production[8, 9] 2021	Mine production[8, 9] 2022[e]	Reserves[10]
United States	175	180	The United States has very little beryl that
Brazil	[e]3	3	can be economically hand sorted from
China	[e]71	70	pegmatite deposits. An epithermal deposit in
Madagascar	[e]1	1	the Spor Mountain area in Utah is a large
Mozambique	13	13	bertrandite resource, which is being mined.
Nigeria	[e]1	1	Proven and probable bertrandite reserves in
Rwanda	[e]1	1	Utah total about 19,000 tons of contained
Uganda	[e]7	7	beryllium. World beryllium reserves are not
World total (rounded)	272	280	available.

World Resources:[10] The world's identified resources of beryllium have been estimated to be more than 100,000 tons. About 60% of these resources are in the United States; by tonnage, the Spor Mountain area in Utah, the McCullough Butte area in Nevada, the Black Hills area in South Dakota, the Sierra Blanca area in Texas, the Seward Peninsula in Alaska, and the Gold Hill area in Utah account for most of the total.

Substitutes: Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. In some applications, certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium may be substituted for beryllium metal or beryllium composites. Copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys (copper-tin-phosphorus) may be substituted for beryllium-copper alloys, but these substitutions can result in substantially reduced performance. Aluminum nitride or boron nitride may be substituted for beryllium oxide.

[e]Estimated. — Zero.

[1]Includes estimated beryllium content of imported ores and concentrates, oxide and hydroxide, unwrought metal (including powders), beryllium articles, waste and scrap, beryllium-copper master alloy, and beryllium-copper plates, sheets, and strip.

[2]Includes estimated beryllium content of exported unwrought metal (including powders), beryllium articles, and waste and scrap.

[3]Change in total inventory from prior yearend inventory. If negative, increase in inventory.

[4]Defined as production + imports – exports ± adjustments for Government and industry stock changes.

[5]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%. Rounded to two significant figures.

[6]Defined as imports – exports ± adjustments for Government and industry stock changes.

[7]See Appendix B for definitions.

[8]In addition to the countries listed, Kazakhstan and Portugal may have produced beryl ore, but available information was inadequate to make reliable estimates of output. Other nations that produced gemstone beryl ore may also have produced some industrial beryl ore.

[9]Based on a beryllium content of 4% from bertrandite and beryl sources.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons, gross weight, unless otherwise noted)

Domestic Production and Use: The United States ceased production of primary refined bismuth in 1997 and is highly import reliant. Bismuth is contained in some lead ores mined domestically. However, the last domestic primary lead smelter closed at yearend 2013; since then, all lead concentrates have been exported for smelting.

About 64% of domestic bismuth consumption was for chemicals used in cosmetic, industrial, laboratory, and pharmaceutical applications. Bismuth use in pharmaceuticals included bismuth subsalicylate (the active ingredient in over-the-counter stomach remedies) and other compounds used to treat burns, intestinal disorders, and stomach ulcers. Bismuth is also used in industrial applications for the manufacture of ceramic glazes, crystalware, and pearlescent pigments.

Bismuth has a wide variety of metallurgical applications, including use as an additive to improve metal integrity of malleable cast iron in the foundry industry and as a nontoxic replacement for lead in brass, free-machining steels, and solders. The use of bismuth in brass for pipe fittings, fixtures, and water meters increased after 2014 when the definition of “lead-free” under the Safe Drinking Water Act was modified to reduce the maximum lead content of “lead-free” pipes and plumbing fixtures to 0.25% from 8%. The melting point of bismuth is relatively low at 271 degrees Celsius, and it is an important component of various fusible alloys, some of which have melting points below that of boiling water. These bismuth-containing alloys can be used in holding devices for grinding optical lenses, as plugs for abandoned oil wells, as a temporary filler to prevent damage to tubes in bending operations, as a triggering mechanism for fire sprinklers, and in other applications in which a low melting point is ideal. Bismuth-tellurium-oxide alloy film paste is used in the manufacture of semiconductor devices.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap[1]	2,470	2,340	1,650	1,980	2,800
Exports, metal, alloys, and scrap[2]	653	636	699	1,010	670
Consumption:					
Apparent[3]	2,040	1,690	1,210	1,030	2,000
Reported	570	548	513	597	600
Price, average,[4] dollars per pound	4.61	3.18	2.72	3.74	3.90
Stocks, yearend, consumer, bismuth metal	346	443	271	297	500
Net import reliance[5] as a percentage of apparent consumption	96	95	93	92	96

Recycling: Recycled bismuth-containing alloy scrap was thought to compose 4% to 8% of U.S. bismuth apparent consumption for the years 2018–22.

Import Sources (2018–21): China,[6] 65%; Republic of Korea, 19%; Mexico, 5%; Belgium, 3%; and other, 8%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Bismuth and articles thereof, including waste and scrap:		
Containing more than 99.99% of bismuth, by weight	8106.10.0000	Free.
Other	8106.90.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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BISMUTH

Events, Trends, and Issues: The estimated annual average domestic dealer price for bismuth in 2022 was an estimated $3.90 per pound, a 4% increase from that in 2021 and the highest annual average price since 2018. Globally, excess stocks continued to keep prices low compared with those in 2007 through 2014, when the average annual dealer price was above $7.84 per pound. Global primary refined production was estimated to remain unchanged from that in 2021 and increased by 3% from that in 2019, before the coronavirus disease 2019 (COVID-19) pandemic. Exports from China through August 2022 remained flat compared with those during the same period in 2021 but increased by 76% from those in 2019. The increase was attributed to the stockpiling of supplies by foreign buyers avoiding shipping disruptions owing to concerns about COVID-19 pandemic-related production interruptions in China and global shipping issues.

U.S. trade data through July 2022 were mixed when compared with the same period in 2021—whereas bismuth imports for consumption increased, exports decreased. In the long term, bismuth demand from the alloying, chemical, and metallurgical industries was expected to remain stable.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[7]
	2021	2022	
United States	—	—	Quantitative estimates of reserves were not available.
Bolivia	60	60	
Bulgaria	50	50	
Canada	50	50	
China	16,000	16,000	
Japan	500	480	
Kazakhstan	230	220	
Korea, Republic of	1,000	950	
Laos	[8]2,070	2,000	
Mexico	10	10	
World total (rounded)	20,000	20,000	

World Resources:[7] World reserves of bismuth are usually estimated based on the bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores. In China and Vietnam, bismuth production is a byproduct or coproduct of tungsten and other metal ore processing. In Japan and the Republic of Korea, bismuth production is a byproduct or coproduct of zinc ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines where bismuth has been the primary product. The Tasna Mine has been inactive since 1996.

Substitutes: Bismuth compounds can be replaced in pharmaceutical applications by alumina, antibiotics, calcium carbonate, and magnesia. Titanium dioxide-coated mica flakes and fish-scale extracts are substitutes in pigment uses. Cadmium, indium, lead, and tin can partially replace bismuth in low-temperature solders. Resins can replace bismuth alloys for holding metal shapes during machining, and glycerine-filled glass bulbs can replace bismuth alloys in triggering devices for fire sprinklers. Free-machining alloys can contain lead, selenium, or tellurium as a replacement for bismuth. Bismuth is an environmentally friendly substitute for lead in plumbing and many other applications, including fishing weights, hunting ammunition, lubricating greases, and soldering alloys.

[e]Estimated. — Zero.

[1]Includes data for the following Harmonized Tariff Schedule of the United States codes: 8106.00.0000 (for the years 2018–21), and 8106.10.0000 and 8106.90.0000 (for the year 2022).

[2]Includes data for the following Schedule B numbers: 8106.00.0000 (for the years 2018–21), and 8106.10.0000 and 8106.90.0000 (for the year 2022).

[3]Defined as secondary production + imports – exports ± adjustments for industry stock changes.

[4]Prices are based on 99.99%-purity metal at warehouse (Rotterdam) in minimum lots of 1 ton. Source: Fastmarkets AMM.

[5]Defined as imports – exports ± adjustments for industry stock changes.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Reported.

BORON

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies in southern California produced borates in 2022, and most of the boron products consumed in the United States were manufactured domestically. Estimated boron production increased in 2022 compared with 2021 production. U.S. boron production and consumption data were withheld to avoid disclosing company proprietary data. The leading boron producer mined borate ores, which contain the minerals kernite, tincal, and ulexite, by open pit methods and operated associated compound plants. Kernite was used to produce boric acid, tincal was used to produce sodium borate, and ulexite was used as a primary ingredient in the manufacture of a variety of specialty glasses and ceramics. A second company produced borates from brines extracted through solution-mining techniques. Boron minerals and chemicals were principally consumed in the north-central and eastern United States. In 2022, the glass and ceramics industries remained the leading domestic users of boron products, accounting for an estimated 65% of total borates consumption. Boron also was used as a component in abrasives, cleaning products, insecticides, and insulation and in the production of semiconductors.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	133	161	174	232	160
Boric acid	51	41	39	54	53
Colemanite (calcium borates)	73	42	18	3	1
Ulexite (sodium borates)	34	38	41	49	36
Exports:					
Boric acid	251	251	257	280	250
Refined borax	610	598	594	607	610
Consumption, apparent[1]	W	W	W	W	W
Price, average unit value of imports, cost, insurance, and freight, dollars per metric ton	404	373	380	394	430
Employment, number	1,350	1,370	1,330	1,330	1,370
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2018–21): All forms: Turkey, 90%; Bolivia, 5%; Chile, 2%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Natural borates:		
Sodium (ulexite)	2528.00.0005	Free.
Calcium (colemanite)	2528.00.0010	Free.
Boric acids	2810.00.0000	1.5% ad valorem.
Borates, refined borax:		
Anhydrous	2840.11.0000	0.3% ad valorem.
Non-anhydrous	2840.19.0000	0.1% ad valorem.

Depletion Allowance: Borax, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Elemental boron is a metalloid with limited commercial applications. Although the term “boron” is commonly referenced, it does not occur in nature in an elemental state. Boron combines with oxygen and other elements to form boric acid or inorganic salts called borates. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on their boric oxide (B_2O_3) content, varying by ore and compound and by the absence or presence of calcium and sodium. Four borate minerals—colemanite, kernite, tincal, and ulexite—account for 90% of the borate minerals used by industry worldwide. Although borates were used in more than 300 applications, more than three-quarters of world consumption was used in ceramics, detergents, fertilizers, and glass.

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BORON

China, Malaysia, Canada, Mexico, India, and Indonesia, in decreasing order of tonnage, are the countries that imported the largest quantities of refined borates from the United States in 2022. Domestic shipments of boric acid were sent to China, the Netherlands, the Republic of Korea, Japan, and Malaysia, in decreasing order of tonnage. Because China has low-grade boron reserves and demand for boron is anticipated to rise in that country, imports from Chile, Russia, Turkey, and the United States were expected to remain steady during the next several years.

Continued investment in new borate refineries and the continued rise in demand were expected to fuel growth in world production for the next few years. An Australian-British multinational mining corporation completed and successfully produced battery-grade lithium from waste rock at its Boron Mine's lithium demonstration plant in 2021. The demonstration will be used as the basis for a feasibility assessment. The California mine site could help create an additional revenue stream from almost a century of waste rock once the project is completed. Initial capacity was expected to be 5,000 tons per year. Two Australian-based mine developers previously confirmed that production of high-quality boron products would be possible from their projects in California and Nevada, respectively. These companies continued to make progress on their respective projects by acquiring some of the permits and funding necessary to begin and continue construction. The project in California began construction in April and was expected to have a focus on specialty boron products for industries related to global decarbonization and food security once production starts. The Nevada project was expected to begin production by 2025. These companies have the potential to become substantial boron producers when their projects are fully developed.

World Production and Reserves: Reserves for China were revised based on Government reports.

	Production—All forms[e]		Reserves[3]
	2021	2022	
United States	W	W	40,000
Argentina, crude ore	130	130	NA
Bolivia, ulexite	200	200	NA
Chile, ulexite	290	300	35,000
China, boric oxide equivalent	380	300	21,000
Germany, compounds	60	60	NA
Peru, crude borates	[4]246	250	4,000
Russia, datolite ore	80	80	40,000
Turkey, refined borates	1,700	1,700	1,200,000
World total[5]	XX	XX	XX

World Resources:[3] Deposits of borates are associated with volcanic activity and arid climates, with the largest economically viable deposits in the Mojave Desert of the United States, the Alpide belt along the southern margin of Eurasia, and the Andean belt of South America. U.S. deposits consist primarily of tincal, kernite, and borates contained in brines, and to a lesser extent, ulexite and colemanite. About 70% of all deposits in Turkey are colemanite, primarily used in the production of heat-resistant glass. At current levels of consumption, world resources are adequate for the foreseeable future.

Substitutes: The substitution of other materials for boron is possible in detergents, enamels, insulation, and soaps. Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamels can use other glass-producing substances, such as phosphates. Insulation substitutes include cellulose, foams, and mineral wools. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Reported.

[5]World totals cannot be calculated because production and reserves are not reported in a consistent manner by all countries.

BROMINE

(Data in metric tons of contained bromine unless otherwise noted)

Domestic Production and Use: Bromine was recovered from underground brines by two companies in Arkansas. Bromine is one of the leading mineral commodities, in terms of value, produced in Arkansas. The two bromine companies in the United States account for a large percentage of world production capacity.

The leading global applications of bromine are for the production of brominated flame retardants (BFRs) and clear brine drilling fluids. Bromine compounds are also used in a variety of other applications, including industrial uses, as intermediates, and for water treatment. U.S. apparent consumption of bromine in 2022 was estimated to be greater than that in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	56,200	56,300	30,700	27,200	27,000
Exports, elemental bromine and compounds[2]	21,900	29,300	36,600	27,900	18,000
Consumption, apparent[3]	W	W	W	W	W
Price, average unit value of imports (cost, insurance, and freight), dollars per kilogram	2.21	2.31	2.67	2.85	3.5
Employment, number[e]	1,050	1,050	1,050	1,050	1,050
Net import reliance[4] as a percentage of apparent consumption	<25	<25	E	E	<25

Recycling: Some bromide solutions were recycled to obtain elemental bromine and to prevent the solutions from being disposed of as hazardous waste. For example, hydrogen bromide is emitted as a byproduct of many organic reactions; this byproduct can be recycled with virgin bromine brines and used as a source of bromine production. Bromine contained in plastics, such as BFRs, can be difficult and costly to remove; therefore, bromine-containing polymers will often be recycled with the virgin polymer and used again in new products. Bromine used in zinc-bromine batteries can be removed and completely recovered as bromine at the battery's end of life, purified, and used for new batteries. Available information was insufficient to estimate the quantity of bromine recovered and recycled.

Import Sources (2018–21):[5] Israel, 80%; Jordan, 12%; China,[6] 4%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Bromine	2801.30.2000	5.5% ad valorem.
Hydrobromic acid	2811.19.3000	Free.
Potassium or sodium bromide	2827.51.0000	Free.
Ammonium, calcium, or zinc bromide	2827.59.2500	Free.
Potassium bromate	2829.90.0500	Free.
Sodium bromate	2829.90.2500	Free.
Methyl bromide[7]	2903.61.0000	Free.
Ethylene dibromide[8]	2903.62.1000	5.4% ad valorem.
Dibromoneopentylglycol	2905.59.3000	Free.
Tetrabromobisphenol A	2908.19.2500	5.5% ad valorem.
Decabromodiphenyl and octabromodiphenyl oxide	2909.30.0700	5.5% ad valorem.

Depletion Allowance: Brine wells, 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The United States maintained its position as one of the leading bromine producers in the world along with China, Israel, and Jordan. In 2022, the leading source of imports of bromine and bromide compounds (gross weight) was Israel. The average import value of bromine and bromine compounds was estimated to have increased by over 20% in 2022 compared with that in 2021. Together, the leading imported bromine products in terms of both gross weight and bromine content were bromides and bromide oxides of ammonium, calcium, or zinc and bromides of sodium or potassium (over 90%). Estimated total imports of bromine and bromine compounds (bromine content) decreased slightly, whereas estimated total exports decreased by over 30% compared with those in 2021.

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BROMINE

In 2021, the U.S. Environmental Protection Agency issued a final rule to reduce the exposure to decabromodiphenyl ether (decaBDE), a BFR considered to be persistent, bioaccumulative, and toxic. The rule prohibited the manufacture, processing, distribution, or importing of decaBDE or products containing decaBDE. The importing, manufacturing, and processing of decaBDE and products to which decaBDE had been added was prohibited effective March 2021, and distribution prohibitions started in January 2022. Longer compliance dates or exclusions were set for certain uses such as aerospace vehicle parts, hospitality curtains, and wire and cable insulation used in nuclear power facilities. Because of health concerns, some States have established their own policies restricting the use of BFRs.

Globally, bromine selling prices were higher in 2022 compared with those in 2021. Domestic sale volumes of bromine and bromine compounds also increased in 2022 compared with those in 2021 owing primarily to sales of BFRs. BFR sales were driven by strong demand for appliance, automotive, construction, and electronic industries. Sales of clear brine drilling fluids, the second leading use of bromine, also increased compared with those in the previous year.

World Production and Reserves:

	Production[e]		Reserves[9]
	2021	2022	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	70,000	70,000	NA
India	5,000	5,000	NA
Israel	[10]182,000	180,000	Large
Japan	18,000	20,000	NA
Jordan	110,000	110,000	Large
Ukraine	4,500	4,500	NA
World total (rounded)	[11]390,000	[11]390,000	Large

World Resources:[9] Bromine is found principally in seawater, evaporitic (salt) lakes, and underground brines associated with petroleum deposits. The Dead Sea, in the Middle East, is estimated to contain 1 billion tons of bromine. Seawater contains about 65 parts per million bromine, or an estimated 100 trillion tons. Bromine is also recovered from seawater as a coproduct during evaporation to produce salt.

Substitutes: Chlorine and iodine may be substituted for bromine in a few chemical reactions and for sanitation purposes. There are no comparable substitutes for bromine in various oil- and gas-well-completion and packer applications. Because plastics have a low ignition temperature, aluminum hydroxide, magnesium hydroxide, organic chlorine compounds, and phosphorus compounds can be substituted for bromine as fire retardants in some uses.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Includes data for the Harmonized Tariff Schedule of the United States codes shown in the "Tariff" section.
[2]Includes data for the following Schedule B numbers: 2801.30.2000, 2827.51.0000, 2827.59.0000, 2903.31.0000, and 2903.39.1520 (for the years 2018–2021), and 2903.61.0000 and 2903.62.1000 (for the year 2022).
[3]Defined as production (sold or used) + imports – exports.
[4]Defined as imports – exports.
[5]Calculated using the gross weight of imports.
[6]Includes Hong Kong.
[7]Prior to 2022, was listed under Harmonized Tariff Schedule of the United States code 2903.39.1520.
[8]Prior to 2022, was listed under Harmonized Tariff Schedule of the United States code 2903.31.0000.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]Reported.
[11]Excludes U.S. production.

CADMIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Two companies in the United States produced cadmium metal in 2022. One company, operating in Tennessee, recovered primary refined cadmium as a byproduct of zinc leaching from roasted sulfide concentrates that would otherwise need to be disposed of as waste. The other company, operating in Ohio, recovered secondary cadmium metal from spent nickel-cadmium (NiCd) batteries. A cadmium concentrate was produced by one company in North Carolina that in late 2019 restarted zinc production from recycled electric-arc-furnace dust obtained from steel mills. Cadmium metal and compounds are mainly consumed for NiCd batteries, but also for alloys, coatings, and pigments. For the past 5 years, the United States has been a net exporter of wrought cadmium products and of cadmium pigments and preparations based on cadmium.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Primary, refined[1]	73	131	211	241	250
Secondary	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	273	385	282	155	21
Wrought cadmium and other articles	1	21	3	2	1
Cadmium waste and scrap	20	86	90	85	35
Cadmium oxide	51	33	28	14	21
Cadmium pigments and preparations based on cadmium compounds	310	108	69	101	170
Exports:					
Unwrought cadmium and powders	40	32	4	51	2
Wrought cadmium and other articles	99	84	482	217	90
Cadmium waste and scrap	(2)	6	(2)	—	4
Cadmium pigments and preparations based on cadmium compounds	565	795	2,120	550	510
Consumption of metal, apparent[3]	W	W	W	W	W
Price, metal, annual average,[4] dollars per kilogram	2.89	2.67	2.29	2.56	3.3
Net import reliance[5] as a percentage of apparent consumption	<75	<75	<75	<50	<25

Recycling: Secondary cadmium is mainly recovered from spent consumer and industrial NiCd batteries. Other waste and scrap from which cadmium can be recycled includes copper-cadmium alloy scrap, some complex nonferrous alloy scrap, cadmium-containing dust from electric-arc furnaces, and cadmium telluride (CdTe) solar panels.

Import Sources (2018–21):[6] Australia, 27%; Germany, 23%; China,[7] 20%; Peru, 12%; and other, 18%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Cadmium oxide	2825.90.7500	Free.
Cadmium sulfide	2830.90.2000	3.1% ad valorem.
Pigments and preparations based on cadmium compounds	3206.49.6010	3.1% ad valorem.
Cadmium waste and scrap	8112.61.0000	Free.
Unwrought cadmium and powders	8112.69.1000	Free.
Wrought cadmium and other articles	8112.69.9000	4.4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most of the world's primary cadmium metal was produced in Asia, and leading global producers, in descending order of production, were China and the Republic of Korea, followed by Japan and Canada. A smaller amount of secondary cadmium metal was recovered from recycling NiCd batteries. Although detailed data on the global consumption of primary cadmium were not available, NiCd battery production was thought to have continued to account for most global cadmium consumption. Other end uses for cadmium and cadmium compounds included alloys, anticorrosive coatings, pigments, and semiconductors for solar cells and for radiation-detecting imaging equipment; research into substitutions for cadmium in uses such as coatings continued.

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CADMIUM

The average monthly cadmium price was $2.92 per kilogram in January and increased to $3.58 per kilogram in May and $3.60 per kilogram in September after a decrease earlier in the year. The average prices reflected seasonal buying patterns in India; as a major consumer of cadmium but without significant production, India was an important determinant of cadmium prices in the spot market.

In August 2022, the U.S. Department of Energy announced the formation of a 3-year consortium among academic institutions, industry, and Government in support of the goals of its Cadmium Telluride Photovoltaics (PV) Accelerator program that was initiated in 2021. These goals included enabling solar cell efficiencies above 24% by 2025 and above 26% by 2030, while steadily reducing the per-watt cost of manufacturing by 60% within 10 years.

In response to the Inflation Reduction Act of 2022, which included incentives for transitioning to renewable energy sources, a major United States-based CdTe thin-film solar-cell producer announced plans to build a fourth domestic manufacturing facility by 2025 and expand capacity at its two existing plants and at a third facility which was scheduled to begin production in 2023. According to the consortium, administered by the National Renewable Energy Laboratory, CdTe solar panels supply 40% of the U.S. utility-scale solar market and 5% of the world market.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[8]
	2021	2022	
United States[1]	241	250	Quantitative estimates of reserves were not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Australia	402	400	
Bulgaria	310	310	
Canada	1,800	1,800	
China	10,000	10,000	
Germany	417	420	
Japan	1,900	1,900	
Kazakhstan	1,200	1,200	
Korea, Republic of	4,000	4,000	
Mexico	859	1,200	
Netherlands	854	500	
Norway	350	350	
Peru	600	300	
Poland	500	500	
Russia	1,000	1,000	
Uzbekistan	300	300	
World total (rounded)	24,700	24,000	

World Resources:[8] Cadmium is generally recovered from zinc ores and concentrates. Sphalerite, the most economically significant zinc ore mineral, commonly contains minor amounts of cadmium, which shares certain similar chemical properties with zinc and often substitutes for zinc in the sphalerite crystal lattice. The cadmium mineral greenockite is frequently associated with weathered sphalerite and wurtzite.

Substitutes: Batteries with other chemistries, particularly lithium-ion, can replace NiCd batteries in many applications. Except where the surface characteristics of a coating are critical (for example, fasteners for aircraft), coatings of aluminum, zinc, or zinc alloys such as tin-zinc and zinc-nickel can be substituted for cadmium in many plating applications. Cerium sulfide is used as a replacement for cadmium pigments, mostly in plastics. Barium-zinc or calcium-zinc stabilizers can replace barium-cadmium stabilizers in flexible polyvinyl chloride (PVC) applications. Amorphous silicon and copper-indium-gallium-selenide photovoltaic cells compete with CdTe in the thin-film solar-cell market. A new thin-film technology based on perovskite material continued to be researched as a potential substitute.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Cadmium metal produced as a byproduct of zinc refining.

[2]Less than ½ unit.

[3]Defined as primary production + secondary production + imports of unwrought cadmium and powders – exports of unwrought cadmium and powders.

[4]Average free market price for 99.95% purity in 10-ton lots; cost, insurance, and freight; global ports. Source: Fastmarkets MB.

[5]Defined as imports of unwrought cadmium and powders – exports of unwrought cadmium and powders.

[6]Unwrought cadmium and powders; Harmonized Tariff Schedule of the United States code 8107.20.0000 prior to 2022 and 8112.69.1000 in 2022.

[7]Includes Hong Kong.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, U.S. portland cement production increased slightly to an estimated 92 million tons, and masonry cement production increased to an estimated 2.5 million tons. Cement was produced at 96 plants in 34 States, and at 2 plants in Puerto Rico. Texas, Missouri, California, and Florida were, in descending order of production, the four leading cement-producing States and accounted for approximately 43% of U.S. production. Overall, the U.S. cement industry's growth continued to be constrained by closed or idle plants, underutilized capacity at others, production disruptions from plant upgrades, and relatively inexpensive imports. In 2022, shipments of cement were estimated to have increased by about 3% from those in 2021 and were valued at $14.6 billion. In 2022, an estimated 70% to 75% of sales were to ready-mixed concrete producers, 11% to concrete product manufacturers, 8% to 10% to contractors, and 5% to 12% to other customer types.

Salient Statistics—United States:[1]	2018	2019	2020	2021	2022[e]
Production:					
Portland and masonry cement[2]	86,400	87,600	89,300	[e]93,000	95,000
Clinker	77,112	78,858	78,951	79,000	80,000
Shipments to final customers, includes exports	99,419	102,823	104,645	109,000	110,000
Imports for consumption:					
Hydraulic cement	13,693	14,836	15,531	19,937	24,000
Clinker	967	997	1,204	1,563	1,100
Exports of hydraulic cement and clinker	919	1,024	884	940	900
Consumption, apparent[3]	98,500	102,000	105,000	[e]110,000	120,000
Price, average mill unit value, dollars per metric ton	121	124	125	[e]130	130
Stocks, cement, yearend	8,580	7,990	7,180	[e]7,000	7,500
Employment, mine and mill, number[e]	12,300	12,500	12,200	12,300	13,000
Net import reliance[4] as a percentage of apparent consumption	14	15	15	18	21

Recycling: Cement is not recycled, but significant quantities of concrete are recycled for use as a construction aggregate. Cement kilns can use waste fuels, recycled cement kiln dust, and recycled raw materials such as slags and fly ash. Various secondary materials can be incorporated as supplementary cementitious materials (SCMs) in blended cements and in the cement paste in concrete.

Import Sources (2018–21):[5] Canada, 30%; Turkey, 26%; Greece, 11%; Mexico, 8%; and other, 25%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Cement clinker	2523.10.0000	Free.
White portland cement	2523.21.0000	Free.
Other portland cement	2523.29.0000	Free.
Aluminous cement	2523.30.0000	Free.
Other hydraulic cement	2523.90.0000	Free.

Depletion Allowance: Not applicable. Certain raw materials for cement production have depletion allowances.

Government Stockpile: None.

Events, Trends, and Issues: The value of total construction put in place in the United States increased by 11% during the first 9 months of 2022 compared with that in the same period in 2021. Residential construction spending increased more than nonresidential construction spending. Despite increased prices owing to increased costs of production, cement shipments increased by about 4% during the first 9 months of 2022 compared with those in the same period in 2021. The leading cement-consuming States continued to be Texas, California, and Florida, in descending order by tonnage.

Increased cement apparent consumption in 2022 resulted from continued economic recovery from the effects of the global coronavirus disease 2019 (COVID-19) pandemic, and the November 2021 passage of the Bipartisan Infrastructure Law. In 2022, regulators implemented new measures designed to aid industry decarbonization efforts, including green procurement strategies and research investments. However, cement industry growth continued to be constrained by increased costs for energy, material, and service inputs; labor and production shortages; and ongoing supply chain disruptions.

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CEMENT

Company merger-and-acquisition activity continued in 2022, including the sale of a United States-based cement company's plant in California to a Japan-based cement company. The Japanese cement company also entered into an agreement to purchase a second cement plant in California from the United States cement company, pending regulatory approval.

Upgrades at a cement plant in Alabama were completed and the facility restarted production in mid-2022. An upgrade of a cement plant in Indiana progressed toward its expected completion date in early 2023. A plant upgrade to increase cement production at a site in Arizona was completed in 2022. Plans to increase capacity at a cement plant in Texas were announced, with completion expected in mid-2025. Upgrades at a terminal in Florida were completed in 2022, and work began to increase capacity at a terminal in Virginia. Plans for new cement terminals in Georgia and Texas were announced. Several minor upgrades were ongoing at some other domestic plants and a few other cement terminals. A Spain-based company reported plans to open a specialty cement facility in Louisiana in 2023.

Numerous companies continued to make announcements aligned with the industry's commitment to sustainability, such as new blended cement product lines, renewable energy plans, decarbonization research initiatives, and other innovations. Following widespread acceptance of portland-limestone cement (PLC) blended cement by various authorities, several cement plants announced their transition to PLC (Type IL). Additionally, some plants reported increased alternative fuel substitution, new carbon capture, utilization and storage projects, usage of new technologies, and (or) business diversification efforts. Many plants have installed emissions-reduction equipment to comply with the 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP). It remained possible that some kilns could be shut, idled, or used at reduced capacity to comply with NESHAP, which would constrain U.S. clinker capacity. In 2022, cement plant closures were announced at cement plants in California and New York.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2021	2022	2021	2022
United States (includes Puerto Rico)	93,000	95,000	100,000	100,000
Brazil	66,000	65,000	60,000	60,000
China	2,400,000	2,100,000	2,000,000	2,000,000
Egypt	50,000	51,000	48,000	48,000
India	350,000	370,000	280,000	290,000
Indonesia	65,000	64,000	79,000	79,000
Iran	62,000	62,000	81,000	81,000
Japan	50,000	50,000	54,000	54,000
Korea, Republic of	50,000	50,000	62,000	62,000
Mexico	52,000	50,000	42,000	42,000
Russia	61,000	62,000	80,000	80,000
Saudi Arabia	54,000	54,000	75,000	75,000
Turkey	82,000	85,000	92,000	92,000
Vietnam	110,000	120,000	90,000	100,000
Other countries (rounded)	850,000	850,000	600,000	600,000
World total (rounded)	4,400,000	4,100,000	3,700,000	3,800,000

World Resources: See the Lime and Stone (Crushed) chapters for cement raw-material resources.

Substitutes: Most portland cement is used to make concrete, mortars, or stuccos, and competes in the construction sector with concrete substitutes, such as aluminum, asphalt, clay brick, fiberglass, glass, gypsum (plaster), steel, stone, and wood. Certain materials, especially fly ash and ground granulated blast furnace slag, develop good hydraulic cementitious properties by reacting with lime, such as that released by the hydration of portland cement. Where readily available (including as imports), these SCMs are increasingly being used as partial substitutes for portland cement in many concrete applications and are components of finished blended cements.

[e]Estimated.

[1]Portland cement plus masonry cement unless otherwise noted; excludes Puerto Rico unless otherwise noted.

[2]Includes cement made from imported clinker.

[3]Defined as production of cement (including from imported clinker) + imports (excluding clinker) – exports ± adjustments for stock changes.

[4]Defined as imports (cement and clinker) – exports.

[5]Hydraulic cement and clinker; includes imports into Puerto Rico.

CESIUM

(Data in metric tons of cesium oxide unless otherwise noted)

Domestic Production and Use: In 2022, no cesium was mined domestically, and the United States was 100% net import reliant for cesium minerals. Pollucite, mainly found in association with lithium-rich, lepidolite-bearing or petalite-bearing zoned granite pegmatites, is the principal cesium ore mineral. Cesium minerals are used as feedstocks to produce a variety of cesium compounds and cesium metal. The primary application for cesium, by gross weight, is in cesium formate brines used for high-pressure, high-temperature well drilling for oil and gas exploration and production. With the exception of cesium formate, cesium is used in relatively small-scale applications, using only a few grams for most applications. Owing to the lack of global availability of cesium, many applications have used mineral substitutes and the use of cesium in any particular application may no longer be viable.

Cesium metal may be used in the production of cesium compounds and photoelectric cells. Cesium bromide may be used in infrared detectors, optics, photoelectric cells, scintillation counters, and spectrophotometers. Cesium carbonate may be used in the alkylation of organic compounds and in energy conversion devices, such as fuel cells, magneto-hydrodynamic generators, and polymer solar cells. Cesium chloride may be used in analytical chemistry applications as a reagent, in high-temperature solders, as an intermediate in cesium metal production, in isopycnic centrifugation, as a radioisotope in nuclear medicine, as an insect repellent in agricultural applications, and in specialty glasses. Cesium hydroxide may be used as an electrolyte in alkaline storage batteries. Cesium iodide may be used in fluoroscopy equipment—Fourier-transform infrared spectrometers—as the input phosphor of X-ray image intensifier tubes, and in scintillators. Cesium nitrate may be used as a colorant and oxidizer in the pyrotechnic industry, in petroleum cracking, in scintillation counters, and in X-ray phosphors. Cesium sulfates are often used as an intermediate form of cesium and may be used in water treatment, fuel cells, and to improve optical quality for scientific instruments.

Cesium isotopes, which are obtained as a byproduct in nuclear fission or formed from other isotopes, such as barium-131, may be used in electronic, medical, metallurgical, and research applications. Cesium isotopes are used as an atomic resonance frequency standard in atomic clocks, playing a vital role in aircraft guidance systems, global positioning satellites, and internet and cellular telephone transmissions. Cesium clocks monitor the cycles of microwave radiation emitted by cesium's electrons and use these cycles as a time reference. Owing to the high accuracy of the cesium atomic clock, the international definition of 1 second is based on the cesium atom. The U.S. civilian time and frequency standard is based on a cesium fountain clock at the National Institute of Standards and Technology in Boulder, CO. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 25 USNO cesium fountain clocks.

A company in Richland, WA, produced a range of cesium-131 medical products for treatment of various cancers. Cesium-137 may be used in industrial gauges, in mining and geophysical instruments, and for sterilization of food, sewage, and surgical equipment. Because of the danger posed by the radiological properties of cesium-137, efforts to find substitutes in its applications continued.

Salient Statistics—United States: Consumption, import, and export data for cesium have not been available since the late 1980s. Because cesium metal is not traded in commercial quantities, a market price is unavailable. No more than a few thousand kilograms of cesium chemicals are thought to be consumed in the United States every year. The United States was 100% net import reliant for its cesium needs.

In 2022, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $76.97 and 99.98% (metal basis) cesium for $97.86, 10% increases from $69.90 and $88.90 in 2021, respectively. In 2022, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, 99.99% (metal basis) cesium chloride, and cesium iodide were $134.62, $82.43, $118.66, $119.70, and $137.34, respectively, with increases ranging from 3% to 9% from prices in 2021.

The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) in 2022 was $84.53 for 50 milliliters and $129.15 for 100 milliliters, increases of 8% from $78.60 and $120.00 in 2021, respectively. The price for 25 grams of 98% (metal basis) cesium formate was $46.10, an 8% increase from $42.60 in 2021.

Recycling: Cesium formate brines are typically rented by oil and gas exploration clients. After completion of the well, the used cesium formate brine is returned and reprocessed for subsequent drilling operations. Cesium formate brines are recycled, recovering nearly 85% of the brines for recycling to be reprocessed for further use.

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CESIUM

Import Sources (2018–21): No reliable data have been available to determine the source of cesium ore imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of cesium ore and refined chemicals. Based on recent import data, it is thought that Germany was a source of refined cesium chemicals.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Alkali metals, other	2805.19.9000	5.5% ad valorem.
Chlorides, other	2827.39.9000	3.7% ad valorem.
Bromides, other	2827.59.5100	3.6% ad valorem.
Iodides, other	2827.60.5100	4.2% ad valorem.
Sulfates, other	2833.29.5100	3.7% ad valorem.
Nitrates, other	2834.29.5100	3.5% ad valorem.
Carbonates, other	2836.99.5000	3.7% ad valorem.
Cesium-137, other	2844.43.0021	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic cesium occurrences will likely remain subeconomic unless market conditions change. No known human health issues are associated with exposure to naturally occurring cesium, and its use has minimal environmental impact. Manufactured radioactive isotopes of cesium have been known to cause adverse health effects. Certain cesium compounds may be toxic if consumed. Food that has been irradiated using the radioisotope cesium-137 has been found to be safe by the U.S. Food and Drug Administration.

During 2022, no primary cesium mine production was reported globally but cesium was thought to have been mined in China. Mine production of cesium from all countries, excluding China, ceased within the past two decades. Mining of cesium in Namibia ceased in the early 2000s. Potential extraction of cesium from pollucite mining at the Tanco Mine in Canada ended in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018. The Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019. Recent reports indicate that, with current processing rates, the world's commercial stockpiles of cesium ore, excluding those in China, may be depleted in the near future.

Throughout 2022, multiple projects that would produce cesium through lepidolite, pollucite, spodumene, and zinnwaldite mining, focused primarily on lithium or cesium extraction, were in the feasibility and exploration stage, and one company was working on mine development. Beginning in late 2021 and early 2022, pollucite ore from the Tanco Mine was being shipped to China for lithium recovery.

World Mine Production and Reserves:[1] There were no official sources for cesium production data in 2022. Cesium reserves are, therefore, estimated based on the occurrence of pollucite, a primary lithium-cesium-rubidium mineral. Most pollucite contains 5% to 32% cesium oxide. No reliable data were available to determine reserves for specific countries; however, Australia, Canada, China, and Namibia were thought to have reserves totaling less than 200,000 tons. Existing stockpiles at multiple former mine sites have continued feeding downstream refineries, though recent reports have indicated stockpiles will be depleted within a few years.

World Resources:[1] Cesium is associated with lithium-bearing pegmatites worldwide, and cesium resources have been identified in Australia, Canada, Namibia, the United States, and Zimbabwe. In the United States, pollucite occurs in pegmatites in Alaska, Maine, and South Dakota. Lower concentrations occur in brines in Chile and China and in geothermal systems in China, Germany, and India. China was thought to have cesium-rich deposits of geyserite, lepidolite, and pollucite, with concentrations highest in Yichun, Jiangxi Province, although no resource, reserve, or production estimates were available.

Substitutes: Cesium and rubidium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications. However, rubidium is mined from similar deposits, in relatively smaller quantities, as a byproduct of cesium production in pegmatites and as a byproduct of lithium production from lepidolite (hard-rock) mining and processing, making it no more readily available than cesium.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

CHROMIUM

(Data in thousand metric tons of contained chromium unless otherwise noted)

Domestic Production and Use: In 2022, the United States consumed an estimated 5% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, chromium ferroalloys, chromium metal, and stainless steel. Imported chromite ore was consumed by one chemical company to produce chromium chemicals. Stainless-steel and heat-resisting-steel producers were the leading consumers of ferrochromium. Stainless steels and superalloys require the addition of chromium via ferrochromium or chromium-containing scrap. The value of chromium material consumption was expected to be about $1.5 billion in 2022, as measured by the value of net imports, excluding stainless steel, which was a 75% increase from $874 million in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	—	—	—	—	—
Recycling[1]	139	137	119	114	100
Imports for consumption[2]	651	530	457	607	620
Exports[2]	212	149	138	114	140
Shipments from Government stockpile[3]	4	4	5	7	5
Consumption (includes recycling):					
Reported	459	482	386	375	310
Apparent[4]	583	521	442	614	590
Price, average unit value of imports, dollars per metric ton:					
Chromite ore (gross weight)	279	248	179	197	340
Ferrochromium (chromium content)[5]	2,549	2,094	1,878	2,837	6,800
Chromium metal (gross weight)	11,344	10,393	7,931	8,757	21,000
Stocks, consumer, yearend	5	5	6	6	6
Net import reliance[6] as a percentage of apparent consumption	76	74	73	81	83

Recycling: In 2022, recycled chromium (contained in reported stainless-steel scrap receipts) accounted for 17% of apparent consumption.

Import Sources (2018–21): Chromite (ores and concentrates): South Africa, 97%; Canada, 2%; and other, 1%.
Chromium-containing scrap:[7] Canada, 48%; Mexico, 42%; Netherlands, 4%; and other, 6%.
Chromium (primary metal):[8] South Africa, 30%; Kazakhstan, 13%; Russia, 9%; Germany, 7%; and other, 41%.
Chromium-containing chemicals: China,[9] 23%; Germany, 20%; Kazakhstan, 19%; and other, 38%. Total imports: South Africa, 37%; Kazakhstan, 10%; Russia, 7%; Germany, 6%; and other, 40%.

Tariff:[10] Item	Number	Normal Trade Relations 12–31–22
Chromium ores and concentrates:		
Not more than 40% chromic oxide (Cr_2O_3)	2610.00.0020	Free.
More than 40% but less than 46% Cr_2O_3	2610.00.0040	Free.
More than or equal to 46% Cr_2O_3	2610.00.0060	Free.
Ferrochromium:		
More than 4% carbon	7202.41.0000	1.9% ad valorem.
More than 3% but less than 4% carbon	7202.49.1000	1.9% ad valorem.
More than 0.5% but less than 3% carbon	7202.49.5010	3.1% ad valorem.
Not more than 0.5% carbon	7202.49.5090	3.1% ad valorem.
Ferrosilicon chromium	7202.50.0000	10% ad valorem.
Chromium metal:		
Unwrought, powder	8112.21.0000	3% ad valorem.
Waste and scrap	8112.22.0000	Free.
Other	8112.29.0000	3% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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CHROMIUM

Government Stockpile:[11, 12]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Ferrochromium:					
High carbon	17.2	—	[13]21.8	—	[13]21.8
Low carbon	26.6	—	—	—	—
Chromium metal	3.47	—	0.454	—	0.454

Events, Trends, and Issues: South Africa was the leading chromite ore producer. Global chromite ore mine production was estimated to have decreased slightly in 2022, owing to constraints from operational challenges in some countries, slow global economic growth, and increasing labor costs. China was the leading ferrochromium- and stainless-steel-producing country and the leading chromium-consuming country. Coronavirus disease 2019 (COVID-19) pandemic-related lockdowns, tight financial conditions, and a decrease in demand could affect ferrochromium and stainless-steel production in China. The Bipartisan Infrastructure Law provided funding for a critical minerals mapping project, which includes chromium, that the U.S. Geological Survey will undertake as part of its Earth Mapping Resources Initiative.

From September 2021 to September 2022, the monthly average high-carbon ferrochromium price increased by 85%. The price of chromium metal increased by 36% in September 2022 compared with the monthly average price in September 2021.

World Mine Production and Reserves: Reserves for the United States were revised based on industry information. Reserves for Finland were revised based on Government reports.

	Mine production[14] 2021	Mine production[14] 2022[e]	Reserves[15] (shipping grade)[16]
United States	—	—	630
Finland	2,270	2,200	8,300
India	4,250	4,200	100,000
Kazakhstan[e]	6,500	6,500	230,000
South Africa	18,600	18,000	200,000
Turkey	6,960	6,900	26,000
Other countries	3,620	3,500	NA
World total (rounded)	42,200	41,000	560,000

World Resources:[15] World resources are greater than 12 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries. World chromium resources are heavily geographically concentrated (95%) in Kazakhstan and southern Africa; United States chromium resources are mostly in the Stillwater Complex in Montana.

Substitutes: Chromium has no substitute in stainless steel, the leading end use, or in superalloys, the major strategic end use. Chromium-containing scrap can substitute for ferrochromium in some metallurgical uses.

[e]Estimated. NA Not available. — Zero.

[1]Recycling production is based on reported receipts of all types of stainless-steel scrap.

[2]Includes chromium chemicals, chromium metal, chromite ores, ferrochromium, and stainless-steel products and scrap.

[3]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.

[4]Defined as production (from mines and recycling) + imports – exports ± adjustments for Government and industry stock changes.

[5]Excludes ferrochromium silicon.

[6]Defined as imports – exports ± adjustments for Government and industry stock changes.

[7]Includes chromium metal scrap and stainless-steel scrap.

[8]Includes chromium metal, ferrochromium, and stainless steel.

[9]Includes Hong Kong.

[10]In addition to the tariff items listed, certain imported chromium materials (see 26 U.S.C., sec. 4661, 4662, and 4672) are subject to excise tax.

[11]See Appendix B for definitions.

[12]Units are thousand metric tons, gross weight.

[13]High-carbon and low-carbon ferrochromium, combined.

[14]Units are thousand metric tons, gross weight, of marketable chromite ore.

[15]See Appendix C for resource and reserve definitions and information concerning data sources.

[16]Units are thousand metric tons of shipping-grade chromite ore, which is deposit quantity and grade normalized to 45% Cr_2O_3, except for the United States, where grade is normalized to 7% Cr_2O_3, and Finland, where grade is normalized to 26% Cr_2O_3.

CLAYS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Production of clays (sold or used) in the United States was estimated to be 26 million tons valued at $1.7 billion in 2022, with about 120 companies operating clay and shale mines in 38 States. The leading 20 companies produced approximately 69% of the U.S. tonnage and 83% of the value for all types of clay. Principal domestic uses for specific clays were estimated to be as follows: ball clay—52% floor and wall tile and 19% sanitaryware; bentonite—49% pet waste absorbents and 23% drilling mud; common clay—46% brick, 26% lightweight aggregate, and 23% cement; fuller's earth—83% absorbents (including oil and grease absorbents, pet waste absorbents, and miscellaneous absorbents); and kaolin—52% fillers, extenders, and binders and 25% ceramics. Fire clay uses were withheld to avoid disclosing company proprietary data.

Exports of clay and shale were estimated to have decreased by 4% in 2022 from those in 2021 after increasing by 18% in 2021 from exports in 2020. In 2022, the United States exported an estimated 890,000 tons of bentonite; Canada, Japan, and Mexico, in decreasing order, were the leading destinations. About 2.1 million tons of kaolin was exported mainly as a paper coating and filler; a component in ceramic bodies; and fillers and extenders in paint, plastic, and rubber products; Mexico, China, and Japan, in decreasing order, were the leading destinations. Lesser quantities of ball clay, fire clay, and fuller's earth were exported for ceramic, refractory, and absorbent uses, respectively.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production (sold or used):					
Ball clay	1,110	[e]1,060	1,090	[e]1,200	1,200
Bentonite	4,570	4,520	4,250	4,590	4,500
Common clay	13,300	13,300	13,000	12,800	13,000
Fire clay	567	603	635	675	720
Fuller's earth[e, 1]	1,880	1,990	1,980	2,130	2,100
Kaolin[e]	5,350	5,060	4,570	4,300	4,600
Total[1, 2]	26,800	26,500	25,500	25,700	26,000
Imports for consumption:					
Artificially activated clays and earths	23	31	31	41	59
Kaolin	330	293	224	149	170
Other	68	66	28	47	61
Total[2]	421	389	284	237	290
Exports:					
Artificially activated clays and earths	149	138	127	140	130
Ball clay	90	85	68	139	170
Bentonite	845	906	728	862	890
Clays, not elsewhere classified	244	204	185	186	200
Fire clay[3]	250	194	190	210	180
Fuller's earth	70	73	77	83	84
Kaolin	2,390	2,280	1,990	2,340	2,100
Total[2]	4,030	3,880	3,360	3,960	3,800
Consumption, apparent[4]	23,200	23,000	22,400	22,000	22,000
Price, average unit value, ex-works, dollars per metric ton:					
Ball clay	55	56	58	58	58
Bentonite	98	98	97	100	97
Common clay	17	18	17	17	17
Fire clay	12	14	12	12	12
Fuller's earth[1]	88	88	89	88	92
Kaolin	160	162	160	154	160
Employment (excludes office workers), number:[e]					
Mine (may not include contract workers)	1,110	1,110	1,060	1,060	1,100
Mill	4,310	4,310	4,260	4,240	4,300
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2018–21): All clay types combined: Brazil, 68%; Mexico, 12%; China, 5%; and other, 15%.

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CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–22
Kaolin and other kaolinic clays, whether or not calcined	2507.00.0000	Free.
Bentonite	2508.10.0000	Free.
Fire clay	2508.30.0000	Free.
Common blue clay and other ball clays	2508.40.0110	Free.
Decolorizing earths and fuller's earth	2508.40.0120	Free.
Other clays	2508.40.0150	Free.
Chamotte or dinas earth	2508.70.0000	Free.
Activated clays and activated earths	3802.90.2000	2.5% ad valorem.
Expanded clays and other mixtures	6806.20.0000	Free.

Depletion Allowance: Ball clay, bentonite, fire clay, fuller's earth, and kaolin, 14% (domestic and foreign); clay used in the manufacture of common brick, lightweight aggregate, and sewer pipe, 7.5% (domestic and foreign); clay used in the manufacture of drain and roofing tile, flowerpots, and kindred products, 5% (domestic and foreign); clay from which alumina and aluminum compounds are extracted, 22% (domestic).

Government Stockpile: None.

Events, Trends, and Issues: In March 2022, a Georgia kaolin producer completed the sale of certain North American assets and mining resources that support the paper and packaging markets to another kaolin producer with headquarters in Georgia. Additionally, another kaolin producer with North American headquarters in Georgia completed an acquisition in September 2022, which included four production sites and related mines, reserves, and two processing facilities in central Georgia.

World Mine Production and Reserves:[6] Global reserves are large, but country-specific data were not available.

	Mine production					
	Bentonite		Fuller's earth		Kaolin	
	2021	2022[e]	2021	2022[e]	2021	2022[e]
United States	4,590	4,500	[1]2,130	[1]2,100	4,300	4,600
Brazil (beneficiated)	220	220	—	—	1,200	1,200
China	2,100	2,100	—	—	8,400	8,400
Czechia	230	230	—	—	[7]3,100	[7]3,100
Denmark	1,000	1,000	—	—	—	—
Greece	[7]1,300	[7]1,300	34	34	—	—
India	3,000	3,000	730	730	[7]8,400	[7]8,400
Iran	700	700	—	—	1,900	1,900
Mexico	79	79	110	110	240	240
Senegal	—	—	117	120	—	—
Spain	210	210	560	560	[7]270	[7]270
Turkey	2,020	2,000	112	110	1,750	1,700
Ukraine	180	180	—	—	2,330	600
Uzbekistan	50	50	—	—	5,000	5,000
Other countries	3,300	3,300	252	250	12,500	13,000
World total (rounded)[2]	19,000	19,000	[1]4,040	[1]4,000	49,300	48,000

World Resources:[6] Resources of all clays are extremely large.

Substitutes: Clays compete with calcium carbonate in filler and extender applications; diatomite, organic pet litters, polymers, silica gel, and zeolites as absorbents; and various siding and roofing types in building construction.

[e]Estimated. E Net exporter. — Zero.

[1]Does not include U.S. production of attapulgite.

[2]Data may not add to totals shown because of independent rounding.

[3]Includes refractory-grade kaolin.

[4]Defined as production (sold or used) + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Includes production of crude ore.

COBALT

(Data in metric tons of contained cobalt unless otherwise noted)

Domestic Production and Use: In 2022, the nickel-copper Eagle Mine in Michigan produced cobalt-bearing nickel concentrate. In Missouri, a company produced nickel-copper-cobalt concentrate from historic mine tailings and was building a hydrometallurgical processing plant near the mine site. In October, commissioning began at a cobalt-copper-gold mine and mill in Idaho, where cobalt concentrate will be produced. This mine and one in Morocco are the only mines in the world where cobalt is the principal product. Most U.S. cobalt supply consisted of imports and secondary (scrap) materials. About six companies in the United States produced cobalt chemicals. An estimated 40% of the cobalt consumed in the United States was used in superalloys, mainly in aircraft gas turbine engines; 35% in a variety of chemical applications; 15% in various other metallic applications; and 10% in cemented carbides for cutting and wear-resistant applications. The total estimated value of cobalt consumed in 2022 was $530 million.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:[e]					
Mine	480	500	600	650	800
Secondary[1]	2,750	2,750	2,010	1,800	1,900
Imports for consumption	11,900	13,900	9,740	9,800	11,000
Exports	6,980	4,080	3,430	4,930	5,100
Consumption (includes secondary):					
Estimated[2]	9,290	9,050	7,260	7,200	7,800
Apparent[e, 3]	7,680	12,500	8,470	6,600	7,800
Price, average, dollars per pound:					
U.S. spot, cathode[4]	37.43	16.95	15.70	24.21	31
London Metal Exchange (LME), cash	32.94	14.88	14.21	23.17	29
Stocks, yearend:					
Industry[e, 2, 5]	1,060	1,090	952	1,010	1,000
LME, U.S. warehouse	130	102	82	50	30
Net import reliance[6] as a percentage of apparent consumption	64	78	76	73	76

Recycling: In 2022, cobalt contained in purchased scrap represented an estimated 24% of estimated cobalt consumption.

Import Sources (2018–21): Cobalt contained in metal, oxide, and salts: Norway, 22%; Canada, 16%; Finland, 12%; Japan, 12%; and other, 38%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Cobalt ores and concentrates	2605.00.0000	Free.
Chemical compounds:		
Cobalt oxides and hydroxides	2822.00.0000	0.1% ad valorem.
Cobalt chlorides	2827.39.6000	4.2% ad valorem.
Cobalt sulfates	2833.29.1000	1.4% ad valorem.
Cobalt carbonates	2836.99.1000	4.2% ad valorem.
Cobalt acetates	2915.29.3000	4.2% ad valorem.
Unwrought cobalt, alloys	8105.20.3000	4.4% ad valorem.
Unwrought cobalt, other	8105.20.6000	Free.
Cobalt mattes and other intermediate products; cobalt powders	8105.20.9000	Free.
Cobalt waste and scrap	8105.30.0000	Free.
Wrought cobalt and cobalt articles	8105.90.0000	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7] See the Lithium chapter for statistics on lithium-cobalt oxide and lithium-nickel-cobalt-aluminum oxide.

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cobalt	302	—	—	—	—
Cobalt alloys, gross weight[8]	14	50	—	—	—

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COBALT

Events, Trends, and Issues: Global cobalt mine and refinery production were forecast to increase to record-high levels in 2022. The increase in mine production was mainly in Congo (Kinshasa) and in Indonesia, where new mining and processing projects were starting production. Congo (Kinshasa) continued to be the world's leading source of mined cobalt, accounting for about 70% of world cobalt mine production. With the exception of some production in the United States, production in Morocco, and artisanally mined cobalt in Congo (Kinshasa), most cobalt is mined as a byproduct of copper or nickel. China was the world's leading producer of refined cobalt, most of which was produced from partially refined cobalt imported from Congo (Kinshasa). China was the world's leading consumer of cobalt, with about 80% of its consumption used by the rechargeable battery industry.

World Mine Production and Reserves: Reserves for Australia, China, and Congo (Kinshasa) were revised based on company and Government reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States	[e]650	800	69,000
Australia	5,295	5,900	[10]1,500,000
Canada	4,361	3,900	220,000
China	[e]2,200	2,200	140,000
Congo (Kinshasa)	[e]119,000	130,000	4,000,000
Cuba	[e]4,000	3,800	500,000
Indonesia	[e]2,700	10,000	600,000
Madagascar	[e]2,800	3,000	100,000
Morocco	[e]2,300	2,300	13,000
Papua New Guinea	2,953	3,000	47,000
Philippines	[e]3,600	3,800	260,000
Russia	[e]8,000	8,900	250,000
Turkey	[e]2,400	2,700	36,000
Other countries	4,567	5,200	610,000
World total (rounded)	165,000	190,000	8,300,000

World Resources:[9] Identified cobalt resources of the United States are estimated to be about 1 million tons. Most of these resources are in Minnesota, but other important occurrences are in Alaska, California, Idaho, Michigan, Missouri, Montana, Oregon, and Pennsylvania. With the exception of resources in Idaho and Missouri, any future cobalt production from these deposits would be as a byproduct of another metal. Identified world terrestrial cobalt resources are about 25 million tons. The vast majority of these resources are in sediment-hosted stratiform copper deposits in Congo (Kinshasa) and Zambia; nickel-bearing laterite deposits in Australia and nearby island countries and Cuba; and magmatic nickel-copper sulfide deposits hosted in mafic and ultramafic rocks in Australia, Canada, Russia, and the United States. More than 120 million tons of cobalt resources have been identified in polymetallic nodules and crusts on the floor of the Atlantic, Indian, and Pacific Oceans.

Substitutes: Depending on the application, substitution for cobalt could result in a loss in product performance or an increase in cost. The cobalt contents of lithium-ion batteries, the leading global use for cobalt, are being reduced; potential commercially available cobalt-free substitutes use iron and phosphorus. Potential substitutes in other applications include barium or strontium ferrites, neodymium-iron-boron alloys, or nickel-iron alloys in magnets; cerium, iron, lead, manganese, or vanadium in paints; cobalt-iron-copper or iron-copper in diamond tools; copper-iron-manganese for curing unsaturated polyester resins; iron, iron-cobalt-nickel, nickel, ceramic-metallic composites (cermets), or ceramics in cutting and wear-resistant materials; nickel-base alloys or ceramics in jet engines; nickel in petroleum catalysts; rhodium in hydroformylation catalysts; and titanium-base alloys in prosthetics.

[e]Estimated. — Zero.

[1]Estimated from consumption of purchased scrap.

[2]Includes reported data and U.S. Geological Survey estimates.

[3]Defined as secondary production + imports – exports ± adjustments for Government and industry stock changes for refined cobalt.

[4]Source: Platts Metals Week. Cobalt cathode is refined cobalt metal produced by an electrolytic process.

[5]Stocks held by consumers and processors; excludes stocks held by trading companies and held for investment purposes.

[6]Defined as imports – exports ± adjustments for Government and industry stock changes for refined cobalt.

[7]See Appendix B for definitions.

[8]Inventory is cobalt alloys; potential acquisitions are samarium-cobalt alloy; excludes potential disposals of aerospace alloys.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 670,000 tons.

COPPER

(Data in thousand metric tons of contained copper unless otherwise noted)

Domestic Production and Use: In 2022, the recoverable copper content of U.S. mine production was an estimated 1.3 million tons, an increase of 6% from that in 2021, and was valued at an estimated $11 billion, 6% less than $11.7 billion in 2021. Arizona was the leading copper-producing State and accounted for approximately 70% of domestic output; copper was also mined in Michigan, Missouri, Montana, Nevada, New Mexico, and Utah. Copper was recovered or processed at 25 mines (17 of which accounted for more than 99% of mine production), 2 primary smelters, 2 electrolytic refineries, and 14 electrowinning facilities. An additional primary smelter and electrolytic refinery have been closed indefinitely since October 2019, and a new secondary smelter was in the process of starting up as of September. Refined copper and scrap were consumed at about 30 brass mills, 14 rod mills, and 500 foundries and miscellaneous manufacturers. Copper and copper alloy products were used in building construction, 46%; electrical and electronic products, 21%; transportation equipment, 16%; consumer and general products, 10%; and industrial machinery and equipment, 7%.[1]

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine, recoverable copper content	1,220	1,260	1,200	1,230	1,300
Refinery:					
Primary (from ore)	1,070	985	874	922	960
Secondary (from scrap)	41	44	43	49	40
Copper recovered from old (post-consumer) scrap[2]	141	166	160	[e]170	160
Imports for consumption:					
Ore and concentrates	32	27	2	11	15
Refined	778	663	676	919	810
Exports:					
Ore and concentrates	253	356	383	347	330
Refined	190	125	41	48	30
Consumption:					
Reported, refined metal	1,820	1,810	1,770	1,770	1,800
Apparent, primary refined and old scrap[3]	1,820	1,820	1,660	1,960	1,900
Price, annual average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	298.7	279.6	286.7	432.3	410
COMEX, high-grade, first position	292.6	272.3	279.9	424.3	400
London Metal Exchange, grade A, cash	296.0	272.4	279.8	422.5	400
Stocks, refined, held by U.S. producers, consumers, and metal exchanges, yearend	244	110	118	117	120
Employment, mine and plant, number	11,700	12,000	11,000	11,400	12,000
Net import reliance[4] as a percentage of apparent consumption	33	37	38	44	41

Recycling: Old (post-consumer) scrap, converted to refined metal, alloys, and other forms, provided an estimated 160,000 tons of copper in 2022, and an estimated 670,000 tons of copper was recovered from new (manufacturing) scrap derived from fabricating operations. Of the total copper recovered from scrap, brass and wire-rod mills accounted for approximately 85%; smelters, refiners, and ingot makers, 10%; and chemical plants, foundries, and miscellaneous manufacturers, 5%. Copper recovered from scrap contributed 32% of the U.S. copper supply.[5]

Import Sources (2018–21): Copper content of blister and anodes: Finland, 90%; and other, 10%. Copper content of matte, ash, and precipitates: Canada, 34%; Belgium, 17%; Japan, 15%; Mexico, 11%; and other, 23%. Copper content of ore and concentrates: Mexico, 82%; Canada, 18%; and other, <1%. Copper content of scrap: Canada, 51%; Mexico, 37%; and other, 12%. Refined copper: Chile, 64%; Canada, 20%; Mexico, 11%; and other, 5%. Refined copper accounted for 86% of all unmanufactured copper imports.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Copper ore and concentrates, copper content	2603.00.0010	1.7¢/kg on lead content.
Unrefined copper anodes	7402.00.0000	Free.
Refined copper and alloys, unwrought	7403.00.0000	1% ad valorem.
Copper wire rod	7408.11.0000	1% or 3% ad valorem.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

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COPPER

Events, Trends, and Issues: In 2022, the largest increase in mined copper output in the United States was at the Bingham Canyon Mine in Utah, where ore grades and recovery rates were higher than those in 2021 following the transition to mining a new area of the open pit. Copper production also rose significantly at the Morenci and Safford Mines in Arizona, reflecting increased mining, milling, and (or) leaching rates. Owing to labor shortages and lower copper ore grades, the most significant decrease in mined copper output was at the Mission Mine in Arizona. The rampups of the Gunnison Mine in Arizona and the Pumpkin Hollow Mine in Nevada continued to be delayed by technical issues. Refined copper production in the United States increased by an estimated 3% in 2022 compared with that in 2021 because of a greater supply of copper concentrates to the Miami smelter in Arizona, which was partially offset by unplanned stoppages and labor shortages at the Garfield smelter in Utah. A new smelter in North Carolina designed to produce copper anodes from scrap was in the process of ramping up as of September, and at least five other domestic facilities that would recover copper from scrap were expected to begin operating within the next few years. In August, a leading copper wire-rod plant in Amarillo, TX, was indefinitely shut down owing to high production costs, maintenance issues, and labor shortages.

The annual average COMEX copper price was projected to be about $4 per pound in 2022, 6% less than that in 2021. Analysts attributed the decreased price primarily to widespread global expectations for reduced economic growth and lower demand for copper in the near future, coronavirus disease 2019 (COVID-19) mitigation measures in China, and increased strength of the United States dollar relative to other currencies.

World Mine and Refinery Production and Reserves: Reserves for Australia, Canada, Chile, China, Peru, Poland, the United States, and Zambia were revised based on company and Government reports.

	Mine production		Refinery production		Reserves[6]
	2021	2022[e]	2021	2022[e]	
United States	1,230	1,300	971	1,000	44,000
Australia	813	830	385	380	[7]97,000
Canada	550	530	287	310	7,600
Chile	5,620	5,200	2,270	2,100	190,000
China	1,910	1,900	10,500	11,000	27,000
Congo (Kinshasa)	1,740	2,200	1,450	1,700	31,000
Germany	—	—	615	620	—
Indonesia	731	920	290	300	24,000
Japan	—	—	1,510	1,600	—
Kazakhstan	510	580	500	510	20,000
Korea, Republic of	—	—	647	660	—
Mexico	734	740	473	470	53,000
Peru	2,300	2,200	336	290	81,000
Poland	391	390	578	590	30,000
Russia	[e]940	1,000	981	1,100	62,000
Zambia	842	770	354	350	19,000
Other countries	2,850	3,400	3,170	3,000	200,000
World total (rounded)	21,200	22,000	25,300	26,000	890,000

World Resources:[6] A U.S. Geological Survey study of global copper deposits indicated that, as of 2015, identified resources contained 2.1 billion tons of copper, and undiscovered resources contained an estimated 3.5 billion tons.[8]

Substitutes: Aluminum substitutes for copper in automobile radiators, cooling and refrigeration tube, electrical equipment, and power cable. Titanium and steel are used in heat exchangers. Optical fiber substitutes for copper in telecommunications applications, and plastics substitute for copper in drain pipe, plumbing fixtures, and water pipe.

[e]Estimated. — Zero.

[1]Distribution reported by the Copper Development Association.

[2]Copper converted to refined metal, alloys, and other forms by brass and wire-rod mills, foundries, refineries, and other manufacturers.

[3]Primary refined production + copper recovered from old scrap + refined imports – refined exports ± refined copper stock change.

[4]Defined as refined imports – refined exports ± refined copper stock change.

[5]Primary refined production + copper recovered from old and new scrap + refined imports – refined exports ± refined copper stock change.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 23 million tons.

[8]Source: Hammarstrom, J.M., Zientek, M.L., Parks, H.L., Dicken, C.L., and the U.S. Geological Survey Global Copper Mineral Resource Assessment Team, 2019, Assessment of undiscovered copper resources of the world, 2015 (ver.1.1, May 24, 2019): U.S. Geological Survey Scientific Investigations Report 2018–5160, 619 p., https://doi.org/10.3133/sir20185160.

DIAMOND (INDUSTRIAL)[1]

(Data in million carats unless otherwise noted)

Domestic Production and Use: In 2022, total domestic primary production of manufactured industrial diamond bort, grit, and dust and powder was estimated to be 150 million carats with a value of $48 million, a 14% increase in quantity and value compared with that in 2021. No industrial diamond stone was produced domestically. One company with facilities in Florida and Ohio and a second company in Pennsylvania accounted for all domestic primary production. At least four companies produced polycrystalline diamond from diamond powder. At least two companies recovered used industrial diamond material from used diamond drill bits, diamond tools, and other diamond-containing wastes for recycling. The major consuming sectors of industrial diamond are computer chip production; construction; drilling for minerals, natural gas, and oil; machinery manufacturing; stone cutting and polishing; and transportation (infrastructure and vehicles). Highway building, milling, and repair and stone cutting consumed most of the industrial diamond stone. About 99% of U.S. industrial diamond apparent consumption was synthetic industrial diamond because its quality can be controlled, and its properties can be customized.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	184	114	130	132	150
Secondary	32	36	35	1.2	1.2
Imports for consumption	574	310	190	261	340
Exports	139	114	90	99	100
Consumption, apparent[2]	652	347	265	295	390
Price, unit value of imports, dollars per carat	0.12	0.14	0.19	0.18	0.19
Net import reliance[3] as a percentage of apparent consumption	67	57	38	55	62
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	—	—	—	—	—
Secondary	0.13	0.10	0.10	0.08	0.08
Imports for consumption	2.52	1.07	0.51	0.33	0.64
Exports	—	—	0.02	—	([4])
Consumption, apparent[2]	2.65	1.17	0.59	0.41	0.71
Price, unit value of imports, dollars per carat	2.96	5.82	8.41	13.0	10
Net import reliance[3] as a percentage of apparent consumption	95	91	83	81	89

Recycling: In 2022, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 1.2 million carats with an estimated value of $400,000. It was estimated that 75,000 carats of diamond stone were recycled with an estimated value of $110,000.

Import Sources (2018–21): Bort, grit, and dust and powder; natural and synthetic: China,[5] 81%; Republic of Korea, 6%; Ireland, 5%; Russia, 4%; and other, 4%. Stones, primarily natural: South Africa, 22%; Congo (Kinshasa), 19%; India, 17%; Sierra Leone, 10%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Industrial Miners' diamonds:		
Carbonados	7102.21.1010	Free.
Other	7102.21.1020	Free.
Industrial diamonds:		
Simply sawn, cleaved, or bruted	7102.21.3000	Free.
Not worked	7102.21.4000	Free.
Grit or dust and powder of natural diamonds:		
80 mesh or finer	7105.10.0011	Free.
Over 80 mesh	7105.10.0015	Free.
Grit or dust and powder of synthetic diamonds:		
Coated with metal	7105.10.0020	Free.
Not coated with metal, 80 mesh or finer	7105.10.0030	Free.
Not coated with metal, over 80 mesh	7105.10.0050	Free.

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DIAMOND (INDUSTRIAL)

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most natural industrial diamond is produced as a byproduct of mining gem-quality diamond. Global natural industrial diamond production was essentially the same in 2022 as in the previous year. Russia, the leading country in the production of natural industrial diamond, produced 17 million carats or 37% of total world production, followed by Congo (Kinshasa), 11 million carats (24%); Botswana, 7 million carats (15%); South Africa, 6 million carats (13%); and Zimbabwe, 4 million carats (9%). These five countries produced 98% of the world's natural industrial diamond. In recent years, mines have closed and output has been lower as mines approach the ends of their lives. The world's largest diamond mines have matured and are past their peak production levels, and several of the largest diamond mines are expected to close by the end of 2025. As these mines are depleted, global production is expected to decline in quantity.

In 2022, U.S. synthetic-industrial-diamond producers did not manufacture any diamond stone, and the combined apparent consumption of all types of industrial diamond increased. Domestic and global consumption of synthetic diamond grit and powder is expected to remain greater than that of natural diamond material. Imports of all types of natural and synthetic industrial diamond imports increased by 29%. In 2022, China was the leading producing country of synthetic industrial diamond, followed by the United States, Russia, Ireland, and South Africa, in descending order of quantity. These five countries produced about 99% of the world's synthetic industrial diamond. Synthetic diamond accounted for more than 99% of global industrial diamond production and consumption. Worldwide production of manufactured industrial diamond totaled more than 15.4 billion carats.

The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and is expected to remain a significant producer and exporter of synthetic industrial diamond as well. U.S. demand for industrial diamond is likely to be strong in the construction sector as the United States continues building, milling, and repairing the Nation's highway system. Industrial diamond is impregnated in or coats the cutting edge of saws used to cut concrete in highway construction and repair work.

World Natural Industrial Diamond Mine Production and Reserves: Reserves for Russia were revised based on company and Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	—	—	NA
Australia	—	—	[7]11
Botswana	7	7	300
Congo (Kinshasa)	11	11	150
Russia	17	17	600
South Africa	6	6	120
Zimbabwe	4	4	NA
Other countries	1	1	120
World total (rounded)	46	46	1,300

World Resources:[6] Natural diamond deposits have been discovered in more than 35 countries. Natural diamond accounts for about 4% of all industrial diamond used; synthetic diamond accounts for the remainder. At least 15 countries have the technology to produce synthetic diamond.

Substitutes: Materials that can compete with industrial diamond in some applications include manufactured abrasives, such as cubic boron nitride, fused aluminum oxide, and silicon carbide. Globally, synthetic diamond, rather than natural diamond, is used for about 99% of industrial applications.

[e]Estimated. NA Not available. — Zero.

[1]See the Gemstones chapter for information on gem-quality diamond.

[2]Defined as manufactured diamond production + secondary diamond production + imports – exports.

[3]Defined as imports – exports.

[4]Less than 500 carats.

[5]Includes Hong Kong.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 10 million carats.

DIATOMITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, production of diatomite, also known as diatomaceous earth, was estimated to be 1.1 million tons with an estimated processed value of $450 million, free on board (f.o.b.) plant. Six companies produced diatomite at 12 mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Approximately 55% of diatomite is used in filtration products. The remaining 45% is used in absorbents, fillers, lightweight aggregates, and other applications. A small amount, less than 1%, is used for specialized pharmaceutical and biomedical purposes. The unit value of diatomite varied widely in 2022, from approximately $10 per ton when used as a lightweight aggregate in portland cement concrete to more than $1,000 per ton for limited specialty markets, including art supplies, cosmetics, and deoxyribonucleic acid (DNA) extraction. The price for diatomite used for filtration was approximately $550 per ton.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production[1]	957	768	822	998	1,100
Imports for consumption	9	10	14	14	13
Exports	68	66	66	68	60
Consumption, apparent[2]	898	712	770	944	1,100
Price, average value, f.o.b. plant, dollars per ton	330	340	330	410	430
Employment, mine and plant, number[e]	370	370	370	370	370
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2018–21): Canada, 62%; Mexico, 13%; Germany, 10%; Argentina, 5%; Japan, 5%; and other, 5%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Siliceous fossil meals, including diatomite	2512.00.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced diatomite sold or used by producers in 2022 was 10% higher than that in 2021. Apparent domestic consumption in 2022 was estimated at 1.1 million tons, 17% more than that in 2021. Exports were estimated to have decreased by 12%. The United States remained the leading global producer and consumer of diatomite. Filtration (including the purification of beer, liquors, and wine and the cleansing of greases and oils) continued to be the leading end use for diatomite. An important application for diatomite is the removal of microbial contaminants, such as bacteria, protozoa, and viruses in public water systems. Domestically, diatomite used in the production of cement was the second-ranked use. Other applications for diatomite include filtration of human blood plasma, pharmaceutical processing, and use as a nontoxic insecticide.

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DIATOMITE

In 2022, the United States accounted for an estimated 44% of total world production; followed by Denmark with 16%; China with 6%; and Argentina, Mexico, and Turkey, each with 4%. Smaller quantities of diatomite were mined in 21 additional countries. The production of diatomite in 2022 remained about the same as that in 2021.

World Mine Production and Reserves: Reserves for China and the Republic of Korea were revised based on Government reports.

	Mine production[e]		Reserves[4]
	2021	2022	
United States[1]	998	1,100	250,000
Argentina	100	100	NA
China	140	140	150,000
Denmark[5] (processed)	420	400	NA
France	75	80	NA
Germany	50	50	NA
Japan	40	40	NA
Korea, Republic of	65	65	2,300
Mexico	96	100	NA
New Zealand	40	40	NA
Peru	85	85	NA
Russia	51	50	NA
Spain	50	50	NA
Turkey	100	100	44,000
Other countries	140	140	NA
World total (rounded)	2,450	2,500	Large

World Resources:[4] Diatomite deposits form from an accumulation of amorphous hydrous silica cell walls of dead diatoms in oceanic and fresh waters. Diatomite is also known as kieselguhr (Germany), tripolite (after an occurrence near Tripoli, Libya), and moler (an impure Danish form). Because U.S. diatomite occurrences are at or near Earth's surface, recovery from most deposits is achieved through low-cost, open pit mining. Outside the United States, however, underground mining is fairly common owing to deposit location and topographic constraints. World resources of crude diatomite are adequate for the foreseeable future.

Substitutes: Many materials can be substituted for diatomite. However, the unique properties of diatomite assure its continued use in many applications. Expanded perlite and silica sand compete for filtration. Filters made from manufactured materials, notably ceramic, polymeric, or carbon membrane filters and filters made with cellulose fibers, are becoming competitive as filter media. Alternate filler materials include clay, ground limestone, ground mica, ground silica sand, perlite, talc, and vermiculite. For thermal insulation, materials such as various clays, exfoliated vermiculite, expanded perlite, mineral wool, and special brick can be used. Transportation costs will continue to determine the maximum economic distance that most forms of diatomite may be shipped and still remain competitive with alternative materials.

[e]Estimated. E Net exporter. NA Not available.

[1]Processed ore sold or used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Includes sales of moler production.

FELDSPAR AND NEPHELINE SYENITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: U.S. feldspar production in 2022 had an estimated value of $45 million. Feldspar was produced by seven companies in California, Idaho, North Carolina, Oklahoma, South Dakota, and Virginia. Feldspar processors reported joint product recovery of mica and silica sand. One company produced nepheline syenite in the United States as a flux, but production data were not available.

Feldspar is ground to about 20 mesh for glassmaking and to 200 mesh or finer for most ceramic and filler applications. It was estimated that domestically produced feldspar was transported by ship, rail, or truck to at least 30 States and to foreign destinations, including Canada and Mexico. In pottery and glass, feldspar and nepheline syenite function as a flux. Glass manufacturing accounted for an estimated 47% of the 2022 end-use distribution of domestic feldspar and nepheline, and ceramic tile, pottery, and other uses, accounted for the remaining 53%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, feldspar, marketable[1]	550	450	430	340	420
Imports for consumption:					
Feldspar	181	64	43	169	270
Nepheline syenite	1,070	508	503	529	500
Exports, feldspar	4	4	3	4	3
Consumption, apparent:[1, 2]					
Feldspar only	730	510	470	510	690
Feldspar and nepheline syenite	1,800	1,000	970	1,000	1,200
Price, average unit value, dollars per metric ton:					
Feldspar only, marketable production	97	107	108	110	110
Nepheline syenite, imports	76	156	163	164	180
Employment, mine, preparation plant, and office, number[e]	240	240	240	220	220
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	24	12	8	33	39
Nepheline syenite	>95	>95	>95	>95	>95

Recycling: Feldspar and nepheline syenite are not recycled by producers; however, glass container producers use cullet (recycled container glass), thereby reducing feldspar and nepheline syenite consumption.

Import Sources (2018–21): Feldspar: Turkey, 94%; Mexico, 4%; and other, 2%. Nepheline syenite: Canada, 100%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Feldspar	2529.10.0000	Free.
Nepheline syenite	2529.30.0010	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, estimated domestic production and sales of feldspar increased by about 24%, and the average unit value of sales was essentially unchanged compared with that in 2021. Estimated imports of feldspar increased by 60% compared with those in 2021, whereas nepheline syenite imports decreased by an estimated 5% in 2022 from those in 2021. Imports of nepheline syenite reported by the U.S. Census Bureau in 2018 were unusually high.

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FELDSPAR AND NEPHELINE SYENITE

In the United States, residential construction, in which feldspar is a raw material commonly used in the manufacture of plate glass, ceramic tiles and sanitaryware, and insulation, was unchanged during the first 10 months of 2022 compared with that in the same period in 2021. Glass—including beverage containers (more than one-half of the feldspar consumed by the glass industry), plate glass, and fiberglass insulation for housing and building construction—accounted for nearly one-half of all end uses of feldspar in the United States. Production and sales of feldspar were expected to increase into 2023, owing in part to an increase in demand for automotive glass manufacturing and for solar glass, used in the production of solar panels.

A company based in Canada continued development of a feldspar-quartz-kaolin project in Idaho that contains high-grade potassium feldspar. Production was expected to be about 30,000 tons per year of potassium feldspar during a 25-year mine life. For several years, the operation has produced a feldspathic sand product with low-iron and low-trace-element concentrations from old mine tailings, which was sold to ceramic tile producers.

World Mine Production and Reserves:[4] Reserves for China were revised based on Government reports.

	Mine production		Reserves[5]
	2021	2022[e]	
United States[1]	340	420	NA
Brazil (beneficiated, marketable)	491	630	150,000
China	[e]2,500	2,400	130,000
Czechia	[e]450	460	22,000
India	[e]6,600	6,600	320,000
Iran	[e]2,000	2,000	630,000
Italy	2,200	2,200	NA
Korea, Republic of	987	1,000	180,000
Mexico	356	320	NA
Pakistan	[e]440	360	NA
Saudi Arabia	549	820	NA
Spain (includes pegmatites)	[e]800	800	NA
Thailand	[e]1,200	1,300	220,000
Turkey	6,100	6,200	240,000
Other countries	2,610	2,600	NA
World total (rounded)	27,600	28,000	Large

World Resources:[5] Identified and undiscovered resources of feldspar are more than adequate to meet anticipated world demand. Quantitative data on resources of feldspar existing in feldspathic sands, granites, and pegmatites generally have not been compiled. Ample geologic evidence indicates that resources are large, although not always conveniently accessible to the principal centers of consumption.

Substitutes: Imported nepheline syenite was the major alternative material for feldspar. Feldspar can be replaced in some of its end uses by clays, electric furnace slag, feldspar-silica mixtures, pyrophyllite, spodumene, or talc.

[e]Estimated. NA Not available.

[1]Rounded to two significant digits to avoid disclosing company proprietary data.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]Feldspar only.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

FLUORSPAR

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, minimal fluorspar (calcium fluoride, CaF_2) was produced in the United States. One company sold fluorspar from stockpiles produced as a byproduct of its limestone quarrying operation in Cave-In-Rock, IL. A second company, which was developing a mine in Utah, received a $5 million loan from the U.S. Department of Agriculture which it expected would be used to fund completion of a metallurgical-grade fluorspar-processing plant, rail spur, and tailings dam. An estimated 40,000 tons of fluorosilicic acid (FSA), equivalent to about 65,000 tons of fluorspar grading 100% CaF_2, was recovered from three phosphoric acid plants processing phosphate rock. A company in Aurora, NC, continued construction on a plant to produce hydrofluoric acid (HF) from FSA. The U.S. Department of Energy continued to produce aqueous HF as a byproduct of the conversion of depleted uranium hexafluoride to depleted uranium oxide at plants in Paducah, KY, and Portsmouth, OH; the aqueous HF was sold into the commercial market.

U.S. fluorspar consumption was satisfied by imports. Domestically, production of HF in Louisiana and Texas was by far the leading use for acid-grade fluorspar. Hydrofluoric acid is the primary feedstock for the manufacture of virtually all fluorine-bearing chemicals, particularly refrigerants and fluoropolymers, and is also a key ingredient in the processing of aluminum and uranium. Fluorspar was also used in cement production, in enamels, as a flux in steelmaking, in glass manufacture, in iron and steel casting, and in welding rod coatings.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorosilicic acid from phosphate rock	33	29	22	40	40
Imports for consumption:					
Acid grade	381	346	427	391	450
Metallurgical grade	78	59	65	59	80
Total fluorspar imports	459	405	492	451	530
Hydrofluoric acid	122	124	103	103	110
Aluminum fluoride	25	38	21	28	22
Cryolite	17	21	26	42	29
Exports, fluorspar, all grades[1]	9	8	9	15	27
Consumption, apparent[2]	450	398	483	436	500
Price, average unit value of imports, cost, insurance, and freight, dollars per metric ton:					
Acid grade	276	304	309	322	360
Metallurgical grade	258	292	149	151	140
Employment, mine, number[e]	18	14	16	17	17
Net import reliance[2] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Synthetic fluorspar may be produced from neutralization of waste in the enrichment of uranium, petroleum alkylation, and stainless-steel pickling; however, undesirable impurities constrain use. Primary aluminum producers recycle HF and fluorides from smelting operations.

Import Sources (2018–21):[3] Mexico, 66%; Vietnam, 16%; South Africa, 7%; Canada, 7%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Metallurgical grade (97% or less CaF_2)	2529.21.0000	Free.
Acid grade (more than 97% CaF_2)	2529.22.0000	Free.
Natural cryolite	2530.90.1000	Free.
Hydrogen fluoride (hydrofluoric acid)	2811.11.0000	Free.
Aluminum fluoride	2826.12.0000	Free.
Sodium hexafluoroaluminate (synthetic cryolite)	2826.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: World production of fluorspar was estimated to have decreased in 2022. Global fluorspar supply, which is highly concentrated, was constrained by the bankruptcy and subsequent idling of a fluorspar mine in Canada and the declaration of force majeure for supply contracts by the world's leading exporting

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mine in Mexico. Although prices from leading exporting countries such as Mexico, South Africa, and Vietnam reportedly increased, overall adverse impacts to supply appear to have been more than offset by decreased consumption in China. Overall, China decreased its fluorspar trade deficit. Chinese exports, including to the United States, increased. Chinese imports also decreased substantially, particularly from Mongolia, which likely contributed to a significant decrease in Mongolia's fluorspar production.

In September, the United States became the 137th country to ratify the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer. The goal of the amendment is to reduce production and consumption of hydrofluorocarbon (HFC) gases, commonly used as aerosols, refrigerants, and solvents, by 80% over the next 30 years and which is expected to reduce projected global warming by as much as 0.5 degree Celsius by the end of the century. The American Innovation and Manufacturing Act of 2020 essentially established all of the HFC phasedown provisions and enforcement mechanisms needed to comply with the Kigali Amendment.

The U.S. Department of Energy awarded $2.8 billion funding from the Bipartisan Infrastructure Law to stimulate domestic development of raw materials used in the production of electric-vehicle batteries. Nearly $280 million in funding was awarded for the construction of a new facility in Louisiana to produce lithium hexafluorophosphate ($LiPF_6$) and for the expansion of polyvinylidene difluoride (PVDF) production capacity in Georgia. $LiPF_6$ is the main salt used in lithium-ion battery electrolytes; PVDF is used as a binder and separator coating. Additionally, more than $500 million was allocated to facilities that were likely to consume fluorochemicals in the processing of spherical graphite and the production of separator materials.

World Mine Production and Reserves: Reserves for China and Morocco were revised based on company and Government reports.

	Mine production		Reserves[4]
	2021	2022[e]	
United States	NA	NA	4,000
Canada	140	18	NA
China	5,700	5,700	49,000
Germany	65	65	NA
Iran	50	50	3,400
Kazakhstan	67	67	NA
Mexico	1,000	970	68,000
Mongolia	650	350	22,000
Morocco	77	77	NA
Pakistan	65	65	NA
South Africa	403	420	41,000
Spain	155	160	10,000
Vietnam	215	220	5,000
Other countries	93	98	55,000
World total (rounded)	8,680	8,300	260,000

World Resources:[4, 6] Large quantities of fluorine are present in phosphate rock. Current U.S. reserves of phosphate rock are estimated to be 1 billion tons, containing about 72 million tons of 100% fluorspar equivalent assuming an average fluorine content of 3.5% in the phosphate rock. World reserves of phosphate rock are estimated to be 71 billion tons, containing about 5 billion tons of 100% fluorspar equivalent.

Substitutes: FSA has been used as an alternative to fluorspar in the production of aluminum fluoride (AlF_3) and HF. Because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. In 2022, a company in Australia was finalizing the design of a pilot plant to recover fluorine from aluminum smelter bath and then produce AlF_3 using either bauxite or aluminum smelting dross. Aluminum smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand, and titanium dioxide have been used as substitutes for fluorspar fluxes.

[e]Estimated. NA Not available.

[1]Includes data for the following Schedule B codes: 2529.21.0000 and 2529.22.0000.

[2]Defined as total fluorspar imports – exports.

[3]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2529.21.0000 and 2529.22.0000.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Measured as 100% CaF_2.

GALLIUM

(Data in kilograms of contained gallium unless otherwise noted)

Domestic Production and Use: No domestic primary (low-purity, unrefined) gallium has been recovered since 1987. Globally, primary gallium is recovered as a byproduct of processing bauxite and zinc ores. One company in New York recovered and refined high-purity gallium from imported primary low-purity gallium metal and new scrap. Imports of gallium metal and gallium arsenide (GaAs) wafers were valued at about $5 million and $220 million, respectively. GaAs was used to manufacture compound semiconductor wafers used in integrated circuits (ICs) and optoelectronic devices, which include laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells. Gallium nitride (GaN) principally was used to manufacture optoelectronic devices. ICs accounted for 74% of domestic gallium consumption, optoelectronic devices accounted for 25%, and research and development accounted for 1%. About 77% of the gallium consumed in the United States was in GaAs, GaN, and gallium phosphide wafers. Gallium metal, triethyl gallium, and trimethyl gallium, used in the epitaxial layering process to fabricate epiwafers for the production of ICs and LEDs, accounted for most of the remainder. Optoelectronic devices were used in aerospace applications, consumer goods, industrial equipment, medical equipment, and telecommunications equipment. Uses of ICs included defense applications, high-performance computers, and telecommunications equipment.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	32,000	5,740	4,430	8,890	12,000
Gallium arsenide wafers (gross weight)	444,000	272,000	178,000	306,000	550,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	15,000	14,900	15,700	17,100	18,000
Price, average unit value of imports, dollars per kilogram:					
High-purity, refined[1]	508	573	596	625	640
Low-purity, primary[2]	185	153	163	254	420
Stocks, consumer, yearend	2,920	2,850	2,920	2,810	2,800
Net import reliance[3] as a percentage of reported consumption	100	100	100	100	100

Recycling: Old scrap, none. Substantial quantities of new scrap generated in the manufacture of GaAs-based devices were reprocessed to recover high-purity gallium at one facility in New York.

Import Sources (2018–21): Metal: China, 53%; Germany and Japan, 13% each; Ukraine, 5%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Imports of gallium metal, GaAs wafers, and GaN wafers continued to account for all U.S. consumption of gallium. In 2022, gallium metal imports increased by an estimated 34% from those in 2021 owing to increased imports from Canada, China, Slovakia, and the United Kingdom. Beginning in 2019, U.S. gallium metal imports decreased substantially from those in previous years because higher tariffs were placed on China's gallium exports to the United States.

Primary low-purity (99.99%-pure) gallium prices in China averaged $510 per kilogram in June 2022, an increase of 34% from $380 per kilogram in January. This followed a 36% increase in China's primary low-purity gallium in 2021, to $375 per kilogram in December from $275 per kilogram in January. The increases in China's gallium prices resulted from several issues. Environmental restrictions placed on Chinese bauxite production in 2019 compelled the country's alumina refineries to import bauxite with lower gallium content from abroad, which increased gallium extraction costs. When the economic impact of the global coronavirus disease 2019 (COVID-19) pandemic reduced gallium demand in early to mid-2020, Chinese gallium producers slowed or shut down operations. Chinese gallium supply was scarce when gallium demand recovered in the second half of 2020 owing increasingly to gallium consumption in fifth-generation (5G) telecommunications networks and neodymium-iron-boron (NdFeB) magnets in China for electric vehicles. Gallium prices increased significantly in the last quarter of 2020, continuing through June 2022. By October, gallium prices in China decreased by 33% to $340 per kilogram owing to reduced demand for NdFeB magnets and an increase in China's primary low-purity gallium production capacity.

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GALLIUM

China's primary low-purity gallium production capacity increased by 100,000 kilograms per year in 2022 to 750,000 kilograms per year. This latest increase followed a series of expansions from a capacity of 140,000 kilograms per year in 2010. China accounted for approximately 86% of worldwide primary low-purity gallium production capacity of an estimated 870,000 kilograms per year. China accounted for 98% of worldwide primary low-purity gallium production.

The remaining primary low-purity gallium producers outside of China most likely restricted output owing to China's dominant production capacity. These producers included Japan, the Republic of Korea, Russia, and Ukraine. Germany, Hungary, and Kazakhstan ceased primary production in 2016, 2015, and 2013, respectively. However, owing to the increase in gallium prices, Germany announced that it would eventually restart primary gallium production.

High-purity refined gallium production in 2022 was estimated to be about 290,000 kilograms, a 16% increase from the revised estimated figure of 250,000 kilograms in 2021. Canada, China, Japan, Slovakia, and the United States were the known principal producers of high-purity refined gallium. The United Kingdom ceased high-purity refined gallium production in 2018. Gallium was recovered from new scrap in Canada, China, Japan, Slovakia, and the United States. World high-purity refined gallium production capacity was an estimated 320,000 kilograms per year, and secondary high-purity gallium production capacity was an estimated 300,000 kilograms per year.

Beginning in 2002, Northrop Grumman has been awarded Defense Advanced Research Project Agency (DARPA) contracts by the U.S. Department of Defense to develop GaN Monolithic Microwave Integrated Circuits for military and commercial uses.

World Production and Reserves: Quantitative estimates of reserves were not available.

	Primary production		Production capacity
	2021	2022[e]	2022
United States	—	—	—
China	[4]423,000	540,000	750,000
Japan	3,000	3,000	[e]10,000
Korea, Republic of	2,000	2,000	[e]16,000
Russia	5,000	5,000	[e]10,000
Ukraine	1,000	1,000	[e]15,000
Other countries[5]	—	—	[e]73,000
World total (rounded)	434,000	550,000	[e]870,000

World Resources:[6] Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of processing bauxite, and the remainder is produced from zinc-processing residues. The average gallium content of bauxite is 50 parts per million. U.S. bauxite deposits consist mainly of subeconomic resources that are not generally suitable for alumina production owing to their high silica content. Some domestic zinc ores contain up to 50 parts per million gallium and could be a significant resource, although no gallium is currently recovered from domestic ores. Gallium contained in world resources of bauxite is estimated to exceed 1 million tons, and a considerable quantity could be contained in world zinc resources. However, less than 10% of the gallium in bauxite and zinc resources is potentially recoverable.

Substitutes: Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third-generation (3G) cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based ICs are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. NA Not available. — Zero.

[1]Estimated based on the average unit values of U.S. imports for 99.999%- and 99.99999%-pure gallium

[2]Estimated based on the average unit values of U.S. imports for 99.99%-pure gallium.

[3]Defined as imports – exports. Excludes gallium arsenide wafers.

[4]Reported.

[5]Other countries thought to still have primary low-purity gallium production capacity include Germany, Hungary, and Kazakhstan.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: In 2022, garnet for industrial use was mined by four companies—one in Idaho, one in Montana, and two in New York. One processing facility operated in Oregon and another operated in Pennsylvania. The estimated value of crude garnet production was about $17 million, and refined material sold or used had an estimated value of $52 million. The major end uses of garnet were, in descending percentage of consumption, for abrasive blasting, water-filtration media, water-jet-assisted cutting, and other end uses, such as in abrasive powders, nonslip coatings, and sandpaper. Domestic industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, filtration plants, glass polishing, the petroleum industry, shipbuilders, textile stonewashing, and wood-furniture-finishing operations.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Crude	101,000	104,000	101,000	81,700	76,000
Refined, sold or used	166,000	147,000	146,000	127,000	120,000
Imports for consumption[2]	265,000	208,000	115,000	144,000	190,000
Exports	18,900	16,700	18,200	20,300	24,000
Consumption, apparent[3]	347,000	296,000	198,000	205,000	240,000
Price, average import unit value, dollars per ton	215	214	250	280	200
Employment, mine and mill, number[e]	170	160	130	120	110
Net import reliance[4] as a percentage of apparent consumption	71	65	49	60	69

Recycling: Garnet was recycled at a plant in Oregon with a recycling capacity of 16,000 tons per year and at a plant in Pennsylvania with a recycling capacity of 25,000 tons per year. Garnet can be recycled multiple times without degradation of its quality. Most recycled garnet is from blast cleaning and water-jet-assisted cutting operations.

Import Sources (2018–21):[e] South Africa, 48%; China,[5] 18%; India, 18%; Australia, 11%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Emery, natural corundum, natural garnet, and other natural abrasives:		
Crude	2513.20.1000	Free.
Other than crude	2513.20.9000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2022, estimated domestic production of crude garnet concentrates decreased by 7% compared with production in 2021. This decrease was due to the closing of the Emerald Creek Garnet Mine in Idaho in July 2022. U.S. garnet production was estimated to be about 8% of total global garnet production. The 2022 estimated domestic sales or use of refined garnet decreased by about 6% compared with sales in 2021.

Garnet imports in 2022 were estimated to have increased by 32% compared with those in 2021. This increase was attributed to increased imports of garnet from Australia, India, and South Africa. In 2022, the average unit value of garnet imports was $200 per ton, a decrease of 29% compared with the average unit value in 2021. In the United States, most domestically produced crude garnet concentrate was priced at about $220 per ton. U.S. exports in 2022 were estimated to have increased by 18%. During 2022, the United States consumed an estimated 240,000 tons of garnet. This was a 17% increase from that in 2021.

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GARNET (INDUSTRIAL)

The U.S. natural gas and petroleum industry is one of the leading garnet-consuming industries, using garnet for cleaning drill pipes and well casings. Natural gas and petroleum producers also use garnet as a reservoir-fracturing proppant, alone or mixed with other proppants. At the end of September 2022, the number of drill rigs operating in the United States was 765 rigs, an increase of 237 rigs over the end of September 2021, likely indicating that more garnet was consumed in well drilling.[6]

The garnet market is very competitive. To increase profitability and remain competitive with imported material, production may be restricted to only high-grade garnet ores or as a byproduct of other salable mineral products that occur with garnet, such as kyanite, marble, metallic ore minerals, mica minerals, sillimanite, staurolite, or wollastonite.

Garnet production in India is still recovering from the effects of the global coronavirus disease 2019 (COVID-19) pandemic and has not yet returned to pre-pandemic levels.

World Mine Production and Reserves: Reserves data for China was revised based on Government reports.

	Mine production		Reserves[7]
	2021	2022[e]	
United States	81,700	76,000	5,000,000
Australia	321,000	370,000	Moderate to large
China	[e]310,000	310,000	2,200,000
India	12,000	15,000	13,000,000
South Africa	[e]140,000	150,000	NA
Other countries	60,000	60,000	6,500,000
World total (rounded)	925,000	980,000	Moderate to large

World Resources:[7] World resources of garnet are large and occur in a wide variety of rocks, particularly gneisses and schists. Garnet also occurs in contact-metamorphic deposits in crystalline limestones, pegmatites, and serpentinites and in vein deposits. In addition, alluvial garnet is present in many heavy-mineral sand and gravel deposits throughout the world. Large domestic resources of garnet also are concentrated in coarsely crystalline gneiss near North Creek, NY; other significant domestic resources of garnet occur in Idaho, Maine, Montana, New Hampshire, North Carolina, and Oregon. In addition to those in the United States, major garnet deposits exist in Australia, Canada, China, India, and South Africa, where they are mined for foreign and domestic markets; deposits in Russia and Turkey also have been mined in recent years, primarily for internal markets. Additional garnet resources are in Chile, Czechia, Pakistan, Spain, Thailand, and Ukraine; small mining operations have been reported in most of these countries.

Substitutes: Other natural and manufactured abrasives can substitute to some extent for all major end uses of garnet. In many cases, however, using the substitutes would entail sacrifices in quality or cost. Fused aluminum oxide and staurolite compete with garnet as a sandblasting material. Ilmenite, magnetite, and plastics compete as filtration media. Corundum, diamond, and fused aluminum oxide compete for lens grinding and for many lapping operations. Emery is a substitute in nonskid surfaces. Fused aluminum oxide, quartz sand, and silicon carbide compete for the finishing of plastics, wood furniture, and other products.

[e]Estimated. NA Not available.

[1]Excludes gem and synthetic garnet.

[2]Sources: U.S. Census Bureau and Trade Mining, LLC; data adjusted by the U.S. Geological Survey.

[3]Defined as crude production + imports – exports.

[4]Defined as imports – exports.

[5]Includes Hong Kong.

[6]Source: Baker Hughes Co., 2022, Rig count overview & summary count: Baker Hughes Co., accessed October 4, 2022, at https://bakerhughesrigcount.gcs-web.com/.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

GEMSTONES[1]

(Data in million dollars unless otherwise noted)

Domestic Production and Use: The combined value of U.S. natural and synthetic gemstone output in 2022 was an estimated $95 million, a 7% increase compared with that in 2021. Domestic gemstone production included agate, beryl, coral, diamond, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise, and many other gem materials. In descending order of production value, Arizona led the Nation in natural gemstone production, followed by Oregon and Nevada. These three States accounted for 47% of the natural gemstone production in the United States. Other top producing States, in descending order of production value, were California, Montana, Maine, Colorado, Arkansas, Utah, and Idaho. Synthetic gemstones were manufactured by eight companies in North Carolina, California, Oregon, Maryland, New York, South Carolina, Wisconsin, and Arizona, in descending order of production value. U.S. synthetic gemstone production increased by 7% compared with that in 2021. Major gemstone end uses were carvings, gem and mineral collections, and jewelry.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:[2]					
Natural[3]	9.47	9.22	9.82	9.48	9.5
Laboratory-created (synthetic)	64.9	94.3	55.0	79.3	85
Imports for consumption	27,700	24,400	16,300	24,600	30,000
Exports, excluding reexports	1,850	1,020	1,330	977	1,600
Consumption, apparent[4]	25,900	23,500	15,000	23,700	28,000
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,120	1,120	1,100	1,100	1,100
Net import reliance[5] as a percentage of apparent consumption	99	99	99	99	99

Recycling: Gemstones are often recycled by being resold as estate jewelry, reset, or recut, but this report does not account for those stones.

Import Sources (2018–21, by value): Diamond: India, 45%; Israel, 28%; Belgium, 11%; South Africa, 5%; and other, 11%. Diamond imports accounted for an average of 89% of the total value of gem imports during the period 2018 to 2021.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
Coral and similar materials, unworked	0508.00.0000	Free.
Imitation gemstones	3926.90.4000	2.8% ad valorem.
Imitation pearls and imitation pearl beads, not strung	7018.10.1000	4% ad valorem.
Imitation gemstones	7018.10.2000	Free.
Pearls, natural, graded and temporarily strung	7101.10.3000	Free.
Pearls, natural, other	7101.10.6000	Free.
Pearls, cultured	7101.21.0000	Free.
Diamonds, unworked or sawn	7102.31.0000	Free.
Diamonds, cut, 0.5 carat or less	7102.39.0010	Free.
Diamonds, cut, more than 0.5 carat	7102.39.0050	Free.
Other nondiamond gemstones, unworked	7103.10.2000	Free.
Other nondiamond gemstones, uncut	7103.10.4000	10.5% ad valorem.
Rubies, cut	7103.91.0010	Free.
Sapphires, cut	7103.91.0020	Free.
Emeralds, cut	7103.91.0030	Free.
Other nondiamond gemstones, cut	7103.99.1000	Free.
Other nondiamond gemstones, worked	7103.99.5000	10.5% ad valorem.
Synthetic diamonds, cut but not set	7104.91.1000	Free.
Synthetic gemstones, worked or cut but not set	7104.99.1000	Free.
Synthetic gemstones, other	7104.99.5000	6.4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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GEMSTONES

Events, Trends, and Issues: In 2022, the U.S. gemstone and jewelry industries had recovered for the most part from the effects of the coronavirus disease 2019 (COVID-19) pandemic-related restrictions, lockdowns, and temporary mine and store closings.

Total world diamond production during 2022 was estimated to have increased slightly from 2021 levels. The largest production increases in 2022 were in Angola, Botswana, and Namibia. The largest production decreases in 2022 were in Canada, Congo (Kinshasa), Lesotho, and Russia. Production would need to increase by about 2% per year during the next 5 years to allow the market to fully rebalance after the COVID-19 pandemic.

Online auctions gained a higher share of rough diamond sales and offset deficits in traditional sales channels. Many jewelry stores successfully shifted sales to their websites; online diamond jewelry sales exceeded 25% of 2022 sales. Global gemstone sales are expected to increase at a steady rate over the next 5 years.

In 2022, U.S. imports for consumption of gemstones were about $30 billion, which was a 22% increase compared with $24.6 billion in 2021. These imports consisted of about $26 billion in gem-quality diamonds, which was an 18% increase compared with $21.8 billion in 2021, and about $4.3 billion in nondiamond gemstones, which was a 49% increase compared with $2.88 billion in 2021. The increase in U.S. gemstone production combined with the increase in U.S. gemstone imports and the increase in gemstone exports produced a 19% increase in apparent consumption to a value of $28 billion. This apparent consumption consisted of $24 billion in gem-quality diamond and $4 billion in nondiamond gemstones. The United States was one of the leading global markets in terms of sales and is expected to continue to dominate global gemstone consumption.

World Gem-Quality Diamond Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2021	2022[e]	
United States	—	—	World reserves of diamond-bearing deposits are substantial. No reserves data were available for other gemstones.
Angola	7,850	10,000	
Botswana	16,000	18,000	
Brazil	143	150	
Canada	17,600	16,000	
Central African Republic	73	73	
Congo (Kinshasa)	2,820	2,500	
Ghana	55	57	
Guinea	219	220	
Lesotho	339	230	
Namibia	1,760	2,300	
Russia	21,900	21,000	
Sierra Leone	671	680	
South Africa	3,890	3,900	
Zimbabwe	423	470	
Other countries	139	130	
World total (rounded)	73,900	76,000	

World Resources:[7] Most diamond ore bodies have a diamond content that ranges from less than 1 carat to about 6 carats per ton of ore. The major diamond reserves are in southern Africa, Australia, Canada, and Russia.

Substitutes: Glass, plastics, and other materials are substituted for natural gemstones. Synthetic gemstones (manufactured materials that have the same chemical and physical properties as natural gemstones) are common substitutes. Simulants (materials that appear to be gems but differ in chemical and physical characteristics) also are frequently substituted for natural gemstones.

[e]Estimated.

[1]Excludes industrial diamond and industrial garnet. See also the Diamond (Industrial) and Garnet (Industrial) chapters.

[2]Estimated minimum production.

[3]Includes production of freshwater shell.

[4]Defined as production (natural and synthetic) + imports – exports (excluding reexports).

[5]Defined as imports – exports (excluding reexports).

[6]Data in thousands of carats of gem-quality diamond.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

GERMANIUM

(Data in kilograms of contained germanium unless otherwise noted)

Domestic Production and Use: In 2022, zinc concentrates containing germanium were produced at mines in Alaska and Tennessee. Germanium-containing concentrates in Alaska were exported to a refinery in Canada for processing and germanium recovery. A zinc smelter in Clarksville, TN, produced germanium leach concentrates recovered from processing zinc concentrates from the Middle Tennessee Zinc Complex. Germanium in the form of compounds and metal was imported into the United States for further processing by industry. A company in Utah produced germanium wafers for solar cells used in satellites from imported and recycled germanium. A refinery in Oklahoma recovered germanium from industry-generated scrap and produced germanium tetrachloride for the production of fiber optics. The estimated value of germanium consumed in 2022, based on the annual average germanium metal price, was $39 million, 10% more than that in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, refinery:					
Primary	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:[e, 1]					
Germanium metal	10,000	14,000	14,000	13,000	14,000
Germanium dioxide	12,000	21,000	12,000	17,000	15,000
Exports, germanium metal and dioxide[e, 1]	3,600	4,500	4,800	7,500	5,800
Shipments from Government stockpile[2]	—	—	—	—	—
Consumption, estimated[3]	30,000	30,000	30,000	30,000	30,000
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,543	1,236	1,046	1,187	1,300
Germanium dioxide	1,084	913	724	770	840
Net import reliance[5] as a percentage of estimated consumption	>50	>50	>50	>50	>50

Recycling: During the manufacture of most optical devices, more than 60% of the germanium metal used is routinely recycled as new scrap. Germanium scrap is also recovered from the windows in decommissioned tanks and other military vehicles. The United States has the capability to recycle new and old scrap.

Import Sources (2018–21):[1, 6] Germanium metal: China, 54%; Belgium, 27%; Germany, 9%; Russia, 8%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad valorem.
Metal, unwrought	8112.92.6000	2.6% ad valorem.
Metal, powder	8112.92.6500	4.4% ad valorem.
Metal, wrought	8112.99.1000	4.4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile:[7]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Germanium metal	14,000	—	5,000	—	5,000
Germanium scrap (gross weight)	6,910	—	—	—	—
Germanium wafers (each)	68,700	—	—	—	—

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GERMANIUM

Events, Trends, and Issues: The major global end uses for germanium were electronics and solar applications, fiber-optic systems, infrared optics, and polymerization catalysts. Other uses included chemotherapy, metallurgy, and phosphors.

The prices for germanium metal and germanium dioxide (Europe, minimum 99.999% purity) increased from January to May and then decreased through late October. The price for germanium metal increased from $1,380 per kilogram to $1,470 per kilogram and then decreased to $1,100 per kilogram. The price for germanium dioxide increased from $885 per kilogram to $970 per kilogram and then decreased to $705 per kilogram.

The Defense Logistics Agency Strategic Materials initiated a program to recycle germanium scrap recovered from decommissioned military equipment. The recycling program was expected to produce up to 3,000 kilograms per year of high-purity germanium ingot that could be consumed for night-vision and thermal-sensing devices and other military uses.

The owner of a zinc smelter in Clarksville, TN, planned to construct a new $90 million gallium and germanium processing plant at the site, according to local news sources. The plant could potentially recover an estimated 40,000 kilograms per year of germanium.

China was a leading global producer and exporter of germanium in 2022. Exports of unwrought germanium, germanium powders, and germanium waste and scrap (China's export code 8112.99.10) for the year through August were 23,100 kilograms, 7% less than exports in the same period in 2021. More than 90% of exports were sent to Germany, Hong Kong, Japan, Belgium, the United States, and Russia, in descending order of quantity.

World Refinery Production and Reserves:

	Refinery production[e, 8]		Reserves[9]
	2021	2022	
United States	W	W	Data on the recoverable germanium content of zinc ores were not available.
China	NA	NA	
Russia	NA	NA	
Other countries	NA	NA	
World total (rounded)	NA	NA	

World Resources:[9] The available resources of germanium are associated with certain zinc and lead-zinc-copper sulfide ores. Substantial U.S. reserves of recoverable germanium are contained in zinc deposits in Alaska, Tennessee, and Washington. Based on an analysis of zinc concentrates, U.S. reserves of zinc may contain as much as 2,500 tons of germanium. Because zinc concentrates are shipped globally and blended at smelters, however, the recoverable germanium in zinc reserves cannot be determined. On a global scale, as little as 3% of the germanium contained in zinc concentrates is recovered. Significant amounts of germanium are contained in ash and flue dust generated in the combustion of certain coals for power generation.

Substitutes: Silicon can be a less-expensive substitute for germanium in certain electronic applications. Some metallic compounds can be substituted in high-frequency electronics applications and in some light-emitting-diode applications. Zinc selenide and germanium glass substitute for germanium metal in infrared applications systems, but often at the expense of performance. Antimony and titanium are substitutes for use as polymerization catalysts.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Data have been adjusted to exclude low-value shipments.

[2]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.

[3]Estimated consumption of germanium contained in metal and germanium dioxide.

[4]Average European price for minimum 99.999% purity. Source: Argus Media group, Argus Metals International.

[5]Defined as imports – exports ± adjustments for Government stock changes.

[6]Import sources are based on gross weight of wrought and unwrought germanium metal and germanium metal powders.

[7]See Appendix B for definitions.

[8]Available information was inadequate to make reliable estimates of world production of germanium.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

GOLD

(Data in metric tons[1] of contained gold unless otherwise noted)

Domestic Production and Use: In 2022, domestic gold mine production was estimated to be 170 tons, 9% less than that in 2021, and the value was estimated to be $10 billion. Gold was produced at more than 40 lode mines in 11 States, at several large placer mines in Alaska, and at numerous smaller placer mines (mostly in Alaska and in the Western States). Nevada was the leading gold-producing State, accounting for about 72% of total domestic production. About 6% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper ores. The top 28 operations yielded about 98% of the mined gold produced in the United States. Commercial-grade gold was produced at 15 refineries. A few dozen companies, out of several thousand companies and artisans, dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and Providence, RI, areas, with lesser concentrations in California, Florida, and Texas.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	226	201	193	187	170
Refinery:					
Primary	205	205	181	[e]170	160
Secondary (new and old scrap)	117	116	92	92	90
Imports for consumption[2]	213	199	545	192	140
Exports[2]	474	360	297	386	430
Consumption, reported[3]	154	151	187	266	250
Stocks, Treasury, yearend[4]	8,130	8,130	8,130	8,130	8,130
Price, dollars per troy ounce[5]	1,272	1,395	1,774	1,801	1,800
Employment, mine and mill, number[6]	11,400	11,600	12,000	12,200	12,000
Net import reliance[7] as a percentage of apparent consumption[8]	E	E	47	E	E

Recycling: In 2022, an estimated 90 tons of new and old scrap was recycled, equivalent to about 36% of reported consumption. The domestic supply of gold from recycling decreased slightly compared with that in 2021.

Import Sources (2018–21): Ores and concentrates: Canada, 89%; Greece, 9%; and Germany, 2%. Dore: Mexico, 45%; Colombia, 12%; Peru, 8%; Nicaragua, 7%; and other, 28%. Bullion: Switzerland, 38%; Canada, 23%; Australia and South Africa, 7% each; and other, 25%. Total: Switzerland, 24%; Mexico, 20%; Canada, 15%; Colombia, 6%; and other, 35%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Precious metal ore and concentrates:		
Gold content of silver ores	2616.10.0080	0.8 ¢/kg on lead content.
Gold content of other ores	2616.90.0040	1.7 ¢/kg on lead content.
Gold bullion	7108.12.1013	Free.
Gold dore	7108.12.1020	Free.
Gold scrap	7112.91.0100	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of gold (see salient statistics above) and the U.S. Department of Defense administers a Governmentwide secondary precious-metals recovery program.

Events, Trends, and Issues: The estimated gold price in 2022 was unchanged from the previous record-high annual price in 2021. The Engelhard daily price of gold in 2022 increased in the first quarter, decreased in the second quarter, and fluctuated in the third quarter. Several factors were reported to have caused the increase in the gold price: gold demand for safe-haven buying increased owing to the continued coronavirus disease 2019 (COVID-19) pandemic, and global investor uncertainty.

In 2022, worldwide gold mine production was estimated to be unchanged compared with that in 2021. Production decreases in Papua New Guinea and the United States were more than offset by production increases in Colombia, Indonesia, and Burkina Faso.

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GOLD

Estimated global gold consumption was in jewelry, 47%; physical bars, 17%; central banks and other institutions, 20%; official coins and medals and imitation coins, 9%; electrical and electronics, 6%; and other, 1%. In the first 9 months of 2022, global consumption of gold in physical bars decreased by 3%, jewelry increased by 5%, electronics decreased by 4%, other industrial applications were essentially unchanged, and coins and medals increased by 15% compared with those in the first 9 months of 2021. Global investments in gold-based exchange-traded funds decreased twofold, while gold holdings in central banks increased by 62% during the same period. Total global consumption in the first 9 months of 2022 increased by 18% compared with that in the first 9 months of 2021.[9]

World Mine Production and Reserves: Reserves for Australia, Canada, China, and Peru were revised based on company and Government reports.

	Mine production		Reserves[10]
	2021	2022[e]	
United States	187	170	3,000
Australia	315	320	[11]8,400
Brazil	61	60	2,400
Burkina Faso	67	70	NA
Canada	223	220	2,300
China	329	330	1,900
Colombia	55	60	NA
Ghana	88	90	1,000
Indonesia	[e]66	70	2,600
Kazakhstan	[e]116	120	1,000
Mali	[e]51	50	800
Mexico	[e]120	120	1,400
Papua New Guinea	[e]54	50	1,100
Peru	[e]97	100	2,900
Russia	320	320	6,800
South Africa	[e]107	110	5,000
Sudan	50	50	NA
Tanzania	60	60	NA
Uzbekistan	100	100	1,800
Other countries	626	620	9,200
World total (rounded)	3,090	3,100	52,000

World Resources:[10] An assessment of U.S. gold resources indicated 33,000 tons of gold in identified (15,000 tons) and undiscovered (18,000 tons) resources.[12] Nearly one-quarter of the gold in undiscovered resources was estimated to be contained in porphyry copper deposits. The gold resources in the United States, however, are only a small portion of global gold resources.

Substitutes: Base metals clad with gold alloys are widely used to economize on gold in electrical and electronic products and in jewelry; many of these products are continually redesigned to maintain high-utility standards with lower gold content. Generally, palladium, platinum, and silver may substitute for gold.

[e]Estimated. E Net exporter. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Includes refined bullion, dore, ores, concentrates, and precipitates. Excludes waste and scrap, official monetary gold, gold in fabricated items, gold in coins, and net bullion flow (in tons) to market from foreign stocks at the New York Federal Reserve Bank.

[3]Includes gold used in the production of consumer purchased bars, coins, and jewelry. Excludes gold as an investment (except consumer purchased bars and coins). Source: World Gold Council.

[4]Includes gold in the Exchange Stabilization Fund. Stocks were valued at the official price of $42.22 per troy ounce.

[5]Engelhard's average gold price quotation for the year. In 2022, the price was estimated by the U.S. Geological Survey based on data from January through November.

[6]Data from the Mine Safety and Health Administration.

[7]Defined as imports – exports.

[8]Defined as mine production + secondary production + imports – exports.

[9]Source: World Gold Council.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 4,200 tons.

[12]Source: U.S. Geological Survey National Mineral Resource Assessment Team, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

GRAPHITE (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2022, natural graphite was not produced in the United States; however, approximately 95 U.S. companies, primarily in the Great Lakes and Northeast regions, consumed 72,000 tons valued at an estimated $140 million. The major uses of natural graphite were batteries, brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2022, U.S. natural graphite imports were an estimated 82,000 tons, consisting of about 77% flake and high-purity, 22% amorphous, and 1% lump and chip graphite.

Graphite consumption is expected to continue to increase, owing largely to growth from the electric-vehicle market. The battery end-use market for graphite has grown by 250% globally since 2018. In the United States, 4 lithium-ion battery manufacturing plants are currently in operation, with an additional 21 in development. At full capacity, these plants are expected to require approximately 1.2 million tons per year of spherical purified graphite, with an estimated 40% to 60% coming from synthetic graphite.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	—	—	—	—	—
Imports for consumption	70,700	50,100	36,000	53,100	82,000
Exports	9,950	5,890	5,930	8,670	9,600
Consumption, apparent[1]	60,700	44,200	30,000	44,400	72,000
Price, average unit value of imports, dollars per metric ton at foreign ports:					
Flake	1,520	1,340	1,340	1,390	1,300
Lump and chip (Sri Lanka)	1,890	2,380	2,940	2,010	2,500
Amorphous	319	511	567	622	560
Net import reliance[1] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Refractory brick and linings, alumina-graphite refractories for continuous metal castings, magnesia-graphite refractory brick for basic oxygen and electric arc furnaces, and insulation brick led the way in the recycling of graphite products. Recycling of refractory graphite material is increasing, with material being recycled into products such as brake linings and thermal insulation. Recovering high-quality flake graphite from steelmaking kish is technically feasible, but currently not practiced. The abundance of graphite in the world market inhibits increased recycling efforts. Information on the quantity and value of recycled graphite is not available.

Import Sources (2018–21): China,[5] 33%; Mexico, 18%; Canada, 17%; Madagascar, 10%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Crystalline flake (not including flake dust)	2504.10.1000	Free.
Powder	2504.10.5000	Free.
Other	2504.90.0000	Free.

Depletion Allowance: Lump and amorphous, 22% (domestic) and flake, 14% (domestic); 14% (foreign).

Government Stockpile:[2]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Graphite	—	900	—	—	—

Events, Trends, and Issues: U.S. natural graphite imports decreased by 29% and 28% in 2019 and 2020, respectively, and then increased by 48% in 2021, and by 55% in 2022. U.S. imports for consumption and U.S. apparent consumption increased by 16% and 19%, respectively, for the 5-year period of 2018 to 2022. The increase in consumption is likely due to rising demand from the lithium-ion battery industry.

In 2022, China was the world's leading graphite producer, producing an estimated 65% of total world production. Approximately 24% of graphite produced in China was amorphous and about 76% was flake. China produced some large flake graphite, but much of its flake graphite production was very small, in the +200-mesh range. China also processed most of the world's spherical graphite.

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GRAPHITE (NATURAL)

North America produced only 1.2% of the world's graphite supply with production in Canada and Mexico. Three companies were developing graphite-mining projects in the United States—two in Alabama and one in Alaska. Two spherical graphite plants were in construction during 2022, located in Kellyton, AL, and Vidalia, LA, with production expected to begin during 2023. In 2022, the Vidalia project was awarded a grant of up to $220 million under the Bipartisan Infrastructure Law towards expanding the production capacity to 45,000 tons per year.

Africa has been a recent focus for graphite exploration, with projects under development in Madagascar, Mozambique, Namibia, and Tanzania. Additional projects were in advanced development stages in Australia, Canada, and Sweden. A Canadian company and an Australian company continued to construct mines in Madagascar and Tanzania, respectively, with production expected to begin by 2023. In 2022, an Australian company commissioned a graphite anode plant in Sweden, becoming the first commercial plant operating in Europe.

In February, Ukraine halted graphite production, citing Russian military action. Operations recommenced in August, although future production was uncertain as the conflict continued. Additionally, the United States and many other countries have suspended normal trade relations with Russia, removing supplies of Russian graphite from much of the global market. Leading up to the conflict, Russia and Ukraine were considered among the top 10 producers of graphite.

World Mine Production and Reserves: Reserves for Brazil, China, and Russia were revised based on company and Government reports.

	Mine production		Reserves[3]
	2021	2022[e]	
United States	—	—	([4])
Austria	500	500	([4])
Brazil	82,000	87,000	74,000,000
Canada	12,000	15,000	([4])
China	820,000	850,000	52,000,000
Germany	250	250	([4])
India	7,000	8,300	8,000,000
Korea, North	8,100	8,100	2,000,000
Korea, Republic of	10,500	17,000	1,800,000
Madagascar	70,000	110,000	26,000,000
Mexico	2,100	1,900	3,100,000
Mozambique	72,000	170,000	25,000,000
Norway	6,290	10,000	600,000
Russia	15,000	15,000	14,000,000
Sri Lanka	3,000	3,000	1,500,000
Tanzania	—	8,000	18,000,000
Turkey	2,700	2,900	90,000,000
Ukraine	10,000	3,000	([4])
Uzbekistan	110	—	7,600,000
Vietnam	5,000	5,000	([4])
World total (rounded)	1,130,000	1,300,000	330,000,000

World Resources:[3] Domestic resources of graphite are relatively small, but the rest of the world's resources exceed 800 million tons of recoverable graphite.

Substitutes: Synthetic graphite powder, scrap from discarded machined shapes, and calcined petroleum coke compete for use in iron and steel production. Synthetic graphite powder and secondary synthetic graphite from machining graphite shapes compete for use in battery applications. Finely ground coke with olivine is a potential competitor in foundry-facing applications. Molybdenum disulfide competes as a dry lubricant but is more sensitive to oxidizing conditions.

[e]Estimated. — Zero.

[1]Defined as imports – exports.

[2]See Appendix B for definitions.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Included in "World total."

[5]Includes Hong Kong.

GYPSUM

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, domestic production of crude gypsum was estimated to be 21 million tons with a value of about $250 million. The leading crude-gypsum-producing States were estimated to be California, Iowa, Kansas, Nevada, Oklahoma, and Texas. Overall, 47 companies produced or processed gypsum in the United States at 52 mines in 16 States. The majority of domestic consumption, which totaled approximately 42 million tons, was used by agriculture, cement production, and manufacturers of wallboard and plaster products. Small quantities of high-purity gypsum, used in a wide range of industrial processes, accounted for the remaining tonnage. At the beginning of 2022, the production capacity of 63 operating gypsum panel manufacturing plants in the United States was about 34 billion square feet[1] per year. Total wallboard sales in 2022 were estimated to be 28 billion square feet.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Crude	21,100	21,700	21,500	21,300	21,000
Synthetic[2]	16,600	14,400	13,000	13,000	14,000
Calcined[3]	17,500	17,900	17,900	18,600	20,000
Wallboard products sold, million square feet[1]	23,700	25,900	26,200	27,300	28,000
Imports, crude, including anhydrite	5,210	6,140	6,030	6,520	6,800
Exports, crude, not ground or calcined	36	37	32	42	40
Consumption, apparent[4]	42,900	42,200	40,500	40,800	42,000
Price, average, dollars per metric ton:					
Crude, free on board (f.o.b.) mine	8.3	8.6	8.6	11	12
Calcined, f.o.b. plant	32	34	35	42	44
Employment, mine and calcining plant, number[e]	4,500	4,500	4,500	4,500	4,500
Net import reliance[5] as a percentage of apparent consumption	12	15	15	16	16

Recycling: Approximately 700,000 tons per year of gypsum scrap that was generated by wallboard manufacturing was recycled onsite. The recycling of wallboard from new construction and demolition sources also took place, although those amounts are unknown. Recycled gypsum was used primarily for agricultural purposes and feedstock for the manufacture of new wallboard. Other potential markets for recycled gypsum include athletic-field marking, cement production (as a stucco additive), grease absorption, sludge drying, and water treatment.

Import Sources (2018–21): Mexico, 35%; Spain, 33%; Canada, 28%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Gypsum, anhydrite	2520.10.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. crude gypsum production was estimated to have decreased slightly, whereas apparent consumption increased by 3% compared with that in 2021. U.S. gypsum imports increased by an estimated 4% compared with those in 2021. Exports, although very low compared with imports and often subject to wide fluctuations, decreased by an estimated 5%.

Demand for gypsum depends principally on construction industry activity, particularly in the United States, where the majority of gypsum consumed is used for agriculture, building plasters, the manufacture of portland cement, and wallboard products. Despite disruptions caused by the global coronavirus disease 2019 (COVID-19) pandemic, the production of gypsum was not affected.

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GYPSUM

The United States, the world's leading crude gypsum producer, produced an estimated 21 million tons. Iran was the second-leading producer with an estimated 16 million tons of crude production, followed by China with 13 million tons. Increased use of wallboard in Asia, coupled with new gypsum product plants, spurred increased production in the region. As wallboard becomes more widely used, worldwide gypsum production is expected to increase.

World Mine Production and Reserves: Reserves for China were revised based on Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	21,300	21,000	700,000
Algeria	[e]2,500	2,500	NA
Brazil	[e]2,000	2,000	450,000
Canada	[e]2,400	2,400	450,000
China	12,600	13,000	1,500,000
France	1,950	2,000	350,000
Germany	5,200	5,200	NA
India	[e]4,300	4,300	37,000
Iran	[e]16,000	16,000	NA
Japan	[e]4,300	4,300	NA
Mexico	[e]5,400	5,400	NA
Oman	12,300	12,000	NA
Pakistan	1,820	1,800	6,000
Russia	[e]4,100	4,100	NA
Saudi Arabia	3,990	4,000	NA
Spain	[e]11,000	11,000	NA
Thailand	[e]9,300	9,300	1,700
Turkey	[e]9,300	9,300	200,000
Uzbekistan	2,200	2,200	NA
Other countries	21,000	22,000	NA
World total (rounded)	153,000	150,000	Large

World Resources:[6] Reserves are large in major producing countries, but data for most are not available. Domestic gypsum resources are adequate but unevenly distributed. Large imports from Canada augment domestic supplies for wallboard manufacturing in the United States, particularly in the eastern and southern coastal regions. Imports from Mexico supplement domestic supplies for wallboard manufacturing along portions of the United States western seaboard. Large gypsum deposits occur in the Great Lakes region, the midcontinent region, and several Western States. Foreign resources are large and widely distributed; 81 countries were estimated to produce gypsum in 2022.

Substitutes: In such applications as stucco and plaster, cement and lime may be substituted for gypsum; brick, glass, metallic or plastic panels, and wood may be substituted for wallboard. Gypsum has no practical substitute in the manufacturing of portland cement. Synthetic gypsum generated by various industrial processes, including flue gas desulfurization of smokestack emissions, is very important as a substitute for mined gypsum in wallboard manufacturing, cement production, and agricultural applications (in descending order by tonnage). In 2022, synthetic gypsum was estimated to account for about 25% of the total domestic gypsum supply.

[e]Estimated. NA Not available.

[1]The standard unit used in the U.S. wallboard industry is square feet; multiply square feet by 0.0929 to convert to square meters. Source: The Gypsum Association.

[2]Synthetic gypsum used; the majority of these data were obtained from the American Coal Ash Association.

[3]From domestic crude gypsum and synthetic gypsum.

[4]Defined as crude gypsum production + synthetic gypsum used + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

HELIUM

(Data in million cubic meters of contained helium gas[1] unless otherwise noted)

Domestic Production and Use: The estimated value of Grade-A helium (99.997% helium or greater) sold during 2022 by private industry was about $820 million. Five plants (three in Texas and two in Kansas) extracted helium from natural gas and produced crude helium that ranged from 50% to 80% helium. Five plants (two in Kansas, one each in Arizona, New Mexico, and Oklahoma) produced gaseous helium that ranged from 95% to 99.5% helium. Four plants (two in Colorado and one each in Utah and Wyoming) extracted helium from natural gas and produced Grade-A helium. Three plants in Kansas and one in Oklahoma accepted crude helium from other producers and the Bureau of Land Management (BLM) pipeline and purified it to Grade-A helium. In 2022, estimated domestic apparent consumption of Grade-A helium was 43 million cubic meters (1.5 billion cubic feet), and it was used for, in descending order by estimated quantity, magnetic resonance imaging, lifting gas, analytical and laboratory applications, electronics and semiconductor manufacturing, welding, engineering and scientific applications, and various other minor applications.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Helium extracted from natural gas[2]	62	72	76	69	60
Withdrawn from storage[3]	28	17	7	7	15
Grade-A helium sales	90	89	83	76	75
Imports for consumption	8	7	7	9	8
Exports	[4]58	58	52	47	40
Consumption, apparent[5]	40	38	38	38	43
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

The estimated price for private industry's Grade-A helium was about $11 per cubic meter ($310 per thousand cubic feet) in 2022, with some producers posting surcharges to this price.

Recycling: In the United States, helium used in large-volume applications is seldom recycled. Some low-volume or liquid boil-off recovery systems are used. In the rest of the world, helium recycling is more common.

Import Sources (2018–21): Qatar, 53%; Canada, 20%; Algeria, 15%; Russia, 5%; and other, 7%.

Tariff:	Item	Number	Normal Trade Relations 12–31–22
Helium		2804.29.0010	3.7% ad valorem.

Depletion Allowance: Allowances are applicable to natural gas from which helium is extracted, but no allowance is granted directly to helium.

Government Stockpile:[7] Under the Helium Stewardship Act of 2013, the BLM manages the Federal Helium Program, which includes all operations of the BLM Crude Helium Enrichment Unit, Cliffside Field helium storage reservoir, in Potter County, TX, and the Government's crude helium pipeline system. Private firms that sell Grade-A helium to Federal agencies are required to purchase a like amount of (in-kind) crude helium from the BLM. The law mandated that the BLM sell at auction Federal Conservation Helium stored in Bush Dome at the Cliffside Field. The last auction was completed in summer 2018. As of the end of fiscal year (FY) 2022, the remaining conservation helium is about 60.7 million cubic meters (2.19 billion cubic feet). The BLM will continue to deliver helium from private storage until all Cliffside Field assets are sold or disposed of. It is expected that all Cliffside Field assets will be disposed of in FY 2023. In FY 2022, privately owned companies purchased about 5.10 million cubic meters (185 million cubic feet) of in-kind crude helium. During FY 2022, the BLM's Amarillo Field Office, Helium Operations, accepted about 9.2 million cubic meters (331 million cubic feet) of private helium for storage and redelivered nearly 17.8 million cubic meters (640 million cubic feet). As of September 30, 2022, about 57.2 million cubic meters (2.06 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

Material	Inventory as of 9–30–22	Authorized for disposal	Disposal plan FY 2023
Helium	60.7	60.7	60.7

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HELIUM

Events, Trends, and Issues: Helium sales in 2022 decreased slightly in the United States owing to several unplanned shutdowns taking place, including the BLM Crude Helium Enrichment Unit, which was not operational from mid-January 2022 through late June 2022. World helium production, excluding the United States, decreased owing to delays of added production capacity in Russia, helium plant shutdowns in Qatar, reduced separation of helium from natural gas in Algeria, and constraints on transportation for helium products.

World Mine Production and Reserves: Reserves for the United States were revised based on Government reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States (extracted from natural gas)	69	60	8,500
United States (from Cliffside Field)	7	15	61
Algeria	[e]14	9	[e]1,800
Australia	[e]4	4	NA
Canada	[e]1	2	NA
China	[e]1	1	NA
Poland	[e]1	1	24
Qatar	[e]61	60	[e]Large
Russia	[e]5	5	[e]1,700
South Africa	[e]1	1	NA
World total (rounded)	[e]164	160	NA

World Resources:[9] Section 16 of Public Law 113–40 required the U.S. Geological Survey (USGS) to complete a national helium gas assessment. The USGS and the BLM coordinated efforts to complete this assessment, which was published by the USGS in fall 2021.[10] The mean volume of recoverable helium within the known geologic natural gas reservoirs in the United States was estimated to be 8,490 million cubic meters (306 billion cubic feet). This does not include the remaining 60.7 million cubic meters (2.19 billion cubic feet) in the Federal helium inventory. The estimated mean for the Midcontinent region was 4,330 million cubic meters (156 billion cubic feet); the Rocky Mountain region, 4,110 million cubic meters (148 billion cubic feet); the North Central region, 52.7 million cubic meters (1.9 billion cubic feet); the Gulf Coast region, 12.5 million cubic meters (0.45 billion cubic feet); and the Alaska region, 1.11 million cubic meters (0.04 billion cubic feet).

Helium resources of the world, exclusive of the United States, were estimated to be about 31.3 billion cubic meters (1.13 trillion cubic feet). The locations and volumes of the major deposits, in billion cubic meters, are Qatar, 10.1; Algeria, 8.2; Russia, 6.8; Canada, 2.0; and China, 1.1.

Substitutes: Nothing substitutes for helium in cryogenic applications if temperatures below −429 degrees Fahrenheit are required. Argon can be substituted for helium in welding, and hydrogen can be substituted for helium in some lighter-than-air applications in which the flammable nature of hydrogen is not objectionable. Hydrogen is also being investigated as a substitute for helium in deep-sea diving applications below 305 meters (1,000 feet).

[e]Estimated. E Net exporter. NA Not available.

[1]Measured at 101.325 kilopascals absolute (14.696 pounds per square inch [psia]) and 15 degrees Celsius (°C) [59 degrees Fahrenheit (°F)]; 27.737 cubic meters of helium = 1,000 cubic feet of helium at 101.325 kilopascals absolute (14.696 psia) and 21.1 °C (70 °F).

[2]Both Grade-A and crude helium.

[3]Extracted from natural gas in prior years.

[4]Exports were adjusted by the U.S. Geological Survey for 2018 as the data reported by the U.S. Census Bureau were unusually high and may have contained misclassified items.

[5]Grade-A helium. Defined as sales + imports – exports.

[6]Defined as imports – exports.

[7]See Appendix B for definitions.

[8]General Engineer (contractor), Bureau of Land Management, Amarillo Field Office—Helium Operations, Amarillo, TX.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Brennan, S.T., Rivera, J.L., Varela, B.A., and Park, A.J., 2021, National assessment of helium resource within known natural gas reservoirs: U.S. Geological Survey Scientific Investigations Report 2021–5085, 5 p., https://doi.org/10.3133/sir20215085.

INDIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Indium was not recovered from ores in the United States in 2022. Several companies produced indium products—including alloys, compounds, high-purity metal, and solders—from imported indium metal. Production of indium tin oxide (ITO) continued to account for most global indium consumption. ITO thin-film coatings were primarily used for electrically conductive purposes in a variety of flat-panel displays—most commonly liquid crystal displays (LCDs). Other indium end uses included alloys and solders, compounds, electrical components and semiconductors, and research. Estimated domestic consumption of refined indium was 160 tons in 2022 and was based on the annual estimated import quantity. There were no readily available recycling or end-use data available for indium. The estimated value of refined indium consumed domestically in 2022, based on the average U.S. warehouse price, was about $40 million.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, refinery	—	—	—	—	—
Imports for consumption	125	95	115	158	160
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	125	95	115	158	160
Price, annual average, dollars per kilogram:					
New York dealer[2]	375	390	395	NA	NA
U.S. warehouse, free on board[3]	285	182	161	223	250
Rotterdam, duties unpaid[4]	281	177	158	217	250
Net import reliance[5] as a percentage of estimated consumption	100	100	100	100	100

Recycling: Indium is most commonly recovered from ITO scrap in Japan and the Republic of Korea. Indium-containing scrap was recycled domestically; however, data on the quantity of indium recovered from scrap were not available.

Import Sources (2018–21): Republic of Korea, 32%; Canada, 22%; China,[6] 18%; France, 9%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Unwrought indium, including powders	8112.92.3000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, the estimated annual average U.S. warehouse price (free on board) was $250 per kilogram, 12% greater than the reported average price 2021. The U.S. price, as reported by Argus Media group, Argus Metals International, began the year at $275 per kilogram and generally trended downward for most of the year to $240 per kilogram at the end of September.

A leading manufacturer of indium products in the United States invested $10 million to expand operations at its facility in Rome, NY. According to the company, the plant produced solder fabrications that were primarily used in advanced electronics, and the expansion would increase the number of manufacturing processes at the plant to 25.

The Utah Geological Survey received a Federal grant to research the genesis and geology of the zinc-copper-indium West Desert deposit in Juab County, UT. The funding was awarded under the U.S. Geological Survey's Earth Mapping Resource Initiative (Earth MRI) program. The research would focus on the spatial and mineralogical distribution of indium throughout the deposit and exploration indicators to help identify similar deposits.

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INDIUM

An indium-producing zinc smelter in Auby, France, was placed on care-and-maintenance status in January owing to high power prices. The smelter resumed production at a reduced rate in March. Annual indium production at the smelter was last reported in 2018 at 43 tons.

China, the leading producer and exporter of indium globally, exported 421 tons of indium in the first 8 months of 2022, a 13% increase compared with exports in the same period in 2021. Exports were primarily sent to the Republic of Korea, 55%; Singapore, 14%; and Hong Kong, 12%. Some zinc smelters in Sichuan and Yunnan Provinces temporarily cut production during the year in response to power supply issues, according to news sources; however, the extent of the cuts and their effect on related byproduct metal production, including indium, could not be quantified.

World Refinery Production and Reserves:

	Refinery production[e, 7]		Reserves[8]
	2021	2022	
United States	—	—	Quantitative estimates of reserves were not available.
Belgium	20	20	
Canada	60	55	
China	540	530	
France	38	20	
Japan	66	66	
Korea, Republic of	190	200	
Peru	12	—	
Russia	5	5	
Uzbekistan	1	1	
World total (rounded)	932	900	

World Resources:[8] Indium is most commonly recovered from the zinc-sulfide ore mineral sphalerite. The indium content of zinc deposits from which it is recovered ranges from less than 1 part per million to 100 parts per million. Although the geochemical properties of indium are such that it occurs in trace amounts in other base-metal sulfides—particularly chalcopyrite and stannite—indium recovery from most deposits of these minerals was not economic.

Substitutes: Antimony tin oxide coatings have been developed as an alternative to ITO coatings in LCDs and have been successfully annealed to LCD glass; carbon nanotube coatings have been developed as an alternative to ITO coatings in flexible displays, solar cells, and touch screens; poly (3,4-ethylene dioxythiophene) (PEDOT) has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes; and copper or silver nanowires have been explored as a substitute for ITO in touch screens. Graphene has been developed to replace ITO electrodes in solar cells and also has been explored as a replacement for ITO in flexible touch screens. Researchers have developed a more adhesive zinc oxide nanopowder to replace ITO in LCDs. Hafnium can replace indium in nuclear reactor control rod alloys.

[e]Estimated. NA Not available. — Zero.

[1]Estimated to equal imports.

[2]Price is based on 99.99%-minimum-purity indium, delivered duty paid by U.S. buyers, in minimum lots of 50 kilograms. Source: S&P Global Platts Metals Week; price was discontinued as of September 11, 2020.

[3]Price is based on 99.99%-minimum-purity indium, free on board U.S. warehouse. Source: Argus Media group, Argus Metals International.

[4]Price is based on 99.99%-minimum-purity indium, duties unpaid in warehouse (Rotterdam). Source: Argus Media group, Argus Metals International.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]Refinery production data for indium were limited or unavailable for most countries. Estimates were derived from trade data, production capacity, and (or) changes in related lead and zinc smelter production.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

IODINE

(Data in metric tons of elemental iodine unless otherwise noted)

Domestic Production and Use: Iodine was produced from brines in 2022 by three companies operating in Oklahoma. U.S. iodine production in 2022 was withheld to avoid disclosing company proprietary data but was estimated to have increased from that in 2021. The annual average cost, insurance, and freight unit value of iodine imports in 2022 was estimated to be $41 per kilogram, about 26% more than that in 2021.

Because domestic and imported iodine was used by downstream manufacturers to produce many intermediate iodine compounds, it was difficult to establish an accurate end-use pattern. Crude iodine and inorganic iodine compounds were thought to account for more than 50% of domestic iodine consumption in 2022. Worldwide, the leading uses of iodine and its compounds were X-ray contrast media, pharmaceuticals, liquid crystal displays (LCDs), and iodophors, in descending order of quantity consumed. Other applications of iodine included animal feed, biocides, fluoride derivatives, food supplements, and nylon.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	W	W	W	W	W
Imports for consumption	4,930	4,300	4,570	4,120	4,600
Exports	1,190	1,230	1,130	1,280	1,000
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	4,620	4,000	3,750	3,720	4,000
Price, crude iodine, average unit value of imports (cost, insurance, and freight), dollars per kilogram	22.46	26.38	31.57	32.72	41
Employment, number[e]	60	60	60	60	60
Net import reliance[2] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled.

Import Sources (2018–21): Chile, 89%; Japan, 10%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IODINE

Events, Trends, and Issues: According to trade publications, spot prices for iodine crystal averaged about $67 per kilogram during the first 9 months of 2022. This was about 77% more than the 2021 annual average of $37.83 per kilogram. Iodine price increases were attributed to strong global demand, particularly in Asia.

In the latter part of 2022, some countries in Europe began distributing and stockpiling potassium iodide tablets amid concerns over the possible use of nuclear weapons by Russia in Ukraine as well as concerns regarding the security of the Zaporizhzhia nuclear powerplant in Ukraine. Potassium iodide tablets can be taken to prevent radioactive iodine from accumulating in the thyroid gland following exposure to nuclear radiation.

As in recent years, Chile was the world's leading producer of iodine, followed by Japan and the United States. Excluding production in the United States, Chile accounted for about two-thirds of world production in 2022. Most of the world's iodine supply comes from three areas: the Chilean desert nitrate mines, the gasfields and oilfields in Japan, and the iodine-rich brine wells in northwestern Oklahoma.

World Mine Production and Reserves: China also produces crude iodine, but output is not officially reported, and available information was inadequate to make reliable estimates of output. Available information was inadequate to make an estimate of iodine reserves in Indonesia for 2022.

	Mine production[e]		Reserves[3]
	2021	2022	
United States	W	W	250,000
Azerbaijan	190	200	170,000
Chile	22,000	22,000	610,000
Indonesia	[4]36	40	NA
Iran	700	700	NA
Japan	8,900	9,000	4,900,000
Russia	3	3	120,000
Turkmenistan	700	700	70,000
World total (rounded)	[5]32,500	[5]33,000	6,100,000

World Resources:[3] Seawater contains 0.06 part per million iodine, and the oceans are estimated to contain approximately 90 billion tons of iodine. Seaweeds of the Laminaria family are able to extract and accumulate up to 0.45% iodine on a dry basis. Although not as economical as the production of iodine as a byproduct of gas, nitrates, and oil, the seaweed industry represented a major source of iodine prior to 1959 and remains a large resource.

Substitutes: No comparable substitutes exist for iodine in many of its principal applications, such as in animal feed, catalytic, nutritional, pharmaceutical, and photographic uses. Bromine and chlorine could be substituted for iodine in biocide, colorant, and ink, although they are usually considered less desirable than iodine. Antibiotics can be used as a substitute for iodine biocides.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. NA Not available.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Reported.

[5]Excludes U.S. production.

IRON AND STEEL[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: The U.S. iron and steel industry produced raw steel in 2022 with an estimated value of about $132 billion, a 13% increase from $118 billion in 2021. Pig iron and raw steel were produced by three companies operating integrated steel mills in 11 locations. Raw steel was produced by 50 companies at 101 minimills. Combined production capacity was about 106 million tons per year. Indiana accounted for an estimated 26% of total raw steel production, followed by Ohio, 12%; Pennsylvania and Illinois, 5% each; Texas, 4%; and Michigan, 3%; with no other State having more than 3% of total domestic raw steel production. Construction accounted for an estimated 46% of total domestic shipments by market classification, followed by transportation (predominantly automotive), 26%; machinery and equipment, 8%; energy, 6%; appliances, 5%; and other applications, 9%.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Pig iron production[2]	24.1	22.3	18.3	22.2	21
Raw steel production	86.6	87.8	72.7	85.8	82
Distribution of raw steel production, percent:					
Basic oxygen furnaces	32	30	29	29	29
Electric arc furnaces	68	70	71	71	72
Continuously cast steel, percent	98.2	99.8	99.8	99.8	99.8
Shipments, steel mill products	86.4	87.3	73.5	85.9	82
Imports, steel mill products:					
Finished	23.3	19.1	14.6	20.6	22
Semifinished	7.3	6.2	5.3	7.9	8
Total	30.6	25.3	20.0	28.5	30
Exports, steel mill products:					
Finished	7.9	6.6	6.7	7.4	8
Semifinished	0.1	0.1	0.1	0.1	0.1
Total	8.0	6.7	6.8	7.5	8
Stocks, service centers, yearend[3]	7.3	7.4	5.8	5.8	5.8
Consumption, apparent (steel mill products)[4]	102	100	82.1	98.9	96
Producer price index for steel mill products (1982=100)[5]	211	204	184	351	400
Employment, average, number:					
Iron and steel mills[5]	82,100	85,700	83,200	78,300	75,000
Steel product manufacturing[6]	56,700	57,800	54,900	52,700	50,000
Net import reliance[7] as a percentage of apparent consumption	15	12	12	13	14

Recycling: See the Iron and Steel Scrap and Iron and Steel Slag chapters.

Import Sources (2018–21): Canada, 21%; Brazil, 15%; Mexico, 14%; Republic of Korea, 9%; and other, 41%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Carbon steel:		
Semifinished	7207.00.0000	Free.
Flat, hot-rolled	7208.00.0000	Free.
Flat, cold-rolled	7209.00.0000	Free.
Galvanized	7210.00.0000	Free.
Bars and rods, hot-rolled	7213.00.0000	Free.
Structural shapes	7216.00.0000	Free.
Stainless steel:		
Semifinished	7218.00.0000	Free.
Flat-rolled sheets	7219.00.0000	Free.
Bars and rods	7222.00.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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IRON AND STEEL

Events, Trends, and Issues: The World Steel Association[8] forecast global finished steel consumption to decrease by 2.3% in 2022 and increase by 1.0% in 2023. End-use consumption of steel products was expected to decline in 2022 following concurrent events affecting consumer demand, including the conflict in Ukraine, continuing coronavirus disease 2019 (COVID-19) mitigation measures in China, rising energy costs and interest rates, and global inflation. In the United States, the apparent consumption of finished steel products was estimated to have increased by 2% in 2022 owing to strong economic recovery from COVID-19 supply disruptions. The Infrastructure Investment and Jobs Act was expected to spur growth in the energy and construction sectors.

The economic conditions in China significantly affected steel production, with finished steel production decreasing by 4% in 2022 and expected to remain unchanged in 2023 owing to extended COVID-19 mitigation strategies that led to decreased demand for real estate and construction investments. In Japan and the Republic of Korea, steel demand was estimated to be lower in 2022 owing to decreases in the construction sector. Production of finished steel products in India was expected to increase by 6% in 2022 owing to infrastructure spending, strong demand for consumer goods, and increased demand in the automotive sector.

World Production:

	Pig iron		Raw steel	
	2021	2022[e]	2021	2022[e]
United States	22	21	86	82
Brazil	28	26	36	33
China	869	830	1,030	990
Germany	26	24	40	38
India	78	83	118	130
Iran	3	3	28	29
Italy	4	4	24	24
Japan	70	71	96	97
Korea, Republic of	46	45	71	69
Mexico	3	3	18	17
Russia	54	50	76	71
Taiwan	15	15	23	23
Turkey	10	10	40	39
Ukraine	21	19	21	19
Vietnam	15	15	23	23
Other countries	81	88	216	230
World total (rounded)	1,350	1,300	1,950	1,900

World Resources: Not applicable. See the Iron Ore chapter for steelmaking raw-material resources.

Substitutes: Iron is the least expensive and most widely used metal. In most applications, iron and steel compete either with less expensive nonmetallic materials or with more expensive materials that have a performance advantage. Iron and steel compete with lighter materials, such as aluminum and plastics in the automotive industry; aluminum, concrete, and wood in construction; and aluminum, glass, paper, and plastics in containers.

[e]Estimated.

[1]U.S. production and shipments data source is the American Iron and Steel Institute; see also the Iron and Steel Scrap and Iron Ore chapters.

[2]More than 95% of pig iron production is transported in molten form to steelmaking furnaces at the same site.

[3]Steel mill products. Source: Metals Service Center Institute, September 2021.

[4]Defined as steel mill product shipments + imports of finished steel mill products – exports of steel mill products ± adjustments for industry stock changes.

[5]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331100.

[6]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 332100.

[7]Defined as imports of finished steel mill products – total exports ± adjustments for industry stock changes.

[8]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 p.

IRON AND STEEL SCRAP[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: In 2022, the total value of domestic purchases of iron and steel scrap (receipts of ferrous scrap by all domestic consumers from brokers, dealers, and other outside sources) and exports was estimated to be $23 billion, a 5% decrease from the $24.3 billion in 2021 and 74% more than the $13.2 billion in 2020. U.S. apparent consumption of steel, the leading end use for iron and steel scrap, was estimated to have decreased by 3% to 96 million tons in 2022 from 98.9 million tons in 2021. Manufacturers of pig iron, raw steel, and steel castings accounted for almost all scrap consumption by the domestic steel industry, using scrap together with pig iron and direct-reduced iron to produce steel products for the appliance, construction, container, machinery, oil and gas, transportation, and various other consumer industries. The ferrous castings industry consumed most of the remaining scrap to produce cast iron and steel products. Relatively small quantities of steel scrap were used for producing ferroalloys, for the precipitation of copper, and by the chemical industry; these uses collectively totaled less than 1 million tons.

In 2022, estimated raw steel production decreased by 4% to 82 million tons from 85.8 million tons in 2021, and net shipments of steel mill products were an estimated 82 million tons, down by 5% from 85.9 million tons in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Home scrap	5.8	5.3	5.1	4.7	4.7
Purchased scrap[2]	59	55	50	52	49
Imports for consumption[3]	5.0	4.3	4.5	5.3	4.8
Exports[3]	17	18	15	16	13
Consumption:					
Reported	52	47	45	46	44
Apparent[4]	52	48	45	46	46
Price, average, delivered, No. 1 heavy melting composite price, dollars per metric ton[5]	326	249	228	418	415
Stocks, consumer, yearend	5.1	3.9	3.9	4.4	4.6
Employment, dealers, brokers, processors, number[e]	27,000	26,000	24,500	25,300	24,000
Net import reliance[6] as a percentage of reported consumption	E	E	E	E	E

Recycling: Recycled iron and steel scrap is a vital raw material for the production of new steel and cast-iron products. The steel and foundry industries in the United States have been structured to recycle scrap and, as a result, are highly dependent upon scrap. Recycling 1 ton of steel conserves 1.1 tons of iron ore, 0.6 ton of coking coal, and 0.05 ton of limestone. Recycling of scrap also conserves energy because the remelting of scrap requires much less energy than the production of iron or steel products from iron ore.

Overall, the scrap recycling rate in the United States has averaged between 80% and 90% during the past decade, with automobiles making up the primary source of old steel scrap. Recycling of automobiles is nearly 100% each year, with rates fluctuating slightly owing to the rate of new vehicle production and general economic trends. More than 15 million tons of steel is recycled from automobiles annually, the equivalent of approximately 12 million cars, from more than 7,000 vehicle dismantlers and 350 car shredders in North America. The recycling of steel from automobiles is estimated to save the equivalent energy necessary to power 18 million homes every year.

Recycling rates, which fluctuate annually, were estimated to be 98% for structural steel from construction, 88% for appliances, 71% for rebar and reinforcement steel, and 70% for steel packaging. The recycling rates for appliance, can, and construction steel are expected to increase in the United States and in emerging industrial countries at an even greater rate. Public interest in recycling continues, and recycling is becoming more profitable and convenient as environmental regulations for primary production increase. Also, consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment

Recycled scrap consists of approximately 58% post-consumer (old, obsolete) scrap, 24% new scrap (produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

Import Sources (2018–21): Canada, 73%; Mexico, 12%; Netherlands, 5%; United Kingdom, 5%; and other, 5%.

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IRON AND STEEL SCRAP

Tariff: Item	Number	Normal Trade Relations 12–31–22
Ferrous waste and scrap:		
Stainless steel	7204.21.0000	Free.
Turnings, shavings, chips, milling waste, sawdust, filings, trimmings, and stampings:		
No. 1 bundles	7204.41.0020	Free.
No. 2 bundles	7204.41.0040	Free.
Borings, shovelings, and turnings	7204.41.0060	Free.
Other	7204.41.0080	Free.
Other:		
No. 1 heavy melting	7204.49.0020	Free.
No. 2 heavy melting	7204.49.0040	Free.
Cut plate and structural	7204.49.0060	Free.
Shredded	7204.49.0070	Free.
Remelting scrap ingots	7204.50.0000	Free.
Powders, of pig iron, spiegeleisen, iron, or steel:		
Alloy steel	7205.21.0000	Free.
Other	7205.29.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In 2022, steel mills maintained normal operating rates of 76% to 82% of production capacity utilization, as compared with the low monthly rate of 54.6% in May 2020. Rates fluctuated slightly from 79.8% in January to 81.9% in April before slowly declining to 76.4% in September. Average composite prices published for No. 1 heavy melting steel scrap increased from the previous high rate in 2021 of $457.66 per ton in November and December to the high for 2022 of $523.27 per ton in March, after which prices declined. The annual average price delivered in the first 9 months of 2022 decreased to $405.35 per ton compared with the full-year annual average of $408.34 per ton in 2021 and contributed to the 5% decrease in the total estimated value of domestic purchases and exports of iron and steel scrap in 2022.

In the first 9 months of 2022, Turkey was the primary destination for exports of ferrous scrap, by tonnage, accounting for 22% of total exports, followed by Mexico, 19%; Bangladesh, 12%; and India and Taiwan, 7% each. The value of exported scrap decreased to an estimated $5.8 billion in 2022 from $6.7 billion in 2021. In the first 9 months of 2022, Canada was the leading source of imports of ferrous scrap, by tonnage, accounting for 73% of total imports, followed by Mexico, 13%; the Netherlands and Sweden, 4% each; and the United Kingdom, 3%.

The World Steel Association[7] forecast global finished steel consumption to decrease by 2.3% in 2022 and increase by 1.0% in 2023. End-use consumption of steel products was expected to decline in 2022 following concurrent events affecting consumer demand, including the conflict in Ukraine, continuing coronavirus disease 2019 (COVID-19) mitigation measures in China, rising energy costs and interest rates, and global inflation.

World Production and Reserves: Because scrap is not mined, the concept of reserves does not apply. World production data for scrap were not available. See the Iron and Steel and Iron Ore chapters.

World Resources: Not applicable. See the Iron Ore chapter.

Substitutes: An estimated 4.9 million tons of direct-reduced iron was consumed in the United States in 2022 as a substitute for iron and steel scrap, down from 5.0 million tons in 2021.

[e]Estimated. E Net exporter.

[1]See also the Iron and Steel, Iron and Steel Slag, and Iron Ore chapters.

[2]Defined as net receipts + exports – imports.

[3]Excludes used rails for rerolling and other uses, and ships, boats, and other vessels for scrapping.

[4]Defined as home scrap + purchased scrap + imports – exports ± adjustments for industry stock changes.

[5]Source: Fastmarkets AMM.

[6]Defined as imports – exports ± adjustments for industry stock changes.

[7]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 p.

IRON AND STEEL SLAG

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: Iron and steel (ferrous) slags are formed by the combination of slagging agents and impurities during the production of crude (or pig) iron and crude steel. The slags are tapped separately from the metals, then cooled and processed, and are primarily used in the construction industry. Data were unavailable on actual U.S. ferrous slag production, but domestic slag sales[1] in 2022 were estimated to be 15 million tons valued at about $795 million. Blast furnace slag was about 49% of the tonnage sold and accounted for 87% of the total value of slag, most of which was granulated. Steel slag produced from basic oxygen and electric arc furnaces accounted for the remainder of sales. Slag was processed by 25 companies servicing active iron and steel facilities or reprocessing old slag piles at about 123 processing plants (including some iron and steel plants with more than one slag-processing facility) in 33 States, including facilities that import and grind unground slag to sell as ground granulated blast furnace slag (GGBFS).

Air-cooled iron slag and steel slag are used primarily as aggregates in concrete (air-cooled iron slag only); asphaltic paving, fill, and road bases; both slag types also can be used as a feed for cement kilns. Almost all GGBFS is used as a partial substitute for portland cement in concrete mixes or in blended cements. Pelletized slag is generally used for lightweight aggregate but can be ground into material similar to GGBFS. Actual prices per ton ranged from a few cents for some steel slags at a few locations to about $120 or more for some GGBFS in 2022. Owing to low unit values, most slag types can be shipped only short distances by truck, but rail and waterborne transportation allow for greater travel distances. Because much higher unit values make it economical to ship GGBFS longer distances, much of the GGBFS consumed in the United States is imported.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production (sales)[e, 1, 2]	16.8	16.3	13.4	15.7	15
Imports for consumption[e, 3]	2.6	2.1	2.3	2.4	2.0
Exports	(4)	(4)	(4)	(4)	(4)
Consumption, apparent[e, 5]	17	16	13	16	15
Price, average unit value, free on board plant, dollars per metric ton[6]	26.50	28.50	31.00	40.50	53
Employment, number[e]	1,500	1,500	1,500	1,500	1,500
Net import reliance[7] as a percentage of apparent consumption	13	10	14	15	13

Recycling: Following removal of entrained metal, slag can be returned to the blast and steel furnaces as ferrous and flux feed, but data on these returns are incomplete. Entrained metal, particularly in steel slag, is routinely recovered during slag processing for return to the furnaces and is an important revenue source for slag processors; data on metal returns are unavailable.

Import Sources (2018–21): Japan, 46%; Brazil, 17%; China, 15%; and other, 22%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Granulated slag	2618.00.0000	Free.
Slag, dross, scalings, and other waste from manufacture of iron and steel:		
Ferrous scale	2619.00.3000	Free.
Other	2619.00.9000	Free.

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IRON AND STEEL SLAG

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The availability of steel slag is tied closely to the rates of raw steel production and the cost consideration of recovering slag for use in low-value downstream applications. The majority of U.S. steel slag production is from electric arc furnaces, which accounted for an estimated 72% of U.S. steel production in 2022 owing to the overall cost advantages of environmental factors, such as less feedstock and power consumption and the price and availability of ferrous scrap feedstock. In recent years, the percentage of basic oxygen furnace steel production has continued to decline as capacity has idled or closed; however, slag stockpiling at furnaces allows for processing of slag for years after closures. The World Steel Association[8] forecast global finished steel consumption to decrease by 2.3% in 2022 and increase by 1.0% in 2023. The U.S. iron and steel industry produced raw steel in 2022 with an estimated value of about $132 billion, a 13% increase from $118 billion in 2021. Pig iron production in the United States was estimated to have decreased by 5% to 21 million tons in 2022 from 22.2 million tons in 2021.

During 2022, domestic GGBFS remained in limited supply because granulation cooling was known to be available at only two active U.S. blast furnaces while, elsewhere, only one domestic plant produced pelletized slag in limited supply. Grinding of granulated blast furnace slag was only done domestically by cement companies.

The domestic supply of fly ash, which is used as an additive in concrete production, rebounded from low production levels in 2020; however, supply remained constrained and was expected to decrease in upcoming years owing to restrictions of mercury and carbon dioxide (CO_2) emissions at coal-fired powerplants, powerplant closures, and conversion of powerplants to natural gas. Demand for GGBFS is likely to increase because its use in cement yields a beneficial product in many applications and reduces the unit CO_2 emissions in the production of the cement.

World Production and Reserves: Because slag is not mined, the concept of reserves does not apply. World production data for slag were not available, but iron slag from blast furnaces may be estimated to be 25% to 30% of crude (pig) iron production, and steel furnace slag may be estimated to be 10% to 15% of raw steel production. In 2022, world iron slag production was estimated to be between 330 million and 390 million tons, and steel slag production was estimated to be between 190 million and 290 million tons.

World Resources: Not applicable.

Substitutes: In the construction sector, ferrous slags compete with natural aggregates (crushed stone and construction sand and gravel) but are far less widely available than the natural materials. As a cementitious additive in blended cements and concrete, GGBFS mainly competes with fly ash, metakaolin, and volcanic ash pozzolans. In this respect, GGBFS reduces the amount of portland cement per ton of concrete, thus allowing more concrete to be made per ton of portland cement. Slags (especially steel slag) can be used as a partial substitute for limestone and some other natural raw materials for clinker (cement) manufacture and compete in this use with fly ash and bottom ash. Some other metallurgical slags, such as copper slag, can compete with ferrous slags in some specialty markets, such as a ferrous feed in clinker manufacture, but are generally in much more restricted supply than ferrous slags.

[e]Estimated.

[1]Processed slag sold during the year, excluding entrained metal.

[2]Data include sales of domestic and imported granulated blast furnace slag and exclude sales of pelletized slag.

[3]U.S. Census Bureau data adjusted by the U.S. Geological Survey to remove nonslag materials (such as cenospheres, fly ash, and silica fume) and slags or other residues of other metallurgical industries (especially copper slag), whose unit values are outside the range expected for granulated slag. In some years, tonnages may be underreported.

[4]Less than 50,000 tons.

[5]Defined as sales – exports.

[6]Rounded to the nearest $0.50 per ton.

[7]Defined as imports – exports.

[8]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 p.

IRON ORE[1]

(Data in thousand metric tons of usable ore unless otherwise noted)

Domestic Production and Use: In 2022, seven open pit iron ore mines (each with associated concentration and pelletizing plants) in Michigan and Minnesota shipped 98% of domestic usable iron ore products, which were consumed in the steel industry in the United States. The remaining 2% of domestic iron ore products were consumed in nonsteel end uses. In 2022, the United States produced iron ore with an estimated value of $5.2 billion, a 22% decrease from $6.7 billion in 2021. Four iron metallic plants—one direct-reduced iron (DRI) plant in Louisiana and three hot-briquetted iron (HBI) plants in Indiana, Ohio, and Texas—operated during the year to supply steelmaking raw materials with an estimated value of $1.3 billion. The United States was estimated to have produced 1.8% and consumed 1.5% of the world's iron ore output.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Iron ore	49,500	46,900	38,100	47,500	46,000
Iron metallics	3,560	3,660	3,500	5,010	4,900
Shipments	50,400	47,000	38,000	43,400	46,000
Imports for consumption	3,790	3,980	3,240	3,740	3,200
Exports	12,700	11,400	10,400	14,300	9,400
Consumption:					
Reported	36,600	34,800	NA	NA	NA
Apparent[2]	41,400	39,100	31,100	36,800	40,000
Price, average unit value reported by mines, dollars per metric ton	93.00	92.94	91.27	141.75	114
Stocks, mine, dock, and consuming plant, yearend	3,100	3,470	3,290	3,170	2,800
Employment, mine, concentrating and pelletizing plant, number	4,860	4,960	4,300	4,980	4,900
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None. See the Iron and Steel Scrap chapter.

Import Sources (2018–21): Brazil, 57%; Canada, 22%; Sweden, 8%; and other, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Iron ores and concentrates:		
Concentrates	2601.11.0030	Free.
Coarse ores	2601.11.0060	Free.
Other ores	2601.11.0090	Free.
Pellets	2601.12.0030	Free.
Briquettes	2601.12.0060	Free.
Sinter	2601.12.0090	Free.
Roasted iron pyrites	2601.20.0000	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Slight decreases in production and trade in 2022 were due to rising global inflation, which resulted in decreased steel demand and consumption. Domestic iron ore production was estimated to be 46 million tons in 2022, a 3% decrease from 47.5 million tons in 2021. Total raw steel production was estimated to have decreased to 82 million tons in 2022 from 85.5 million tons in 2021. The World Steel Association[4] forecast global finished steel consumption to decrease by 2.3% in 2022 and increase by 1.0% in 2023. End-use consumption of steel products was expected to decline in 2022 following concurrent events affecting consumer demand, including the conflict in Ukraine, continuing coronavirus disease 2019 (COVID-19) mitigation measures in China, and rising energy costs and interest rates.

Overall, global prices trended downward to an average year-to-date unit value of $128.65 per ton in the first 9 months of 2022, a 28% decrease from the 2021 average year-to-date unit value of $178.27 per ton, but the 2022 average year-to-date unit value was a 28% increase from the 2020 average year-to-date unit value of $100.83 per ton. Based on reported prices for iron ore fines (62% iron content) imported into China (cost, insurance, and freight into Tianjin Port), the highest monthly average price during the first 9 months of 2022 was $152.07 per ton in March compared with the high of $214.43 per ton in June 2021. The lowest monthly average price during the same period in 2022 was $99.80 per ton in September compared with the low of $96.24 per ton in November 2021.

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IRON ORE

In November, one company petitioned the Minnesota Supreme Court for a review of State mineral leases that were terminated by the Minnesota Department of Natural Resources. In October, another company began construction on a $150 million project to build a direct-reduced grade pellet plant that could be sold or feed a potential future DRI or HBI plant. An iron ore mine in northern Minnesota was expected to deplete its reserves of iron ore around 2025, and the company's leadership was seeking the land and mineral rights to a nearby deposit where construction of a new mine and facility was stalled and the mineral leases were expected to be reassigned in the near future.

World Mine Production and Reserves: Reserves for Australia, Peru, and Russia were revised based on company and Government reports.

	Mine production				Reserves[5] (million metric tons)	
	Usable ore		Iron content			
	2021	2022[e]	2021	2022[e]	Crude ore	Iron content
United States	47,500	46,000	30,100	29,000	3,000	1,000
Australia	912,000	880,000	565,000	540,000	[6]51,000	[6]27,000
Brazil	431,000	410,000	273,000	260,000	34,000	15,000
Canada	57,500	58,000	34,500	35,000	6,000	2,300
Chile	17,700	16,000	11,200	10,000	NA	NA
China	394,000	380,000	246,000	240,000	20,000	6,900
India	273,000	290,000	169,000	180,000	5,500	3,400
Iran	72,900	75,000	47,900	49,000	2,700	1,500
Kazakhstan	64,100	66,000	13,100	14,000	2,500	900
Mauritania	12,800	13,000	8,000	8,100	NA	NA
Mexico	10,800	11,000	6,810	6,900	NA	NA
Peru	18,100	17,000	12,100	11,000	2,600	1,200
Russia	96,000	90,000	66,700	63,000	29,000	14,000
South Africa	73,100	76,000	46,500	48,000	1,000	670
Sweden	40,200	39,000	28,600	28,000	1,300	600
Turkey	16,100	17,000	9,710	10,000	130	38
Ukraine	83,800	76,000	52,400	47,000	[7]6,500	[7]2,300
Other countries	56,700	59,000	4,900	5,000	18,000	9,500
World total (rounded)	2,680,000	2,600,000	1,630,000	1,600,000	180,000	85,000

World Resources:[5] U.S. resources are estimated to be 110 billion tons of iron ore containing about 27 billion tons of iron. U.S. resources are mainly low-grade taconite-type ores from the Lake Superior district that require beneficiation and agglomeration prior to commercial use. World resources are estimated to be greater than 800 billion tons of crude ore containing more than 230 billion tons of iron.

Substitutes: The only source of primary iron is iron ore, used directly as direct-shipping ore or converted to briquettes, concentrates, DRI, iron nuggets, pellets, or sinter. DRI, iron nuggets, and scrap are extensively used for steelmaking in electric arc furnaces and in iron and steel foundries. Technological advancements have been made that allow hematite to be recovered from tailings basins and pelletized.

[e]Estimated. E Net exporter. NA Not available.

[1]Data are for iron ore used as a raw material in steelmaking—excluding iron metallics such as DRI, HBI, and iron nuggets—unless otherwise noted. See also the Iron and Steel and Iron and Steel Scrap chapters.

[2]Defined as production + imports – exports ± adjustments for industry stock changes.

[3]Defined as imports – exports ± adjustments for industry stock changes.

[4]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 p.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 23 billion tons of crude ore and 10 billion tons of iron content.

[7]For Ukraine, reserves consist of the A and B categories of the Soviet reserves classification system.

IRON OXIDE PIGMENTS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Iron oxide pigments (IOPs) were mined domestically by two companies in Alabama and Georgia. Mine production, which was withheld to avoid disclosing company proprietary data, was slightly higher in 2022 compared with that in 2021. Five companies, including the two producers of natural IOPs, processed and sold about 29,000 tons of finished natural and synthetic IOPs with an estimated value of $29 million. About 50% of natural and synthetic finished IOPs were used in concrete and other construction materials; 15% each in industrial chemicals and in foundry sands and other foundry uses; 5% each in animal feed and in paint and coatings; 3% each in plastics and in glass and ceramics; and the remaining 4% in other uses.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOPs	48,200	19,200	18,300	26,900	29,000
Imports for consumption	179,000	159,000	173,000	192,000	200,000
Exports, pigment grade	11,100	11,000	9,120	9,910	12,000
Consumption, apparent[1]	216,000	167,000	182,000	200,000	220,000
Price, average unit value, dollars per kilogram[2]	1.58	0.69	0.72	0.70	0.75
Employment, mine and mill, number	60	55	47	55	55
Net import reliance[3] as a percentage of apparent consumption	78	89	90	87	87

Recycling: None.

Import Sources (2018–21): Natural: Cyprus, 40%; Spain, 30%; France, 14%; Austria, 13%; and other, 3%. Synthetic: China,[4] 43%; Germany, 34%; Brazil, 8%; and other, 15%. Total: China,[4] 42%; Germany, 33%; Brazil, 7%; Canada, 5%; and other, 13%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Natural:		
Micaceous iron oxides	2530.90.2000	2.9% ad valorem.
Earth colors	2530.90.8015	Free.
Iron oxides and hydroxides containing 70% or more by weight Fe_2O_3:		
Synthetic:		
Black	2821.10.0010	3.7% ad valorem.
Red	2821.10.0020	3.7% ad valorem.
Yellow	2821.10.0030	3.7% ad valorem.
Other	2821.10.0040	3.7% ad valorem.
Earth colors	2821.20.0000	5.5% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IRON OXIDE PIGMENTS

Events, Trends, and Issues: In the United States, residential construction, in which IOPs are commonly used to color concrete block and brick, ready-mixed concrete, and roofing tiles, increased slightly during the first 9 months of 2022 compared with that in the same period in 2021. IOPs are also used in paints and coatings for the aerospace, automotive, and marine industries. Vehicle production in the United States through August 2022 was 4.9% higher than that in 2021. IOPs' characteristics of chemical and thermal stability, color strength, low cost, and weather resistance make IOPs a primary choice for colorant for coatings and construction materials.

Imports of natural and synthetic pigments were estimated to have increased by 4% in 2022. Exports of pigment-grade IOPs were estimated to have increased by 21% in 2022 compared with those in 2021, mostly owing to an increase in exports to Chile, China, France, and the United Kingdom. Approximately 49% of pigment-grade IOPs exports went to Mexico; the other leading countries for exports were China (21%), Belgium (10%), and Chile (5%).

IOPs are produced by several companies, but the three largest producers with facilities in multiple countries account for approximately 50% of the global IOP production capacity, with other companies in China accounting for a majority of the rest of the capacity. Some expansions of IOP production capacity in China were announced in early 2022.

World Mine Production and Reserves: Reserves for Pakistan were revised based on company reports.

	Mine production[e]		Reserves[5]
	2021	2022	
United States	W	W	Moderate
Cyprus (umber)	3,100	3,500	Moderate
France	5,000	5,000	NA
Germany[6]	400,000	400,000	Moderate
India (ocher)	3,000,000	2,700,000	37,000,000
Italy	33,000	30,000	NA
Pakistan (ocher)	100,000	100,000	Large
Spain (ocher and red iron oxide)	9,000	9,000	Large
World total (rounded)	[7]NA	[7]NA	Large

World Resources:[5] Domestic and world resources for production of IOPs are adequate. Adequate resources are available worldwide for the manufacture of synthetic IOPs.

Substitutes: Milled IOPs are thought to be the most commonly used natural minerals for pigments. Because IOPs are color stable, low cost, and nontoxic, they can be economically used for imparting black, brown, red, and yellow coloring in large and relatively low-value applications. Other minerals may be used as colorants, but they generally cannot compete with IOPs because of their higher costs and more limited availability. Synthetic IOPs are widely used as colorants and compete with natural IOPs in many color applications. Organic colorants are used for some colorant applications, but many of the organic compounds fade over time from exposure to sunlight.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Defined as sold or used, finished natural and synthetic iron oxide pigments + imports – exports.

[2]Average unit value for finished iron oxide pigments sold or used by U.S. producers.

[3]Defined as imports – exports.

[4]Includes Hong Kong.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Includes natural and synthetic iron oxide pigments.

[7]A significant number of other countries, including Austria, Azerbaijan, Brazil, China, Honduras, Iran, Kazakhstan, Lithuania, Paraguay, Russia, South Africa, Turkey, Ukraine, and the United Kingdom, may produce iron oxide pigments, but available information was inadequate to make reliable estimates of output.

KYANITE AND RELATED MINERALS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In Virginia, one firm with integrated mining and processing operations produced an estimated 100,000 tons of kyanite worth $40 million from two hard-rock open pit mines and synthetic mullite by calcining kyanite. Two other companies, one in Alabama and another in Georgia, produced synthetic mullite from materials mined from four sites; each company sourced materials from one site in Alabama and one site in Georgia. Synthetic mullite production data were withheld to avoid disclosing company proprietary data. Commercially produced synthetic mullite is made by sintering or fusing such feedstock materials as kyanite, kaolin, bauxite, or bauxitic kaolin. Natural mullite occurrences typically are rare and not economical to mine.

Of the kyanite-mullite output, 90% was estimated to have been used in refractories and 10% in other uses, including abrasive products, such as motor vehicle brake shoes and pads and grinding and cutting wheels; ceramic products such as electrical insulating porcelains, sanitaryware, and whiteware; foundry products and precision casting molds; and other products. An estimated 60% to 70% of the refractory use was by the iron and steel industries, and the remainder was by industries that manufacture cement, chemicals, glass, nonferrous metals, and other materials.

Andalusite was commercially mined from an andalusite-pyrophyllite-sericite deposit in North Carolina and processed as a blend of primarily andalusite for use by producers of refractories in making firebrick. Another company mined mineral sands within the southeastern United States; product blends that included kyanite and (or) sillimanite were marketed to the abrasive, foundry, and refractory industries.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Kyanite, mine	[1]89,200	[1]91,300	[1]67,100	[1]105,000	100,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	8,590	6,960	714	1,390	6,200
Exports (kyanite)	43,000	40,100	37,400	48,000	46,000
Consumption, apparent[2]	W	W	W	W	W
Price, average unit value of exports (free alongside ship),[3, 4] dollars per metric ton	347	358	369	369	400
Employment, number:[e, 5]					
Kyanite, mine, office, and plant	150	150	140	140	140
Synthetic mullite, office and plant	200	200	200	200	200
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2018–21):[4] South Africa, 72%; Peru, 14%; France, 9%; United Kingdom, 5%; and other, <1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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KYANITE AND RELATED MINERALS

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, decreased by about 4% in the first 8 months of 2022 compared with that in the same period in 2021, indicating a similar change in consumption of kyanite-mullite refractories. Total world steel production decreased by about 5% during the first 8 months of 2022 compared with that in the same period in 2021. The decrease in world steel production during the first 8 months of 2022 was the result of ongoing logistical issues and high input costs. The steel industry continued to be the largest consumer of refractories.

A company in South Africa that accounted for nearly one-third of global andalusite output remained in business rescue status. In mid-2019, the company entered into business rescue proceedings attributed to financial problems but was expected to emerge from business rescue status and be transferred to a new owner. In January 2021, the company announced that a new investor and owner had been approved.

Andalusite production in 2022 remained constrained by challenges that disrupted market conditions. Andalusite mines in South Africa were adversely affected by electricity supply issues, flooding, and shipping problems. Andalusite output from Peru was expected to remain significantly higher than that in 2020 but was not expected to meet overall market demand. Andalusite exports from France were higher than those from Peru, but reported production statistics remained unavailable. In India, mining of new groups of minerals, including andalusite, was approved, but some sillimanite mines had previously been reclassified as beach sand minerals mines and, as a result, those mines were no longer considered sillimanite-producing mines. Additional factors that contributed to market uncertainty included the conflict in Ukraine, increased costs for raw materials, increased rates for freight, and higher sales prices. If andalusite producers are unable to meet demand, market participants may consider alternatives such as bauxite and mullite. Development of and production from new bauxite sources in Brazil and Guyana continued to progress in 2022.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2021	2022[e]	
United States (kyanite)	[1]105,000	100,000	Large
France (andalusite)	[e]65,000	65,000	NA
India (kyanite and sillimanite)	[e]15,000	15,000	7,200,000
Peru (andalusite)	[e]42,000	42,000	NA
South Africa (andalusite)	[e]170,000	160,000	NA
World total (rounded)	[8]NA	[8]NA	NA

World Resources:[7] Large resources of kyanite and related minerals are known to exist in the United States. The chief resources are in deposits of micaceous schist and gneiss, mostly in the Appalachian Mountains and in Idaho. Other resources are in aluminous gneiss in southern California. These resources are not economical to mine at present. The characteristics of kyanite resources in the rest of the world are thought to be similar to those in the United States. Significant resources of andalusite are known to exist in China, France, Peru, and South Africa; kyanite resources have been identified in Brazil, India, and Russia; and sillimanite has been identified in India.

Substitutes: Two types of synthetic mullite (fused and sintered), superduty fire clays, and high-alumina materials are substitutes for kyanite in refractories. Principal raw materials for synthetic mullite are bauxite, kaolin and other clays, and silica sand.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Source: Virginia Department of Energy.

[2]Defined as production + imports – exports.

[3]Calculated from U.S. Census Bureau export data.

[4]Includes data for the following Harmonized Tariff Schedule of the United States code: 2508.50.0000.

[5]Estimated based on data from the U.S. Department of Labor, Mine Safety and Health Administration.

[6]Defined as imports – exports.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]In addition to the countries and (or) localities listed, Brazil and China may have produced kyanite and related minerals, but information was not available to make reliable estimates of output.

LEAD

(Data in thousand metric tons of contained lead unless otherwise noted)

Domestic Production and Use: Lead was produced domestically by five lead mines in Missouri plus as a byproduct at two zinc mines in Alaska and two silver mines in Idaho. The value of the lead in concentrates of ore mined in 2022 was an estimated $710 million, 3% less than that in 2021. Nearly all lead concentrate production has been exported since the last primary lead refinery closed in 2013. The value of the secondary lead produced in 2022 was $2.4 billion, essentially unchanged from that in 2021. The lead-acid battery industry accounted for an estimated 92% of reported U.S. lead consumption during 2022. Lead-acid batteries were primarily used as starting-lighting-ignition (SLI) batteries for automobiles, as industrial-type batteries for standby power for computer and telecommunications networks, and for motive power.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine, lead in concentrates	280	274	306	294	280
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,140	1,070	1,030	975	950
Imports for consumption:					
Lead in concentrates	—	(1)	(1)	1	(1)
Refined metal, unwrought	563	501	382	613	700
Exports:					
Lead in concentrates	251	259	265	262	270
Refined metal, unwrought (gross weight)	67	25	17	22	25
Consumption, apparent[2]	1,640	1,550	1,400	1,570	1,600
Price, average, cents per pound:[3]					
North American market	110.9	99.9	91.2	113.0	115
London Metal Exchange (LME), cash	101.8	90.6	82.7	100.0	97
Employment, mine and mill (average), number[4]	1,800	1,770	1,750	1,860	1,900
Net import reliance[5] as a percentage of apparent consumption, refined metal	30	31	26	38	42

Recycling: In 2022, an estimated 950,000 tons of secondary lead was produced, an amount equivalent to 59% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2018–21): Refined metal: Canada, 42%; Mexico, 18%; Republic of Korea, 14%; and other, 26%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Lead ores and concentrates, lead content	2607.00.0020	1.1¢/kg on lead content.
Refined lead	7801.10.0000	2.5% on the value of the lead content.
Antimonial lead	7801.91.0000	2.5% on the value of the lead content.
Alloys of lead	7801.99.9030	2.5% on the value of the lead content.
Other unwrought lead	7801.99.9050	2.5% on the value of the lead content.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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LEAD

Events, Trends, and Issues: During the first 10 months of 2022, the average LME cash price for lead was 97 cents per pound, essentially unchanged from the annual average price in 2021. Global stocks of lead in LME-approved warehouses were 27,625 tons at the end of October, which was 49% less than those at yearend 2021.

In 2022, domestic mine production and production of secondary lead decreased by an estimated 5% and 3%, respectively, from that in 2021. U.S. apparent consumption of refined lead increased slightly from that in 2021, and the net import reliance increased to 42% from 38%. In the first 9 months of 2022, 24.6 million spent SLI lead-acid batteries were exported, 4% less than exports in the same period in 2021.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2022 was forecast to decrease by 0.3% to 12.34 million tons and refined lead consumption to increase by 0.8% to 12.42 million tons.

World Mine Production and Reserves: Reserves estimates for China, Peru, Russia, Sweden, and the United States were revised based on new information from company or Government reports.

	Mine production		Reserves[7]
	2021	2022[e]	
United States	294	280	4,600
Australia	485	440	[8]37,000
Bolivia	93	90	1,600
China	1,960	2,000	12,000
India	215	240	2,500
Iran	[e]50	50	2,000
Mexico	272	270	5,600
Peru	264	250	5,300
Russia	[e]200	200	6,000
Sweden	65	65	1,700
Tajikistan	[e]56	55	NA
Turkey	[e]75	75	860
Other countries	510	510	5,900
World total (rounded)	4,550	4,500	85,000

World Resources:[7] Identified world lead resources total more than 2 billion tons. In recent years, significant lead resources have been identified in association with zinc and (or) silver or copper deposits in Australia, China, Ireland, Mexico, Peru, Portugal, Russia, and the United States (Alaska).

Substitutes: Substitution by plastics has reduced the use of lead in cable covering and cans. Tin has replaced lead in solder for potable water systems. The electronics industry has moved toward lead-free solders and flat-panel displays that do not require lead shielding. Steel and zinc are common substitutes for lead in wheel weights. Lithium-ion, nickel-cadmium, and nickel-metal hydride batteries are common alternatives to lead-acid batteries in certain applications. Currently, most all-electric vehicles and plug-in hybrid electric vehicles use lithium-ion batteries.

[e]Estimated. NA Not available. — Zero.

[1]Less than ½ unit.

[2]Defined as primary refined production + secondary refined production from old scrap + refined imports – refined exports.

[3]Source: S&P Global Platts Metals Week.

[4]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct. Data from the Mine Safety and Health Administration.

[5]Defined as refined imports – refined exports.

[6]Source: International Lead and Zinc Study Group, 2022, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 24, [4] p.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 12 million tons.

LIME[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, an estimated 17 million tons of quicklime and hydrated lime was produced (excluding independent commercial hydrators[2]), valued at about $2.3 billion. Lime was produced by 28 companies—18 with commercial sales and 10 that produced lime strictly for internal use (for example, sugar companies). These companies had 73 primary lime plants (plants operating quicklime kilns) in 28 States and Puerto Rico. One primary lime plant was idle in 2022. Of the 28 companies, 5 operated only hydrating plants in nine States. In 2022, the five leading U.S. lime companies produced quicklime or hydrated in 22 States and accounted for about 79% of U.S. lime production. Principal producing States were Kentucky, Missouri, Ohio, and Texas. Major markets for lime were, in descending order of consumption, steelmaking, chemical and industrial applications (such as the manufacture of fertilizer, glass, paper and pulp, and precipitated calcium carbonate, and in sugar refining), flue gas treatment, construction, water treatment, and nonferrous-metal mining.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[2, 3]	18,000	16,900	15,800	16,800	17,000
Imports for consumption	370	342	308	323	350
Exports	424	347	266	335	300
Consumption, apparent[4]	18,000	16,900	15,900	16,800	17,000
Price, average value, dollars per ton at plant:					
Quicklime	125.2	128.3	131.4	133.4	140
Hydrated	151.6	154.6	156.0	159.6	160
Net import reliance[5] as a percentage of apparent consumption	E	E	<1	E	<1

Recycling: Large quantities of lime are regenerated by paper mills. Some municipal water-treatment plants regenerate lime from softening sludge. Quicklime is regenerated from waste hydrated lime in the carbide industry. Data for these sources were not included as production in order to avoid double counting.

Import Sources (2018–21): Canada, 90%; Mexico, 7%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Calcined dolomite	2518.20.0000	3% ad valorem.
Quicklime	2522.10.0000	Free.
Slaked lime	2522.20.0000	Free.
Hydraulic lime	2522.30.0000	Free.

Depletion Allowance: Limestone produced and used for lime production, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, domestic lime production was estimated to be essentially unchanged from that in 2021. In 2020, a decline in lime production was a result of plants temporarily closing owing to the global coronavirus disease 2019 (COVID-19) pandemic. As the economy continues to rebound from the effects of the pandemic, so does the lime industry. However, some of the lime producers have increased product pricing owing to increased costs of production. In 2022, a total of 73 quicklime plants were in operation along with 10 hydrating plants. Hydrated lime is a dry calcium hydroxide powder made from reacting quicklime with a controlled amount of water in a hydrator. It is used in chemical and industrial, construction, and environmental applications.

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LIME

World Lime Production and Limestone Reserves:

	Production[6]		Reserves[7]
	2021	2022[e]	
United States	16,800	17,000	Adequate for all countries listed.
Australia	2,000	2,000	
Belgium[8]	1,500	1,500	
Brazil	8,400	8,400	
Bulgaria	1,520	1,500	
Canada (shipments)	1,590	1,600	
China	310,000	310,000	
France	2,600	2,600	
Germany	5,600	5,600	
India	16,000	16,000	
Iran	3,900	3,900	
Italy[8]	3,600	3,600	
Japan (quicklime only)	6,650	7,000	
Korea, Republic of	5,200	5,200	
Malaysia	1,500	1,500	
Poland (hydrated and quicklime)	1,700	1,700	
Romania	1,430	1,400	
Russia (industrial and construction)	11,400	11,000	
Slovenia	1,120	1,200	
South Africa	1,000	1,000	
Spain	1,800	1,800	
Turkey	4,800	4,800	
Ukraine	2,350	2,000	
United Kingdom	1,500	1,500	
Other countries	15,600	16,000	
World total (rounded)	430,000	430,000	

World Resources:[7] Domestic and world resources of limestone and dolomite suitable for lime manufacture are very large.

Substitutes: Limestone is a substitute for lime in many applications, such as agriculture, fluxing, and sulfur removal. Limestone, which contains less reactive material, is slower to react and may have other disadvantages compared with lime, depending on the application; however, limestone is considerably less expensive than lime. Calcined gypsum is an alternative material in industrial plasters and mortars. Cement, cement kiln dust, fly ash, and lime kiln dust are potential substitutes for some construction uses of lime. Magnesium hydroxide is a substitute for lime in pH control, and magnesium oxide is a substitute for dolomitic lime as a flux in steelmaking.

[e]Estimated. E Net exporter.

[1]Data are for quicklime, hydrated lime, and refractory dead-burned dolomite. Includes Puerto Rico.

[2]To avoid double counting quicklime production, excludes independent commercial hydrators that purchase quicklime for hydration.

[3]Sold or used by producers.

[4]Defined as production + imports – exports. Includes some double counting based on nominal, undifferentiated reporting of company export sales as U.S. production.

[5]Defined as imports – exports.

[6]Only countries that produced 1 million tons of lime or more are listed separately.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Includes hydraulic lime.

LITHIUM

(Data in metric tons of contained lithium unless otherwise noted)

Domestic Production and Use: Commercial-scale lithium production in the United States was from one continental brine operation in Nevada. Lithium was also commercially produced from the brine-sourced waste tailings of a Utah-based magnesium producer. Two companies produced a wide range of downstream lithium compounds in the United States from domestic or imported lithium carbonate, lithium chloride, and lithium hydroxide. Domestic production data were withheld to avoid disclosing company proprietary data.

Although lithium markets vary by location, global end-use markets were estimated as follows: batteries, 80%; ceramics and glass, 7%; lubricating greases, 4%; continuous casting mold flux powders, 2%; air treatment, 1%; medical, 1%; and other uses, 5%. Lithium consumption for batteries increased significantly in recent years because rechargeable lithium batteries have been used extensively in the growing market for electric vehicles and portable electronic devices, and increasingly have been used in electric tools, and grid storage applications. Lithium minerals were used directly as ore concentrates in ceramics and glass applications.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	W	W	W	W	W
Imports for consumption	3,420	2,620	2,460	2,640	3,400
Exports	1,660	1,660	1,200	1,870	2,700
Consumption, estimated[1]	3,000	2,000	2,000	2,000	3,000
Price, annual average-nominal, battery-grade lithium carbonate, dollars per metric ton[2]	16,000	11,700	8,400	12,600	37,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>50	>25	>50	>25	>25

Recycling: Construction of lithium battery recycling plants increased at a rapid pace. As of November 2022, about 44 companies in Canada and the United States and 47 companies in Europe recycled lithium batteries or planned to do so. Automobile companies and battery recyclers partnered to supply the automobile industry with a source of battery materials.

Import Sources (2018–21): Argentina, 51%; Chile, 40%; China, 4%; Russia, 3%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Lithium oxide and hydroxide	2825.20.0000	3.7% ad valorem.
Lithium carbonate:		
U.S. pharmaceutical grade	2836.91.0010	3.7% ad valorem.
Other	2836.91.0050	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4, 5]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Lithium-cobalt oxide	752	—	—	—	—
Lithium-nickel-cobalt-aluminum oxide	2,698	—	—	—	—

Events, Trends, and Issues: Excluding U.S. production, worldwide lithium production in 2022 increased by 21% to approximately 130,000 tons from 107,000 tons in 2021 in response to strong demand from the lithium-ion battery market and increased prices of lithium. Global consumption of lithium in 2022 was estimated to be 134,000 tons, a 41% increase from 95,000 tons in 2021.

Spot lithium carbonate prices in China (cost, insurance, and freight [c.i.f.]) increased from approximately $35,000 per ton in January to about $67,000 per ton in November. For fixed contracts, the annual average U.S. lithium carbonate price was $37,000 per ton in 2022, almost three times higher than that in 2021. Spot lithium hydroxide prices in China (free on board) increased from approximately $35,300 per ton in January to about $78,000 per ton in November. Spot spodumene (6% lithium oxide) prices in China (c.i.f.) increased from approximately $4,900 per ton in January to about $5,800 per ton in November.

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LITHIUM

Six mineral operations in Australia, one mineral tailings operation in Brazil, two brine operations each in Argentina and Chile, and three mineral and two brine operations in China accounted for the majority of world lithium production. Additionally, smaller operations in Brazil, Canada, China, Portugal, the United States, and Zimbabwe also contributed to world lithium production. Owing to the rapid increase in demand and prices of lithium in 2022, established lithium operations worldwide increased or were in the process of increasing production capacity.

The U.S. Department of Energy selected 12 lithium-based projects funded with $1.6 billion from the 2022 U.S. Bipartisan Infrastructure Law to support new commercial-scale domestic facilities to extract and process lithium, manufacture battery components, recycle batteries, and develop new technologies to increase U.S. lithium reserves.

Lithium supply security has become a top priority for technology companies in Asia, Europe, and North America. Strategic alliances and joint ventures among technology companies and exploration companies continued to be established to ensure a reliable, diversified supply of lithium for battery suppliers and vehicle manufacturers. Brine-based lithium sources were in various stages of development or exploration in Argentina, Bolivia, Chile, China, and the United States; mineral-based lithium sources were in various stages of development or exploration in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Ethiopia, Finland, Germany, Ghana, Kazakhstan, Mali, Namibia, Nigeria, Peru, Portugal, Russia, Serbia, Spain, Thailand, the United States, and Zimbabwe; lithium-clay sources were in various stages of development or exploration in Mexico and the United States.

World Mine Production and Reserves: Reserves for Argentina, Australia, Brazil, Canada, Chile, China, the United States, Zimbabwe, and "Other countries" were revised based on information from company and Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	W	W	1,000,000
Argentina	5,970	6,200	2,700,000
Australia	55,300	61,000	[7]6,200,000
Brazil	[e]1,700	2,200	250,000
Canada	—	500	930,000
Chile	28,300	39,000	9,300,000
China	[e]14,000	19,000	2,000,000
Portugal	[e]900	600	60,000
Zimbabwe	[e]710	800	310,000
Other countries[8]	—	—	3,300,000
World total (rounded)	[9]107,000	[9]130,000	26,000,000

World Resources:[6] Owing to continuing exploration, identified lithium resources have increased substantially worldwide and total about 98 million tons. Identified lithium resources in the United States—from continental brines, claystone, geothermal brines, hectorite, oilfield brines, and pegmatites—are 12 million tons. Identified lithium resources in other countries have been revised to 86 million tons. Identified lithium resources are distributed as follows: Bolivia, 21 million tons; Argentina, 20 million tons; Chile, 11 million tons; Australia, 7.9 million tons; China, 6.8 million tons; Germany, 3.2 million tons; Congo (Kinshasa), 3 million tons; Canada, 2.9 million tons; Mexico, 1.7 million tons; Czechia, 1.3 million tons; Serbia, 1.2 million tons; Russia, 1 million tons; Peru, 880,000 tons; Mali, 840,000 tons; Brazil, 730,000 tons; Zimbabwe, 690,000 tons; Spain, 320,000 tons; Portugal, 270,000 tons; Namibia; 230,000 tons; Ghana, 180,000 tons; Finland, 68,000 tons; Austria, 60,000 tons; and Kazakhstan, 50,000 tons.

Substitutes: Substitution for lithium compounds is possible in batteries, ceramics, greases, and manufactured glass. Examples are calcium, magnesium, mercury, and zinc as anode material in primary batteries; calcium and aluminum soaps as substitutes for stearates in greases; and sodic and potassic fluxes in ceramics and glass manufacture.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as production + imports – exports ± adjustments for Government and industry stock changes. Rounded to one significant digit to avoid disclosing company proprietary data.

[2]Lithium carbonate price assessments for spot and long-term contracts. Source: Benchmark Mineral Intelligence Ltd.

[3]Defined as imports – exports ± adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]Units are kilograms, gross weight.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 3.8 million tons.

[8]Other countries with reported reserves: Austria, Congo (Kinshasa), Czechia, Finland, Germany, Ghana, Mali, Mexico, Namibia, Serbia, and Spain.

[9]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

[Data in thousand metric tons of contained magnesium oxide (MgO) unless otherwise noted][2]

Domestic Production and Use: Seawater and natural brines accounted for about 67% of U.S. magnesium compound production in 2022. The value of shipments of all types of magnesium compounds was estimated to be $460 million, a 5% increase from the revised value in 2021. Magnesium compounds were recovered from seawater by one company in California and another company in Delaware, from well brines by one company in Michigan, and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada.

In the United States, about 75% of magnesium compounds were consumed in the form of caustic-calcined magnesia, magnesium chloride, magnesium hydroxide, and magnesium sulfates across the following industries and uses, in descending order of quantity, environmental, chemical, agricultural, and deicing. The remaining magnesium compounds were consumed for refractories in the form of dead-burned magnesia, fused magnesia, and olivine. Across all industries, the leading magnesium compounds consumed, in descending order of quantity, were magnesium oxide (caustic-calcined magnesia, dead burned magnesia, and fused magnesia), magnesium hydroxide, magnesium chloride, and magnesium sulfate.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	405	376	363	432	450
Shipments (gross weight)	610	563	547	634	660
Imports for consumption	551	564	480	655	640
Exports	116	88	66	86	140
Consumption, apparent[3]	840	852	777	1,001	950
Employment, plant, number[e]	270	270	260	270	280
Net import reliance[4] as a percentage of apparent consumption	52	56	53	57	53

Recycling: Some magnesia-based refractories are recycled, either for reuse as refractory material or for use as construction aggregate.

Import Sources (2018–21): Caustic-calcined magnesia: China,[5] 74%; Canada, 20%; Israel, 3%; and other, 3%. Crude magnesite: China,[5] 87%; Singapore, 10%; and other, 3%. Dead-burned and fused magnesia: China,[5] 68%; Brazil, 16%; Turkey, 5%; Mexico, 3%; and other, 8%. Magnesium chloride: Israel, 60%; Netherlands, 26%; China,[5] 5%; and other, 9%. Magnesium hydroxide: Mexico, 57%; Netherlands, 15%; Israel, 11%; Austria, 7%; and other, 10%. Magnesium sulfates: China,[5] 58%; India, 15%; Germany, 10%; Vietnam, 4%; and other, 13%. Total imports: China,[5] 61%; Israel, 10%; Canada, 7%; Brazil, 6%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Crude magnesite	2519.10.0000	Free.
Dead-burned and fused magnesia	2519.90.1000	Free.
Caustic-calcined magnesia	2519.90.2000	Free.
Kieserite	2530.20.1000	Free.
Epsom salts	2530.20.2000	Free.
Magnesium hydroxide and peroxide	2816.10.0000	3.1% ad valorem.
Magnesium chloride	2827.31.0000	1.5% ad valorem.
Magnesium sulfate (synthetic)	2833.21.0000	3.7% ad valorem.

Depletion Allowance: Brucite, 10% (domestic and foreign); dolomite, magnesite, and magnesium carbonate, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign); and olivine, 22% (domestic) and 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, consumption of dead-burned and fused magnesia is expected to decrease in the United States and globally by an estimated 4% and 5%, respectively, compared with that in 2021 based on steel production data through August. Coronavirus disease 2019 (COVID-19) pandemic-related shutdowns in China, especially in manufacturing dominated Provinces and port cities, contributed to the decrease in consumption of magnesium compounds. Domestic consumption for all magnesium compounds has somewhat followed the general trend of the performance of the U.S. manufacturing industry. Globally, China is the leading producer of magnesia and magnesite and remains the principal exporter of magnesia to the United States and much of the world.

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MAGNESIUM COMPOUNDS

In August 2022, a China-based magnesia and refractories producer commenced operations in Mayfield, KY. The new plant was designed to produce between 50,000 and 60,000 tons per year of refractory products. Feed material for the plant was sourced from company-owned mines located overseas. Products produced by the plant included resin bonded magnesia-carbon and magnesia-alumina-carbon refractory bricks for use in furnaces servicing the steel industry.

In the third quarter of 2022, North America's largest producer of epsom salts opened a bulk production facility in Hazelwood, NC. In spring 2023, an Austria-based magnesia and refractories producer plans to open its North American corporate headquarters in Tampa, FL.

World Magnesite Mine Production and Reserves:[6] In addition to magnesite reserves, vast reserves of magnesium exist in well and lake brines and seawater from which magnesium compounds can be recovered. Reserves for China were revised based on company and Government reports.

	Mine production[e]		Reserves[7]
	2021	2022	
United States	W	W	35,000
Australia	2,700	2,600	[8]290,000
Austria	800	800	49,000
Brazil	1,600	1,500	200,000
Canada	190	180	NA
China	18,000	17,000	580,000
Greece	540	510	280,000
India	99	100	82,000
Iran	200	190	12,000
Russia	1,000	950	2,300,000
Slovakia	500	480	370,000
Spain	650	620	35,000
Turkey	1,900	1,800	110,000
Other countries	400	400	2,500,000
World total (rounded)	[9]29,000	[9]27,000	6,800,000

World Resources:[7] Resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread. Identified world magnesite and brucite resources total 13 billion tons and several million tons, respectively. Resources of dolomite, forsterite, magnesium-bearing evaporite minerals, and magnesia-bearing brines are estimated to constitute a resource of billions of tons. Magnesium hydroxide can be recovered from seawater. Serpentine could be used as a source of magnesia but global resources, including in tailings of asbestos mines, have not been quantified but are thought to be very large.

Substitutes: Alumina, chromite, and silica substitute for magnesia in some refractory applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See also the Magnesium Metal chapter.

[2]Reported as magnesium content through Mineral Commodity Summaries 2016. Based on input from consumers, producers, and others involved in the industry, reporting magnesium compound data in terms of contained magnesium oxide was determined to be more useful than reporting in terms of magnesium content. Calculations were made using the following magnesium oxide (MgO) contents: magnesite, 47.8%; magnesium chloride, 42.3%; magnesium hydroxide, 69.1%; and magnesium sulfate, 33.5%.

[3]Defined as production + imports – exports.

[4]Defined as imports – exports.

[5]Includes Hong Kong.

[6]Gross weight of magnesite (magnesium carbonate) in thousand tons.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 37 million tons.

[9]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, primary magnesium was produced by one company in Utah at an electrolytic process smelter that recovered magnesium from brines from the Great Salt Lake. Secondary magnesium was recovered from scrap at smelters that produced magnesium ingot and castings and from aluminum alloy scrap at secondary aluminum smelters. Primary magnesium production in 2022 was estimated to have decreased significantly from that in 2021. Information regarding U.S. primary magnesium production was withheld to avoid disclosing company proprietary data. The leading use for primary magnesium metal, which accounted for 58% of reported consumption, was in castings, principally used for the automotive industry. Aluminum-base alloys that were used for packaging, transportation, and other applications accounted for 20% of primary magnesium metal consumption; desulfurization of iron and steel, 14%; and all other uses, 8%. About 35% of the secondary magnesium was consumed for structural uses, and about 65% was used in aluminum alloys.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	109	103	95	103	120
Imports for consumption	47	59	61	50	97
Exports	12	10	15	8	5
Consumption:					
Reported, primary	56	57	54	51	50
Apparent[2]	W	W	W	W	W
Price, annual average:[3]					
U.S. spot Western, dollars per pound	2.17	2.45	2.49	3.55	7.60
European free market, dollars per metric ton	2,550	2,425	2,149	5,008	5,500
Stocks, producer, yearend	W	W	W	W	W
Employment, number[e]	400	400	400	400	400
Net import reliance[4] as a percentage of apparent consumption	>25	>25	>25	>25	>50

Recycling: In 2022, about 37,000 tons of secondary magnesium was recovered from old scrap and 83,000 tons was recovered from new scrap. Aluminum-base alloys accounted for about 58% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 42%.

Import Sources (2018–21): Magnesium metal (99.8% purity): Israel, 31%; Russia, 29%; Turkey, 27%; Canada, 6%; and other, 7%. Magnesium alloys (magnesium content): Taiwan, 28%; Czechia, 16%; Germany and Israel, 14% each; and other, 28%. Sheet, powder, and other (magnesium content): Austria, China,[5] and Mexico, 20% each; Canada, 17%; and other, 23%. Scrap: Canada, 38%; Mexico, 19%; China,[5] 14%; Taiwan, 6%; and other, 23%. Combined total (includes magnesium content of alloys, metal, powder, and other): Canada, 21%; Israel, 11%; Mexico, 10%; Taiwan, 9%; and other, 49%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Unwrought metal	8104.11.0000	8% ad valorem.
Unwrought alloys	8104.19.0000	6.5% ad valorem.
Waste and scrap	8104.20.0000	Free.
Powders and granules	8104.30.0000	4.4% ad valorem.
Wrought metal	8104.90.0000	14.8¢/kg on magnesium content + 3.5% ad valorem.

Depletion Allowance: Dolomite, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Production issues continued throughout the year at the only U.S. primary magnesium smelter. On September 29, 2021, the producer of primary magnesium in Utah declared force majeure on supply contracts, citing equipment failures. Details on the amount of capacity affected and the expected restart date were not reported by the company. In 2022, some customers reported temporarily shutting down some facilities citing magnesium shortages including a facility in Indiana that produces aluminum can sheet which shut down some capacity in July until September when an alternative source of magnesium was obtained. The shutdown of capacity in Utah was cited as the reason why the average annual U.S. spot Western price nearly doubled from the annual average price in 2021. In August, the producer applied for a permit to extend the brine intake canals on the Great Salt

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MAGNESIUM METAL

Lake into deeper water, but in December the permit was denied by State regulators. The producer stated that the declining water level after several years of drought threatened to disrupt production.

Magnesium prices in Europe decreased significantly during the first half of the year compared with those of the last quarter of 2021 when they reached record highs. By the end of January 2022, the price range in Europe was $8,400 to $8,700 per metric ton and it continued to decline, reaching a range of $3,700 to $3,900 per metric ton at the end of July. For the remainder of the year, the price range in Europe declined, reaching a range of $3,400 to $3,550 per metric ton at the end of November, a price range not observed since May 2021. The 2022 annual average price range for magnesium in Europe was 10% higher than that for 2021.

One company planned to build a pilot plant in Ohio to test magnesium production from dolomite. A company in Quebec, Canada, planned to construct a primary magnesium smelter to produce magnesium from serpentine-bearing asbestos tailings. In Australia, a company started construction of a 1,000-ton-per-year demonstration plant to recover magnesium from coal fly ash, with production scheduled to start by the end of June 2023.

The use of magnesium in automobile parts continued to increase as automobile manufacturers sought to decrease vehicle weight for increased fuel efficiency. Magnesium castings have substituted for aluminum, iron, and steel in some automobiles. The substitution of aluminum for steel in automobile sheet continued to increase consumption of magnesium in aluminum alloy sheet. A shortage of computer chips was cited for some automobile manufacturers decreasing production despite strong demand, resulting in some diecasters decreasing magnesium consumption.

World Primary Production and Reserves:

	Smelter production		Reserves[6]
	2021	2022[e]	
United States	W	W	Magnesium metal can be derived from seawater, natural brines, dolomite, serpentine, and other minerals. The reserves for this metal are sufficient to supply current and future requirements.
Brazil	20	20	
China	[e]930	900	
Israel	18	20	
Kazakhstan	16	15	
Russia	[e]58	50	
Turkey	13	13	
Ukraine	10	2	
World total (rounded)[7]	1,070	1,000	

World Resources:[6] Resources from which magnesium may be recovered range from large to virtually unlimited and are globally widespread. Resources of dolomite, serpentine, and magnesium-bearing evaporite minerals are enormous. Magnesium-bearing brines are estimated to constitute a resource in the billions of tons, and magnesium could be recovered from seawater along world coastlines.

Substitutes: Aluminum and zinc may substitute for magnesium in castings and wrought products. The relatively light weight of magnesium is an advantage over aluminum and zinc in castings and wrought products in most applications; however, its high cost is a disadvantage relative to these substitutes. For iron and steel desulfurization, calcium carbide may be used instead of magnesium. Magnesium is preferred to calcium carbide for desulfurization of iron and steel because calcium carbide produces acetylene in the presence of water.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See also the Magnesium Compounds chapter.

[2]Defined as primary production + secondary production from old scrap + imports – exports ± adjustments for industry stock changes.

[3]Source: S&P Global Platts Metals Week.

[4]Defined as imports – exports ± adjustments for industry stock changes.

[5]Includes Hong Kong.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Excludes U.S. production.

MANGANESE

(Data in thousand metric tons, gross weight, unless otherwise noted)

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by five companies at six facilities with plants principally in the Eastern and Midwestern States. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Additional quantities of ore were used for nonmetallurgical purposes, such as in the production of animal feed, brick colorant, dry cell batteries, and fertilizers. Manganese ferroalloys were produced at two plants.

Salient Statistics—United States:[1]	2018	2019	2020	2021	2022[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ores and concentrates	440	434	367	497	650
Ferromanganese	427	332	223	329	330
Silicomanganese	412	351	269	313	420
Exports:					
Manganese ores and concentrates	3	1	1	1	1
Ferromanganese	10	5	5	9	2
Silicomanganese	4	2	2	5	4
Shipments from Government stockpile:[2]					
Manganese ore	—	—	—	2	—
Ferromanganese and manganese metal, electrolytic	13	10	54	21	11
Consumption, reported:					
Manganese ore[3]	369	442	378	399	370
Ferromanganese	348	336	325	335	340
Silicomanganese	[4]139	[4]143	229	237	240
Consumption, apparent, manganese content[5]	796	748	621	717	890
Price, average, manganese content, cost, insurance, and freight, China, dollars per metric ton unit[6]	7.16	5.63	4.59	5.27	6.50
Stocks, producer and consumer, yearend:					
Manganese ore[3]	191	175	143	220	230
Ferromanganese	27	44	35	40	40
Silicomanganese	21	39	31	34	34
Net import reliance[7] as a percentage of apparent consumption, manganese content	100	100	100	100	100

Recycling: Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.

Import Sources (2018–21): Manganese ore: Gabon, 67%; South Africa, 19%; Mexico, 12%; and other, 2%. Ferromanganese: Australia, 19%; Malaysia, 18%; South Africa, 17%; Norway, 15%; and other, 31%. Silicomanganese: Georgia, 28%; South Africa, 22%; Australia, 21%; and other, 29%. Manganese contained in principal manganese imports:[8] Gabon, 25%; South Africa, 19%; Australia, 12%; Georgia, 8%; and other, 36%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Ores and concentrates:		
Containing less than 47% manganese	2602.00.0040	Free.
Containing 47% or more of manganese	2602.00.0060	Free.
Manganese dioxide	2820.10.0000	4.7% ad valorem.
High-carbon ferromanganese	7202.11.5000	1.5% ad valorem.
Ferrosilicon manganese (silicomanganese)	7202.30.0000	3.9% ad valorem.
Metal, unwrought:		
Flake containing at least 99.5% manganese	8111.00.4700	14% ad valorem.
Other	8111.00.4900	14% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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MANGANESE

Government Stockpile:[9]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Manganese ore, metallurgical grade	291	—	292	—	151
Ferromanganese, high carbon	104	—	45	—	45
Manganese metal, electrolytic	—	5	—	5	—

Events, Trends, and Issues: Global production of steel, the leading use of manganese, decreased in 2022 compared with production in 2021 owing to supply chain disruptions resulting from the conflict between Russia and Ukraine and intermittent coronavirus disease 2019 (COVID-19) pandemic-related lockdowns in China. Global production of manganese ore was estimated to be unchanged from that in 2021. The leading countries for manganese ore production were, in descending order on a contained-weight basis, South Africa, Gabon, and Australia. On a contained-weight basis, total U.S. manganese imports were estimated to have increased by almost 20% in 2022 compared with those in 2021. By September 2022, average spot market prices for manganese ore, 44% grade, from China had increased by 23% compared with the annual average spot price in 2021.

World Mine Production (manganese content) and Reserves: Reserves for China were revised based on Government reports.

	Mine production 2021	Mine production 2022[e]	Reserves[10]
United States	—	—	—
Australia	3,260	3,300	[11]270,000
Brazil	542	400	270,000
Burma	206	200	NA
China	991	990	280,000
Côte d'Ivoire	362	360	NA
Gabon	4,340	4,600	61,000
Georgia	224	220	NA
Ghana	940	940	13,000
India	453	480	34,000
Kazakhstan, concentrate	90	110	5,000
Malaysia	356	360	NA
Mexico	226	230	5,000
South Africa	7,200	7,200	640,000
Ukraine, concentrate	600	400	140,000
Vietnam	146	150	NA
Other countries	150	150	Small
World total (rounded)	20,100	20,000	1,700,000

World Resources:[10] Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs. South Africa accounts for an estimated 70% of the world's manganese resources.

Substitutes: Manganese has no satisfactory substitute in its major applications.

[e]Estimated. NA Not available. — Zero.

[1]Manganese content typically ranges from 35% to 54% for manganese ore and from 74% to 95% for ferromanganese.

[2]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.

[3]Exclusive of ore consumed directly at iron and steel plants and associated yearend stocks.

[4]Imports more nearly represent amount consumed than does reported consumption.

[5]Defined as imports – exports ± adjustments for Government and industry stock changes. Manganese content based on estimates of average content for all significant components—including ferromanganese, manganese dioxide, manganese ore, manganese waste and scrap, silicomanganese, unwrought manganese metal, and wrought manganese metal.

[6]For average metallurgical-grade ore containing 44% manganese. Source: CRU Group.

[7]Defined as imports – exports ± adjustments for Government and industry stock changes.

[8]Includes imports of ferromanganese, manganese dioxide, manganese ore, silicomanganese, and unwrought manganese metal.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 135 million tons.

MERCURY

(Data in metric tons of contained mercury unless otherwise noted)

Domestic Production and Use: Mercury has not been produced as a principal mineral commodity in the United States since 1992. In 2022, mercury was recovered as a byproduct from processing gold-silver ore at several mines in Nevada; however, production data were not reported. Secondary, or recycled, mercury was recovered from batteries, compact and traditional fluorescent lamps, dental amalgam, medical devices, and thermostats, as well as mercury-contaminated soils. The U.S. Environmental Protection Agency reported a revised domestic production of 45 tons in 2018 (the last year for which data were available), and about 82 tons of mercury was stored by manufacturers or producers. The reported domestic consumption of mercury and mercury in compounds in products was 16 tons. The leading domestic end uses of mercury and mercury compounds were dental amalgam, 43%; relays, sensors, switches, and valves, 41%; bulbs, lamps, and lighting, 8%; formulated products (buffers, catalysts, fixatives, and vaccination uses), 7%; and batteries and other end uses, 1%. A large quantity of mercury (about 245 tons) is used domestically in manufacturing processes such as catalysts or as a cathode in the chlorine-caustic soda (chloralkali) process. Almost all the mercury is reused in the process. The leading manufacturing processes that use mercury are mercury-cell chloralkali plants. In 2022, only one mercury-cell chloralkali plant operated in the United States. Until December 31, 2012, domestic- and foreign-sourced mercury was refined and then exported for global use, primarily for small-scale gold mining in many parts of the world. Beginning January 1, 2013, export of elemental mercury from the United States was banned, with some exceptions, under the Mercury Export Ban Act of 2008. Effective January 1, 2020, exports of five mercury compounds were added to that ban.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption, metal (gross weight)	6	9	3	1	2
Exports, metal (gross weight)	—	—	—	—	—
Price, average unit value of imports, dollars per kilogram	7	23	26	29	33
Net import reliance[1] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: In 2022, eight facilities operated by six companies in the United States accounted for most of the secondary mercury produced and were authorized by the U.S. Department of Energy (DOE) to temporarily store mercury until the DOE's long-term facility opens. Mercury-containing automobile convenience switches, barometers, compact and traditional fluorescent bulbs, computers, dental amalgam, medical devices, and thermostats were collected by smaller companies and shipped to the refining companies for retorting to reclaim the mercury. In addition, many collection companies recovered mercury when retorting was not required. With the rapid replacement of compact and traditional fluorescent lighting by light-emitting-diode (LED) lighting, more mercury was being recycled.

Import Sources (2018–21): Canada, 69%; China, 31%; and other, <1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Mercury	2805.40.0000	1.7% ad valorem.
Amalgams	2843.90.0000	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[2] The Defense Logistics Agency Strategic Materials held and managed an inventory of 4,437 tons of mercury in storage at the Hawthorne Army Depot in Hawthorne, NV. On December 3, 2019, the DOE selected a site near Andrews, TX, to store up to 6,800 tons of mercury. Sales of mercury from the stockpiles remained suspended.

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Mercury	4,437	—	—	—	—

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MERCURY

Events, Trends, and Issues: Owing to mercury toxicity and concerns for the environment and human health, overall mercury use has declined in the United States and worldwide. According to the United Nations Environment Programme (UNEP) Global Mercury Partnership 2018 report, the top five leading sources of anthropogenic mercury emissions were artisanal and small-scale gold mining (37.7%), stationary combustion of coal (21.3%), nonferrous-metal production (14.7%), cement production (10.5%), and waste from products (6.6%). Mercury is no longer used in most batteries and paints manufactured in the United States. Some button-type batteries, cleansers, fireworks, folk medicines, grandfather clocks, pesticides, and skin-lightening creams and soaps may still contain mercury. Mercury compounds were used as catalysts in the coal-based manufacture of vinyl chloride monomer in China. In some parts of the world, mercury was used in the recovery of gold in artisanal and small-scale mining operations. Conversion to nonmercury technology for chloralkali production and the ultimate closure of the world's mercury-cell chloralkali plants may release a large quantity of mercury to the global market for recycling, sale, or, owing to export bans in Europe and the United States, long-term storage.

Byproduct mercury production is expected to continue from large-scale domestic and foreign gold-silver mining and processing, as is secondary production of mercury from an ever-diminishing supply of mercury-containing products. Domestic mercury consumption will continue to decline owing to increased use of LED lighting and consequent reduced use of conventional fluorescent tubes and compact fluorescent bulbs and continued substitution of non-mercury-containing products in control, dental, and measuring applications.

World Mine Production and Reserves:

	Mine production[e]		Reserves[3]
	2021	2022	
United States	NA	NA	Quantitative estimates of reserves were not available. China, Kyrgyzstan, and Peru have the largest reserves.
China	2,000	2,000	
Kyrgyzstan	20	6	
Mexico (net exports)	39	40	
Morocco	2	2	
Norway	20	20	
Peru (exports)	30	30	
Tajikistan	120	120	
World total (rounded)[4]	2,200	2,200	

World Resources:[3] China, Kyrgyzstan, Mexico, Peru, Russia, Slovenia, Spain, and Ukraine have most of the world's estimated 600,000 tons of mercury resources. Mexico reclaims mercury from Spanish colonial silver-mining waste. In Spain, once a leading producer of mercury, mining at its centuries-old Almaden Mine stopped in 2003. In the United States, mercury occurrences are in Alaska, Arkansas, California, Nevada, and Texas. The declining consumption of mercury, except for small-scale gold mining, indicates that these resources are sufficient for centuries of use.

Substitutes: Ceramic composites substitute for the dark-gray mercury-containing dental amalgam. "Galinstan," an alloy of gallium, indium, and tin, replaces the mercury used in traditional mercury thermometers, and digital thermometers have replaced traditional thermometers. At chloralkali plants around the world, mercury-cell technology is being replaced by newer diaphragm and membrane-cell technology. LEDs that contain indium substitute for mercury-containing fluorescent lamps. Lithium, nickel-cadmium, and zinc-air batteries replace mercury-zinc batteries in the United States; indium compounds substitute for mercury in alkaline batteries; and organic compounds are being used instead of mercury fungicides in latex paint.

[e]Estimated. NA Not available. — Zero.

[1]Defined as imports – exports ± adjustments for Government stock changes.

[2]See Appendix B for definitions.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

MICA (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Scrap and flake mica production, excluding low-quality sericite, was estimated to be 42,000 tons valued at $4.2 million. Mica was mined in Georgia, North Carolina, and South Dakota. Scrap mica was recovered principally from mica and sericite schist and as a byproduct from the production of feldspar and kaolin and the beneficiation of industrial sand. Eight companies produced an estimated 67,000 tons of ground mica valued at about $21 million from domestic and imported scrap and flake mica. Most of the domestic production was processed into small-particle-size mica by either wet or dry grinding. Primary uses were joint compound, oil-well-drilling additives, paint, roofing, and rubber products.

A minor amount of sheet mica has been produced as incidental production from feldspar mining in North Carolina in the past several years. Data on sheet mica production were not available in 2022. The domestic consuming industry was dependent on imports to meet demand for sheet mica. Most sheet mica was fabricated into parts for electrical and electronic equipment.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Scrap and flake:					
Production:[e, 1]					
Sold and used	42,000	40,100	34,600	40,600	42,000
Ground	68,400	61,300	59,900	66,800	67,000
Imports[2]	28,100	27,300	20,400	24,100	21,000
Exports[3]	6,030	5,500	3,980	4,850	7,600
Consumption, apparent[e, 4]	64,100	61,900	50,000	59,900	55,000
Price, average, dollars per metric ton:[e]					
Scrap and flake	116	105	120	100	100
Ground:					
Dry	308	316	303	299	300
Wet	422	394	337	336	340
Net import reliance[5] as a percentage of apparent consumption	34	35	31	32	24
Sheet:					
Sold and used	W	W	W	NA	NA
Imports[6]	1,890	3,150	2,840	3,980	4,200
Exports[7]	686	779	528	633	950
Consumption, apparent[e, 4]	1,200	2,370	2,310	3,350	3,300
Price, average value, muscovite and phlogopite mica, dollars per kilogram:[e]					
Block	W	W	W	W	W
Splittings	1.65	1.66	1.57	1.88	1.80
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Scrap and flake: Canada, 39%; China, 38%; India, 8%; Finland, 4%; and other, 11%. Sheet: China, 72%; Brazil, 9%; Belgium, 4%, Austria, 3%, and other, 12%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Split block mica	2525.10.0010	Free.
Mica splittings	2525.10.0020	Free.
Unworked, other	2525.10.0050	Free.
Mica powder	2525.20.0000	Free.
Mica waste	2525.30.0000	Free.
Plates, sheets, and strips of agglomerated or reconstituted mica	6814.10.0000	2.7% ad valorem.
Worked mica and articles of mica, other	6814.90.0000	2.6% ad valorem.

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MICA (NATURAL)

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic production of scrap and flake mica was estimated to have increased by 3% in 2022 compared with that in 2021. Apparent consumption of scrap and flake mica decreased by 8% owing to higher exports of mica powder in 2022. Apparent consumption of sheet mica was estimated to have been essentially unchanged from that in 2021. No environmental concerns are associated with the manufacture and use of mica products. Supplies of sheet mica for United States consumption were expected to continue to be from imports, primarily from China with some imports from Brazil.

World Mine Production and Reserves: World production of sheet mica has remained steady; however, reliable production data for some countries that were thought to be major contributors to the world total were unavailable.

	Scrap and flake			Sheet		
	Mine production[e]		Reserves[8]	Mine production[e]		Reserves[8]
	2021	2022		2021	2022	
United States	40,600	42,000	Large	W	NA	Very small
Canada	15,000	16,000	Large	NA	NA	NA
China	100,000	100,000	Large	NA	NA	NA
Finland	[9]55,900	60,000	Large	NA	NA	NA
France	19,000	19,000	Large	NA	NA	NA
India	16,000	16,000	Large	1,000	1,000	110,000
Korea, Republic of	[9]11,000	13,000	11,000,000	—	—	NA
Madagascar	70,000	65,000	Large	—	—	NA
Turkey	[9]1,670	1,700	620,000	—	—	NA
Other countries	55,000	54,000	Large	200	200	Moderate
World total (rounded)	384,000	390,000	Large	NA	NA	NA

World Resources:[8] Resources of scrap and flake mica are available in clay deposits, granite, pegmatite, and schist, and are considered more than adequate to meet anticipated world demand in the foreseeable future. World resources of sheet mica have not been formally evaluated because of the sporadic occurrence of this material. Large deposits of mica-bearing rock are known to exist in countries such as Brazil, India, and Madagascar. Limited resources of sheet mica are available in the United States. Domestic resources were subeconomic because of the high cost of the hand labor required to mine and process sheet mica from pegmatites.

Substitutes: Some lightweight aggregates, such as diatomite, perlite, and vermiculite, may be substituted for ground mica when used as filler. Ground synthetic fluorophlogopite, a fluorine-rich mica, may replace natural ground mica for uses that require the thermal and electrical properties of mica. Many materials can be substituted for mica in numerous electrical, electronic, and insulation uses. Substitutes include acrylic, cellulose acetate, fiberglass, fishpaper, nylatron, nylon, phenolics, polycarbonate, polyester, styrene, polyvinyl chloride, and vulcanized fiber. Mica paper made from scrap mica can be substituted for sheet mica in electrical and insulation applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Excludes low-quality sericite used primarily for brick manufacturing.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0050, <$6.00 per kilogram; 2525.20.0000; and 2525.30.0000.

[3]Includes data for the following Schedule B codes: 2525.10.0000, <$6.00 per kilogram; 2525.20.0000; and 2525.30.0000.

[4]Defined as sold or used by producing companies + imports – exports.

[5]Defined as imports – exports.

[6]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0010; 2525.10.0020; 2525.10.0050, >$6.00 per kilogram; 6814.10.0000; and 6814.90.0000.

[7]Includes data for the following Schedule B codes: 2525.10.0000, >$6.00 per kilogram; 6814.10.0000; and 6814.90.0000.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Reported.

MOLYBDENUM

(Data in metric tons of contained molybdenum unless otherwise noted)

Domestic Production and Use: Total U.S. mine production of molybdenum concentrate increased slightly to 42,000 tons of contained molybdenum in 2022 compared with 41,100 tons in 2021. Molybdenum concentrate production at primary molybdenum mines continued at two U.S. operations in Colorado, accounting for 33% of total U.S. molybdenum concentrate production. Molybdenum concentrate production from mines where molybdenum was a byproduct continued at seven U.S. operations (four in Arizona and one each in Montana, Nevada, and Utah), accounting for 67% of total U.S. molybdenum concentrate production. Three roasting plants converted molybdenite concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	41,400	43,600	51,100	41,100	42,000
Imports for consumption	37,300	34,200	24,700	30,200	33,000
Exports	48,200	67,200	62,500	60,000	53,000
Consumption:					
Reported[1]	16,700	16,400	15,800	15,900	16,000
Apparent[2]	31,300	10,400	13,100	11,100	22,000
Price, average value, dollars per kilogram[3]	27.04	26.50	19.90	35.30	39.25
Stocks, consumer materials	1,940	1,980	1,980	2,020	2,100
Employment, mine and plant, number	940	950	950	940	940
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Molybdenum is recycled as a component of catalysts, ferrous scrap, and superalloy scrap. Ferrous scrap consists of revert, new, and old scrap. Revert scrap refers to remnants manufactured in the steelmaking process. New scrap is generated by steel mill customers and recycled by scrap collectors and processors. Old scrap is largely molybdenum-bearing alloys recycled after serving their useful life. The amount of molybdenum recycled as part of new and old steel and other scrap may be as much as 30% of the apparent supply of molybdenum. There are no processes for the separate recovery and refining of secondary molybdenum from its alloys. Molybdenum is not recovered separately from recycled steel and superalloys, but the molybdenum content of the recycled alloys is significant, and the molybdenum content is reused. Recycling of molybdenum-bearing scrap will continue to be dependent on the markets for the principal alloy metals in which molybdenum is contained, such as iron, nickel, and chromium.

Import Sources (2018–21): Ferromolybdenum: Chile, 69%; Republic of Korea, 26%; and other, 5%. Molybdenum ores and concentrates: Peru, 60%; Mexico, 15%; Chile, 14%; and other, 11%. Total: Peru, 40%; Chile, 28%; Mexico, 10%; Canada, 9%; and other, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Molybdenum ore and concentrates, roasted	2613.10.0000	12.8¢/kg on molybdenum content + 1.8% ad valorem.
Molybdenum ore and concentrates, other	2613.90.0000	17.8¢/kg on molybdenum content.
Molybdenum chemicals:		
Molybdenum oxides and hydroxides	2825.70.0000	3.2% ad valorem.
Molybdates of ammonium	2841.70.1000	4.3% ad valorem.
Molybdates, all others	2841.70.5000	3.7% ad valorem.
Molybdenum pigments, molybdenum orange	3206.20.0020	3.7% ad valorem.
Ferroalloys, ferromolybdenum	7202.70.0000	4.5% ad valorem.
Molybdenum metals:		
Powders	8102.10.0000	9.1¢/kg on molybdenum content + 1.2% ad valorem.
Unwrought	8102.94.0000	13.9¢/kg on molybdenum content + 1.9% ad valorem.
Wrought bars and rods	8102.95.3000	6.6% ad valorem.
Wrought plates, sheets, strips, and so forth	8102.95.6000	6.6% ad valorem.
Wire	8102.96.0000	4.4% ad valorem.
Waste and scrap	8102.97.0000	Free.
Other	8102.99.0000	3.7% ad valorem.

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MOLYBDENUM

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, the estimated average molybdic oxide price increased by 11% compared with that in 2021. Molybdenum prices have not reached this high of a level since 2008. Estimated U.S. imports for consumption increased by 8% compared with those in 2021. U.S. exports decreased by 12% from those in 2021. Estimated apparent consumption in 2022 increased by 96% compared with that in 2021.

Global molybdenum production in 2022 was essentially unchanged compared with that in 2021. In descending order of production, China, Chile, the United States, Peru, and Mexico provided 93% of total global production. Molybdenum producers in China continued to face difficulties owing to tightening of environmental regulations making it more difficult to obtain mining permits. Molybdenum prices in China reached decade-high levels as molybdenum-bearing steel consumption remained high. In Chile, molybdenum producers continued to struggle with persistently lower ore grades. However, molybdenum was expected to continue to make strong contributions in global power generation and infrastructure projects as countries begin to prioritize climate change.

World Mine Production and Reserves: Reserves for Canada, China, the Republic of Korea, Peru, and Uzbekistan were revised based on company and Government reports.

	Mine production		Reserves[5]
	2021	2022[e]	(thousand metric tons)
United States	41,100	42,000	2,700
Argentina	—	—	100
Armenia	7,760	7,800	150
Canada	1,390	970	72
Chile	49,400	44,000	1,400
China	95,300	100,000	3,700
Iran	3,100	3,500	43
Korea, Republic of	408	400	8
Mexico	16,300	16,000	130
Mongolia	2,970	2,300	NA
Peru	34,100	32,000	2,400
Russia	[e]1,700	1,700	430
Turkey	—	—	360
Uzbekistan	[e]1,600	1,600	21
World total (rounded)	255,000	250,000	12,000

World Resources:[5] Identified resources of molybdenum in the United States are about 5.4 million tons, and in the rest of the world, about 20 million tons. Molybdenum occurs as the principal metal sulfide in large low-grade porphyry molybdenum deposits and as an associated metal sulfide in low-grade porphyry copper deposits. Resources of molybdenum are adequate to supply world needs for the foreseeable future.

Substitutes: There is little substitution for molybdenum in its major application in steels and cast irons. In fact, because of the availability and versatility of molybdenum, industry has sought to develop new materials that benefit from its alloying properties. Potential substitutes include boron, chromium, niobium (columbium), and vanadium in alloy steels; tungsten in tool steels; graphite, tantalum, and tungsten for refractory materials in high-temperature electric furnaces; and cadmium-red, chrome-orange, and organic-orange pigments for molybdenum orange.

[e]Estimated. E Net exporter. NA Not available. — Zero.

[1]Reported consumption of primary molybdenum products.

[2]Defined as production + imports – exports ± adjustments for industry stock changes.

[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide. Source: CRU Group.

[4]Defined as imports – exports ± adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

NICKEL

(Data in metric tons of contained nickel unless otherwise noted)

Domestic Production and Use: In 2022, the underground Eagle Mine in Michigan produced approximately 18,000 tons of nickel in concentrate, which was exported to smelters in Canada and overseas. Nickel in crystalline sulfate was produced as a byproduct of smelting and refining platinum-group-metal ores mined in Montana. In Missouri, a company produced nickel-copper-cobalt concentrate from historic mine tailings and was building a hydrometallurgical processing plant near the mine site. A nickel beneficiation project was to be built in North Dakota using $115 million awarded from the Bipartisan Infrastructure Law. In the United States, the leading uses for primary nickel are alloys and steels, electroplating, and other uses including catalysts and chemicals. Stainless and alloy steel and nickel-containing alloys typically account for more than 85% of domestic consumption.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	17,600	13,500	16,700	18,400	18,000
Refinery, byproduct	W	W	W	W	W
Imports:					
Ores and concentrates	3	4	95	18	—
Primary	144,000	119,000	105,000	108,000	130,000
Secondary	45,100	37,700	31,800	34,400	34,000
Exports:					
Ores and concentrates	18,000	14,300	13,400	14,900	18,000
Primary	9,780	12,800	11,300	11,600	11,000
Secondary	59,400	47,800	46,300	29,100	43,000
Consumption:					
Reported, primary	107,000	105,000	[e]85,000	[e]77,000	80,000
Reported, secondary, purchased scrap	123,000	111,000	[e]100,000	[e]100,000	96,000
Apparent, primary[1]	136,000	106,000	[e]94,000	[e]98,000	120,000
Apparent, total[2]	259,000	217,000	[e]200,000	[e]200,000	220,000
Price, average annual, London Metal Exchange (LME), cash:					
Dollars per metric ton	13,114	13,903	13,772	18,476	25,000
Dollars per pound	5.948	6.306	6.25	8.38	11
Stocks, yearend:					
Consumer	16,300	13,400	[e]14,000	[e]14,000	14,000
LME U.S. warehouses	2,268	1,974	1,734	1,296	6
Net import reliance[3, 4] as a percentage of total apparent consumption	52	49	48	49	56

Recycling: Most secondary nickel was in the form of nickel content of stainless-steel scrap. Nickel in alloyed form was recovered from the processing of nickel-containing waste. Most recycled nickel was used to produce new alloys and stainless steel. In 2022, as part of the Bipartisan Infrastructure Law, more than $600 million was allocated to projects to recover nickel from spent lithium-ion batteries and for the synthesis of nickel-containing precursor and cathode active materials. In 2022, recycled nickel in all forms accounted for approximately 56% of apparent consumption.

Import Sources (2018–21): Primary nickel: Canada, 45%; Norway, 9%; Australia, 8%; Finland, 7%; and other, 31%. Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 38%; Mexico, 26%; United Kingdom, 9%; and other, 27%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Nickel ores and concentrates, nickel content	2604.00.0040	Free.
Ferronickel	7202.60.0000	Free.
Unwrought nickel, not alloyed	7502.10.0000	Free.
Nickel waste and scrap	7503.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5] The U.S. Department of Energy is holding nickel ingot contaminated by low-level radioactivity at Paducah, KY, and shredded nickel scrap at Oak Ridge, TN. See the Lithium chapter for statistics on lithium-nickel-cobalt-aluminum oxide.

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NICKEL

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Nickel alloys, gross weight	759	—	—	—	—

Events, Trends, and Issues: In 2022, the annual average LME nickel cash price was estimated to have increased by 35% compared with that in 2021 which was attributed to increasing use of nickel in electric vehicle batteries and continued strong demand for stainless steel. Nickel prices were particularly volatile early in the year. In March, after the onset of the conflict between Russia and Ukraine, prices surged, which disrupted nickel trading on the LME for approximately two weeks. Monthly average prices peaked in March, but began to decline through July, and stabilized for the remainder of the year.

Estimated global nickel mine production increased by about 20%, with almost all of the increased production attributed to Indonesia. The largest share of the increase was facilitated by the ongoing commissioning of integrated nickel pig iron and stainless-steel projects. In addition, several companies continued to develop projects to produce intermediate matte or mixed nickel-cobalt hydroxide that were intended to be used as feedstock to produce battery-grade nickel sulfate.

On February 24, 2022, a U.S. critical minerals list was published in the Federal Register (87 FR 10381). The changes in the 2022 list from the prior list published in 2018 (83 FR 23295) were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

World Mine Production and Reserves: Reserves for Canada, China, New Caledonia, and the United States were revised based on company and Government reports.

	Mine production 2021	Mine production 2022[e]	Reserves[6]
United States	18,400	18,000	[7]370,000
Australia	151,000	160,000	[8]21,000,000
Brazil	76,000	83,000	16,000,000
Canada	134,000	130,000	2,200,000
China	109,000	110,000	2,100,000
Indonesia	1,040,000	1,600,000	21,000,000
New Caledonia[9]	186,000	190,000	7,100,000
Philippines	387,000	330,000	4,800,000
Russia	205,000	220,000	7,500,000
Other countries	429,000	440,000	20,000,000
World total (rounded)	2,730,000	3,300,000	>100,000,000

World Resources:[6] Identified land-based resources averaging approximately 0.5% nickel or greater contain at least 300 million tons of nickel, with about 60% in laterites and 40% in sulfide deposits. Extensive nickel resources also are found in manganese crusts and nodules on the ocean floor.

Substitutes: Low-nickel, duplex, or ultrahigh-chromium stainless steels have been substituted for austenitic grades in construction. Nickel-free specialty steels are sometimes used in place of stainless steel in the power-generating and petrochemical industries. Titanium alloys can substitute for nickel metal or nickel-base alloys in corrosive chemical environments.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as primary imports – primary exports ± adjustments for industry stock changes, excluding secondary consumer stocks.

[2]Defined as apparent primary consumption + reported secondary consumption.

[3]Defined as imports – exports ± adjustments for consumer stock changes.

[4]The calculation of net import reliance includes the nickel content of stainless steel and alloy scrap. Excluding scrap, net import reliance would be nearly 100%.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Includes reserve data for three projects. An additional three domestic projects have defined resources but have not yet defined reserves.

[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 9.5 million tons.

[9]Overseas Territory of France.

NIOBIUM (COLUMBIUM)

(Data in metric tons of contained niobium unless otherwise noted)

Domestic Production and Use: Significant U.S. niobium mine production has not been reported since 1959. Companies in the United States produced niobium-containing materials from imported niobium concentrates, oxides, and ferroniobium. Niobium was consumed mostly in the form of ferroniobium by the steel industry and as niobium alloys and metal by the aerospace industry. Major end-use distribution of domestic niobium consumption was estimated as follows: steels, about 75%, and superalloys, about 25%. The estimated value of niobium consumption was $440 million, as measured by the value of imports.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	—	—	—	—	—
Imports for consumption[1]	11,200	10,100	7,200	8,290	8,800
Exports[1]	955	668	793	1,010	1,200
Shipments from Government stockpile[2]	−76	−84	−88	−1	0
Consumption:[e]					
Apparent[3]	10,100	9,360	6,320	7,280	7,600
Reported[4]	6,850	6,680	6,040	6,140	5,600
Price, average unit value, ferroniobium, dollars per kilogram[5]	21	22	20	20	24
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Niobium was recycled when niobium-bearing steels and superalloys were recycled; scrap recovery, specifically for niobium content, was negligible. The amount of niobium recycled is not available, but it may be as much as 20% of apparent consumption.

Import Sources (2018–21): Niobium and tantalum ores and concentrates: Australia, 42%; Rwanda, 21%; Congo (Kinshasa), 12%; Mozambique, 7%; and other, 18%. Niobium oxide: Brazil, 72%; Estonia, 5%; China, 2%; Germany, 1%; and other, 20%. Ferroniobium and niobium metal: Brazil, 67%; Canada, 28%; Russia, 3%, Germany, 1%, and other, 1%. Total imports: Brazil, 66%; Canada, 25%; and other, 9%. Of U.S. niobium material imports (by contained weight), 74% was ferroniobium, 16% was niobium metal, 9% was niobium oxide, and 1% was niobium ores and concentrates.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Niobium oxide	2825.90.1500	3.7% ad valorem.
Ferroniobium:		
Less than 0.02% phosphorus or sulfur, or less than 0.4% silicon	7202.93.4000	5% ad valorem.
Other	7202.93.8000	5% ad valorem.
Niobium:		
Waste and scrap[6]	8112.92.0700	Free.
Powders and unwrought metal	8112.92.4000	4.9% ad valorem.
Other[6]	8112.99.9100	4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Ferroniobium (gross weight)	544	—	—	—	—
Niobium metal (gross weight)	10	—	—	—	—

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NIOBIUM (COLUMBIUM)

Events, Trends, and Issues: In 2022, U.S. niobium apparent consumption (measured in niobium content) was estimated to be 7,600 tons, a 4% increase from that in 2021. One domestic company developing its Elk Creek project in Nebraska announced the results of its 2022 feasibility study. According to the study, the mining and processing operation is expected to produce 7,350 tons per year of ferroniobium, 102 tons per year of scandium trioxide, and 12,060 tons per year of titanium dioxide over a 38-year mine life. The project would be the only niobium mine and primary niobium-processing facility in the United States, with construction to begin after financing is received as required permits have been obtained.

Brazil continued to be the world's leading niobium producer, accounting for approximately 89% of global production, followed by Canada with about 8%. According to international trade statistics under the Harmonized Tariff Schedule of the United States code 7202.93 (ferroniobium), Brazil's total exports were 56,700 tons from January through August 2022, 6% less than during the same period in 2021. Most of Brazil's exports were sent to China, followed by the Netherlands and Singapore.

In 2022, a leading niobium producer in Brazil announced plans to invest $1.7 billion in its production assets to double its sales volume by 2030. The company completed its most recent facility upgrades in late 2021, increasing its total production capacity of ferroniobium to 150,000 metric tons per year (approximately 98,000 tons per year of niobium content). The completion of those projects would provide a significant increase in production in Brazil over the next decade.

World Mine Production and Reserves: Reserves for the United States were revised based on company reports.

	Mine production		Reserves[8]
	2021	2022[e]	
United States	—	—	210,000
Brazil	78,700	71,000	16,000,000
Canada	7,500	6,500	1,600,000
Congo (Kinshasa)	580	600	NA
Russia	450	450	NA
Rwanda	158	210	NA
Other countries	170	190	NA
World total (rounded)	87,600	79,000	>17,000,000

World Resources:[8] World resources of niobium are more than adequate to supply projected needs. Most of the world's identified resources of niobium occur as pyrochlore in carbonatite (igneous rocks that contain more than 50%-by-volume carbonate minerals) deposits and are outside the United States.

Substitutes: The following materials can be substituted for niobium, but a performance loss or higher cost may ensue: ceramic matrix composites, molybdenum, tantalum, and tungsten in high-temperature (superalloy) applications; molybdenum, tantalum, and titanium as alloying elements in stainless and high-strength steels; and molybdenum and vanadium as alloying elements in high-strength low-alloy steels.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated niobium content of ferroniobium, niobium and tantalum ores and concentrates, niobium oxide, and niobium powders and unwrought metal.

[2]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.

[3]Defined as imports – exports ± adjustments for Government stock changes.

[4]Only includes ferroniobium and nickel niobium.

[5]Unit value is weighted average unit value of gross weight of U.S. ferroniobium trade (imports plus exports.)

[6]This category includes niobium-containing material and other material.

[7]See Appendix B for definitions.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

NITROGEN (FIXED)—AMMONIA

(Data in thousand metric tons contained nitrogen unless otherwise noted)

Domestic Production and Use: Ammonia was produced by 16 companies at 35 plants in 16 States in the United States during 2022; 2 additional plants were idle for the entire year. About 60% of total U.S. ammonia production capacity was in Louisiana, Oklahoma, and Texas because of their large reserves of natural gas, the dominant domestic feedstock for ammonia. In 2022, U.S. producers operated at about 86% of rated capacity. The United States was one of the world's leading producers and consumers of ammonia. Urea, ammonium nitrate, nitric acid, ammonium phosphates, and ammonium sulfate were, in descending order of quantity produced, the major derivatives of ammonia produced in the United States.

Approximately 88% of apparent domestic ammonia consumption was for fertilizer use, including anhydrous ammonia for direct application, urea, ammonium nitrates, ammonium phosphates, and other nitrogen compounds. Ammonia also was used to produce explosives, plastics, synthetic fibers and resins, and numerous other chemical compounds.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[1]	13,100	13,500	14,000	12,700	13,000
Imports for consumption	2,530	2,020	1,990	2,080	2,100
Exports	224	338	369	231	700
Consumption, apparent[2]	15,300	15,200	15,700	14,600	14,000
Stocks, producer, yearend	490	420	310	270	390
Price, average, free on board gulf coast,[3] dollars per short ton	281	232	213	578	1,100
Employment, plant, number[e]	1,600	1,600	1,600	1,600	1,600
Net import reliance[4] as a percentage of apparent consumption	14	11	11	13	9

Recycling: None.

Import Sources (2018–21): Trinidad and Tobago, 58%; Canada 40%; Venezuela, 1%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Ammonia, anhydrous	2814.10.0000	Free.
Urea	3102.10.0000	Free.
Ammonium sulfate	3102.21.0000	Free.
Ammonium nitrate	3102.30.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The Henry Hub spot natural gas price ranged between $3.58 and $9.85 per million British thermal units for most of the year, with an average of about $6.63 per million British thermal units. Natural gas prices in 2022 were higher than those in 2021—a result of below-average storage levels of natural gas and strong demand for U.S. liquified natural gas. The Energy Information Administration, U.S. Department of Energy, projected that Henry Hub natural gas spot prices would average around $6.00 per million British thermal units in 2023.

The weekly average gulf coast ammonia price was $1,030 per short ton at the beginning of 2022 and increased to $1,150 per short ton in late October. The average ammonia price for 2022 was estimated to be $1,100 per short ton. In 2022, high natural gas prices resulted in higher ammonia prices.

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NITROGEN (FIXED)—AMMONIA

A long period of stable and low natural gas prices in the United States made it economical for companies to upgrade existing ammonia plants and construct new nitrogen facilities. The additional capacity has reduced ammonia imports. Expansion in the ammonia industry took place throughout the past 5 years; however, no additional U.S. ammonia capacity increases have been announced.

Global ammonia capacity is expected to increase by a total of 4% during the next 4 years. About one-third of the capacity additions were expected to take place in Belarus and Russia. As part of the capacity increase, several countries have proposed decarbonized ammonia plants. Consumption of ammonia for fertilizer is expected to increase by 1% per year depending on availability and cost with the largest increases expected in Latin America.

Large corn plantings maintain the continued demand for nitrogen fertilizers in the United States. According to the U.S. Department of Agriculture, U.S. corn growers planted 36.2 million hectares of corn in crop-year 2022 (July 1, 2021, through June 30, 2022), which was 4% less than the area planted in crop-year 2021. Corn acreage in crop-year 2023 is expected to increase because of anticipated higher returns for corn compared with those of other crops.

World Ammonia Production and Reserves:

	Plant production		Reserves[5]
	2021	2022[e]	
United States	12,700	13,000	Available atmospheric nitrogen and sources of natural gas for production of ammonia were considered adequate for all listed countries.
Algeria	2,600	2,600	
Australia	1,700	1,700	
Canada	3,760	3,800	
China	42,000	42,000	
Egypt	4,000	4,000	
Germany	2,290	2,000	
India	12,100	12,000	
Indonesia	6,000	6,000	
Iran	4,000	4,000	
Malaysia	1,400	1,400	
Netherlands	2,000	2,000	
Nigeria	1,100	1,100	
Oman	1,730	1,700	
Pakistan	3,400	3,400	
Poland	2,100	2,100	
Qatar	3,270	3,300	
Russia	16,300	16,000	
Saudi Arabia	4,300	4,300	
Trinidad and Tobago	4,050	4,200	
Ukraine	2,170	2,000	
Uzbekistan	1,200	1,100	
Vietnam	1,050	1,200	
Other countries	14,500	13,000	
World total (rounded)	150,000	150,000	

World Resources:[5] The availability of nitrogen from the atmosphere for fixed nitrogen production is unlimited. Mineralized occurrences of sodium and potassium nitrates, such as those found in the Atacama Desert of Chile, contribute minimally to the global nitrogen supply.

Substitutes: Nitrogen is an essential plant nutrient that has no substitute. No practical substitutes for nitrogen explosives and blasting agents are known.

[e]Estimated.

[1]Source: The Fertilizer Institute; data adjusted by the U.S. Geological Survey.

[2]Defined as production + imports – exports ± adjustments for industry stock changes.

[3]Source: Green Markets.

[4]Defined as imports – exports ± adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

PEAT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The estimated free on board (f.o.b.) mine value of marketable peat sold by producers in the conterminous United States was approximately $10 million in 2022. Peat was harvested and processed by 28 companies in 11 of the conterminous United States. Florida was the leading producing State. The other leading producing States were Illinois, Maine, Michigan, and Minnesota, and these top five States accounted for 98% of peat sold. Reed-sedge peat accounted for approximately 87% of the total volume produced, followed by sphagnum moss with 10%. Domestic peat applications included earthworm culture medium, golf course construction, mixed fertilizers, mushroom culture, nurseries, packing for flowers and plants, seed inoculants, and vegetable cultivation. In the industrial sector, peat was used as an oil absorbent and as an efficient filtration medium for the removal of waterborne contaminants in mine waste streams, municipal storm drainage, and septic systems.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	389	366	354	324	340
Sales by producers	409	420	386	386	350
Imports for consumption	1,200	1,160	1,390	1,630	1,500
Exports	37	46	46	37	37
Consumption, apparent[1]	1,580	1,400	1,690	1,970	1,700
Price, average unit value, f.o.b. mine, dollars per metric ton	27.53	25.77	26.25	38.52	28
Stocks, producer, yearend	196	280	288	235	290
Employment, mine and plant, number[e]	520	520	510	510	510
Net import reliance[2] as a percentage of apparent consumption	75	74	79	84	81

Recycling: None.

Import Sources (2018–21): Canada, 96%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Peat	2703.00.0000	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Peat is an important component of plant-growing media, and the demand for peat generally follows that of horticultural applications. In the United States, the short-term outlook was for production to average about 350,000 tons per year, and imported peat from Canada was expected to continue to account for more than 80% of domestic consumption. Imports for 2022 were estimated to have decreased to 1.5 million tons from 1.6 million tons in 2021, and exports were estimated to have remained about the same as those in 2021 at 37,000 tons. In 2022, peat stocks were estimated to have increased to approximately 290,000 tons from 235,000 tons in 2021. Based on estimated world production for 2022, the world's leading peat producers were, in descending order of production, Finland, Germany, Sweden, Latvia, Belarus, and Canada.

In many parts of the world, concerns about climate change prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's ability to act as a carbon sink. Ireland's peat production ended in 2021, as the country transitioned to alternative fuel sources. Ireland continued to produce peat briquettes but was expected to stop by 2024. Irish horticultural growers are importing peat to compensate for the lack of a domestic supply. Peat alternatives are currently not able to provide comparable crop yields in terms of growing quality and quantity.

Finland continued to work toward its goal of becoming carbon neutral by 2035. To achieve this, peat production was to be phased out in favor of other forms of noncarbon energy. In 2022, only about 14% of Finland's energy consumption was supplied by peat and other fossil fuels. About 53% of Finland's energy supply was generated using renewable energy sources, whereas 33% was produced by nuclear energy. Several European countries, including Belarus, Ireland, Scotland, and Sweden, were planning or implementing peatland restoration projects to help combat greenhouse-gas emissions and restore wildlife habitats. In August 2022, the United Kingdom announced a ban on peat sales to amateur gardeners by 2024 in an effort to protect peatlands. These initiatives were expected to decrease peat production across Europe in the future.

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PEAT

World Mine Production and Reserves: Reserves for countries that reported by volume only and had insufficient data for conversion to tonnage were combined and included with "Other countries."

	Mine production		Reserves[3]
	2021	2022[e]	
United States	324	340	150,000
Belarus	1,720	1,700	2,600,000
Canada	1,650	1,700	720,000
Estonia	347	350	570,000
Finland	5,430	5,400	6,000,000
Germany	2,600	2,600	([4])
Ireland	—	—	([4])
Latvia	2,000	2,000	150,000
Lithuania	479	480	210,000
Poland	1,100	1,000	([4])
Russia	1,250	1,200	1,000,000
Sweden	2,320	2,300	([4])
Ukraine	441	440	([4])
Other countries[e]	340	440	1,400,000
World total (rounded)	20,000	20,000	13,000,000

World Resources:[3] Peat is a renewable resource, continuing to accumulate on 60% of global peatlands. However, the volume of global peatlands has been decreasing at a rate of 0.05% per year owing to harvesting and land development. Many countries evaluate peat resources based on volume or area because the variations in densities and thickness of peat deposits make it difficult to estimate tonnage. Volume data have been converted using the average bulk density of peat produced in each of those countries. More than 50% of the U.S. peat resources are located in undisturbed areas of Alaska.

Substitutes: Natural organic materials, such as composted yard waste and coir (coconut fiber), compete with peat in horticultural applications. Shredded paper and straw are used to hold moisture for some grass-seeding applications. The superior water-holding capacity and physiochemical properties of peat limit substitution alternatives in most applications.

[e]Estimated. — Zero.

[1]Defined as production + imports – exports ± adjustments for industry stock changes.

[2]Defined as imports – exports ± adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Included with "Other countries."

PERLITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, the quantity of domestic processed crude perlite sold and used was estimated to be 520,000 tons with a value of $34 million. Crude ore production was from nine mines operated by six companies in six Western States. New Mexico continued to be the leading producing State. Domestic apparent consumption of crude perlite was estimated to be 720,000 tons. Processed crude perlite was expanded at 51 plants in 27 States. The applications for expanded perlite were building construction products, 44%; horticultural aggregate, 19%; fillers, 15%; filter aids, 14%; and other, 8%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Mine production, crude ore	504	629	845	884	880
Sold and used, processed crude perlite	444	397	493	496	520
Imports for consumption[1]	200	180	160	170	230
Exports[1]	16	19	25	27	29
Consumption, apparent[2]	630	560	630	640	720
Price, average value, free on board mine, dollars per ton	69	64	61	64	66
Employment, mine and mill, number	130	140	140	150	150
Net import reliance[3] as a percentage of apparent consumption	30	29	21	23	28

Recycling: Not available.

Import Sources (2018–21): Greece, 92%; China, 5%; Mexico, 2%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Vermiculite, perlite, and chlorites, unexpanded	2530.10.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Perlite is a siliceous volcanic glass that expands up to 20 times its original volume when rapidly heated. In horticultural uses, expanded perlite is used to provide moisture retention and aeration without compaction when added to soil. Horticultural perlite is useful to both commercial growers and hobby gardeners. Owing primarily to cost, some commercial greenhouse growers in the United States have recently switched to a wood fiber material instead of perlite. Perlite, however, remained a preferred soil amendment for segments of greenhouse growers because it does not degrade or compact over lengthy growing times and is inert. Construction applications for expanded perlite are numerous because it is fire resistant, an excellent insulator, and lightweight. Novel and small markets for perlite have increased during the past 10 years; cosmetics, environmental remediation, and personal care products have become increasing markets for perlite.

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PERLITE

The value of total construction put in place in the United States increased by about 11% during the first 6 months of 2022 compared with that of the same period in 2021, indicating a similar change in consumption of perlite. Construction products remained the largest domestic market for perlite. Increased interest in commercial greenhouse and hobby gardening may also correspond to increased consumption of horticultural-grade perlite.

Based on estimated world production for 2022, the world's leading producers were, in descending order of production, China, Turkey, Greece, and the United States, accounting for about 35%, 26%, 17%, and 12%, respectively, of world production. Although China was the leading producer, most of its perlite production was thought to be consumed internally. Greece and Turkey remained the leading exporters of perlite.

World Mine Production and Reserves: Reserves data for China were revised based on Government reports.

	Production		Reserves[4]
	2021	2022[e]	
United States	[5]496	[5]520	50,000
Argentina[e]	18	20	NA
Armenia[e]	80	180	NA
China[e]	1,500	1,500	78,000
Greece[e]	700	710	120,000
Hungary[e]	77	80	49,000
Iran[e]	32	30	73,000
Mexico[e]	24	20	NA
New Zealand[e]	18	20	NA
Slovakia[e]	37	40	NA
Turkey[e]	1,100	1,100	57,000
Other countries[e]	70	40	NA
World total (rounded)	4,150	4,300	NA

World Resources:[4] Perlite occurrences in Arizona, California, Idaho, Nevada, New Mexico, and Oregon may contain large resources. Significant deposits have been reported in China, Greece, Turkey, and a few other countries. Available information was insufficient to make reliable estimates of resources in many perlite-producing countries.

Substitutes: In construction applications, diatomite, expanded clay and shale, pumice, and slag can be substituted for perlite. For horticultural uses, coco coir, pumice, vermiculite, and wood pulp are alternative soil additives and are sometimes used in conjunction with perlite.

[e]Estimated. NA Not available.

[1]Exports and imports were estimated by the U.S. Geological Survey from U.S. Census Bureau combined data for vermiculite, perlite, and chlorites, unexpanded. Data are rounded to two significant digits.

[2]Defined as processed crude perlite sold and used + imports – exports. Data are rounded to two significant digits.

[3]Defined as imports − exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Processed ore sold and used by producers.

PHOSPHATE ROCK

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, phosphate rock ore was mined by five companies at nine mines in four States and processed into an estimated 21 million tons of marketable product, valued at $1.9 billion, free on board (f.o.b.) mine. Florida and North Carolina accounted for more than 75% of total domestic output; the remainder was produced in Idaho and Utah. Marketable product refers to beneficiated phosphate rock with phosphorus pentoxide (P_2O_5) content suitable for phosphoric acid or elemental phosphorus production. More than 95% of the phosphate rock mined in the United States was used to manufacture wet-process phosphoric acid and superphosphoric acid, which were used as intermediate feedstocks in the manufacture of granular and liquid ammonium phosphate fertilizers and animal feed supplements. About 25% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium phosphate (DAP) and monoammonium phosphate (MAP) fertilizer and merchant-grade phosphoric acid. The balance of the phosphate rock mined was for the manufacture of elemental phosphorus, which was used to produce phosphorus compounds for industrial applications, primarily glyphosate herbicide.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, marketable	25,800	23,300	23,500	21,600	21,000
Sold or used by producers	23,300	23,400	22,600	21,900	21,000
Imports for consumption	2,770	2,140	2,520	2,460	2,400
Consumption, apparent[1]	26,000	25,500	25,100	24,400	24,000
Price, average value, f.o.b. mine,[2] dollars per metric ton	70.80	68.00	75.90	83.10	90
Stocks, producer, yearend	10,600	9,830	11,000	10,700	10,000
Employment, mine and beneficiation plant, number[e]	1,900	1,900	1,800	2,000	2,000
Net import reliance[3] as a percentage of apparent consumption	2	11	5	11	12

Recycling: None.

Import Sources (2018–21): Peru, 95%; and Morocco, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Natural calcium phosphates:		
Unground	2510.10.0000	Free.
Ground	2510.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic production and consumption of phosphate rock were lower in 2022, owing to slightly lower production of elemental phosphorus and phosphoric acid. Domestic fertilizer production and consumption also were lower because of adverse weather conditions in some areas of the United States during the spring planting season, rail delays, high fertilizer costs, and hurricane damage to some production facilities. In Idaho, all three producers continued to develop new mines that will replace existing mines within the next decade.

World production of phosphate rock was estimated to have been slightly lower in 2022. The conflict between Russia and Ukraine caused some reduction of exports of phosphate rock and fertilizers from Russia. Although fertilizer materials were exempt from sanctions, some countries did not allow Russian ships in their ports.

In 2022, the global phosphate fertilizer market experienced supply disruptions, high fertilizer prices in the first half of the year, and lower consumption in some regions. The most significant supply disruption was from China placing restrictions on exports of DAP and MAP. This reduced Chinese exports by about 5 million tons. Other countries increased exports but were unable to compensate for the loss to the world market. Global consumption of P_2O_5 contained in fertilizers was estimated to have decreased slightly to about 48 million tons in 2022.

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PHOSPHATE ROCK

World Mine Production and Reserves: Reserves for China and Tunisia were revised based on Government reports. Reserves for Israel were revised based on company reports.

	Mine production		Reserves[4]
	2021	2022[e]	
United States	21,600	21,000	1,000,000
Algeria	[e]1,400	1,800	2,200,000
Australia	[e]2,500	2,500	[5]1,100,000
Brazil	[e]6,000	5,500	1,600,000
China[6]	[e]90,000	85,000	1,900,000
Egypt	[e]5,000	5,000	2,800,000
Finland	990	1,000	1,000,000
India	[e]1,400	1,400	46,000
Israel	2,430	3,000	60,000
Jordan	10,000	10,000	1,000,000
Kazakhstan	[e]1,500	1,500	260,000
Mexico	488	450	30,000
Morocco	38,100	40,000	50,000,000
Peru	4,200	4,200	210,000
Russia	[e]14,000	13,000	600,000
Saudi Arabia	[e]9,200	9,000	1,400,000
Senegal	[e]2,100	2,600	50,000
South Africa	2,130	1,600	1,600,000
Togo	[e]1,000	1,500	30,000
Tunisia	3,730	4,000	2,500,000
Turkey	[e]600	800	50,000
Uzbekistan	[e]900	900	100,000
Vietnam	[e]4,500	4,500	30,000
Other countries	1,950	1,600	2,600,000
World total (rounded)	226,000	220,000	72,000,000

World Resources:[4] Some world reserves were reported only in terms of ore tonnage and grade. Phosphate rock resources occur principally as sedimentary marine phosphorites. The largest sedimentary deposits are found in northern Africa, the Middle East, China, and the United States. Significant igneous occurrences are found in Brazil, Canada, Finland, Russia, and South Africa. Large phosphate resources have been identified on the continental shelves and on seamounts in the Atlantic Ocean and the Pacific Ocean. World resources of phosphate rock are more than 300 billion tons. There are no imminent shortages of phosphate rock.

Substitutes: There are no substitutes for phosphorus in agriculture.

[e]Estimated.

[1]Defined as phosphate rock sold or used by producers + imports. U.S. producers stopped exporting phosphate rock in 2003.

[2]Marketable phosphate rock, weighted value, all grades.

[3]Defined as imports ± adjustments for industry stock changes.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 124 million tons.

[6]Production data for large mines only, as reported by the National Bureau of Statistics of China.

PLATINUM-GROUP METALS

(Palladium, platinum, iridium, osmium, rhodium, and ruthenium)
[Data in kilograms of contained platinum-group metals (PGMs) unless otherwise noted]

Domestic Production and Use: One company in Montana produced PGMs with an estimated value of about $880 million. Small quantities of primary PGMs also were recovered as byproducts of copper-nickel mining in Michigan; however, this material was sold to foreign companies for refining. The leading domestic use for PGMs was in catalytic converters to decrease harmful emissions from automobiles. PGMs are also used in catalysts for bulk-chemical production and petroleum refining; dental and medical devices; electronic applications, such as in computer hard disks, hybridized integrated circuits, and multilayer ceramic capacitors; glass manufacturing; investment; jewelry; and laboratory equipment.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Mine production:[1]					
Palladium	14,300	14,300	14,600	13,700	11,000
Platinum	4,160	4,150	4,200	4,020	3,300
Imports for consumption:[2]					
Palladium	92,900	84,300	76,400	72,600	63,000
Platinum	58,500	42,300	64,800	67,900	56,000
PGM waste and scrap	40,700	35,200	185,000	185,000	49,000
Iridium	1,020	875	1,620	2,310	1,700
Osmium	25	([3])	1	1	—
Rhodium	14,500	15,000	20,700	16,500	13,000
Ruthenium	17,900	11,200	13,900	18,000	15,000
Exports:[4]					
Palladium	52,900	55,500	48,600	43,900	45,000
Platinum	18,900	17,400	28,900	29,400	28,000
PGM waste and scrap	31,700	20,800	33,200	37,800	38,000
Rhodium	2,010	1,210	1,480	1,350	720
Other PGMs	2,500	1,330	1,440	2,180	1,200
Consumption, apparent:[5, 6]					
Palladium	96,300	85,100	80,300	81,400	68,000
Platinum	53,700	37,000	48,200	53,500	42,000
Price, dollars per troy ounce:[7]					
Palladium	1,036.43	1,544.31	2,205.27	2,419.18	2,200
Platinum	882.66	866.94	886.02	1,094.31	980
Iridium	1,293.27	1,485.80	1,633.51	5,158.40	4,700
Rhodium	2,225.30	3,918.78	11,205.06	20,254.10	17,000
Ruthenium	244.41	262.59	271.83	576.12	600
Employment, mine, number	1,242	1,379	1,475	1,598	1,600
Net import reliance[6, 8] as a percentage of apparent consumption:					
Palladium	42	34	35	35	26
Platinum	74	67	75	72	66

Recycling: About 110,000 kilograms of palladium and platinum was recovered globally from new and old scrap in 2022, including about 40,000 kilograms of palladium and 11,000 kilograms of platinum recovered from automobile catalytic converters in the United States.

Import Sources (2018–21): Palladium: Russia, 34%; South Africa, 30%; Italy, 8%, Germany, 8%; and other, 20%. Platinum: South Africa, 34%; Germany, 18%; Switzerland, 14%; Italy, 7%; and other, 27%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free. See footnotes for specific Harmonized Tariff Schedule of the United States codes.

Depletion Allowance: 22% (domestic), 14% (foreign).

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PLATINUM-GROUP METALS

Government Stockpile:[9]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Iridium	15	—	15	—	15
Platinum	261	—	261	—	261

Events, Trends, and Issues: Production at a domestic mine continued but was constrained owing to operational challenges and flooding that took place in June 2022. Production of PGMs in South Africa, the world's leading producer of PGM-containing mined material, decreased compared with that in 2021 owing to operational challenges at some mines, including disruptions to the supply of electricity, temporary closures of processing facilities, and scheduled maintenance of smelters. A slow economic recovery from coronavirus disease 2019 (COVID-19) pandemic shutdowns and declining capital investments also negatively affected production. Constrained automobile production owing to semiconductor chip shortages, declining diesel passenger vehicle production, inflation, and slow economic growth are expected to result in decreased demand for palladium, platinum, and rhodium used in catalytic converters. Demand could be offset, however, by the development of PGM-based proton-exchange membrane fuel cells (also known as polymer electrolyte membrane fuel cells) used in hydrogen storage and transportation technologies.

The estimated annual average price of ruthenium in 2022 increased by 4% compared with that in 2021, whereas the estimated prices for rhodium, platinum, palladium, and iridium decreased by 16%, 10%, 9%, and 9%, respectively.

World Mine Production and Reserves:

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2021	2022[e]	2021	2022[e]	
United States	13,700	11,000	4,020	3,300	900,000
Canada	15,000	15,000	6,000	6,000	310,000
Russia	[e]86,000	88,000	[e]21,000	20,000	5,500,000
South Africa	84,300	80,000	142,000	140,000	63,000,000
Zimbabwe	12,400	12,000	14,700	15,000	1,200,000
Other countries	2,540	2,500	4,270	4,200	NA
World total (rounded)	214,000	210,000	192,000	190,000	70,000,000

World Resources:[10] World resources of PGMs are estimated to total more than 100 million kilograms. The largest resources and reserves are in the Bushveld Complex in South Africa.

Substitutes: Palladium has been substituted for platinum in most gasoline-engine catalytic converters because of the historically lower price for palladium relative to that of platinum. About 25% of palladium can routinely be substituted for platinum in diesel catalytic converters; the proportion can be as much as 50% in some applications. For some industrial end uses, one PGM can substitute for another, but with losses in efficiency.

[e]Estimated. NA Not available. — Zero.

[1]Estimated from published sources.

[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 7110.11.0010, 7110.11.0020, 7110.11.0050, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0010, 7110.41.0020, 7110.41.0030, 7110.49.0010, 7112.92.0000, 7112.92.0100, and 7118.90.0020.

[3]Less than ½ unit.

[4]Includes data for the following Schedule B codes: 7110.11.0000, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0000, 7110.49.0000, 7112.92.0000, and 7112.92.0100.

[5]Defined as primary production + secondary production + imports – exports.

[6]Excludes imports and (or) exports of waste and scrap.

[7]Engelhard Corp. unfabricated metal.

[8]Defined as imports – exports.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

POTASH

[Data in thousand metric tons of potassium oxide (K_2O) equivalent unless otherwise noted]

Domestic Production and Use: In 2022, the estimated sales value of marketable potash, free on board (f.o.b.) mine, was $760 million, which was 38% higher than that in 2021. The majority of U.S. production was from southeastern New Mexico, where two companies operated two underground mines and one deep-well solution mine. Sylvinite and langbeinite ores in New Mexico were beneficiated by flotation, dissolution-recrystallization, heavy-media separation, solar evaporation, and (or) combinations of these processes. In Utah, two companies operated three facilities. One company extracted underground sylvinite ore by deep-well solution mining. Solar evaporation crystallized the sylvinite ore from the brine solution, and a flotation process separated the muriate of potash (MOP) from byproduct sodium chloride. The firm also processed subsurface brines by solar evaporation and flotation to produce MOP at its other facility. Another company processed brine from the Great Salt Lake by solar evaporation to produce potassium sulfate or sulfate of potash (SOP) and other byproducts.

Potash denotes a variety of mined and manufactured salts that contain the element potassium in water-soluble form. In agriculture, the term potash refers to potassic fertilizers, which are potassium chloride (KCl), SOP, and potassium magnesium sulfate (SOPM) or langbeinite. MOP is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride for fertilizer use. The fertilizer industry used about 85% of U.S. potash sales, and the remainder was used for chemical and industrial applications. About 70% of the potash produced was SOPM and SOP, which are required to fertilize certain chloride-sensitive crops. The remainder of production was MOP and was used for agricultural and chemical applications.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, marketable[1]	520	510	460	480	440
Sales by producers, marketable[1]	520	480	500	490	440
Imports for consumption	5,710	5,150	5,370	6,480	7,000
Exports	105	145	147	112	300
Consumption, apparent[1, 2]	6,100	5,500	5,700	6,900	7,100
Price, average, f.o.b. mine, dollars per ton of K_2O equivalent:					
All products[3]	750	820	850	1,120	1,700
MOP	440	480	450	650	1,000
Employment, mine and mill, number	900	900	900	900	900
Net import reliance[4] as a percentage of apparent consumption	92	91	92	93	94

Recycling: None.

Import Sources (2018–21): Canada, 79%; Russia, 9%; Belarus, 7%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Potassium nitrate	2834.21.0000	Free.
Potassium chloride	3104.20.0000	Free.
Potassium sulfate	3104.30.0000	Free.
Potassic fertilizers, other	3104.90.0100	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, U.S. consumption was estimated to have increased by about 3% compared with that in 2021. World potash supply was affected by economic sanctions on Belarus and Russia and resulted in higher prices and lower consumption. World potash consumption in 2022 for fertilizers was estimated to have decreased to between 35 to 39 million tons from 40.6 million tons in 2021. In January 2022, the Government of Lithuania, citing national security concerns, cancelled the rail transport contract that allowed the state-run producer in Belarus to ship potash from the port of Klaipeda on the Baltic Sea, its only marine export facility. This followed the enactment of economic sanctions on Belarus in 2021 by the European Union (EU) and the United States, which banned the import of potash. Belarus was the third-leading potash supplier prior to 2022, shipping more than 6 million tons per year of K_2O equivalent. Some Belarus potash was shipped by rail through Russia to other countries in the region and from a Russian port later in the year, but exports and production of potash were significantly lower in 2022.

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POTASH

Following Russian troops taking control of parts of eastern Ukraine in February, the EU, the United States, and other countries placed economic sanctions on Russia. Fertilizer products, including potash, were exempt; however, the EU placed import quotas on potash from Russia. United States sanctions on certain Russian companies, financial institutions, and individuals limited the amount of potash that could be imported. Russia responded by suspending fertilizer exports to countries that it deemed unfriendly. Russia continued exports to China, India, and some countries in Africa and South America, but its exports were about 30% lower in 2022 compared with those in 2021. As a result of the reduction in world supplies of potash, producers in Canada announced production increases over the next year by more than 600,000 tons of K_2O equivalent. Canadian production capacity was planned to increase by more than 3 million tons per year of K_2O equivalent by 2025. Production in other exporting countries was expected to increase as well.

A new potash mine was in the development stage in Osceola County, MI. The proposed solution mine would have an initial production capacity of 650,000 tons per year of MOP and was planned to increase up to 1 million tons per year of MOP. The company planned to start production in 2025.

World annual potash production capacity was projected to increase to about 66 million tons in 2025 from 64 million tons in 2022. Most of the increase would be MOP from new mines and expansion projects in Belarus, Canada, and Russia. New SOP mines were planned in Australia and Eritrea, and a polyhalite mine in the United Kingdom would also contribute to the capacity growth. New MOP mines in Brazil, Canada, Ethiopia, Morocco, Spain, and the United States were planned to begin operation past 2025.

World Mine Production and Reserves: Reserves for China were revised based on Government reports.

	Mine production		Reserves[5]	
	2021	2022[e]	Recoverable ore	K_2O equivalent
United States[1]	480	440	970,000	220,000
Belarus	[e]7,630	3,000	3,300,000	750,000
Brazil	270	270	10,000	2,300
Canada	14,200	16,000	4,500,000	1,100,000
Chile	858	850	NA	100,000
China	[e]6,000	6,000	NA	170,000
Germany	[e]2,800	2,800	NA	150,000
Israel	2,380	2,500	NA	[6]Large
Jordan	1,560	1,700	NA	[6]Large
Laos	[e]260	600	500,000	75,000
Russia	9,100	5,000	NA	400,000
Spain	365	450	NA	68,000
Other countries	350	350	1,500,000	300,000
World total (rounded)	46,300	40,000	>11,000,000	>3,300,000

World Resources:[5] Estimated domestic potash resources total about 7 billion tons. Most of these lie at depths between 1,800 and 3,100 meters in a 3,110-square-kilometer area of Montana and North Dakota as an extension of the Williston Basin deposits in Manitoba and Saskatchewan, Canada. The Paradox Basin in Utah contains resources of about 2 billion tons, mostly at depths of more than 1,200 meters. The Holbrook Basin of Arizona contains resources of about 0.7 to 2.5 billion tons. A large potash resource lies about 2,100 meters under central Michigan and contains more than 75 million tons. Estimated world resources total about 250 billion tons.

Substitutes: No substitutes exist for potassium as an essential plant nutrient and as an essential nutritional requirement for animals and humans. Manure and glauconite (greensand) are low-potassium-content materials that can be profitably transported only short distances to crop fields. Glauconite is used as a potassium source for organic farming.

[e]Estimated. NA Not available.

[1]Data are rounded to no more than two significant digits to avoid disclosing company proprietary data.

[2]Defined as sales + imports – exports.

[3]Includes MOP, SOP, and SOPM. Does not include other chemical compounds that contain potassium.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Israel and Jordan recover potash from the Dead Sea, which contains nearly 2 billion tons of potassium chloride.

PUMICE AND PUMICITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 510,000 tons with an estimated processed value of about $30 million, free on board (f.o.b.) plant. That represented an increase in both quantity and value from the 2021 reported production of 504,000 tons valued at $23.2 million. Pumice and pumicite were mined in California, Idaho, Kansas, New Mexico, and Oregon. The porous, lightweight properties of pumice are well suited for its main uses. Mined pumice was used in the production of abrasives, concrete admixtures and aggregates, lightweight building blocks, horticultural purposes, and other uses, including absorbent, filtration, laundry stone washing, and road use.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine[1]	496	565	578	504	510
Imports for consumption	159	136	90	87	100
Exports	11	11	8	11	15
Consumption, apparent[2]	644	690	660	581	600
Price, average unit value, f.o.b. mine or mill, dollars per metric ton	32	28	31	46	50
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	23	18	12	13	14

Recycling: Little to no known recycling.

Import Sources (2018–21): Greece, 92%; Iceland, 5%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Pumice, crude or in irregular pieces, including crushed	2513.10.0010	Free.
Pumice, other	2513.10.0080	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced pumice and pumicite sold or used in 2022 was estimated to be slightly more than that in 2021. Imports and exports were estimated to have increased compared with those in 2021. Almost all imported pumice originated from Greece in 2022 and primarily supplied markets in the eastern and gulf coast regions of the United States.

Pumice and pumicite are plentiful in the Western States, but legal challenges and public land designations could limit access to known deposits. Production of pumice and pumicite is sensitive to mining and transportation costs.

All known domestic pumice and pumicite mining in 2022 was accomplished through open pit methods, generally in remote areas away from major population centers. Although the generation and disposal of reject fines in mining and milling may result in local dust issues at some operations, such environmental impacts were thought to be restricted to relatively small geographic areas.

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PUMICE AND PUMICITE

World production of pumice and related material was estimated to be 15 million tons in 2022, which was essentially unchanged from that in 2021. Turkey, followed by Uganda, was the leading global producer of pumice and pumicite. Pumice is used more extensively as a building material outside the United States, which explained the large global production of pumice relative to that of the United States. In Europe, basic home construction uses stone and concrete as the preferred building materials. Prefabricated lightweight concrete walls, which may contain pumice as lightweight aggregate, are often produced and shipped to construction locations. Because of their cementitious properties, light weight, and strength, pumice and pumicite perform well in European-style construction.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2021	2022[e]	
United States[1]	[5]504	510	Large in the United States.
Algeria[6]	900	900	Quantitative estimates of reserves for
Cameroon[6]	110	110	most countries were not available.
Chile[6]	670	670	
Ecuador[6]	800	800	
Ethiopia	510	510	
France[6]	280	300	
Greece[6]	960	960	
Guadeloupe	200	200	
Guatemala	570	570	
Iceland	100	100	
Jordan	900	900	
Saudi Arabia[6]	550	550	
Spain	240	240	
Syria[6]	200	200	
Tanzania	160	160	
Turkey	5,400	5,400	
Uganda	1,130	1,100	
Other countries[6]	710	820	
World total (rounded)	14,900	15,000	

World Resources:[4] The identified U.S. resources of pumice and pumicite, estimated to be more than 25 million tons, are concentrated in the Western States. The estimated total resources (identified and undiscovered) in the Western and Great Plains States are at least 250 million tons and may total more than 1 billion tons. Large resources of pumice and pumicite have been identified on all continents.

Substitutes: The costs of transportation determine the maximum economic distance pumice and pumicite can be shipped and still remain competitive with alternative materials. Competitive materials that may be substituted for pumice and pumicite include crushed aggregates, diatomite, expanded shale and clay, and vermiculite.

[e]Estimated.

[1]Quantity sold and used by producers.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

[5]Reported.

[6]Includes pozzolan and (or) volcanic tuff.

QUARTZ CRYSTAL (INDUSTRIAL)

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Industrial cultured quartz crystal is electronic-grade quartz crystal that is manufactured, not mined. In the past, cultured quartz crystal was primarily produced using lascas[1] as raw quartz feed material. Lascas mining and processing in Arkansas ended in 1997. In 2022, two companies produced cultured quartz crystal in the United States. However, production data were withheld in order to avoid disclosing company proprietary data. In addition to lascas, these companies may use cultured quartz crystal that has been rejected during the manufacturing process, owing to crystallographic imperfections, as feed material. The companies likely use a mix of cultured quartz and imported lascas as feed material. In the past several years, cultured quartz crystal has been increasingly produced overseas, primarily in Asia. Electronic applications accounted for most industrial uses of quartz crystal; other uses included special optical applications.

Virtually all quartz crystal used for electronics was cultured, rather than natural, crystal. Electronic-grade quartz crystal is used to make frequency controls, frequency filters, and timers in electronic circuits employed for a wide range of products, such as communications equipment, computers, and many consumer goods, such as electronic games and television receivers.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine (lascas)	—	—	—	—	—
Cultured quartz crystal	W	W	W	W	W
Imports for consumption:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	16,100	54,800	114,000	69,300	83,000
Exports:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	43,400	40,900	37,100	39,300	[2]60,000
Price, dollars per kilogram:[e, 3]					
As-grown cultured quartz	300	200	200	200	200
Lumbered quartz[4]	500	500	400	300	300
Net import reliance[5] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: An unspecified amount of rejected cultured quartz crystal was used as feed material for the production of cultured quartz crystal.

Import Sources (2018–21): Import statistics specific to lascas are not available because they are combined with other types of quartz. Cultured quartz crystal (piezoelectric quartz, unmounted): China,[6] 90%; Japan, 3%; Russia, 2%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad valorem.

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QUARTZ CRYSTAL (INDUSTRIAL)

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7] The National Defense Stockpile contains 11 weight classes for natural quartz crystal that range from 0.2 kilogram to more than 10 kilograms. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Quartz crystal	7,127	—	7,148	—	7,148

Events, Trends, and Issues: Increased imports of piezoelectric quartz in the past several years are likely the result of increased demand for frequency-control oscillators and vibration sensors for aerospace, automotive, and telecommunication applications. Growth of the consumer electronics market (for example, communications equipment, electronic games, personal computers, and tablet computers) is also likely to remain a factor in sustaining global production of cultured quartz crystal.

World Mine Production and Reserves:[8] This information is unavailable, but the global reserves for lascas are thought to be large.

World Resources:[8] Limited resources of natural quartz crystal suitable for direct electronic or optical use are available throughout the world. World dependence on these resources will continue to decline because of the increased acceptance of cultured quartz crystal as an alternative material. Additionally, techniques using rejected cultured quartz crystal as feed material may result in decreased dependence on lascas for growing cultured quartz.

Substitutes: Silicon is increasingly being used as a substitute for quartz crystal for frequency-control oscillators in electronic circuits. Other materials, such as aluminum orthophosphate (the very rare mineral berlinite), langasite, lithium niobate, and lithium tantalate, which have larger piezoelectric coupling constants, have been studied and used. Centrosymmetric materials that have induced piezoelectricity have also been studied. The cost competitiveness of these materials, as opposed to cultured quartz crystal, is dependent on the type of application that the material is used for and the processing required.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Lascas is a nonelectronic-grade quartz used as a feedstock for growing cultured quartz crystal and for production of fused quartz.

[2]Export data were adjusted by the U.S. Geological Survey. The U.S. Census Bureau reported 193,000 kilograms of exports through August 2022. The data were being reviewed by the U.S. Census Bureau for errors.

[3]Price is estimated from a combination of reported prices, trade data prices, and industry trends.

[4]As-grown cultured quartz that has been processed by sawing and grinding.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix B for definitions.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

RARE EARTHS[1]

[Data in metric tons of rare-earth-oxide (REO) equivalent unless otherwise noted]

Domestic Production and Use: Rare earths were mined domestically in 2022. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined as a primary product at a mine in Mountain Pass, CA. Monazite, a phosphate mineral, was produced as a separated concentrate or included as an accessory mineral in heavy-mineral-sand concentrates in the southeastern United States. Mixed rare-earth compounds were also produced in the western United States. The estimated value of rare-earth compounds and metals imported by the United States in 2022 was $200 million, a 25% increase from $160 million in 2021. The estimated leading domestic end use of rare earths was catalysts. A significant amount of rare earths are imported as permanent magnets embedded in finished goods. Other end uses were ceramics and glass, metallurgical applications and alloys, and polishing.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:[e]					
Mineral concentrates	14,000	28,000	39,000	42,000	43,000
Compounds and metals	—	—	—	120	250
Imports:[e, 2]					
Compounds	10,800	12,200	6,510	7,690	11,000
Metals:					
Ferrocerium, alloys	297	330	271	330	420
Rare-earth metals, scandium, and yttrium	526	627	363	580	520
Exports:[e, 2]					
Ores and compounds	17,900	28,300	40,000	44,000	44,000
Metals:					
Ferrocerium, alloys	1,250	1,290	625	825	1,700
Rare-earth metals, scandium, and yttrium	28	83	25	20	21
Consumption, apparent, compounds and metals[3]	9,600	11,200	5,400	6,060	9,300
Price, average, dollars per kilogram:[4]					
Cerium oxide, 99.5% minimum	2	2	2	2	1
Dysprosium oxide, 99.5% minimum	179	239	261	400	390
Europium oxide, 99.99% minimum	53	35	31	31	30
Lanthanum oxide, 99.5% minimum	2	2	2	2	1
Mischmetal, 65% cerium, 35% lanthanum	6	6	5	6	7
Neodymium oxide, 99.5% minimum	50	45	49	49	130
Terbium oxide, 99.99% minimum	455	507	670	1,300	2,000
Employment, mine and mill, annual average, number	190	202	185	293	370
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	100	100	100	>95	>95
Mineral concentrates	E	E	E	E	E

Recycling: Limited quantities of rare earths are recovered from batteries, permanent magnets, and fluorescent lamps.

Import Sources (2018–21): Rare-earth compounds and metals: China,[7] 74%; Malaysia, 8%; Estonia and Japan, 5% each; and other, 8%. Compounds and metals imported from Estonia, Japan, and Malaysia were derived from mineral concentrates and chemical intermediates produced in Australia, China, and elsewhere.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Rare-earth metals	2805.30.0000	5% ad valorem.
Cerium compounds	2846.10.0000	5.5% ad valorem.
Other rare-earth compounds:		
Oxides or chlorides	2846.90.2000	Free.
Carbonates	2846.90.8000	3.7% ad valorem.
Ferrocerium and other pyrophoric alloys	3606.90.3000	5.9% ad valorem.

Depletion Allowance: Monazite, 22% on thorium content and 14% on rare-earth content (domestic), 14% (foreign); bastnäsite and xenotime, 14% (domestic and foreign).

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RARE EARTHS

Government Stockpile:[8] In the addition to the materials listed below, the FY 2022 and FY 2023 potential acquisitions include cerium, 550 tons; lanthanum, 1,300 tons; neodymium, 600 tons; praseodymium, 70 tons; rare-earth magnet block, 100 tons; and samarium cobalt alloy, 50 tons.

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Dysprosium	0.2	20	—	—	—
Europium (gross weight)	35.8	—	—	—	—
Ferrodysprosium	0.5	—	—	—	—
Yttrium	25	25	—	—	—

Events, Trends, and Issues: Global mine production was estimated to have increased to 300,000 tons of REO equivalent. China's Ministry of Industry and Information Technology raised 2022 quotas for rare-earth mining and separation to 210,000 tons and 202,000 tons of REO equivalent, respectively. The mine production quota was allocated to 190,850 tons of light rare earths and 19,150 tons of ion-adsorption clays.

World Mine Production and Reserves: Reserves for Australia and the United States were revised based on company and Government reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States	42,000	43,000	2,300,000
Australia	[e]24,000	18,000	[10]4,200,000
Brazil	[e]500	80	21,000,000
Burma	[e]35,000	12,000	NA
Burundi	[e]200	—	NA
Canada	—	—	830,000
China	[11]168,000	[11]210,000	44,000,000
Greenland	—	—	1,500,000
India	[e]2,900	2,900	6,900,000
Madagascar	[e]6,800	960	NA
Russia	[e]2,600	2,600	21,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	[e]8,200	7,100	NA
Vietnam	400	4,300	22,000,000
Other countries	60	80	280,000
World total (rounded)	290,000	300,000	130,000,000

World Resources:[9] Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other mineral commodities. In North America, measured and indicated resources of rare earths were estimated to include 3.6 million tons in the United States and more than 14 million tons in Canada.

Substitutes: Substitutes are available for many applications but generally are less effective.

[e]Estimated. E Net exporter. NA Not available. — Zero.

[1]Data include lanthanides and yttrium but exclude most scandium. See also the Scandium and Yttrium chapters.

[2]REO equivalent or content of various materials were estimated. Source: U.S. Census Bureau.

[3]Defined as production + imports – exports.

[4]Source: Argus Media group, Argus Metals International.

[5]Defined as imports – exports.

[6]In 2018–2020, all domestic production of mineral concentrates was exported or held in inventory, and all compounds and metals consumed were assumed to be imported material.

[7]Includes Hong Kong.

[8]Gross weight. See Appendix B for definitions.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 2.98 million tons.

[11]Production quota; does not include undocumented production.

RHENIUM

(Data in kilograms of contained rhenium unless otherwise noted)

Domestic Production and Use: During 2022, rhenium-containing products including ammonium perrhenate (APR), metal powder, and perrhenic acid were produced as byproducts from roasting molybdenum concentrates from porphyry copper-molybdenum deposits in Arizona and Montana. U.S. primary production was approximately 9,000 kilograms in 2022, a 3% decrease from that in 2021. The United States continued to be a leading producer of secondary rhenium, recovering rhenium from nickel-base superalloy scrap, spent oil-refining catalysts, and foundry revert. The major uses of rhenium were in superalloys used in high-temperature turbine engine components and in petroleum-reforming catalysts, representing an estimated 80% and 15%, respectively, of end uses. Bimetallic platinum-rhenium catalysts were used in petroleum reforming for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Rhenium improves the high-temperature (>1,000 degrees Celsius) strength properties of some nickel-base superalloys. Rhenium alloys were used in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and other applications.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[1]	8,220	8,360	8,830	9,290	9,000
Imports for consumption					
Rhenium, unwrought and powders[2]	32,000	31,500	15,900	15,900	10,000
Ammonium perrhenate[3]	7,400	12,800	9,320	6,000	10,000
Exports	NA	NA	NA	NA	360
Consumption, apparent[4]	47,600	52,600	34,000	31,200	29,000
Price, average value, gross weight, dollars per kilogram:[5]					
Metal pellets, 99.99% pure	1,470	1,300	1,030	977	1,100
Ammonium perrhenate	1,410	1,280	1,090	866	910
Employment, number	Small	Small	Small	Small	Small
Net import reliance[6] as a percentage of apparent consumption	83	84	74	70	69

Recycling: Nickel-base superalloy scrap and scrapped turbine blades and vanes continued to be recycled hydrometallurgically to produce rhenium metal for use in new superalloy melts. The scrapped parts were also processed to generate engine revert—a high-quality, lower cost superalloy meltstock—by an increasing number of companies, mainly in Canada, Estonia, France, Germany, Japan, Poland, Russia, and the United States. Rhenium-containing catalysts were also recycled. The rhenium recycled from spent catalysts was either returned to the oil companies or to the catalyst producer for production of new catalysts in what is considered a closed-loop system.

Import Sources (2018–21): Ammonium perrhenate: Kazakhstan, 27%; Poland, 16%; Canada, 15%; Germany, 15%; and other, 27%. Rhenium metal powder: Chile, 84%; Canada, 8%; Germany, 6%; and other, 2%. Total imports: Chile, 63%; Canada, 10%; Germany, 8%; Kazakhstan, 7%; and other, 12%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad valorem.
Rhenium, unwrought, waste and scrap; powders	8112.41.0000	Free.
Rhenium, unwrought, waste and scrap	8112.41.1000	Free.
Rhenium, unwrought and powders	8112.41.5000	3% ad valorem.
Rhenium, unwrought and powders	8112.92.5000	3% ad valorem.
Rhenium (and other metals), wrought	8112.99.9100	4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, the price of catalytic-grade APR averaged $910 per kilogram, a 6% increase from the annual average price in 2021. The rhenium metal pellet price averaged $1,100 per kilogram in 2022, a 15% increase from the annual average price in 2021.

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RHENIUM

In 2022, apparent consumption in the United States was 8% less than that in 2021. During 2022, the United States continued to rely on imports for much of its supply of rhenium. Canada, Chile, Germany, Kazakhstan, and Poland supplied most of the imported rhenium. Imports of APR increased by 66% in 2022 compared with those in the previous year. Imports of rhenium metal decreased by 37% in 2022 compared with those in the previous year. World rhenium production in 2022 decreased slightly compared with that in 2021.

The United States and Germany continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Canada, Estonia, France, Japan, Poland, and Russia. Available information was insufficient to make U.S. secondary production estimates; however, industry sources estimated that U.S. capacity was between 18,000 and 20,000 kilograms per year of rhenium. Industry sources estimated that approximately 25,000 kilograms of secondary rhenium was produced worldwide in 2022. There were no primary rhenium projects in 2022 that were expected to significantly contribute to rhenium availability in the near future.

On February 24, 2022, a final U.S. critical minerals list was published in the Federal Register (87 FR 10381). The 2022 critical minerals list was an update of the list of critical minerals published in 2018 in the Federal Register (83 FR 23295). The 2022 critical minerals list contained 50 individual mineral commodities instead of 35 minerals and mineral groups. The changes in the 2022 list from the prior list were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

World Mine Production and Reserves:

	Mine production[e,7]		Reserves[8]
	2021	2022	
United States	9,290	9,000	400,000
Armenia	260	260	95,000
Chile[9]	30,000	29,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	500	500	190,000
Korea, Republic of	2,800	2,800	NA
Poland	9,290	9,500	NA
Russia	NA	NA	310,000
Uzbekistan	4,900	4,900	NA
World total (rounded)	59,500	58,000	Large

World Resources:[8] Most rhenium occurs with molybdenum in porphyry copper deposits. Identified U.S. resources are estimated to be about 7 million kilograms. Rhenium also is associated with copper minerals in sedimentary deposits in Armenia, Kazakhstan, Poland, Russia, and Uzbekistan, where ore is processed for copper recovery and the rhenium-bearing residues are recovered at copper smelters.

Substitutes: Substitutes for rhenium in platinum-rhenium catalysts are continually being evaluated. Iridium and tin have achieved commercial success in one such application. Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium's share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects. Materials that can substitute for rhenium in various end uses are as follows: cobalt and tungsten for coatings on copper X-ray targets, rhodium and rhodium-iridium for high-temperature thermocouples, tungsten and platinum-ruthenium for coatings on electrical contacts, and tungsten and tantalum for electron emitters.

[e]Estimated. NA Not available.

[1]Based on 80% recovery of estimated rhenium contained in molybdenum disulfide concentrates. Secondary rhenium production not included.

[2]Includes Harmonized Tariff Schedule of the United States (HTS) code 8112.92.5000 (2018–2021) and HTS code 8112.41.5000 (2022). Does not include wrought forms or waste and scrap.

[3]The rhenium content of ammonium perrhenate is 69.42%.

[4]Defined as production + imports – exports.

[5]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate. Source: Argus Media group, Argus Metals International.

[6]Defined as imports – exports.

[7]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Estimated rhenium recovered from roaster residues from Belgium, Chile, Mexico, and Peru.

RUBIDIUM

(Data in metric tons of rubidium oxide unless otherwise noted)

Domestic Production and Use: In 2022, no rubidium was mined in the United States; however, occurrences of rubidium-bearing minerals are known in Alaska, Arizona, Idaho, Maine, South Dakota, and Utah. Rubidium is also associated with some evaporate mineral occurrences in other States. Rubidium is not a major constituent of any mineral. Rubidium concentrate is produced as a byproduct of pollucite (cesium) and lepidolite (lithium) mining and is imported from other countries for processing in the United States.

Applications for rubidium and its compounds include biomedical research, electronics, pyrotechnics, and specialty glass. Specialty glasses are the leading market for rubidium; rubidium carbonate may be used to reduce electrical conductivity, which improves stability and durability in fiber-optic telecommunications networks. Biomedical applications may include rubidium salts used in antishock agents and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope may be used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride may be used as an antidepressant. Rubidium atoms are used in academic research, including the development of quantum-mechanics-based computing devices, a future application with potential for relatively high consumption of rubidium. Quantum computing research uses ultracold rubidium atoms in a variety of applications. Quantum computers, which have the ability to perform more complex computational tasks than traditional computers by calculating in two quantum states simultaneously, were under development with potential for entering the experimental phase by 2025.

Rubidium's photoemissive properties make it useful for electrical-signal generators in motion-sensor devices, night-vision devices, photoelectric cells (solar panels), and photomultiplier tubes. Rubidium may be used as an atomic resonance-frequency-reference oscillator for telecommunications network synchronization, playing a vital role in global positioning systems. Rubidium-rich feldspars may be used in ceramic applications for spark plugs and electrical insulators because of their high dielectric constant. Rubidium hydroxide may be used in fireworks to oxidize mixtures of other elements and produce violet hues. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 4 USNO rubidium fountain clocks.

Salient Statistics—United States: Consumption, export, and import data were not available. Some concentrate was imported to the United States in prior years for further processing. Industry information during the past decade suggests a domestic consumption rate of less than 2,000 kilograms per year. The United States was 100% import reliant for rubidium minerals.

In 2022, one company offered 1-gram ampoules of 99.75% (metal basis) rubidium for $100.80, an 8% increase from $93.40 in 2021, and 100-gram ampoules of the same material for $1,818.60, a 9% increase from $1,673.00 in 2021. The price for 10-gram ampoules of 99.8% (metal basis) rubidium formate hydrate was $278.25.

In 2022, the prices for 10 grams of 99.8% (metal basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $54.81, $77.70, $52.71, $67.10, and $52.50, respectively. The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $61.53 for 50 milliliters and $109.20 for 100 milliliters, a 7% and 17% increase, respectively, from those in 2021.

Recycling: None.

Import Sources (2018–21): No reliable data have been available to determine the source of rubidium ore or compounds imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of rubidium ore.

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RUBIDIUM

Tariff: Item	Number	Normal Trade Relations 12–31–22
Alkali metals, other	2805.19.9000	5.5% ad valorem.
Chlorides, other	2827.39.9000	3.7% ad valorem.
Bromides, other	2827.59.5100	3.6% ad valorem.
Iodides, other	2827.60.5100	4.2% ad valorem.
Sulfates, other	2833.29.5100	3.7% ad valorem.
Nitrates, other	2834.29.5100	3.5% ad valorem.
Carbonates, other	2836.99.5000	3.7% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic rubidium occurrences will remain subeconomic unless market conditions change, such as the development of new end uses or increased consumption for existing end uses, which in turn could lead to increased prices. No known human health issues are associated with exposure to naturally occurring rubidium, and its use has minimal environmental impact.

During 2022, no rubidium production was reported globally but rubidium was thought to have been produced in China. Production of rubidium from all countries, excluding China, ceased within the past two decades. Mining of rubidium in Namibia ceased in the early 2000s. Pollucite mining at the Tanco Mine in Canada (with the potential extraction of byproduct rubidium) ended in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018. The Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019. Recent reports indicate that with current processing rates, the world's commercial stockpiles of rubidium ore, excluding those in China, may be depleted in the near future.

Throughout 2022, multiple projects that could produce rubidium as a byproduct of lepidolite, pollucite, spodumene, or zinnwaldite mining, focused primarily on lithium or cesium extraction, were in the exploration and feasibility stages, and one company was working on mine development. Beginning in late 2021 and early 2022, pollucite ore from the Tanco Mine was being shipped to China for lithium recovery.

World Mine Production and Reserves:[1] There were no official sources for rubidium production data in 2022. Lepidolite and pollucite, the principal rubidium-containing minerals in global rubidium reserves, can contain up to 3.5% and 1.5% rubidium oxide, respectively. Rubidium-bearing mineral resources are found in zoned pegmatites. Mineral resources exist globally, but extraction and concentration are mostly cost prohibitive. No reliable data were available to determine reserves for specific countries; however, Australia, Canada, China, and Namibia were thought to have reserves totaling less than 200,000 tons. Existing stockpiles at multiple former mine sites have continued feeding downstream refineries.

World Resources:[1] Significant rubidium-bearing pegmatite occurrences have been identified in Afghanistan, Australia, Canada, China, Denmark, Germany, Japan, Kazakhstan, Namibia, Peru, Russia, the United Kingdom, the United States, and Zambia. Minor quantities of rubidium are reported in brines in northern Chile and China and in evaporites in the United States (New Mexico and Utah), France, and Germany.

Substitutes: Rubidium and cesium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

SALT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Domestic production of salt was estimated at 42 million tons in 2022, essentially unchanged compared with that in 2021. The total value of salt sold or used was estimated to be $2.5 billion, a slight increase from $2.4 billion in 2021. Salt was produced by 26 companies that operated 64 plants in 16 States. The top producing States were Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 94% of the salt in the United States in 2022. The estimated percentage of salt sold or used was, by type, rock salt, 43%; salt in brine, 40%; vacuum pan salt, 9%; and solar salt, 8%.

Highway deicing accounted for about 42% of total salt consumed. The chemical industry accounted for about 39% of total salt sales, with salt in brine accounting for 91% of the salt used for chemical feedstock. Chlorine and caustic soda manufacturers were the main consumers within the chemical industry. The remaining markets for salt were distributors, 9%; food processing, 4%; agricultural, 3%; general industrial, 2%; and primary water treatment, 1%.

Salient Statistics—United States:[1]	2018	2019	2020	2021	2022[e]
Production	43,900	[e]45,000	[e]43,000	[e]42,000	42,000
Sold or used by producers	44,200	[e]45,000	[e]43,000	[e]42,000	42,000
Imports for consumption	17,900	18,700	15,800	18,100	18,000
Exports	986	1,020	1,250	1,060	700
Consumption:					
Apparent[2]	61,100	62,500	[e]58,000	[e]59,000	59,000
Reported	53,000	51,800	[e]49,000	[e]50,000	49,000
Price, average unit value of bulk, pellets and packaged salt, free on board (f.o.b.) mine and plant, dollars per metric ton:					
Vacuum and open pan salt	214.12	211.57	[e]215	[e]220	230
Solar salt	114.32	126.18	[e]120	[e]125	130
Rock salt	60.78	59.90	[e]58	[e]57	60
Salt in brine	8.30	7.56	[e]8.00	[e]8.00	8.50
Employment, mine and plant, number[e]	4,100	4,100	4,000	4,100	4,000
Net import reliance[3] as a percentage of apparent consumption	28	28	25	29	29

Recycling: None.

Import Sources (2018–21): Chile, 29%; Canada, 28%; Mexico, 13%; Egypt, 11%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Demand for salt in 2022 remained lower than 2019 levels after the coronavirus disease 2019 (COVID-19) pandemic affected production and consumption of salt throughout the world in 2020 and 2021. Increased energy costs also negatively affected salt markets as increased processing and especially transportation costs negatively affected the ability to import and export salt at competitive prices for some international transactions.

For much of the 2021–22 winter, temperatures were near or above average with lower or average precipitation throughout most of the traditional U.S. snowbelt. The number of winter weather events including freezing rain, sleet, and snow is a better predictor of demand for rock salt than total snowfall. Several low snowfall or icing events usually require more salt for highway deicing than a single large snowfall event. Rock salt production and imports in 2022 were estimated to be near or slightly less than those in 2021 because demand from many local and State transportation departments were essentially unchanged from the previous year.

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SALT

For the 2022–23 winter, the National Oceanic and Atmospheric Administration predicted a La Niña weather pattern for the third consecutive year. A strong La Niña historically favors an average to warmer temperature pattern, but a moderate La Niña favors a colder winter. Based on several factors, the forecasts slightly favor higher precipitation winter than a normal winter for the Midwest, interior Northeast along the Canadian border, and northwestern area of the United States. Within this area, only the upper Midwest and the northwestern area of the United States were predicted to experience below-average temperatures. A warmer and drier pattern than average was predicted for the southern area of the United States. These forecasts would indicate that demand for rock salt could increase slightly in the upper the Midwest and northwestern areas of the United States but decrease in the northeastern United States.

Demand for salt brine used in the chloralkali industry was expected to increase in 2023 as demand for caustic soda and polyvinyl chloride increases globally, especially in Asia. Salt exports from Australia and especially India have increased in recent years to meet the increasing demand in China, but tensions between China and both countries could affect trade.

World Production and Reserves:

	Mine production		Reserves[4]
	2021	2022[e]	
United States[1]	[e]42,000	42,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	12,200	13,000	
Brazil	[e]7,400	7,400	
Canada	11,800	11,000	
Chile	8,570	9,000	
China	[e]64,000	64,000	
France	5,400	5,500	
Germany	[e]15,000	15,000	
India	[e]45,000	45,000	
Iran	[e]2,700	2,700	
Italy	1,900	2,000	
Mexico	[e]9,000	9,000	
Netherlands	6,120	6,200	
Pakistan	[e]3,000	3,300	
Poland	[e]4,000	4,000	
Russia	[e]6,500	6,000	
Saudi Arabia	2,330	2,400	
Spain	[e]4,200	4,200	
Turkey	[e]6,900	6,900	
Ukraine	[e]1,800	1,000	
United Kingdom	[e]2,400	2,800	
Other countries	[e]31,000	32,000	
World total (rounded)	294,000	290,000	

World Resources:[4] World continental resources of salt are vast, and the salt content in the oceans is nearly unlimited. Domestic resources of rock salt and salt from brine are primarily in Kansas, Louisiana, Michigan, New York, Ohio, and Texas. Saline lakes and solar evaporation salt facilities are in Arizona, California, Nevada, New Mexico, Oklahoma, and Utah. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

Substitutes: No economic substitutes or alternatives for salt exist in most applications. Calcium chloride and calcium magnesium acetate, hydrochloric acid, and potassium chloride can be substituted for salt in deicing, certain chemical processes, and food flavoring, but at a higher cost.

[e]Estimated.

[1]Excludes production from Puerto Rico.

[2]Defined as sold or used by producers + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SAND AND GRAVEL (CONSTRUCTION)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2022, 960 million tons of construction sand and gravel valued at $10 billion was produced by an estimated 3,300 companies operating 6,200 pits and 200 sales and (or) distribution yards in 50 States. Leading producing States were, in order of decreasing tonnage, California, Texas, Arizona, Minnesota, Washington, Utah, Michigan, Colorado, Ohio, and New York, which together accounted for about 53% of total output. An estimated 42% of construction sand and gravel was used as portland cement concrete aggregates, 26% for road base and coverings, 13% for construction fill, 10% for asphaltic concrete aggregate and for other bituminous mixtures, and 6% for other miscellaneous uses. The remaining 3% was used for concrete products, filtration, golf course maintenance, plaster and gunite sands, railroad ballast, road stabilization, roofing granules, and snow and ice control.

The estimated output of construction sand and gravel in the United States shipped for consumption in the first 9 months of 2022 was 724 million tons, a slight increase compared with that in the same period in 2021. Third-quarter shipments for consumption increased slightly compared with those in the same period in 2021. Additional production information, by quarter, for each State, geographic division, and the United States is reported by the U.S. Geological Survey in its quarterly Mineral Industry Surveys for construction sand and gravel and crushed stone.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	912	914	888	942	960
Imports for consumption	6	5	5	5	4
Exports	(2)	(2)	(2)	(2)	(2)
Consumption, apparent[3]	918	919	893	946	960
Price, average unit value, dollars per metric ton	9.18	9.65	9.93	10.36	11
Employment, mine and mill, number[4]	38,600	39,600	37,900	37,800	37,000
Net import reliance[5] as a percentage of apparent consumption	1	1	1	(2)	(2)

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain sand and gravel aggregate, were recycled on a limited but increasing basis in most States. In 2022, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2018–21): Canada, 95%; Mexico, 2%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Sand, other	2505.90.0000	Free.
Pebbles and gravel	2517.10.0015	Free.

Depletion Allowance: Common varieties, 5% (domestic and foreign).

Government Stockpile: None.

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SAND AND GRAVEL (CONSTRUCTION)

Events, Trends, and Issues: U.S. construction sand and gravel production was about 960 million tons in 2022, a slight increase compared with that in 2021. Apparent consumption also increased to 960 million tons. Consumption of construction sand and gravel increased in 2022 because of growth in the private and public construction markets. Usually, commercial and heavy-industrial construction activity, infrastructure funding, labor availability, new single-family housing unit starts, and weather affect growth in construction sand and gravel production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to infrastructure improvements around the Nation. The underlying factors that would support a rise in prices of construction sand and gravel are expected to be present in 2023, especially in and near metropolitan areas.

The construction sand and gravel industry continued to be concerned with environmental, health, permitting, safety, and zoning regulations. On November 15, 2021, the Infrastructure Investment and Jobs Act was signed into law. The legislation reauthorizes surface transportation programs for 5 years and invests $110 billion in additional funding to repair roads and bridges and support major, transformational projects. Movement of sand and gravel operations away from densely populated regions was expected to continue where zoning regulations and local sentiment discouraged them. Resultant regional shortages of construction sand and gravel and higher fuel costs could result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2021	2022[e]	
United States	942	960	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources:[6] Sand and gravel resources are plentiful throughout the world. However, because of environmental regulations, geographic distribution, and quality requirements for some uses, sand and gravel extraction is uneconomical in some cases. The most important commercial sources of sand and gravel have been glacial deposits, river channels, and river flood plains. Use of offshore deposits in the United States is mostly restricted to beach erosion control and replenishment. Other countries routinely mine offshore deposits of aggregates for onshore construction projects.

Substitutes: Crushed stone, the other major construction aggregate, is often substituted for natural sand and gravel, especially in more densely populated areas of the Eastern United States. Crushed stone remains the dominant choice for construction aggregate use. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2022.

[e]Estimated. NA Not available.

[1]See also the Sand and Gravel (Industrial) and Stone (Crushed) chapters.

[2]Less than ½ unit.

[3]Defined as production + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their sand and gravel production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

SAND AND GRAVEL (INDUSTRIAL)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, industrial sand and gravel production was an estimated 97 million tons valued at an estimated $5.7 billion. The quantity of industrial sand and gravel sold or used increased by 30% and the value increased by 78% compared with that in 2021. Industrial sand and gravel was produced by 122 companies from 201 operations in 32 States. The leading producing States were, in descending order of production, Texas, Wisconsin, Illinois, Louisiana, Missouri, Oklahoma, Arkansas, Alabama, California, and Tennessee. Combined production from these States accounted for about 87% of total domestic sales and use. Approximately 75% of the U.S. tonnage was used as hydraulic-fracturing sand (frac sand) and well-packing and cementing sand; and 10% as glassmaking sand. Other common uses were, in decreasing quantity of use, foundry sand, whole grain fillers for building products, filtration sand, and recreational sand, which accounted for 9%, combined. Other minor uses were, in decreasing quantity of use, chemicals, abrasives, roofing granules, silicon and ferrosilicon, ceramics, fillers, filtration gravel, traction, and metallurgic flux, which accounted for 3%, combined. Other unspecified uses accounted for 3%, combined.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Sold or used	126,000	108,000	75,800	74,600	97,000
Imports for consumption	392	389	417	350	350
Exports	6,550	5,620	4,070	5,430	6,400
Consumption, apparent[2]	120,000	103,000	72,100	69,500	91,000
Price, average value, dollars per metric ton	56.10	46.10	29.50	42.40	58
Employment, quarry and mill, number[e]	8,000	7,500	4,500	5,300	6,000
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Recycled cullet (pieces of glass) represents a significant proportion of reused silica. About 33% of glass containers are recycled. Some abrasive, foundry, frac sands are recycled or reclaimed.

Import Sources (2018–21): Canada, 87%; Vietnam, 3%; Brazil, Taiwan, and Turkey, 2% each; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Sand containing 95% or more silica and not more than 0.6% iron oxide	2505.10.1000	Free.

Depletion Allowance: Industrial sand or pebbles, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of industrial sand and gravel was estimated to be 91 million tons in 2022, a 31% increase from that in 2021. The most important driving force in the industrial sand and gravel industry remained the production and sale of hydraulic-fracturing sand. For several years, the consumption of frac sand increased as hydrocarbon exploration in the United States transitioned to natural gas and petroleum extracted from shale deposits. However, industrial sand and gravel consumption decreased in recent years, primarily as a result of decreased natural-gas- and petroleum-well drilling in North America and oil well completion activity. These decreases were exacerbated by restrictions imposed as the result of the global coronavirus disease 2019 (COVID-19) pandemic. These restrictions resulted in a significant decline in consumption of petroleum products, which in turn prompted a decrease in demand for frac sand. In 2022, industrial sand and gravel consumption increased as demand for frac sand increased. The increased demand for frac sand also led to higher prices for frac sand. Imports of industrial sand and gravel in 2022 were an estimated 350,000 tons, unchanged from those in 2021. Imports of silica are generally of two types—small shipments of very high purity silica or a few large shipments of lower grade silica shipped only under special circumstances (for example, very low freight rates). The United States remained a net exporter of industrial sand and gravel; U.S. exports of industrial sand and gravel were an estimated 6,400,000 tons, an 18% increase from those in 2021.

The United States was the world's leading producer and consumer of industrial sand and gravel based on estimated world production figures. Collecting definitive data on industrial sand and gravel production for most nations is difficult because of the wide range of terminology and specifications used by different countries. The United States remained a major exporter of industrial sand and gravel, shipping it to almost every region of the world. High global demand for U.S. industrial sand and gravel is attributed to its high quality and to the advanced processing techniques used in the United States for many grades of industrial sand and gravel, meeting specifications for virtually any use.

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SAND AND GRAVEL (INDUSTRIAL)

The industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2022, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration (OSHA) finalized regulations to further restrict exposure to crystalline silica at quarry sites and in other industries that use materials containing it.

Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations, and logistical issues, including ongoing development and permitting of operations producing hydraulic-fracturing sand. These factors may result in future sand and gravel operations being located farther from high-population centers. Increased efforts to reduce cost, emissions, and the risk of exposure to crystalline silica have led to an increase of undried “wet sand” being sold or used as frac sand instead of conventional “dry sand.” Industrial sand was used for commercial thermal energy storage for the first time in 2022.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2021	2022[e]	
United States	74,600	97,000	Large. Industrial sand and gravel deposits are widespread.
Argentina	[e]3,600	3,900	
Australia	[e]4,000	4,000	
Bulgaria	[e]8,150	8,600	
Canada	4,650	5,000	
China	[e]87,700	88,000	
France	[e]11,000	12,000	
Germany	[e]9,870	11,000	
India	[e]11,900	12,000	
Indonesia	[e]3,540	3,500	
Italy	[e]13,000	14,000	
Malaysia	[e]3,900	4,500	
Mexico	[e]2,500	2,700	
Netherlands	[e]54,000	54,000	
Poland	[e]5,180	5,500	
Russia	[e]7,300	7,300	
South Africa	[e]2,080	2,300	
Spain	[e]5,990	6,000	
Turkey	11,200	11,000	
United Kingdom	[e]5,300	5,300	
Other countries	[e]23,200	25,000	
World total (rounded)	353,000	380,000	

World Resources:[4] Sand and gravel resources of the world are large. However, because of their geographic distribution, environmental restrictions, and quality requirements for some uses, extraction of these resources is sometimes uneconomical. Quartz-rich sand and sandstone, the main sources of industrial silica sand, occur throughout the world.

Substitutes: Alternative materials that can be used for glassmaking and for foundry and molding sands are chromite, olivine, staurolite, and zircon sands. Although costlier and mostly used in deeper wells, alternative materials that can be used as proppants are sintered bauxite and kaolin-based ceramic proppants.

[e]Estimated. E Net exporter.

[1]See also the Sand and Gravel (Construction) chapter.

[2]Defined as production (sold or used) + imports – exports.

[3]Defined as imports – exports.

[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SCANDIUM[1]

(Data in metric tons of scandium oxide equivalent unless otherwise noted)

Domestic Production and Use: Domestically, scandium was neither mined nor recovered from process streams or mine tailings in 2022. Scandium was last produced domestically in 1969 primarily from the scandium-yttrium silicate mineral thortveitite and from byproduct leach solutions from uranium operations. Limited capacity to produce ingot and distilled scandium metal existed at facilities in Ames, IA; Tolleson, AZ; and Urbana, IL. The principal uses for scandium in 2022 were in aluminum-scandium alloys and solid oxide fuel cells (SOFCs). Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Price, yearend:					
Compounds, dollars per gram:					
Acetate, 99.9% purity, 5-gram lot size[2]	44	45	45	43	46
Chloride, 99.9% purity, 5-gram lot size[2]	125	129	133	137	140
Fluoride, 99.9% purity (99.99% purity in 2022), 1- to 5-gram lot size[3]	206	209	214	216	250
Iodide, 99.999% purity, 5-gram lot size[2]	165	157	161	161	170
Oxide, 99.99% purity, 5-kilogram lot size[4]	4.6	3.9	3.8	2.2	2.1
Metal:					
Scandium, dollars per gram:[2]					
Distilled dendritic, 2-gram lot size	226	233	233	238	260
Ingot, 5-gram lot size	132	134	134	137	150
Scandium-aluminum alloy, dollars per kilogram:[4]					
1-kilogram lot size	360	300	340	350	350
1,000-kilogram lot size	NA	NA	NA	NA	98
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Although no definitive data exist listing import sources, imported material was mostly from Europe, China, Japan, and the Philippines.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Rare-earth metals:		
Unspecified, not alloys	2805.30.0050	5% ad valorem.
Unspecified, alloyed	2805.30.0090	5% ad valorem.
Compounds of rare-earth metals:		
Mixtures of oxides of yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of chlorides of yttrium or scandium as the predominant metal	2846.90.2082	Free.
Mixtures of other rare-earth carbonates, including scandium	2846.90.8075	3.7% ad valorem.
Mixtures of other rare-earth compounds, including scandium	2846.90.8090	3.7% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global supply and consumption of scandium oxide was estimated to be about 20 to 30 tons per year with a global capacity estimate of 80 tons per year. Scandium was recovered from titanium, zirconium, cobalt, and nickel process streams. China, the Philippines, and Russia were the leading producers. Prices quoted for scandium oxide in the United States in 2022 continued to decrease over a 5-year period.

In the United States, a metallurgical testing program with the goal of production of scandium from the polymetallic Elk Creek project in Nebraska continued, and additional financing for the project was announced. Probable reserves were estimated to be 36 million tons containing 70.2 parts per million (2,600 tons) of scandium. Plans for the project included downstream production of ferroniobium, titanium dioxide, and scandium oxide. At the La Paz Scandium and Rare Earths project in Arizona, efforts were ongoing—metallurgical test work was completed, and drilling continued in 2022.

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SCANDIUM

The Defense Logistics Agency-sponsored Small Business Innovative Research program is supporting business development to produce high-purity scandium from titanium dioxide acid waste and support commercial-scale efforts. In September, the Department of Defense through the Defense Manufacturing Community Support Program awarded over $4 million to the Supply Chain of Recovered Elements Consortium (SCORE) to utilize mine and industrial waste to extract scandium which would then go into the domestic aluminum alloys supply chain. Research continued to develop methods for separating scandium from coal and coal byproducts. SOFC sourcing of scandium was expanding beyond China to include Japan and the Philippines.

A global mining and polymetallic metal producer completed commissioning of a 3-ton-per-year nameplate capacity scandium commercial-scale plant at its metallurgical complex in Sorel-Tracy, Quebec, Canada, making it the first North American producer of high-purity scandium oxide that will be used to make an aluminum alloy. High-grade scandium resources in Crater Lake, Quebec, exceed 20 million tons according to a Preliminary Economic Assessment.

In Australia, several polymetallic projects were under development and seeking permitting, financing, and offtake agreements including the Sunrise, Nyngan, and Owendale projects. Sunrise Energy Metals in New South Wales has been granted Major Project Status. Additional exploration began at the Sconi project in Queensland.

In the Philippines, the Taganito high-pressure acid-leach nickel commercial plant is recovering 7 to 8 tons per year of scandium oxide. Scandium oxalate production in 2021 was 16 tons, and production in 2022 through June was 9.7 tons.

In Russia, high-purity scandium oxide was recovered from red mud at an industrial site at the Ural Aluminum Smelter by using new process technology. In Greece, a pilot-scale plant demonstrated scandium extraction from bauxite residue using sulfuric acid leaching and selective-ion recovery producing a concentrate containing 22% scandium by weight.

In China, a large state-owned enterprise in Shanghai had 50 tons per year of scandium oxide production capacity with a long-term plan to increase to 100 tons per year. Another company in Henan Province had a 10-ton-per-year scandium oxide capacity with plans to increase output to 20 tons per year.

World Mine Production and Reserves:[6] No scandium was recovered from mining operations in the United States. As a result of its low concentration, scandium is produced exclusively as a byproduct during processing of various ores or recovered from previously processed tailings or residues. Historically, scandium was produced as byproduct material in China (iron ore, rare earths, titanium, and zirconium), Kazakhstan (uranium), the Philippines (nickel), Russia (apatite and uranium), and Ukraine (uranium). Foreign mine production data for 2021 and 2022 were not available.

World Resources:[6] Resources of scandium were abundant. Scandium's crustal abundance is greater than that of lead. Scandium lacks affinity for the common ore-forming anions; therefore, it is widely dispersed in the lithosphere and forms solid solutions with low concentrations in more than 100 minerals. Scandium resources have been identified in Australia, Canada, China, Finland, Guinea, Kazakhstan, Madagascar, Norway, the Philippines, Russia, South Africa, Ukraine, and the United States.

Substitutes: Titanium and aluminum high-strength alloys as well as carbon-fiber materials may substitute in high-performance scandium-alloy applications. Under certain conditions, light-emitting diodes may displace mercury-vapor high-intensity lamps that contain scandium iodide. In some applications that rely on scandium's unique properties, substitution is not possible.

[e]Estimated.

[1]See also the Rare Earths chapter. Scandium is one of the 17 rare-earth elements.

[2]Source: Alfa Aesar, a part of Thermo Fisher Scientific Inc.

[3]Source: Sigma-Aldrich, a part of MilliporeSigma.

[4]Source: Stanford Materials Corp.

[5]Defined as imports – exports. Quantitative data were not available.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

SELENIUM

(Data in metric tons of contained selenium unless otherwise noted)

Domestic Production and Use: Selenium is primarily recovered as a byproduct of the electrolytic refining of copper, where it accumulates in the residues of copper anodes. In 2022, two electrolytic copper refineries operated in the United States, one in Texas and one in Utah, and produced selenium-bearing anode slimes. Domestic selenium production, consumption, and stocks were withheld to avoid disclosing company proprietary data.

Selenium is used as an active ingredient in antidandruff shampoos; in agriculture as a fertilizer additive to increase plant tolerance to environmental stressors; in blasting caps to control delays; in catalysts to enhance selective oxidation; in copper, lead, and steel alloys to improve machinability; in the electrolytic production of manganese metal to increase yields; in glass manufacturing to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass; in gun bluing to improve cosmetic appearance and provide corrosion resistance; in photocells and solar cells used in electronics for its photovoltaic and photoconductive properties; in pigments to produce a red color; in plating solutions to improve appearance and durability; in rubber compounding chemicals to act as a vulcanizing agent; and in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells. Selenium is also an essential micronutrient and is used as a dietary supplement for humans and livestock.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, refinery[1]	W	W	W	W	W
Imports for consumption:					
Selenium	445	465	366	346	360
Selenium dioxide	12	5	18	71	10
Exports[2]	158	361	147	227	270
Consumption, apparent[3]	W	W	W	W	W
Price, average, dollars per pound:					
United States[4]	16.85	9.15	6.61	8.25	10.00
Europe[5]	17.68	9.27	6.67	8.38	9.00
Stocks, producer, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>75	>50	>75	>50	>50

Recycling: Domestic production of secondary selenium was estimated to be very small because most scrap from older photocopiers and electronic materials was exported for recovery of the contained selenium.

Import Sources (2018–21): Selenium: Philippines, 21%; Mexico, 15%; Germany, 13%; China,[7] 9%; and other, 42%. Selenium dioxide: Republic of Korea, 79%; China, 8%; Germany, 6%; Philippines, 5%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
Selenium	2804.90.0000	Free.
Selenium dioxide	2811.29.2000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The selenium content of domestic copper anode slimes was estimated to have increased in 2022. The annual average price for selenium in the United States was an estimated $10 per pound, an increase of 21% from that in 2021. Producers in China, which accounted for about 40% of estimated global output of refined selenium in 2022, raised their price offers for selenium to counteract increasing production costs. The supply of selenium is directly affected by the supply of the materials from which it is a byproduct, primarily copper.

In China, coronavirus disease 2019 (COVID-19) pandemic lockdowns throughout the country affected the demand for selenium from the ceramics, glass, and manganese industries, and multiple leading manganese producers in the country reportedly reduced output. The leading global end use for selenium in 2022 was estimated to be for the production of electrolytic manganese in China. In June 2022, the Government of China released a development plan for renewable energy and set goals of generating 25% of energy consumption and installing 1.2 million megawatts of capacity for wind and solar power by 2030. If realized, the proposals would likely increase the demand for selenium from the solar industry for thin-film CIGS solar panels. End uses for selenium in global consumption were, in descending order by estimated quantity, metallurgy (including electrolytic manganese metal production), glass manufacturing, agriculture, chemicals and pigments, electronics, and other applications.

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SELENIUM

World Refinery Production and Reserves: The values shown for reserves are the estimated selenium content of copper reserves, with the exception of China. Reserves for China were revised based on Government reports, and reserves for India and Sweden were revised based on company reports.

	Refinery production[e, 8]		Reserves[9]
	2021	2022	
United States	W	W	10,000
Belgium	200	200	—
Canada	57	65	6,000
China	1,260	1,300	6,100
Finland	80	65	NA
Germany	300	300	—
India	14	15	500
Japan	720	730	—
Peru	36	40	13,000
Poland	74	75	3,000
Russia	300	350	20,000
Sweden	5	5	500
Turkey	50	50	NA
Other countries[10]	21	25	22,000
World total (rounded)[11]	3,100	3,200	81,000

World Resources:[9] Reserves for selenium are based on identified copper deposits and average selenium content. Other potential sources of selenium include lead, nickel, and zinc ores. Coal generally contains between 0.5 and 12 parts per million selenium, or about 80 to 90 times the average for copper deposits. The recovery of selenium from coal fly ash, although technically feasible, does not appear likely to be economical in the foreseeable future.

Substitutes: Amorphous silicon and cadmium telluride are the two principal competitors with CIGS in thin-film photovoltaic solar cells. Organic pigments have been developed as substitutes for cadmium sulfoselenide pigments. Silicon is the major substitute for selenium in low- and medium-voltage rectifiers. Sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal but is not as energy efficient. Other substitutes include bismuth, lead, and tellurium in free-machining alloys; bismuth and tellurium in lead-free brasses; cerium oxide as either a colorant or decolorant in glass; and tellurium in pigments and rubber.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Selenium content of copper anode slimes.

[2]Includes Schedule B code 2804.90.0000 (selenium) only because there is no exclusive Schedule B code for selenium dioxide.

[3]Production + imports (excluding selenium dioxide) – exports ± adjustments for industry stock changes.

[4]Average annual price for selenium powder, free on board, U.S. warehouse, 99.5% minimum purity. Source: Argus Media group, Argus Metals International.

[5]Average annual price for selenium powder, in warehouse, Rotterdam, 99.5% minimum purity. Source: Argus Media group, Argus Metals International.

[6]Defined as imports (excluding selenium dioxide) – exports ± adjustments for industry stock changes.

[7]Includes Hong Kong.

[8]Insofar as possible, data include refinery output only; countries that produced selenium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues but did not recover refined selenium from these materials were excluded to avoid double counting.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Refinery production data include Serbia, South Africa, and Uzbekistan. Australia, Iran, Kazakhstan, Mexico, and the Philippines may also have produced refined selenium, but output was not reported, and available information was inadequate to make reliable production estimates.

[11]Excludes U.S. production.

SILICON

(Data in thousand metric tons of contained silicon unless otherwise noted)

Domestic Production and Use: Silicon materials were produced at six facilities in 2022, all east of the Mississippi River. Most ferrosilicon was consumed in the ferrous foundry and steel industries, predominantly in the Eastern United States, and was sourced primarily from domestic quartzite (silica). The main consumers of silicon metal were producers of aluminum alloys and the chemical industry, in particular for the manufacture of silicones. The semiconductor and solar energy industries, which manufacture chips for computers and photovoltaic cells from high-purity silicon, respectively, also consumed silicon metal.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, ferrosilicon[1] and silicon metal[2]	430	310	277	313	310
Imports for consumption:					
Ferrosilicon, all grades	140	127	140	125	200
Silicon metal	116	124	97	96	120
Exports:					
Ferrosilicon, all grades	12	8	4	7	8
Silicon metal	45	40	31	53	49
Consumption, apparent,[3] ferrosilicon[1] and silicon metal[2]	637	517	481	475	570
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% silicon[4]	104.24	102.35	103.38	137.94	NA
Ferrosilicon, 75% silicon[5]	107.58	89.15	87.40	192.28	350
Silicon metal[2, 5]	134.15	105.70	96.84	220.31	400
Stocks, producer, ferrosilicon[1] and silicon metal,[2] yearend	19	15	12	11	17
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades	<50	<50	>50	<50	>50
Silicon metal[2]	<25	<50	<50	<25	<50
Total	32	40	42	34	45

Recycling: Insignificant.

Import Sources (2018–21): Ferrosilicon: Russia, 40%; Canada, 14%; Brazil, 12%; Malaysia, 9%; and other, 25%. Silicon metal: Brazil, 31%; Canada, 24%; Norway, 14%; Thailand, 7%; and other, 24%. Total: Russia, 22%; Brazil, 20%; Canada, 18%; Norway, 8%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Silicon:		
More than or equal to 99.99% silicon	2804.61.0000	Free.
More than or equal to 99.00% but less than 99.99% silicon	2804.69.1000	5.3% ad valorem.
Other	2804.69.5000	5.5% ad valorem.
Ferrosilicon:		
More than 55% but less than or equal to 80% silicon:		
More than 3% calcium	7202.21.1000	1.1% ad valorem.
Other	7202.21.5000	1.5% ad valorem.
More than 80% but less than or equal to 90% silicon	7202.21.7500	1.9% ad valorem.
More than 90% silicon	7202.21.9000	5.8% ad valorem.
Other:		
More than 2% magnesium	7202.29.0010	Free.
Other	7202.29.0050	Free.

Depletion Allowance: Quartzite, 14% (domestic and foreign); gravel, 5% (domestic and foreign).

Government Stockpile: None.

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SILICON

Events, Trends, and Issues: Combined domestic ferrosilicon and silicon metal production in 2022, expressed in terms of contained silicon, was unchanged from that in 2021. One producer restarted a silicon metal production facility in early 2022 owing to increased demand for silicon metal in North America. By August 2022, average U.S. spot market prices increased by over 80% for both 75%-grade ferrosilicon and silicon metal compared with the annual averages in 2021.

Excluding the United States, ferrosilicon accounted for over 60% of world silicon production on a silicon-content basis in 2022. The leading countries for ferrosilicon production were, in descending order on a silicon-content basis, China, Russia, and Norway. For silicon metal, the leading producers were, in descending order on a silicon-content basis, China, Brazil, and Norway. China accounted for almost 70% of total global estimated production of silicon materials in 2022. Global production of silicon materials, on a silicon-content basis, was estimated to be about 4% less than that in 2021. Global production of steel, the leading use of ferrosilicon, decreased in 2022 compared with production in 2021 owing to supply chain disruptions resulting from the conflict between Russia and Ukraine and intermittent coronavirus disease 2019 (COVID-19) pandemic-related lockdowns in China.

In August, the President signed the Creating Helpful Incentives to Produce Semiconductors and Science (CHIPS) Act of 2022; the Act supports an increase in U.S. semiconductor manufacturing by providing grants for semiconductor manufacturing, grants for research investments, and tax incentives for chip manufacturing.

World Production and Reserves:

	Production[e, 7]		Reserves[8]
	2021	2022	
United States	313	310	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates were not available.
Australia	50	50	
Bhutan[9]	85	85	
Brazil	389	400	
Canada	49	49	
China	6,400	6,000	
France	127	120	
Germany	63	63	
Iceland	111	110	
India[9]	59	59	
Kazakhstan	122	120	
Malaysia[9]	85	92	
Norway	362	360	
Poland[9]	49	49	
Russia	644	640	
Spain	60	57	
Ukraine[9]	49	19	
Other countries	128	210	
World total (rounded)	9,150	8,800	

World Resources:[8] World and domestic resources for making silicon metal and alloys are abundant and, in most producing countries, adequate to supply world requirements for many decades. The source of the silicon is silica in various natural forms, such as quartzite.

Substitutes: Aluminum, silicon carbide, and silicomanganese can be substituted for ferrosilicon in some applications. Gallium arsenide and germanium are the principal substitutes for silicon in semiconductor and infrared applications.

[e]Estimated. NA Not available.

[1]Ferrosilicon grades include the two standard grades of ferrosilicon—50% silicon and 75% silicon—plus miscellaneous silicon alloys.

[2]Metallurgical-grade silicon metal.

[3]Defined as production + imports – exports ± adjustments for industry stock changes.

[4]Source: CRU Group, transaction prices based on weekly averages. Average spot prices for ferrosilicon, 50% grade, were discontinued in April 2022.

[5]Source: S&P Global Platts Metals Week, mean import prices based on monthly averages.

[6]Defined as imports – exports ± adjustments for industry stock changes.

[7]Production quantities are the silicon content of combined totals for ferrosilicon and silicon metal, except as noted.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]Silicon content of ferrosilicon only.

SILVER

(Data in metric tons[1] of contained silver unless otherwise noted)

Domestic Production and Use: In 2022, U.S. mines produced approximately 1,100 tons of silver with an estimated value of $720 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 31 domestic base- and precious-metal operations. Alaska continued as the country's leading silver-producing State, followed by Nevada. There were 24 U.S. refiners that reported production of commercial-grade silver with an estimated total output of 2,700 tons from domestic and foreign ores and concentrates and from new and old scrap. The physical properties of silver include high ductility, electrical conductivity, malleability, and reflectivity. In 2022, the estimated domestic uses for silver were physical investment (bars), 34%; electrical and electronics, 27%; coins and medals, 13%; photovoltaics (PV), 10%; jewelry and silverware, 6%; brazing and solder, 3%; and other industrial uses and photography, 7%. Other applications for silver include use in antimicrobial bandages, clothing, pharmaceuticals, and plastics; batteries; bearings; brazing and soldering; catalytic converters in automobiles; electroplating; inks; mirrors; photography; photovoltaic solar cells; water purification; and wood treatment. Mercury and silver, the main components of dental amalgam, are biocides, and their use in amalgam inhibits recurrent decay.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	934	981	1,080	1,020	1,100
Refinery:					
Primary	1,420	1,360	1,400	1,920	1,800
Secondary (new and old scrap)	632	627	582	908	900
Imports for consumption[2]	4,840	4,760	6,730	6,160	4,600
Exports[2]	604	220	140	137	230
Consumption, apparent[3]	5,780	6,270	8,250	7,950	6,400
Price, bullion, average, dollars per troy ounce[4]	15.73	16.24	20.58	25.23	21
Stocks, yearend:					
Industry	170	52	55	56	50
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	9,150	9,860	12,334	11,064	9,200
Employment, mine and mill, number[6]	971	995	1,180	1,440	1,300
Net import reliance[7] as a percentage of apparent consumption	73	74	80	76	69

Recycling: In 2022, approximately 900 tons of silver was recovered from new and old scrap, accounting for about 14% of apparent consumption.

Import Sources (2018–21):[2] Mexico, 47%; Canada, 21%; Poland, 5%; Chile, 4%; and other, 23%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Silver ores and concentrates	2616.10.0040	0.8 ¢/kg on lead content.
Bullion	7106.91.1010	Free.
Dore	7106.91.1020	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of silver (see salient statistics above).

Events, Trends, and Issues: The estimated average silver price in 2022 was $21 per troy ounce, 17% lower than the average price in 2021. The price began the year at $22.80 per troy ounce, increased to a high of $26.45 per troy ounce on March 8, then decreased to a low of $17.85 per troy ounce on September 1. The price of silver began to increase in September into December.

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SILVER

In 2022, global consumption of silver was estimated to have reached 38,000 tons, a new record and a 16% increase from that in 2021. Coin and bar consumption increased by 18% in 2022, increasing for the sixth year in a row. Physical investment in India nearly doubled compared with that in 2021. In 2022, consumption of silver for industrial uses was estimated to have increased by 5% compared with that in 2021 owing to the installation of fifth-generation (5G) telecommunications infrastructure, increased production of PV, increased production of light duty vehicles (LDVs), and more silver used in newer LDVs. Consumption of silver in jewelry and silverware was estimated to have increased by 29% and 72%, respectively.[8]

World silver mine production increased by 4% in 2022 to an estimated 26,000 tons, principally as a result of increased production from mines in Chile and other countries as silver mines were still recovering from shutdowns in 2020 in response to the coronavirus disease 2019 (COVID-19) pandemic. Domestic silver mine production was estimated to have increased by 8% in 2022 to 1,100 tons compared with 1,020 tons produced in 2021.

World Mine Production and Reserves: Reserves for Australia, China, Peru, and Poland were revised based on Government reports. Reserves for Argentina and the United States were revised based on company reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States	1,020	1,100	23,000
Argentina	[e]720	840	6,500
Australia	1,360	1,400	[10]92,000
Bolivia	1,290	1,300	22,000
Chile	1,280	1,600	26,000
China	3,500	3,600	71,000
India	[e]610	630	7,200
Mexico	6,110	6,300	37,000
Peru	3,310	3,100	98,000
Poland	1,300	1,300	65,000
Russia	1,320	1,200	45,000
Other countries	3,200	3,500	57,000
World total (rounded)	25,000	26,000	550,000

World Resources:[9] Although silver was a principal product at several mines, silver was primarily obtained as a byproduct from lead-zinc, copper, and gold mines, in descending order of silver production. The polymetallic ore deposits from which silver was recovered account for more than two-thirds of U.S. and world resources of silver. Most recent silver discoveries have been associated with gold occurrences; however, copper and lead-zinc occurrences that contain byproduct silver will continue to account for a significant share of reserves and resources in the future.

Substitutes: Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for traditional photographic applications for silver. Surgical pins and plates may be made with stainless steel, tantalum, and titanium in place of silver. Stainless steel may be substituted for silver flatware. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles.

[e]Estimated.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Silver content of base metal ores and concentrates, ash and residues, refined bullion, and dore; excludes coinage and waste and scrap material.

[3]Defined as mine production + secondary production + imports – exports ± adjustments for Government and industry stock changes.

[4]Engelhard's industrial bullion quotations. Source: S&P Global Platts Metals Week.

[5]Source: U.S. Mint. Balance in U.S. Mint only; includes deep storage and working stocks.

[6]Source: U.S. Department of Labor, Mine Safety and Health Administration (MSHA). Only includes mines where silver is the primary product.

[7]Defined as imports – exports ± adjustments for Government and industry stock changes.

[8]Source: DiRienzo, Michael, and Newman, Philip, 2022, Global silver demand rising to a new high in 2022: Silver Institute press release, November 17.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 27,000 tons.

SODA ASH

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The total value of domestic natural soda ash (sodium carbonate) produced in 2022 was an estimated $1.4 billion[1] and the quantity produced was an estimated 11 million tons, slightly less than that in 2021. The U.S. soda ash industry comprised four companies in Wyoming operating five plants and one company in California operating one plant. The five producing companies have a combined nameplate capacity of 13.9 million tons per year (15.3 million short tons per year). Borax, salt, and sodium sulfate were produced as coproducts of sodium carbonate production in California. Chemical caustic soda, sodium bicarbonate, and sodium sulfite were manufactured as coproducts at several of the Wyoming soda ash plants. Sodium bicarbonate was produced at an operation in Colorado using soda ash feedstock shipped from the company's Wyoming facility.

Based on 2022 quarterly reports, the estimated distribution of soda ash by end use was glass, 48%; chemicals, 28%; miscellaneous uses, 8%; distributors, 5%; soap and detergents, 5%; flue gas desulfurization, 4%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[2]	11,900	11,700	9,990	11,300	11,000
Imports for consumption	51	115	[e]98	[e]130	100
Exports	6,960	7,020	5,590	6,900	6,400
Consumption:					
Apparent[3]	4,980	4,810	[e]4,480	[e]4,450	4,600
Reported	4,850	4,720	4,440	4,640	4,600
Price, average unit value of sales (natural source), free on board (f.o.b.) mine or plant:					
Dollars per metric ton	148.69	153.24	140.70	133.37	140
Dollars per short ton	134.89	139.02	127.64	120.99	130
Stocks, producer, yearend	297	289	305	278	260
Employment, mine and plant, number[e]	2,600	2,600	2,400	2,400	2,400
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: No soda ash was recycled by producers; however, glass container producers use cullet glass, thereby reducing soda ash consumption.

Import Sources (2018–21): Turkey, 89%; Bulgaria, 3%; Mexico, 2%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Disodium carbonate	2836.20.0000	1.2% ad valorem.

Depletion Allowance: Natural, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Production, exports, and consumption in 2022 continued at similar levels as seen before the global coronavirus disease 2019 (COVID-19) pandemic. More than one-half of U.S. production of soda ash was exported, but exports for 2022 were estimated to have decreased by 7% compared with those in 2021. Domestic consumption reported by producers and apparent consumption in 2022 were close to the amounts consumed in 2021.

China produced an estimated 27 million tons of mostly synthetic soda ash in 2022 and was the leading producing country followed by, in descending order, the United States and Turkey. Other countries annually producing 1 million tons or more were France, Germany, Italy, Poland, and Russia.

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SODA ASH

Relatively low production costs and lower environmental impacts provide U.S. natural soda ash producers some advantage over producers of synthetic soda ash. The production of synthetic soda ash normally consumes more energy and releases more carbon dioxide than that of natural soda ash.

After increasing capacity of natural soda ash during recent years, total production capacity in Turkey was estimated to be between 4 million and 5 million tons per year, and soda ash shipments in Turkey, especially for export, have increased during the past few years. Total United States imports, mostly from Turkey, have recently been about 100,000 tons per year, which was more than double the average quantity of annual imports during the past decade.

World Mine Production and Reserves:

	Mine production		
	2021	2022[e]	Reserves[5, 6]
Natural:			
United States	11,300	11,000	[7]23,000,000
Botswana	262	260	400,000
Ethiopia	[e]18	20	400,000
Kenya	[e]250	250	7,000
Turkey	[e]4,200	4,400	880,000
Other countries[8]	NA	NA	280,000
World total, natural	16,000	16,000	25,000,000
World total, synthetic	40,100	42,000	XX
World total, natural and synthetic	56,100	58,000	XX

World Resources:[6] Natural soda ash is obtained from trona and sodium carbonate-rich brines. The world's largest deposit of trona is in the Green River Basin of Wyoming. About 47 billion tons of identified soda ash resources could be recovered from the 56 billion tons of bedded trona and the 47 billion tons of interbedded or intermixed trona and halite, which are in beds more than 1.2 meters thick. Underground room-and-pillar mining, using conventional and continuous mining, is the primary method of mining Wyoming trona ore. This method has an average 45% mining recovery, whereas average recovery from solution mining is 30%. Improved solution-mining techniques, such as horizontal drilling to establish communication between well pairs, could increase this extraction rate and enable companies to develop some of the deeper trona beds. Wyoming trona resources are being depleted at the rate of about 15 million tons per year (8.3 million tons of soda ash). Searles Lake and Owens Lake in California contain an estimated 810 million tons of soda ash reserves. At least 95 natural sodium carbonate deposits have been identified in the world, the resources of only some of which have been quantified. Although soda ash can be manufactured from salt and limestone, both of which are practically inexhaustible, synthetic soda ash is costlier to produce and generates environmental wastes.

Substitutes: Caustic soda can be substituted for soda ash in certain uses, particularly in the pulp and paper, water treatment, and certain chemical sectors. Soda ash, soda liquors, or trona can be used as feedstock to manufacture chemical caustic soda, which is an alternative to electrolytic caustic soda.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable.

[1]Does not include values for soda liquors and mine waters.

[2]Natural only.

[3]Defined as production + imports – exports ± adjustments for industry stock changes.

[4]Defined as imports – exports ± adjustments for industry stock changes.

[5]The reported quantities are sodium carbonate only. About 1.8 tons of trona yield 1 ton of sodium carbonate.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]From trona, nahcolite, and dawsonite deposits.

[8]China is thought to produce natural trona but because the majority of soda ash production is synthetic, China's production is included in "World total, synthetic".

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2022, 1.5 billion tons of crushed stone valued at more than $21 billion was produced by an estimated 1,340 companies operating 3,290 quarries and 170 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Florida, Missouri, Pennsylvania, Ohio, Georgia, North Carolina, Tennessee, Kentucky, and Indiana, which together accounted for about 55% of total crushed stone output. Of the total domestic crushed stone produced in 2022, about 70% was limestone and dolomite; 15%, granite; 6%, traprock; 5%, miscellaneous stone; 3%, sandstone and quartzite; and the remaining 1% was divided, in descending order of tonnage, among marble, volcanic cinder and scoria, calcareous marl, slate, and shell. An estimated 74% of crushed stone was used as a construction aggregate, mostly for road construction and maintenance; 17% for cement manufacturing; 5% for lime manufacturing; 1% for agricultural uses; and the remaining 3% for other chemical, special, and miscellaneous uses and products.

The output of crushed stone in the United States shipped for consumption in the first 9 months of 2022 was 1.14 billion tons, an increase of 3% compared with that in the same period in 2021. Third-quarter shipments for consumption increased by 3% compared with those in the same period in 2021. Additional production information, by quarter, for each State, geographic division, and the United States is reported by the U.S. Geological Survey in its quarterly Mineral Industry Surveys for construction sand and gravel and crushed stone.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production	1,390	1,460	1,440	1,500	1,500
Recycled material	30	31	32	33	33
Imports for consumption	21	24	20	19	18
Exports	(2)	(2)	(2)	(2)	(2)
Consumption, apparent[3]	1,440	1,510	1,490	1,550	1,600
Price, average unit value, dollars per metric ton	11.61	12.33	12.69	13.21	14.00
Employment, quarry and mill, number[4]	68,500	69,000	68,000	68,900	69,000
Net import reliance[5] as a percentage of apparent consumption	1	2	1	1	1

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain crushed stone aggregate, were recycled on a limited but increasing basis in most States. In 2022, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2018–21): Mexico, 53%; Canada, 28%; The Bahamas, 13%; Honduras, 5%; and other, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
Chalk:		
Crude	2509.00.1000	Free.
Other	2509.00.2000	Free.
Limestone, except pebbles and gravel	2517.10.0020	Free.
Crushed or broken stone	2517.10.0055	Free.
Marble granules, chippings and powder	2517.41.0000	Free.
Stone granules, chippings and powders	2517.49.0000	Free.
Limestone flux; limestone and other calcareous stone	2521.00.0000	Free.

Depletion Allowance: For some special uses, 14% (domestic and foreign); if used as ballast, concrete aggregate, riprap, road material, and similar purposes, 5% (domestic and foreign).

Government Stockpile: None.

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STONE (CRUSHED)

Events, Trends, and Issues: U.S. crushed stone production was about 1.50 billion tons in 2022, essentially unchanged compared with 1.50 billion tons in 2021. Apparent consumption increased to 1.6 billion tons. Consumption of crushed stone increased in 2022 because of growth in the private and public construction markets. Usually, commercial and heavy-industrial construction activity, infrastructure funding, labor availability, new single-family housing unit starts, and weather affect rates of crushed stone production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to infrastructure improvements around the Nation. The underlying factors that would support a rise in prices of crushed stone are expected to be present in 2023, especially in and near metropolitan areas.

The crushed stone industry continued to be concerned with environmental, health, safety, and zoning regulations. On November 15, 2021, the Infrastructure Investment and Jobs Act was signed into law. The legislation reauthorizes surface transportation programs for 5 years and invests $110 billion in additional funding to repair roads and bridges and support major, transformational projects. Shortages in some urban and industrialized areas are expected to continue to increase owing to local zoning regulations and land-development alternatives. These issues are expected to continue and to cause new crushed stone quarries to be located away from large population centers. Resultant regional shortages of crushed stone and higher fuel costs could result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2021	2022[e]	
United States	1,500	1,500	Adequate, except where special types are needed or where local shortages exist.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources:[6] Stone resources are plentiful throughout the world. The supply of high-purity limestone and dolomite suitable for specialty uses is limited in many geographic areas. The largest resources of high-purity limestone and dolomite in the United States are in the central and eastern parts of the country.

Substitutes: Crushed stone substitutes for roadbuilding include sand and gravel, and iron and steel slag. Substitutes for crushed stone used as construction aggregates include construction sand and gravel, iron and steel slag, sintered or expanded clay or shale, perlite, or vermiculite. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2022.

[e]Estimated. NA Not available.

[1]See also the Sand and Gravel (Construction) and Stone (Dimension) chapters.

[2]Less than ½ unit.

[3]Defined as production + recycled material + imports – exports.

[4]Including office staff. Source: Mine Safety and Health Administration.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their crushed stone production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

STONE (DIMENSION)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Approximately 2.5 million tons of dimension stone, valued at $520 million, was sold or used by U.S. producers in 2022. Dimension stone was produced by approximately 200 companies operating 231 quarries in 34 States. Leading producing States were, in descending order by tonnage, Texas, Wisconsin, Indiana, and Vermont. These four States accounted for about 68% of the production quantity and contributed about 58% of the value of domestic production. Approximately 49%, by tonnage, of dimension stone sold or used was limestone, followed by granite (19%), sandstone (18%), dolomite and slate (4% each), and the remaining 6% was divided, in descending order of tonnage, among marble, traprock, miscellaneous stone, and quartzite. By value, the leading sales or uses were for limestone (47%), followed by granite (26%), sandstone (10%), and marble and slate (5% each); the remaining 7% was divided, in descending order of total value, among dolomite, traprock, quartzite, and miscellaneous stone. Rough stone represented 59% of the tonnage and 56% of the value of all the dimension stone sold or used by domestic producers, including exports. The leading uses and distribution of rough stone, by tonnage, were in building and construction (66%) and in irregular-shaped stone (26%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (43%), curbing (13%), slabs and blocks for building and construction (10%), and flagging (9%).

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Sold or used by producers:[2]					
Quantity	2,660	2,520	2,130	2,330	2,500
Value, million dollars	437	415	414	466	520
Imports for consumption, value, million dollars	2,090	1,890	1,750	2,200	2,400
Exports, value, million dollars	70	59	47	47	49
Consumption, apparent, value, million dollars[3]	2,460	2,250	2,120	2,620	2,900
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	3,900	3,900	3,800	3,700	3,800
Net import reliance[5] as a percentage of apparent consumption (based on value)	82	82	80	82	82
Granite only, sold or used by producers:					
Quantity	484	430	436	464	470
Value, million dollars	108	105	110	128	130
Imports, value, million dollars	915	862	794	903	910
Exports, value, million dollars	19	17	13	11	13
Consumption, apparent, value, million dollars[3]	1,000	950	892	1,020	1,000
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	800	800	800	800	800
Net import reliance[5] as a percentage of apparent consumption (based on value)	89	89	88	87	87

Recycling: Small amounts of dimension stone were recycled, principally by restorers of old stone work.

Import Sources (2018–21, by value): All dimension stone: Brazil, 23%; China,[6] 22%; Italy, 18%; India, 14%; and other, 23%. Granite only: Brazil, 44%; India, 21%; China,[6] 19%; Italy, 6%; and other, 10%.

Tariff: Dimension stone tariffs ranged from free to 6.5% ad valorem, according to type, degree of preparation, shape, and size, for countries with normal trade relations in 2022. Most crude or roughly trimmed stone was imported at 3.7% ad valorem or less.

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STONE (DIMENSION)

Depletion Allowance: All dimension stone, 14% (domestic and foreign); slate used or sold as sintered or burned lightweight aggregate, 7.5% (domestic and foreign); dimension stone used for rubble and other nonbuilding purposes, 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The United States remained one of the world's leading markets for dimension stone. In 2022, total imports of dimension stone increased in value by about 9% compared with those in 2021. The dimension stone market continued to recover to pre-coronavirus disease 2019 (COVID-19) pandemic levels, with production having steadily increased since 2020. In 2022, dimension stone exports increased by 4% to about $49 million. Apparent consumption, by value, was estimated to be $2.9 billion in 2022—an 11% increase compared with that in 2021.

The dimension stone industry continued to be concerned with safety and health regulations and environmental restrictions in 2022, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration finalized new regulations to further restrict exposure to crystalline silica at quarry sites and other industrial operations that use materials containing it. Final implementation of the new regulations took effect in 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2021	2022[e]	
United States	2,330	2,500	Adequate, except for certain
Other countries	NA	NA	special types and local shortages.
World total	NA	NA	

World Resources:[7] Dimension stone resources of the world are sufficient. Resources can be limited on a local level or occasionally on a regional level by the lack of a particular kind of stone that is suitable for dimension purposes.

Substitutes: Substitutes for dimension stone include aluminum, brick, ceramic tile, concrete, glass, plastics, resin-agglomerated stone, and steel.

[e]Estimated. NA Not available.

[1]See also the Stone (Crushed) chapter.

[2]Includes granite, limestone, and other types of dimension stone.

[3]Defined as sold or used + imports – exports.

[4]Excludes office staff.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

STRONTIUM

(Data in metric tons of contained strontium unless otherwise noted)

Domestic Production and Use: Although deposits of strontium minerals occur widely throughout the United States, none have been mined in the United States since 1959. Domestic production of strontium carbonate, the principal strontium compound, ceased in 2006. Virtually all the strontium mineral celestite consumed in the United States since 2006 is thought to have been used as an additive in drilling fluids for oil and natural-gas wells. A few domestic companies produced small quantities of downstream strontium chemicals from imported strontium carbonate.

Based on import data, the estimated end-use distribution in the United States for strontium, including celestite and strontium compounds, was drilling fluids, 65%; ceramic ferrite magnets and pyrotechnics and signals, 13% each; and other uses, including electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass, accounted for the remaining 9%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	16,900	7,960	1,060	106	7,200
Strontium compounds[2]	6,350	5,560	4,440	5,020	5,100
Exports, strontium compounds[3]	32	20	32	6	13
Consumption, apparent:[4]					
Celestite	16,900	7,960	1,060	106	7,200
Strontium compounds	6,320	5,540	4,410	5,010	5,100
Total	23,200	13,500	5,470	5,120	12,000
Price, average unit value of celestite imports at port of exportation, dollars per ton	78	82	89	209	140
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Celestite: Mexico, 100%. Strontium compounds: Germany, 47%; Mexico, 45%; China, 4%; and other, 4%. Total imports: Mexico, 75%; Germany, 21%; China, 2%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Celestite	2530.90.8010	Free.
Strontium compounds:		
Strontium metal	2805.19.1000	3.7% ad valorem.
Strontium oxide, hydroxide, peroxide	2816.40.1000	4.2% ad valorem.
Strontium nitrate	2834.29.2000	4.2% ad valorem.
Strontium carbonate	2836.92.0000	4.2% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Apparent consumption of total strontium increased significantly in 2022. Apparent consumption of strontium compounds increased slightly, but apparent consumption of celestite increased to within 10% of that in 2019. The increase in 2022 was likely the result of improved economic conditions following the economic downturn attributed to the global coronavirus disease 2019 (COVID-19) pandemic in 2020, and the prolonged economic recovery period in 2021. World celestite production in 2022 was estimated to have remained essentially unchanged from that in 2021.

On February 24, 2022, a final U.S. critical minerals list was published in the Federal Register (87 FR 10381). The 2022 critical minerals list was an update of the list of critical minerals published in 2018 in the Federal Register (83 FR 23295). The 2022 critical minerals list contained 50 individual mineral commodities instead of 35 minerals and mineral groups. The changes in the 2022 list from the prior list were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

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STRONTIUM

Imports of celestite increased significantly 2022, likely the result of increased use of celestite in natural-gas- and oil-well-drilling fluids. Drilling activity increased by nearly 60% in the first 8 months of 2022 compared with that in the same period in 2021, but still remained about 30% below that seen in the same period in 2019 before the pandemic. In recent years, nearly all celestite imports were from Mexico and were thought to be used as additives in drilling fluids for oil and natural gas exploration and production. For these applications, celestite is ground but undergoes no chemical processing. A small quantity of high-value celestite imports were reported; these were most likely mineral specimens. Although no strontium carbonate was produced in the United States, celestite is the raw material from which strontium carbonate and other strontium compounds are produced.

Strontium carbonate is the most commonly traded strontium compound and is used as the raw material from which other strontium compounds are derived. Strontium carbonate is sintered with iron oxide to produce permanent ceramic ferrite magnets. Strontium nitrate, the second most commonly traded strontium compound, contributes a brilliant red color to fireworks and signal flares. Smaller quantities of these and other strontium compounds and strontium metal were consumed in several other applications, including electrolytic production of zinc, glass production, master alloys, and pigments and fillers. Imports of strontium compounds were estimated to have increased slightly in 2022.

World Mine Production and Reserves:[5] Reserves for China were revised based on Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	—	—	NA
Argentina	[e]700	700	NA
China	[e]80,000	80,000	16,000,000
Iran	[e]110,000	110,000	NA
Mexico	21,400	22,000	NA
Spain	[e]130,000	130,000	NA
World total (rounded)	[e]340,000	340,000	Large

World Resources:[6] World resources of strontium may exceed 1 billion tons.

Substitutes: Barium can be substituted for strontium in ferrite ceramic magnets; however, the resulting barium composite will have a reduced maximum operating temperature when compared with that of strontium composites. Substituting for strontium in pyrotechnics is hindered by difficulty in obtaining the desired brilliance and visibility imparted by strontium and its compounds. In drilling mud, barite is the preferred material, but celestite may substitute for some barite, especially when barite prices are high.

[e]Estimated. NA Not available. — Zero.

[1]The strontium content of celestite is 43.88%, assuming an ore grade of 92%, which was used to convert units of celestite to strontium content.

[2]Strontium compounds (with their respective strontium contents) include metal (100.00%); oxide, hydroxide, and peroxide (70.00%); carbonate (59.35%); and nitrate (41.40%). These factors were used to convert gross weight of strontium compounds to strontium content.

[3]Calculated from Schedule B of the United States code 2836.92.0000 for strontium carbonate. Other strontium compounds exports are not included because these shipments likely consisted of materials misclassified as strontium compounds.

[4]Defined as imports − exports.

[5]Gross weight of celestite in metric tons.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

SULFUR

(Data in thousand metric tons of contained sulfur unless otherwise noted)

Domestic Production and Use: In 2022, recovered elemental sulfur and byproduct sulfuric acid were produced at 93 operations in 27 States. Total shipments were valued at about $1.3 billion. Elemental sulfur production was estimated to be 8.0 million tons; Louisiana and Texas accounted for about 46% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 34 companies at 88 plants in 26 States. Byproduct sulfuric acid, representing about 7% of production of sulfur in all forms, was recovered at five nonferrous-metal smelters in four States by four companies. Domestic elemental sulfur accounted for 65% of domestic consumption, and byproduct sulfuric acid accounted for about 5%. The remaining 30% of sulfur consumed was provided by imported sulfur and sulfuric acid. About 90% of sulfur consumed was in the form of sulfuric acid.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Recovered elemental	9,000	8,110	7,310	7,470	8,000
Other forms	672	596	581	600	600
Total (rounded)	9,670	8,710	7,890	8,070	8,600
Shipments, all forms	9,690	8,700	7,900	8,060	8,500
Imports for consumption:					
Recovered elemental[e]	2,230	1,840	2,230	2,370	1,900
Sulfuric acid	996	971	1,190	1,070	1,100
Exports:					
Recovered elemental	2,390	2,200	1,310	1,900	1,600
Sulfuric acid	112	72	64	129	100
Consumption, apparent, all forms[1]	10,400	9,240	9,950	9,470	9,800
Price, average unit value, free on board, mine and (or) plant, dollars per metric ton of elemental sulfur	81.20	51.10	24.60	92.30	150
Stocks, producer, yearend	118	124	109	113	120
Employment, mine and (or) plant, number	2,400	2,400	2,400	2,400	2,400
Net import reliance[2] as a percentage of apparent consumption	7	6	21	15	13

Recycling: Typically, between 2.5 million and 5 million tons of spent sulfuric acid is reclaimed from petroleum refining and chemical processes during any given year.

Import Sources (2018–21): Elemental: Canada, 72%; Russia, 15%; Kazakhstan, 10%; and other, 3%. Sulfuric acid: Canada, 59%; Mexico, 19%; Spain, 7%; Germany, 4%; and other, 11%. Total sulfur imports: Canada, 68%; Russia, 10%; Kazakhstan, 7%; Mexico, 6%; and other, 9%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Sulfur, crude or unrefined	2503.00.0010	Free.
Sulfur, all kinds, other	2503.00.0090	Free.
Sulfur, sublimed or precipitated	2802.00.0000	Free.
Sulfuric acid	2807.00.0000	Free.

Depletion Allowance: 22% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Total U.S. sulfur production in 2022 was estimated to have increased by 7% from that in 2021, and shipments increased by 5% from those in 2021. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations increased by 7%. Domestically, refinery sulfur production is expected to remain about the same as refining utilization remains high. Domestic byproduct sulfuric acid is expected to remain relatively constant, unless one or more of the remaining nonferrous-metal smelters close.

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SULFUR

Domestic phosphate rock consumption in 2022 was estimated to have decreased from that in 2021, which resulted in the lower consumption of sulfur to process the phosphate rock into phosphate fertilizers. New sulfur demand associated with phosphate fertilizer projects is expected mostly in Africa and east Asia.

World sulfur production was unchanged compared with that in 2021. In 2022, world sulfur supplies were hampered by a decrease in the sulfur trade in part related to sanctions on Russia. However, sulfur production from the Middle East will increase sulfur availability. Also, an increase in nickel production to produce battery materials will increase sulfur demand.

Contract sulfur prices in Tampa, FL, began 2022 at around $282 per long ton. The sulfur price increased to $481 per long ton in early April, and then decreased to $352 per long ton in mid-July. Fourth-quarter 2022 prices were $90 per long ton. In the past few years, sulfur prices have been variable, a result of the volatility in the demand for sulfur. High sulfur prices in 2022 were a result of supply issues.

World Production and Reserves:

	Production, all forms		Reserves[3]
	2021	2022[e]	
United States	8,070	8,600	Reserves of sulfur in crude oil, natural gas, and sulfide ores are large. Because most sulfur production is a result of the processing of fossil fuels, supplies are expected to be adequate for the foreseeable future. Because petroleum and sulfide ores can be processed long distances from where they are produced, sulfur production may not be in the country to which the reserves were attributed. For instance, sulfur from Saudi Arabian oil may be recovered at refineries in the United States.
Australia	900	900	
Canada	4,880	4,900	
Chile	1,500	1,500	
China[4]	18,800	18,000	
Finland	712	710	
Germany	592	600	
India	3,540	3,500	
Iran	2,200	2,200	
Japan	3,150	3,200	
Kazakhstan	4,600	4,600	
Korea, Republic of	3,080	3,100	
Kuwait	620	600	
Poland	995	1,000	
Qatar	1,700	2,000	
Russia	7,530	7,300	
Saudi Arabia	7,000	7,000	
Turkmenistan	700	700	
United Arab Emirates	5,200	6,000	
Other countries	5,600	5,600	
World total (rounded)	81,400	82,000	

World Resources:[3] Resources of elemental sulfur in evaporite and volcanic deposits, and sulfur associated with natural gas, petroleum, tar sands, and metal sulfides, total about 5 billion tons. The sulfur in gypsum and anhydrite is almost limitless, and 600 billion tons of sulfur is contained in coal, oil shale, and shale that is rich in organic matter. Production from these sources would require development of low-cost methods of extraction. The domestic sulfur resource is about one-fifth of the world total.

Substitutes: Substitutes for sulfur at present or anticipated price levels are not satisfactory; some acids, in certain applications, may be substituted for sulfuric acid, but usually at a higher cost.

[e]Estimated.

[1]Defined as shipments + imports – exports ± adjustments for industry stock changes.

[2]Defined as imports – exports ± adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Sulfur production in China includes byproduct elemental sulfur recovered from natural gas and petroleum, the estimated sulfur content of byproduct sulfuric acid from metallurgy, and the sulfur content of sulfuric acid from pyrite.

TALC AND PYROPHYLLITE[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Three companies operated five talc-producing mines in three States during 2022, and domestic production of crude talc was estimated to be nearly unchanged at 580,000 tons valued at $26 million. Talc was mined in Montana, Texas, and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 560,000 tons valued at about $180 million. Talc produced and sold in the United States was used in paper, 23%; ceramics (including automotive catalytic converters), 18%; plastics, 18%; paint, 16%; rubber, 4%; and roofing, 2%. The remaining 19% was for agriculture, cosmetics, export, insecticides, and other miscellaneous uses.

One company in North Carolina mined and processed pyrophyllite in 2021. Domestic production data were withheld to avoid disclosing company proprietary data and were estimated to have increased from those in 2021. Pyrophyllite was sold for refractory, paint, and ceramic products.

Salient Statistics—United States:	2018	2019	2020	2021	2022e
Production, mine	648	578	491	577	580
Sold by producers	537	515	461	556	560
Imports for consumption	313	280	189	278	330
Exports	260	229	186	232	200
Consumption, apparent[2]	590	566	464	602	690
Price, average, milled, dollars per metric ton[3]	227	240	265	321	320
Employment, mine and mill, number:[4]					
Talc	208	202	187	154	150
Pyrophyllite	30	31	31	32	30
Net import reliance[5] as a percentage of apparent consumption	9	9	1	8	19

Recycling: Insignificant.

Import Sources (2018–21): Pakistan, 44%; Canada, 28%; China,[6] 15%; and other, 13%. Large quantities of crude talc were thought to have been mined in Afghanistan before being milled in and exported from Pakistan.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Natural steatite and talc:		
Not crushed, not powdered	2526.10.0000	Free.
Crushed or powdered	2526.20.0000	Free.
Talc, steatite, and soapstone; cut or sawed	6815.99.2000	Free.

Depletion Allowance: Block steatite talc, 22% (domestic), 14% (foreign); other talc and pyrophyllite, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Canada, China, and Pakistan were the principal sources for United States talc imports in recent years. Imports from Pakistan have increased in recent years and accounted for nearly one-half of total imports. Imports from Canada have supplied nearly one-third of the total, whereas imports from China have increased recently to about 15% of total imports. Belgium and Malaysia were the primary destinations for United States talc exports, collectively receiving about one-half of exports. Imports of talc and related materials were estimated to have increased by about 19% in 2022 compared with those in 2021, whereas exports were estimated to have decreased by at least 10%. U.S. talc consumption, imports, production, and sales increased in 2022, with estimated mine production returning to 2019 levels. Apparent consumption of talc increased as trade continued to rebound in 2022 following a decrease caused by the global coronavirus disease 2019 (COVID-19) pandemic.

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TALC AND PYROPHYLLITE

The amount of talc used in paper and plastic production increased in 2021 and 2022. Ceramic tile and sanitaryware formulations and the technology for firing ceramic tile changed over recent decades, reducing the amount of talc required for the manufacture of some ceramic products. For paint, the industry shifted its focus to production of water-based paint (a product for which talc is not well suited because it is hydrophobic) from oil-based paint in order to reduce volatile emissions. The amount of talc used for paper manufacturing began to decrease beginning in the 1990s, and some talc used for pitch control was replaced by chemical agents. For cosmetics, manufacturers of body dusting powders shifted much of their production from talc-based to corn-starch-based products.

World Mine Production and Reserves: Reserves for China were revised based on Government reports.

	Mine production[e]		Reserves[7]
	2021	2022	
United States (crude)	[8]577	[8]580	140,000
Afghanistan	628	600	Large
Brazil (crude and beneficiated)[9]	660	660	45,000
Canada (unspecified minerals)	150	150	NA
China (unspecified minerals)	1,100	1,100	56,000
Finland	[10]297	300	Large
France (crude)	350	350	Large
India[9]	1,750	1,750	110,000
Italy (includes steatite)	165	165	NA
Japan[9]	160	160	100,000
Korea, Republic of[9]	[10]355	300	81,000
Pakistan	140	230	NA
Turkey[9]	[10]220	220	NA
Other countries (includes crude)[9]	690	690	Large
World total (rounded)	[8]7,240	[8]7,300	Large

World Resources:[7] The United States is self-sufficient in most grades of talc and related minerals, but lower priced imports have replaced domestic minerals for some uses. Talc occurs in the United States from New England to Alabama in the Appalachian Mountains and the Piedmont region, as well as in California, Montana, Nevada, Texas, and Washington. Domestic and world identified resources are estimated to be approximately five times the quantity of reserves.

Substitutes: Substitutes for talc include bentonite, chlorite, feldspar, kaolin, and pyrophyllite in ceramics; chlorite, kaolin, and mica in paint; calcium carbonate and kaolin in paper; bentonite, kaolin, mica, and wollastonite in plastics; and kaolin and mica in rubber.

[e]Estimated. NA Not available.

[1]All statistics exclude pyrophyllite unless otherwise noted.

[2]Defined as sold by producers + imports – exports.

[3]Average ex-works unit value of milled talc sold by U.S. producers, based on data reported by companies.

[4]Includes only companies that mine talc or pyrophyllite. Excludes office workers and mills that process imported or domestically purchased material.

[5]Defined as imports – exports.

[6]Includes Hong Kong.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Excludes U.S. production of pyrophyllite.

[9]Includes pyrophyllite.

[10]Reported.

TANTALUM

(Data in metric tons of contained tantalum unless otherwise noted)

Domestic Production and Use: Significant U.S. tantalum mine production has not been reported since 1959. Domestic tantalum resources are of low grade, some are mineralogically complex, and most are not commercially recoverable. Companies in the United States produced tantalum alloys, capacitors, carbides, compounds, and tantalum metal from imported tantalum ores and concentrates and tantalum-containing materials. Tantalum metal and alloys were recovered from foreign and domestic scrap. Domestic tantalum consumption was not reported by consumers. Major end uses for tantalum included alloys for gas turbines used in the aerospace and oil and gas industries; tantalum capacitors for automotive electronics, mobile accessories, and personal computers; tantalum carbides for cutting and boring tools; and tantalum oxide (Ta_2O_5) was used in glass lenses to make lighter weight camera lenses that produce a brighter image. The value of tantalum consumed in 2022 was estimated to exceed $320 million as measured by the value of imports.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,660	1,380	1,230	1,380	1,700
Exports[1]	681	423	417	628	480
Shipments from Government stockpile[2]	—	—	−16	−10	—
Consumption, apparent[3]	975	956	814	740	1,200
Price, tantalite, annual average, dollars per kilogram of Ta_2O_5 content[4]	214	161	158	158	150
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-containing electronic components and from tantalum-containing cemented carbide and superalloy scrap. The amount of tantalum recycled was not available, but it may account for as much as 30% of consumption by domestic primary processors.

Import Sources (2018–21): Tantalum ores and concentrates: Australia, 43%; Rwanda, 21%; Congo (Kinshasa), 12%; Mozambique, 7%; and other, 17%. Tantalum metal and powder: China,[6] 42%; Germany, 23%; Kazakhstan, 12%; Thailand, 9%; and other, 14%. Tantalum waste and scrap: Indonesia, 23%; China,[6] 17%; Japan, 15%; and other, 45%. Total: China,[6] 24%; Germany, 12%; Australia, 10%; Indonesia, 8%; and other, 46%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Tantalum ores and concentrates	2615.90.6060	Free.
Tantalum oxide[7]	2825.90.9000	3.7% ad valorem.
Potassium fluorotantalate[7]	2826.90.9000	3.1% ad valorem.
Tantalum, unwrought:		
Powders	8103.20.0030	2.5% ad valorem.
Alloys and metal	8103.20.0090	2.5% ad valorem.
Tantalum, waste and scrap	8103.30.0000	Free.
Tantalum, other	8103.99.0000	4.4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[8]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Tantalum carbide powder	—	—	1.71	—	—
Tantalum niobium concentrate (gross weight)	92	—	—	—	—
Tantalum metal[9] (gross weight)	0.085	—	0.09	—	0.09
Tantalum alloy (gross weight)	0.0015	—	—	—	—

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TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption was estimated to have increased by 66% from that in 2021. In 2022, estimated U.S. imports for consumption increased by 25%. The tantalum imported was in the form of waste and scrap (42%), metal and powder (37%), and ores and concentrates (21%). Waste and scrap imports had the most significant increase, more than doubling from those in 2021. Estimated U.S. exports decreased by 24% in 2022. In 2022, the average monthly price of tantalum ore was valued at $150 per kilogram of Ta_2O_5 content, a decrease of 5% compared with that in 2021.

Global tantalum production and consumption were estimated to have increased in 2022 as steel production in most countries continued to rebound from decreases owing to the global coronavirus disease 2019 (COVID-19) pandemic. Buyers sought more raw material supplies after maintaining low stocks in 2021 and there was increased demand from the electronics industry. In 2022, China remained the leading export destination and accounted for approximately 20% of tantalum ores and concentrates, waste and scrap, and metal consumption. Brazil, Congo (Kinshasa), Nigeria, and Rwanda accounted for about 85% of estimated global tantalum production in 2022.

World Mine Production and Reserves: Reserves for Australia and China were revised based on Government reports.

	Mine production		Reserves[10]
	2021	2022[e]	
United States	—	—	—
Australia	44	57	[11]99,000
Bolivia	1	1	NA
Brazil	[e]360	370	40,000
Burundi	39	39	NA
China	[e]76	78	180,000
Congo (Kinshasa)	790	860	NA
Ethiopia	32	24	NA
Mozambique	37	34	NA
Nigeria	110	110	NA
Russia	[e]39	39	NA
Rwanda	269	350	NA
Uganda	38	38	NA
World total (rounded)	1,840	2,000	NA

World Resources:[10] Identified world resources of tantalum, most of which are in Australia, Brazil, Canada, and China are considered adequate to supply projected needs. The United States has about 55,000 tons of tantalum resources in identified deposits, most of which were considered subeconomic at 2022 prices for tantalum.

Substitutes: The following materials can be substituted for tantalum, but a performance loss or higher costs may ensue: niobium and tungsten in carbides; aluminum, ceramics, and niobium in electronic capacitors; glass, molybdenum, nickel, niobium, platinum, stainless steel, titanium, and zirconium in corrosion-resistant applications; and hafnium, iridium, molybdenum, niobium, rhenium, and tungsten in high-temperature applications.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated tantalum content of synthetic tantalum-niobium concentrates, niobium and tantalum ores and concentrates, tantalum waste and scrap, unwrought tantalum alloys and powder, and other tantalum articles. Synthetic concentrates and niobium ores and concentrates were assumed to contain 32% Ta_2O_5. Tantalum ores and concentrates were assumed to contain 37% Ta_2O_5. Ta_2O_5 is 81.897% tantalum.

[2]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.

[3]Defined as production + imports – exports ± adjustments for Government stock changes.

[4]Source: CRU Group. The estimate for 2022 includes data available through April 2022.

[5]Defined as imports – exports ± adjustments for Government stock changes.

[6]Includes Hong Kong.

[7]This category includes tantalum-containing material and other material.

[8]See Appendix B for definitions.

[9]Potential disposals are for tantalum scrap in the Government stockpile.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 39,000 tons.

TELLURIUM

(Data in metric tons of contained tellurium unless otherwise noted)

Domestic Production and Use: Tellurium is primarily recovered as a byproduct of the electrolytic refining of copper, where it accumulates in the residues of copper anodes. In 2022, two electrolytic copper refineries operated in the United States, one in Texas and one in Utah, and produced copper telluride from tellurium-bearing anode slimes. Copper telluride from the Utah facility was processed by another company in Utah, and copper telluride from the Texas facility was thought to have been exported. Downstream companies refined imported commercial-grade tellurium to produce high-purity tellurium, tellurium compounds for specialty applications, and tellurium dioxide. Domestic tellurium production, consumption, and stocks were withheld to avoid disclosing company proprietary data.

Tellurium was predominantly used in the production of cadmium telluride (CdTe) for thin-film solar cells. Another important end use was for the production of bismuth telluride (BiTe), which is used in thermoelectric devices for both cooling and energy generation. Metallurgical uses were as an alloying additive in steel to improve machining characteristics, as a minor additive in copper alloys to improve machinability without reducing conductivity, in lead alloys to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. It was used in the chemical industry as a vulcanizing agent and accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production. Other uses included those in photoreceptor and thermoelectric devices, blasting caps, and as a pigment to produce various colors in glass and ceramics.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, refinery[1]	W	W	W	W	W
Imports for consumption	192	59	12	42	50
Exports	4	1	([2])	2	([2])
Consumption, apparent[3]	W	W	W	W	W
Price, average, dollars per kilogram:					
United States[4]	79.55	68.11	59.37	69.72	70
Europe[5]	73.67	60.45	56.05	67.26	66
Stocks, producer, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>95	>95	>95	>95	>75

Recycling: For traditional metallurgical and chemical uses, there was little or no scrap from which to extract secondary tellurium because these uses of tellurium are highly dispersive or dissipative. A very small amount of tellurium was recovered from scrapped selenium-tellurium photoreceptors employed in older photocopiers in Europe. A plant in the United States recycled tellurium from CdTe solar cells, but the amount recycled was limited because most CdTe solar cells were relatively new and had not reached the end of their useful life.

Import Sources (2018–21): Canada, 52%; Germany, 24%; China,[7] 12%; Philippines, 8%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The estimated tellurium content of copper telluride recovered from domestic copper anode slimes increased in 2022. In May, a company in the United States began operating a new tellurium circuit with an annual production capacity of 20 tons at its electrolytic copper refinery in Utah. The company produced copper telluride that was processed by another company in Utah and primarily supplied to the U.S. solar industry. The leading U.S. manufacturer of solar modules announced plans to expand the capacity of its existing production facilities and to build a fourth facility, contingent upon permitting and regulatory approvals. The company expected to increase its total annual capacity in the United States to approximately 10 gigawatts of solar modules by 2025.

In 2022, the annual average price for tellurium in the United States was an estimated $70 per kilogram, essentially unchanged from $69.72 per kilogram in 2021. Production costs for tellurium increased from those in 2021, but the higher costs were likely partially offset by increased supply in the United States. The supply of tellurium is directly affected by the supply of the materials from which it is a byproduct, primarily copper.

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TELLURIUM

In June 2022, the Government of China released a development plan for renewable energy and set goals of generating 25% of energy consumption and installing 1.2 billion kilowatts of capacity for wind and solar power by 2030. If realized, the proposals would likely increase the demand for tellurium from the solar industry for thin-film CdTe solar panels. China was the leading producer of refined tellurium in 2022 and accounted for 53% of estimated global output. Estimated end uses for tellurium in global consumption were solar power cells, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

World Refinery Production and Reserves: The values shown for reserves reflect the estimated tellurium content of copper reserves, with the exception of China and Sweden. Reserves for Sweden were reported by the only tellurium producer in the country. Reserves for China were revised based on Government reports, and reserves for Russia and South Africa were revised based on company reports. These estimates assume that more than one-half of the tellurium contained in unrefined copper anodes is recoverable.

	Refinery production[e, 8]		Reserves[9]
	2021	2022	
United States	W	W	3,500
Bulgaria	4	4	NA
Canada	44	50	800
China	330	340	3,000
Japan	68	70	—
Russia	70	80	4,500
South Africa	4	4	800
Sweden	[10]41	40	670
Uzbekistan	48	50	NA
Other countries[11]	NA	NA	19,000
World total (rounded)[12]	610	640	32,000

World Resources:[9] Reserves for tellurium are based on identified copper deposits and average tellurium content. More than 90% of tellurium has been produced from anode slimes as a byproduct of electrolytic copper refining, and the remainder was derived from skimmings at lead refineries and from flue dusts and gases generated during the smelting of bismuth, copper, and lead-zinc ores. Other potential sources of tellurium include bismuth telluride and gold telluride ores.

Substitutes: Several materials can replace tellurium in most of its uses, but usually with losses in efficiency or product characteristics. Amorphous silicon and copper-indium-gallium selenide are the two principal competitors of CdTe in thin-film photovoltaic solar cells. Bismuth selenide and organic polymers can be used to substitute for some BiTe thermal devices. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and (or) selenium can act as vulcanization agents in place of tellurium. The selenides and sulfides of niobium and tantalum can serve as electrical-conducting solid lubricants in place of tellurides of those metals.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Refined tellurium production and estimated tellurium content of copper telluride recovered from copper anode slimes.

[2]Less than ½ unit. Export data reported by the U.S. Census Bureau in 2020 were adjusted by the U.S. Geological Survey.

[3]Production + imports – exports ± adjustments for industry stock changes.

[4]Average annual price for 99.95%-minimum-purity tellurium, free on board, U.S. warehouse. Source: Argus Media group, Argus Metals International.

[5]Average annual price for 99.99%-maximum-purity tellurium, in warehouse, Rotterdam. Source: Argus Media group, Argus Metals International.

[6]Defined as imports – exports ± adjustments for industry stock changes.

[7]Includes Hong Kong.

[8]Insofar as possible, data relate to refinery output only; countries that produced tellurium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues but did not recover refined tellurium from these materials were excluded to avoid double counting.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]Reported.

[11]In addition to the countries listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland may have produced refined tellurium, but output was not reported, and available information was inadequate to make reliable production estimates.

[12]Excludes U.S. production.

THALLIUM

(Data in kilograms unless otherwise noted)

Domestic Production and Use: There has been no domestic production of thallium since 1981. Small quantities of thallium are consumed annually, but variations in pricing and value data make it difficult to estimate the value of consumption. The primary end uses included the following: radioisotope thallium-201 used for medical purposes in cardiovascular imaging; thallium used as an activator (sodium iodide crystal doped with thallium) in gamma radiation detection equipment; thallium-barium-calcium-copper-oxide high-temperature superconductors; thallium used in lenses, prisms, and windows for infrared detection and transmission equipment; thallium-arsenic-selenium crystal filters used for light diffraction in acousto-optical measuring devices; and thallium used in mercury alloys for low-temperature measurements. Other uses include as an additive in glass to increase its refractive index and density, a catalyst for organic compound synthesis, and a component in high-density liquids for gravity separation of minerals.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	—	—	57	—	—
Waste and scrap	23	27	—	—	13
Other articles	41	38	—	7	—
Exports:					
Unwrought metal and powders	100	290	300	190	—
Waste and scrap	853	133	359	—	—
Other articles	[1]31,400	[1]79,100	580	378	400
Consumption, estimated[2]	64	65	57	7	13
Price, metal, dollars per kilogram[e, 3]	NA	7,600	8,200	8,400	9,400
Net import reliance[4] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2018–2021): China, 40%; Russia, 30%; Norway, 14%; United Kingdom, 12%; and Israel, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Unwrought and powders	8112.51.0000	4% ad valorem.
Waste and scrap	8112.52.0000	Free.
Other	8112.59.0000	4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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THALLIUM

Events, Trends, and Issues: Despite there having been no domestic production of thallium since 1981, exports of thallium have outweighed imports in recent years, which dwindled to near zero in most recent years particularly for unwrought metal and powders. As of September 2022, however, there were no exports of unwrought metal and powders, either a result of inventory depletion or because of reduced worldwide demand. This inventory was thought to be the result of unusually high import quantities from 2008 to 2011, in part because of a global shortage of technetium-99m, which is used as a replacement for thallium in most medical imaging. Data on inventory drawdown of thallium for domestic use were not available. In 2022, estimated exports of thallium articles remained comparable to those in 2021. In 2018 and 2019, reported exports of thallium articles had been unusually high in quantity; these exports had likely been misclassified material. The minor quantities of imports suggests that inventories of thallium remain adequate for domestic needs and for production of articles for export.

The leading global uses for thallium were gamma radiation detection equipment, high-temperature superconductors, infrared optical materials, low-melting glasses, photoelectric cells, and radioisotopes. Demand for thallium for use in medical nuclear-imaging applications declined owing to superior performance and availability of alternatives, such as the medical isotope technetium-99m, although thallium continued to be used in cardiovascular stress testing. Because of thallium's unique properties, new uses for thallium continued to be investigated. In 2022, ongoing research included improvements in scintillators (for radiation detection) that contain thallium as a key component for increased efficiency, and new thallium compounds for use in optoelectronics.

Thallium metal and its compounds are highly toxic materials and are strictly controlled to prevent harm to humans and the environment. Thallium and its compounds can be absorbed into the human body by skin contact, ingestion, or inhalation of dust or fumes. Under its national primary drinking water regulations for public water supplies, the U.S. Environmental Protection Agency has set an enforceable Maximum Contaminant Level of 2 parts per billion thallium in drinking water.

World Refinery Production and Reserves:[5] Thallium is produced commercially in only a few countries as a byproduct recovered from flue dust in the roasting of copper, lead, and zinc ores. Because most producers withhold thallium production data, global production data were limited. In 2022, global production of thallium was estimated to be about 10,000 kilograms. China, Kazakhstan, and Russia were thought to be leading producers of primary thallium. Since 2005, substantial thallium-rich deposits have been identified in Brazil, China, North Macedonia, and Russia. Quantitative estimates of reserves were not available, owing to the difficulty in identifying deposits where thallium can be extracted economically. Previous estimates of reserves were based on the thallium content of zinc ores.

World Resources:[5] Although thallium is reasonably abundant in the Earth's crust, estimated at about 0.7 part per million, it exists mostly in association with potassium minerals in clays, granites, and soils, and it is not generally considered to be commercially recoverable from those materials. The major source of recoverable thallium is trace amounts found in sulfide ores of copper, lead, zinc, and other metallic elements. As such, world resources of thallium are adequate to supply world requirements.

Substitutes: Although other materials and formulations can substitute for thallium in gamma radiation detection equipment and optics used for infrared detection and transmission, thallium materials are presently superior and more cost effective for these very specialized uses. The medical isotope technetium-99m can be used in cardiovascular-imaging applications instead of thallium. Nontoxic substitutes, such as tungsten compounds, are being marketed as substitutes for thallium in high-density liquids for gravity separation of minerals.

[e]Estimated. NA Not available. — Zero.

[1]Includes material that may have been misclassified.

[2]Estimated to be equal to imports.

[3]Estimated price of 99.99%-pure granules in 100-gram lots.

[4]Defined as imports – exports. Consumption and exports of unwrought thallium were from imported material or from a drawdown in unreported inventories.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

THORIUM

(Data in kilograms, gross weight, unless otherwise noted)

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2022, monazite may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates, but thorium was not separated or recovered by any domestic facility. Essentially, all thorium compounds and alloys consumed by the domestic industry were derived from imports. The number of companies that processed or fabricated various forms of thorium for commercial use was not available. Thorium's use in most products was generally limited because of concerns over its naturally occurring radioactivity. Imports of thorium compounds are sporadic owing to changes in consumption and fluctuations in consumer inventory levels. The estimated value of thorium compounds imported for consumption by the domestic industry in 2022 was $85,000 (based on data through August 2022), compared with $175,200 in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine (monazite)[1]	[2]520,000	[2]1,700,000	[2]960,000	W	W
Imports for consumption:					
Ore and concentrates (monazite)	1,000	—	3,000	16,000	—
Compounds (oxide, nitrate, and so forth)	9,000	3,970	1,920	5,790	2,900
Exports:					
Ore and concentrates (monazite)	520,000	1,700,000	960,000	W	W
Compounds (oxide, nitrate, and so forth)[3]	21,000	154,000	60,000	46,000	31,000
Consumption, apparent:[4]					
Ore and concentrates (monazite)	1,000	—	3,000	W	W
Compounds (oxide, nitrate, and so forth)	NA	NA	NA	NA	NA
Price, average unit value of imports, compounds, dollars per kilogram:[5]					
India	72	72	NA	NA	NA
France	29	29	29	29	26
Net import reliance[6] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2018–21): Ores and concentrates (monazite): China, 80%; United Kingdom, 15%; and Canada, 5%. Thorium compounds: France, 56%; India, 43%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Thorium ore and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad valorem.

Depletion Allowance: Monazite, 22% on thorium content and 14% on rare-earth and yttrium content (domestic); 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic demand for thorium alloys, compounds, and metals was limited. In addition to research purposes, various commercial uses of thorium included catalysts, high-temperature ceramics, magnetrons in microwave ovens, metal-halide lamps, nuclear medicine, optical coatings, tungsten filaments, and welding electrodes.

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THORIUM

Exports of unspecified thorium compounds were 20,300 kilograms through August 2022. About one-half of the exports had a unit value of less than $50 per kilogram, so it is possible that they were misclassified. Owing to potentially misclassified material and variations in the type and purity of thorium compounds, the unit value of exports can vary widely by month and by exporting customs district.

Globally, monazite was produced primarily for its rare-earth-element content, and only a small fraction of the byproduct thorium was recovered and consumed. Thailand was the leading producer of monazite. Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. In international trade, China was the leading importer of monazite; Thailand, Madagascar, Vietnam and Nigeria were China's leading import sources, in descending order of quantity.

The Eneabba mineral sands project (Australia) was producing monazite concentrates for export and, in April 2022, it completed a feasibility study for construction of a fully integrated rare-earths refinery. Monazite is a featured product at the Moma Mine (Mozambique); monazite resources were greater than 100 times the current mining rate (the mine increased production in the third quarter of 2022). The license application of the Kvanefjeld project (Greenland) is in arbitration. The Steenkampskraal Mine (South Africa) obtained a favorable ruling regarding its current mining rights and obtained substantial investment to progress mining activities.

Several companies and countries were active in the pursuit of commercializing a new generation of nuclear reactors that would use thorium as a fuel material. Thorium-based nuclear research and development programs have been or were underway in Australia, Belgium, Brazil, Canada, China, Czechia, Denmark, Finland, France, Germany, India, Israel, Italy, Japan, the Republic of Korea, the Netherlands, Norway, Russia, the United Kingdom, and the United States.

World Mine Production and Reserves:[7] Production and reserves are associated with the recovery of monazite in heavy-mineral-sand deposits. Without demand for the rare earths, monazite likely would not be recovered for its thorium content under current market conditions.

World Resources:[7] The world's leading thorium resources are found in placer, carbonatite, and vein-type deposits. Thorium is found in several minerals, including monazite, thorite, and thorianite. According to the World Nuclear Association,[8] worldwide identified thorium resources were an estimated 6.4 million tons of thorium. Thorium resources are found throughout the world, most notably in Australia, Brazil, India, and the United States. India has the largest resources (850,000 tons), followed by Brazil (630,000 tons) and Australia and the United States (600,000 tons each).

Substitutes: Nonradioactive substitutes have been developed for many applications of thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, yttrium, and zirconium can substitute for magnesium-thorium alloys in aerospace applications. Cerium, lanthanum, yttrium, and zirconium oxides can substitute for thorium in welding electrodes. Several replacement materials (such as yttrium fluoride and proprietary materials) are in use as optical coatings instead of thorium fluoride.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Monazite may have been produced as a separate concentrate or included as an accessory mineral in heavy-mineral concentrates.
[2]Estimated to be equal to exports.
[3]Includes material that may have been misclassified.
[4]Defined as production + imports – exports. Production is only for ore and concentrates. Monazite is produced for the production of rare-earth compounds and not for thorium recovery. The apparent consumption calculation for thorium compounds results in a negative value for thorium compounds.
[5]Calculated from U.S. Census Bureau import data.
[6]Defined as imports – exports; however, a meaningful net import reliance could not be calculated owing to uncertainties in the classification of material being imported and exported.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Source: World Nuclear Association, 2017, Thorium: London, United Kingdom, World Nuclear Association, February.

TIN

(Data in metric tons of contained tin unless otherwise noted)

Domestic Production and Use: Tin has not been mined or smelted in the United States since 1993 or 1989, respectively. Twenty-five firms accounted for over 95% of the primary tin consumed domestically in 2022. The major uses for tin in the United States were chemicals, 23%; tinplate, 22%; alloys, 11%; solder, 10%; babbitt, brass and bronze, and tinning, 7%; bar tin, 2%; and other, 25%. Based on the average S&P Global Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin in 2022 was $1.3 billion, and the estimated value of tin recovered from old scrap domestically in 2022 was $330 million.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, secondary:[e]					
Old scrap	9,890	10,500	9,550	9,030	10,000
New scrap	8,100	8,100	8,000	7,600	8,000
Imports for consumption:					
Refined	36,800	34,100	31,600	38,100	34,000
Tin alloys, gross weight	1,430	1,020	843	1,100	720
Tin waste and scrap, gross weight	47,700	30,400	20,700	18,600	11,000
Exports:					
Refined	941	1,300	519	1,290	1,400
Tin alloys, gross weight	885	1,200	1,130	630	470
Tin waste and scrap, gross weight	5,980	2,470	1,200	2,800	2,900
Shipments from Government stockpile, gross weight[1]	13	18	-7	437	—
Consumption, apparent, refined[2]	42,300	43,200	40,600	47,800	43,000
Price, average, cents per pound:[3]					
New York dealer	936	868	799	1,580	1,600
London Metal Exchange (LME), cash	914	846	777	1,478	1,500
Stocks, consumer and dealer, yearend	10,100	10,300	10,400	8,900	8,600
Net import reliance[4] as a percentage of apparent consumption, refined	77	76	76	81	77

Recycling: About 18,000 tons of tin from old and new scrap was estimated to have been recycled in 2022. Of this, about 10,000 tons was recovered from old scrap at 1 detinning plant and about 22 secondary nonferrous-metal-processing plants, accounting for 22% of apparent consumption.

Import Sources (2018–21): Refined tin: Peru, 25%; Indonesia, 24%; Bolivia, 17%; Malaysia, 16%; and other, 18%. Waste and scrap: Canada, 98%; Mexico, 1%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Unwrought tin:		
Tin, not alloyed	8001.10.0000	Free.
Tin alloys, containing, by weight:		
5% or less lead	8001.20.0010	Free.
More than 5% but not more than 25% lead	8001.20.0050	Free.
More than 25% lead	8001.20.0090	Free.
Tin waste and scrap	8002.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Tin (gross weight)	3,578	—	4,000	—	688

Events, Trends, and Issues: The estimated amount of tin recycled domestically in 2022 increased by 8% compared with that in 2021. The estimated annual average New York dealer price for refined tin in 2022 was 1,600 cents per pound, a slight increase compared with that in 2021. The estimated annual average LME cash price for refined tin in 2022 was 1,500 cents per pound, unchanged from that in 2021. In 2022, the monthly average New York dealer tin price decreased from March to October.

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TIN

In May, a copper products manufacturer based in Germany purchased a United States metals recycling company capable of processing scrap, including tin, at the rate of 100,000 tons per year. Also in May, a company announced plans to build a $340 million electronic-waste and nonferrous-metals recycling plant in Fort Wayne, IN. The facility will have the capacity to recycle up to 45,000 tons per year of feedstock; construction was expected to begin in 2023 and conclude by 2025. In June, construction began on a secondary smelter for complex recyclable materials in Richmond County, GA. The facility will have the capacity to process up to 90,000 tons per year of recyclables and will recover multiple metals, including tin. The facility, which would cost approximately $320 million to construct, was expected to begin operations in the first half of 2024.

Throughout the year, smelters were temporarily closed in China owing to coronavirus disease 2019 (COVID-19) pandemic-related mitigation measures and annual maintenance. Intermittent truck driver strikes in Spain caused disruptions and halted shipments of tin and tungsten concentrates. In 2022, mining began from a new pit at the Penouta Mine in northwestern Spain, a deposit containing a measured and indicated resource of 76.3 million tons at 443 parts per million tin. In March, the indicated and inferred resources at the Mpama South deposit in Congo (Kinshasa) were updated to 105,000 tons of contained tin. Additionally, the company mining the deposit announced an expansion to begin in late 2023 that would increase its tin production to approximately 20,000 tons per year.

World Mine Production and Reserves: Reserves for Australia, China, Malaysia, Peru, and Russia were revised based on company and Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	—	—	—
Australia	8,772	9,700	[7]570,000
Bolivia	19,628	18,000	400,000
Brazil	15,517	18,000	420,000
Burma	[e]36,900	31,000	700,000
China	[e]90,000	95,000	720,000
Congo (Kinshasa)	[e]16,700	20,000	130,000
Indonesia	[e]70,000	74,000	800,000
Laos	[e]1,980	1,900	NA
Malaysia	5,000	5,000	NA
Nigeria	[e]1,600	1,700	NA
Peru	26,995	29,000	130,000
Russia	3,000	2,700	430,000
Rwanda	[e]2,000	2,200	NA
Vietnam	[e]5,400	5,200	11,000
Other countries	1,180	1,100	310,000
World total (rounded)	305,000	310,000	4,600,000

World Resources:[6] Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those of the rest of the world. World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

Substitutes: Aluminum, glass, paper, plastic, or tin-free steel substitute for tin in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, alternative copper-base alloys, and plastics for bronze; plastics for bearing metals that contain tin; and compounds of lead and sodium for some tin chemicals.

[e]Estimated. NA Not available. — Zero.

[1]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.

[2]Defined as production from old scrap + refined tin imports – refined tin exports ± adjustments for Government and industry stock changes.

[3]Source: S&P Global Platts Metals Week.

[4]Defined as refined imports – refined exports ± adjustments for Government and industry stock changes.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 300,000 tons.

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Titanium sponge metal was produced by one operation in Utah. Production data were withheld to avoid disclosing company proprietary data. The facility in Salt Lake City, UT, with an estimated capacity of 500 tons per year, produced titanium that was further refined for use in electronics. A second sponge facility in Henderson, NV, with an estimated capacity of 12,600 tons per year, was idled since 2020 owing to market conditions. A third facility, in Rowley, UT, with an estimated capacity of 10,900 tons per year, has remained on care-and-maintenance status since 2016.

Although detailed 2022 consumption data were withheld to avoid disclosing proprietary data, the majority of titanium metal was used in aerospace applications, and the remainder was used in armor, chemical processing, marine hardware, medical implants, power generation, and consumer other applications. The value of imported sponge was about $250 million, a significant increase compared with $148 million in 2021.

In 2022, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3.4 billion. The leading uses of TiO_2 pigment were, in descending order, paints (including lacquers and varnishes), plastics, and paper. Other uses of TiO_2 pigment included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption[e]	23,700	30,000	19,200	16,000	28,000
Exports	533	869	711	117	120
Consumption, apparent[2]	W	W	W	[3]16,000	[3]28,000
Consumption, reported	35,200	W	W	W	W
Price, dollars per kilogram[4]	10.70	10.70	10.60	11.20	11
Stocks, industry, yearend[e]	10,700	W	W	W	W
Employment, number[e]	150	150	150	20	20
Net import reliance[5] as a percentage of apparent consumption	>50	>50	>50	>95	>95
TiO_2 pigment:					
Production	1,150,000	1,000,000	1,000,000	1,100,000	1,100,000
Imports for consumption	268,000	226,000	262,000	251,000	260,000
Exports	528,000	401,000	386,000	494,000	420,000
Consumption, apparent[2]	890,000	825,000	876,000	857,000	940,000
Price, dollars per metric ton[4]	2,730	2,750	2,710	2,920	3,400
Producer price index (1982=100), yearend[6]	205	NA	NA	NA	NA
Employment, number[e]	3,050	3,050	3,100	3,200	3,200
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Owing to limited responses from voluntary surveys, consumption data of titanium scrap metal for the titanium metal industry were withheld. Consumption data of titanium scrap for the steel, superalloy, and other industries were not available.

Import Sources (2018–21): Sponge metal: Japan, 89%; Kazakhstan, 9%; Ukraine, 1%, and other, 1%. TiO_2 pigment: Canada, 42%; China, 16%; Germany, 10%; Belgium, 5%; and other, 27%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Titanium oxides (unfinished TiO_2 pigments)	2823.00.0000	5.5% ad valorem.
TiO_2 pigments, 80% or more TiO_2	3206.11.0000	6% ad valorem.
TiO_2 pigments, other	3206.19.0000	6% ad valorem.
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3.7% ad valorem.
Unwrought titanium metal	8108.20.0000	15% ad valorem.
Titanium waste and scrap metal	8108.30.0000	Free.
Other titanium metal articles	8108.90.3000	5.5% ad valorem.
Wrought titanium metal	8108.90.6000	15% ad valorem.

Depletion Allowance: Not applicable.

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TITANIUM AND TITANIUM DIOXIDE

Government Stockpile: None.

Events, Trends, and Issues: The 500-ton-per-year Salt Lake City, UT, plant was the only active domestic producer of titanium sponge, and the Salt Lake City operations primarily supported the production of electronic-grade materials. Consequently, U.S. producers of titanium ingot and downstream products were reliant on imports of titanium sponge and scrap. Rebounding demand from the aerospace and other industries resulted in a 75% increase in imports of titanium sponge compared with those in 2021. Japan (82%), Kazakhstan (9%), and Saudi Arabia (7%) were the leading import sources for titanium sponge in 2022. U.S. imports of titanium scrap were about 17,000 tons. The United Kingdom and Germany (14% each), France (11%), Canada (10%), and Japan (9%) were the leading import sources for titanium waste and scrap in 2022. In 2022, the annual average duty-paid unit value of scrap imports was about $7.50 per kilogram compared with $4.80 per kilogram in 2021. In 2022, several companies were planning to expand domestic downstream production capacity. In Pennsylvania, one company was adding 7,300 metric tons per year of ingot melting capacity as well as additional forging capabilities. Another company planned to construct a new melt facility in West Virginia, although the annual capacity was not yet available. A third company expected to complete an initial 125 tons per year of titanium powder capacity using new technology and recycled metal feedstock. Following the onset of the conflict between Russia and Ukraine, major European and domestic aerospace consumers of titanium were seeking alternative sources of supply. Prior to the conflict, Ukraine was the leading source of titanium mineral concentrates suppling Russia's titanium metal industry.

Domestic production of TiO_2 pigment in 2022 was an estimated 1.1 million tons. Although heavily reliant on imports of titanium mineral concentrates, the United States was a net exporter of TiO_2 pigments. Exports of TiO_2 pigments decreased in 2022 while imports increased.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production[e]		Capacity, 2022[7]	
	2021	2022	Sponge	Pigment
United States	W	W	500	1,370,000
Australia	—	—	—	260,000
Canada	—	—	—	104,000
China	140,000	150,000	181,000	5,000,000
Germany	—	—	—	472,000
India	250	250	500	108,000
Japan	49,200	50,000	68,800	322,000
Kazakhstan	15,000	16,000	26,000	1,000
Mexico	—	—	—	300,000
Russia	27,000	25,000	46,500	55,000
Saudi Arabia	5,700	11,000	15,600	210,000
Ukraine	6,100	1,000	12,000	120,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	784,000
World total (rounded)	[8]240,000	[8]260,000	350,000	9,400,000

World Resources:[9] Resources of titanium minerals are discussed in the Titanium Mineral Concentrates chapter.

Substitutes: Few materials possess titanium metal's strength-to-weight ratio and corrosion resistance. In high-strength applications, titanium competes with aluminum, composites, intermetallics, steel, and superalloys. Aluminum, nickel, specialty steels, and zirconium alloys may be substituted for titanium for applications that require corrosion resistance. Ground calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide as a white pigment.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]See also the Titanium Mineral Concentrates chapter.

[2]Defined as production + imports – exports.

[3]Excludes domestic production of sponge in Utah.

[4]Landed duty-paid value based on U.S. imports for consumption.

[5]Defined as imports – exports.

[6]Source: U.S. Department of Labor, Bureau of Labor Statistics.

[7]Yearend operating capacity.

[8]Excludes U.S. production.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

TITANIUM MINERAL CONCENTRATES[1]

[Data in thousand metric tons of contained titanium dioxide (TiO_2) unless otherwise noted]

Domestic Production and Use: In 2022, one company recovered ilmenite and rutile concentrates from its surface-mining operations near Nahunta, GA, and Starke, FL. A second company processed existing mine tailings to recover a mixed heavy-mineral concentrate in California. Based on reported data through September, the estimated value of titanium mineral and synthetic concentrates imported into the United States in 2022 was $780 million. Abrasive sands, monazite, and zircon were coproducts of domestic titanium minerals mining operations. More than 95% of titanium mineral concentrates were consumed by domestic TiO_2 pigment producers. The remainder was used in welding-rod coatings and for manufacturing carbides, chemicals, and titanium metal.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[2]	100	100	100	100	200
Imports for consumption	1,090	1,160	807	969	950
Exports, all forms[e]	32	8	18	30	120
Consumption, apparent[2, 3]	1,200	1,300	900	1,000	1,000
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, free on board (f.o.b.) Australia[4]	1,025	1,150	1,175	1,450	1,500
Ilmenite and leucoxene, bulk, f.o.b. Australia[5]	407	478	459	595	580
Ilmenite, average unit value of imports[6]	219	186	215	240	290
Slag, 80%–95% TiO_2, average unit value of imports[6]	738	792	757	774	830
Employment, mine and mill, number	296	310	315	290	330
Net import reliance[7] as a percentage of apparent consumption	91	92	89	90	81

Recycling: None.

Import Sources (2018–21): South Africa, 39%; Australia, 15%; Madagascar, 14%; Canada, 10%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Synthetic rutile	2614.00.3000	Free.
Ilmenite and ilmenite sand	2614.00.6020	Free.
Rutile concentrate	2614.00.6040	Free.
Titanium slag	2620.99.5000	Free.

Depletion Allowance: Ilmenite and rutile, 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of titanium mineral concentrates is tied to production of TiO_2 pigments that are primarily used in paint, paper, and plastics. Demand for these primary uses is related to changes in the gross domestic product. Domestic apparent consumption of titanium mineral concentrates in 2022 was estimated to have been unchanged from that in 2021. Inventory changes were not included in the apparent consumption calculation. Exports of titanium mineral concentrates increased significantly owing to increased recovery from mine tailings.

In 2022, as of September, South Africa (37%), Madagascar (16%), Mozambique (15%), and Australia (9%) were the leading sources of titanium mineral concentrates imports to the United States. Mining and heavy-mineral-sand-processing operations were expanded near Starke, FL, and preliminary technical and economic study studies were completed at a heavy-mineral-sands project near Camden, TN. The project plans also included production of synthetic rutile from ilmenite using a proprietary process.

In 2022, China continued to be the leading producer and consumer of titanium mineral concentrates, accounting for more than one-third of global production of ilmenite. Mozambique and South Africa also were leading producers of titanium mineral concentrates. China's imports of titanium mineral concentrates were about 3.4 million tons in gross weight, a decrease of 10% compared with those in 2021. As of October, Mozambique (47%), Kenya (9%), and Vietnam (8%) were the leading sources of titanium mineral concentrates to China. In Saudi Arabia, commissioning of a project to produce up to 500,000 tons per year of titanium slag resumed in 2022 after being delayed in 2021. Exploration projects for heavy-mineral sands were being developed in Australia, Brazil, Canada, China, Finland, Greenland, Kenya, Malawi, Mozambique, Norway, Papua New Guinea, Russia, Senegal, and Tanzania.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for China, Madagascar, and "Other countries" were revised based on company and Government reports.

	Mine production		Reserves[8]
	2021	2022[e]	
Ilmenite:			
United States[2, 9]	100	200	2,000
Australia	600	660	[10]160,000
Brazil	33	32	43,000
Canada[11]	430	470	31,000
China	3,400	3,400	190,000
India	204	200	85,000
Kenya	181	180	390
Madagascar[11]	414	300	22,000
Mozambique	1,100	1,200	26,000
Norway	468	430	37,000
Senegal	482	520	NA
South Africa[11]	900	900	30,000
Ukraine	316	200	5,900
Vietnam	122	160	1,600
Other countries	137	77	14,000
World total (ilmenite, rounded)[9]	8,900	8,900	650,000
Rutile:			
United States	([9])	([9])	([9])
Australia	190	190	[10]31,000
India	12	11	7,400
Kenya	72	73	170
Madagascar	—	—	520
Mozambique	8	8	890
Senegal	9	9	NA
Sierra Leone	123	130	490
South Africa	95	95	6,500
Tanzania	—	—	20
Ukraine	95	57	2,500
Other countries	14	14	NA
World total (rutile, rounded)[9]	618	590	49,000
World total (ilmenite and rutile, rounded)	9,500	9,500	700,000

World Resources:[8] Ilmenite accounts for about 90% of the world's consumption of titanium minerals. World resources of anatase, ilmenite, and rutile total more than 2 billion tons.

Substitutes: Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings.

[e]Estimated. NA Not available. — Zero.

[1]See also the Titanium and Titanium Dioxide chapter.

[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.

[3]Defined as production + imports – exports.

[4]Source: Fast Markets IM; average of yearend price.

[5]Source: Zen Innovations AG, Global Trade Tracker.

[6]Landed duty-paid unit value based on U.S. imports for consumption. Source: U.S. Census Bureau.

[7]Defined as imports – exports.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

[9]U.S. rutile production and reserves data are included with ilmenite.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves for ilmenite and rutile were estimated to be 37 million and 9.2 million tons, respectively.

[11]Mine production of titaniferous magnetite is primarily used to produce titaniferous slag.

TUNGSTEN

(Data in metric tons of contained tungsten unless otherwise noted)

Domestic Production and Use: No domestic production of commercial tungsten concentrates has been reported since 2015. Approximately six U.S. companies had the capability to convert tungsten concentrates, ammonium paratungstate (APT), tungsten oxide, and (or) scrap to tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals. An estimated 60% of the tungsten consumed in the United States was used in cemented carbide parts for cutting and wear-resistant applications, primarily in the construction, metalworking, mining, and oil- and gas-drilling industries. The remainder was used to make various alloys and specialty steels; electrodes, filaments, wires, and other components for electrical, electronic, heating, lighting, and welding applications; and chemicals for various applications. The estimated value of apparent consumption in 2022 was approximately $800 million.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Ores and concentrates	4,050	2,760	2,020	1,590	2,000
Other forms[1]	10,400	11,100	8,660	10,400	12,000
Exports:					
Ores and concentrates	284	583	480	441	600
Other forms[2]	3,210	2,780	2,470	2,970	4,200
Shipments from Government stockpile:[3]					
Concentrate	1,180	663	728	1,030	700
Other forms	—	—	34	93	—
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent,[4] all forms	W	W	W	W	W
Price,[5] concentrate, average in-warehouse Rotterdam, dollars per dry metric ton unit of tungsten trioxide[6]	261	198	172	225	270
Stocks, industry, concentrate and other forms, yearend	W	W	W	W	W
Net import reliance[7] as a percentage of apparent consumption	>50	>50	>50	>50	>50

Recycling: The estimated quantity of secondary tungsten produced and the amount consumed from secondary sources by processors and end users in 2022 were withheld to avoid disclosing company proprietary data.

Import Sources (2018–21): Tungsten contained in ores, concentrates, and other forms:[1] China,[8] 29%; Germany, 11%; Bolivia, 9%; Vietnam, 6%; and other, 45%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Ores	2611.00.3000	Free.
Concentrates	2611.00.6000	37.5¢/kg on tungsten content.
Tungsten oxides	2825.90.3000	5.5% ad valorem.
Ammonium tungstates	2841.80.0010	5.5% ad valorem.
Tungsten carbides	2849.90.3000	5.5% ad valorem.
Ferrotungsten	7202.80.0000	5.6% ad valorem.
Tungsten powders	8101.10.0000	7% ad valorem.
Tungsten waste and scrap	8101.97.0000	2.8% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[9]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Metal powder	—	—	125	—	—
Ores and concentrates	6,000	—	1,360	—	1,130
Tungsten alloys, gross weight[10]	5	—	—	—	—

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TUNGSTEN

Events, Trends, and Issues: World tungsten supply was dominated by production in China and exports from China. China's Government regulated its tungsten industry by prohibiting foreign investment in exploration and mining, limiting the number of mining and export licenses and imposing quotas on concentrate production and processing. Production of tungsten concentrate outside China was estimated to have increased in 2022 but remained less than 20% of world production. The increase was from existing operations. Additional production, primarily from reopened mines in Australia, the Republic of Korea, and the United Kingdom, was forecast to begin in 2023. Scrap continued to be an important source of raw material for the world tungsten industry.

Tungsten consumption is strongly influenced by economic conditions and industrial activity. China continued to be the world's leading tungsten consumer. In 2022, China's tungsten consumption by vehicle and other manufacturing industries was negatively affected by lockdowns to control coronavirus disease 2019 (COVID-19) pandemic outbreaks. In the United States, increased oil and gas drilling and a recovery of the aerospace industry resulted in an estimated increase in tungsten consumption. Potential areas of future growth in tungsten consumption include new applications such as powders for additive manufacturing and the use of tungsten in lithium-ion batteries.

World Mine Production and Reserves: Reserves for China, Portugal, Spain, and "Other countries" were revised based on company and Government reports.

	Mine production		Reserves[11]
	2021	2022[e]	
United States	—	—	NA
Austria	[e]900	900	10,000
Bolivia	1,563	1,400	NA
China	[e]71,000	71,000	1,800,000
Portugal	502	500	3,100
Russia	[e]2,300	2,300	400,000
Rwanda	[e]1,340	1,100	NA
Spain	[e]400	700	56,000
Vietnam	4,800	4,800	100,000
Other countries	973	1,400	1,400,000
World total (rounded)	83,800	84,000	3,800,000

World Resources:[11] World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits. Significant tungsten resources have been identified on every continent except Antarctica.

Substitutes: Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide, niobium carbide, or titanium carbide; ceramics; ceramic-metallic composites (cermets); and tool steels. Most of these options reduce, rather than replace, the amount of tungsten used. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels, although most molybdenum steels still contain tungsten; lighting based on carbon nanotube filaments, induction technology, and light-emitting diodes for lighting based on tungsten electrodes or filaments; depleted uranium or lead for tungsten or tungsten alloys in applications requiring high density or the ability to shield radiation; and depleted uranium alloys or hardened steel for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles. In some applications, substitution would result in increased cost or a loss in product performance.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Includes ammonium and other tungstates; ferrotungsten; tungsten carbides; tungsten metal powders; tungsten oxides, chlorides, and other tungsten compounds; unwrought tungsten; wrought tungsten forms; and tungsten waste and scrap.

[2]Includes ammonium and other tungstates, ferrotungsten, tungsten carbides, tungsten metal powders, unwrought tungsten, wrought tungsten forms, and tungsten waste and scrap.

[3]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.

[4]Defined as mine production + secondary production + imports – exports ± adjustments for Government and industry stock changes.

[5]Source: Argus Media Group, Argus Metals International.

[6]A metric ton unit of tungsten trioxide contains 7.93 kilograms of tungsten.

[7]Defined as imports – exports ± adjustments for Government and industry stock changes.

[8]Includes Hong Kong.

[9]See Appendix B for definitions.

[10]Tungsten-rhenium ingot.

[11]See Appendix C for resource and reserve definitions and information concerning data sources.

VANADIUM

(Data in metric tons of contained vanadium unless otherwise noted)

Domestic Production and Use: Vanadium production in Utah from the mining of uraniferous sandstones on the Colorado Plateau ceased in early 2020 and was not restarted in 2022. Secondary vanadium production continued in Arkansas, Ohio, and Pennsylvania where processed waste materials (petroleum residues, spent catalysts, utility ash) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, and vanadium pentoxide. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2022. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production from primary ore and concentrate	—	460	17	—	—
Production from ash, residues, and spent catalysts[e]	2,600	3,000	2,900	3,200	4,400
Imports for consumption:					
Aluminum-vanadium master alloy	281	222	101	35	30
Ash and residues[1, 2]	2,810	2,120	1,550	1,680	1,800
Ferrovanadium	2,970	2,280	1,360	2,170	2,700
Oxides and hydroxides, other	98	105	67	69	100
Vanadium chemicals[3]	992	733	942	957	790
Vanadium metal[4]	28	45	([5])	1	2
Vanadium ores and concentrates[1]	330	108	2	4	67
Vanadium pentoxide	4,600	3,620	1,670	1,740	1,500
Exports:					
Aluminum-vanadium master alloy	90	29	13	72	40
Ash and residues[1]	1,430	1,280	503	930	910
Ferrovanadium	575	295	210	173	220
Oxides and hydroxides, other	53	750	51	235	400
Vanadium metal[4]	39	27	1	4	10
Vanadium ores and concentrates[1]	48	95	92	81	140
Vanadium pentoxide	563	423	50	17	170
Consumption:					
Apparent[6]	11,900	9,790	7,670	8,340	9,500
Reported	9,280	9,900	7,920	8,030	8,400
Price, average, vanadium pentoxide,[7] dollars per pound	16.40	12.17	6.68	8.17	9.20
Stocks, yearend[8]	250	257	269	271	270
Net import reliance[9] as a percentage of apparent consumption	78	65	62	62	54

Recycling: Recycling of vanadium is mainly associated with reprocessing vanadium catalysts into new catalysts. The range in vanadium content in spent catalysts varies depending on the crude oil feedstock and the uncertainty associated with the quantity of vanadium recycled from spent chemical process catalysts was significant.

Import Sources (2018–21): Ferrovanadium: Austria, 38%; Canada, 38%; Russia, 10%; Japan, 4%; and other, 10%. Vanadium pentoxide: Brazil, 50%; South Africa, 32%; China, 6%; Russia, 4%; and other, 8%. Total: Canada, 31%; China, 13%; Brazil, 8%; South Africa, 7%; and other, 41%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Vanadium ores and concentrates	2615.90.6090	Free.
Vanadium-bearing ash and residues	2620.40.0030	Free.
Vanadium-bearing ash and residues, other	2620.99.1000	Free.
Vanadium pentoxide, anhydride	2825.30.0010	5.5% ad valorem.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad valorem.
Ferrovanadium	7202.92.0000	4.2% ad valorem.
Vanadium metal	8112.92.7000	2% ad valorem.
Vanadium and articles thereof[10]	8112.99.2000	2% ad valorem.
Vanadium chemicals	([3])	5.5% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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VANADIUM

Events, Trends, and Issues: Estimated U.S. apparent consumption of vanadium in 2022 increased by 11% from that in 2021. The estimated average Chinese vanadium pentoxide price in 2022 increased by 12% compared with the 2021 price, and the estimated United States ferrovanadium price increased by 55% to $24.00 per pound in 2022 compared with that in 2021.

China continued to be the world's top vanadium producer, producing the majority of its vanadium from vanadiferous iron ore processed for steel production. In the first half of 2022, a rise in coronavirus disease 2019 (COVID-19) cases led the Chinese Government to impose COVID-19 restrictions, causing a decrease in China's steel production. The vanadium market had anticipated vanadium disruptions owing to the ongoing conflict between Russia and Ukraine. However, according to analysts, vanadium pentoxide trade flows between Russia and Czechia have been relatively unaffected by the conflict and Czechian ferrovanadium exports to customers in China, India, Japan, the Netherlands, Turkey, Ukraine, and the United States have also had limited disruptions. Uncertainty surrounding the supply of Russian material was expected to continue.

Vanadium redox flow battery (VRFB) technology continued to be an increasingly important part of large-scale energy storage as it allows for high-safety, large-scale, environmentally friendly, medium- and long-term energy storage. Installations of VRFB projects increased worldwide as energy companies looked to support renewable energy projects as many countries attempt to lower their carbon emissions.

World Mine Production and Reserves: Reserves for Australia were revised based on company and Government reports.

	Mine production		Reserves[11]
	2021	2022[e]	(thousand metric tons)
United States	—	—	45
Australia	—	—	[12]7,400
Brazil	5,780	6,200	120
China	70,300	70,000	9,500
Russia	20,100	17,000	5,000
South Africa	8,800	9,100	3,500
World total (rounded)	105,000	100,000	26,000

World Resources:[11] World resources of vanadium exceed 63 million tons. Vanadium occurs in deposits of phosphate rock, titaniferous magnetite, and uraniferous sandstone and siltstone, in which it constitutes less than 2% of the host rock. Significant quantities are also present in bauxite and carboniferous materials, such as coal, crude oil, oil shale, and tar sands. Because vanadium is typically recovered as a byproduct or coproduct, demonstrated world resources of the element are not fully indicative of available supplies.

Substitutes: Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. Currently, no acceptable substitute for vanadium is available for use in aerospace titanium alloys.

[e]Estimated. — Zero.

[1]Reported by the U.S. Census Bureau as metric tons of vanadium pentoxide. To convert vanadium pentoxide content to vanadium content multiply by 0.56.

[2]Includes estimates for data suppressed by U.S. Census Bureau in the years 2020 through 2022.

[3]Includes Harmonized Tariff Schedule of the United States codes for chloride oxides and hydroxides of vanadium (2827.49.1000), hydrides and nitrides of vanadium (2850.00.2000), vanadium sulfates (2833.29.3000), vanadium chlorides (2827.39.1000) and vanadates (2841.90.1000).

[4]Includes waste and scrap.

[5]Less than ½ unit.

[6]Defined as primary production + secondary production + imports – exports ± adjustments for industry stock changes.

[7]Chinese annual average vanadium pentoxide prices. Source: CRU Group.

[8]Includes ferrovanadium, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.

[9]Defined as imports – exports ± adjustments for industry stock changes.

[10]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium and is the main master alloy for the vanadium industry. Unwrought aluminum-vanadium master alloy (Harmonized Tariff Schedule of the United States code 7601.20.9030) was not included.

[11]See Appendix C for resource and reserve definitions and information concerning data sources.

[12]For Australia, Joint Ore Reserves Committee or equivalent reserves were 1.7 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: One company located in Virginia produced approximately 100,000 tons of vermiculite concentrate; data have been rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data. Flakes of raw vermiculite concentrate are micaceous in appearance and contain interlayer water in their structure. When the flakes are heated rapidly to a temperature above 870 degrees Celsius, the water flashes into steam, and the flakes expand into accordionlike particles. This process is called exfoliation or expansion, and the resulting ultralightweight material is chemically inert, fire resistant, and odorless. Most vermiculite concentrate, whether produced in the United States or imported, was shipped to 15 exfoliating plants in nine States. The end uses for exfoliated vermiculite were estimated to be agriculture and horticulture, 32%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 25%; insulation, 13%; and other, 30%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[1, 2]	100	100	100	100	100
Imports for consumption[e]	37	39	40	33	30
Exports[e]	13	8	8	10	7
Consumption:					
Apparent, concentrate[e, 3]	120	130	130	120	120
Reported, exfoliated	79	79	81	78	80
Price, range of value, concentrate, ex-plant, dollars per metric ton	140–575	NA	NA	NA	NA
Employment, number[e]	70	70	70	70	50
Net import reliance[4] as a percentage of apparent consumption[e, 5]	20	20	20	20	20

Recycling: Insignificant.

Import Sources (2018–21): South Africa, 64%; Brazil, 35%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Vermiculite, perlite, and chlorites, unexpanded	2530.10.0000	Free.
Exfoliated vermiculite, expanded clays, foamed slag, and similar expanded materials	6806.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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VERMICULITE

Events, Trends, and Issues: In recent years, two companies mined crude vermiculite domestically; however, a company with operations in South Carolina did not expect to produce vermiculite in 2022. Data for U.S. exports and imports of vermiculite were combined with data for other mineral products by the U.S. Census Bureau. U.S. imports were estimated to be about 30,000 tons in 2022, a decrease which could be related to disruptions in the global supply chain. Most imports came from Brazil and South Africa in 2022. Historically, South Africa was the leading principal source of imports; however, in 2022, Brazil supplied more imports than South Africa.

Exploration and development of vermiculite deposits containing medium, large, and premium (coarser) grades (greater than 5-millimeter particle size) are likely to continue because of the higher demand for those grades. Demand for vermiculite remains strong. With less domestic production, as well as global supply issues, vermiculite exfoliation operations are experiencing difficulties obtaining crude vermiculite (especially medium and coarse grade), which is increasing lead times and could result in consumers using substitute materials. Producers will continue to investigate ways to increase the use of the finer grades in existing products and as a substitute for coarser vermiculite while continuing to develop new and innovative applications.

World Mine Production and Reserves: Reserves data for China were revised based on Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	[1, 2]100	[1, 2]100	25,000
Brazil	60	60	6,600
Bulgaria	10	10	NA
China	39	39	340
India	1	3	1,600
Mexico	([7])	([7])	NA
Russia	29	29	NA
South Africa	160	160	14,000
Turkey	19	19	NA
Uganda	14	14	NA
Uzbekistan	2	2	NA
Zimbabwe	30	30	NA
World total (rounded)	464	470	NA

World Resources:[6] In addition to the producing mine in Virginia, there are vermiculite occurrences in Colorado, Nevada, North Carolina, South Carolina, Texas, and Wyoming that contain estimated resources of 2 million to 3 million tons. Significant deposits have been reported in Australia, Russia, Uganda, and some other countries, but reserve and resource information comes from many sources, and in most cases, it is not clear whether the numbers refer to vermiculite alone or vermiculite plus other minerals and host rock and overburden.

Substitutes: Expanded perlite is a substitute for exfoliated vermiculite in lightweight concrete and plaster. Other denser but less costly alternatives in these applications include expanded clay, shale, slag, and slate. Alternate materials for loose-fill fireproofing insulation include fiberglass, perlite, and slag wool. In agriculture, substitutes include bark and other plant materials, peat, perlite, sawdust, and synthetic soil conditioners.

[e]Estimated. NA Not available.

[1]Concentrate sold or used by producers.

[2]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.

[3]Defined as concentrate sold or used by producers + imports – exports.

[4]Defined as imports – exports.

[5]Data are rounded to one significant digit to avoid disclosing company proprietary data.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]Less than ½ unit.

WOLLASTONITE

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2022. U.S. production of wollastonite (sold or used by producers) was withheld to avoid disclosing company proprietary data but was estimated to have increased from that in 2021. Economic resources of wollastonite typically form as a result of thermal metamorphism of siliceous limestone during regional deformation or chemical alteration of limestone by siliceous hydrothermal fluids along faults or contacts with magmatic intrusions. Deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah; however, New York is the only State where long-term continuous mining has taken place.

The U.S. Geological Survey does not collect consumption statistics for wollastonite, but consumption was estimated to have increased slightly in 2022 compared with that in 2021. Ceramics (frits, sanitaryware, and tile), friction products (primarily brake linings), metallurgical applications (flux and conditioner), paint (architectural and industrial paints), plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds), and miscellaneous uses (including adhesives, concrete, glass, and sealants) accounted for wollastonite sales in the United States.

In ceramics, wollastonite decreases shrinkage and gas evolution during firing; increases green and fired strength; maintains brightness during firing; permits fast firing; and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding, a source for calcium oxide, a slag conditioner, and protects the surface of molten metal during the continuous casting of steel. As an additive in paint, it improves the durability of the paint film, acts as a pH buffer, improves resistance to weathering, reduces gloss and pigment consumption, and acts as a flatting and suspending agent. In plastics, wollastonite improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, stable at high temperatures, and improves flexural and tensile strength.

Salient Statistics—United States: The United States was thought to be a net exporter of wollastonite in 2022. Comprehensive trade data were not available for wollastonite because it is imported and exported under generic Harmonized Tariff Schedule of the United States and Schedule B codes, respectively, that include multiple mineral commodities. Prices for domestically produced wollastonite were estimated to be between $340 to $370 per metric ton. Price data for globally produced wollastonite were unavailable. Products with finer grain sizes and acicular (highly elongated) particles sold for higher prices. Surface treatment, when necessary, also increased the selling price. Approximately 60 people were employed at wollastonite mines and mills in 2022 (excluding office workers) in the United States.

Recycling: None.

Import Sources (2018–21): Comprehensive trade data were not available, but wollastonite was primarily imported from Canada and Mexico.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

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WOLLASTONITE

Events, Trends, and Issues: Construction starts of new housing units through August 2022 increased by 2.7% compared with those during the same period in 2021 with the largest increase in starts being in two- to four-unit dwellings. Sales of wollastonite to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, were thought to have increased. However, sales of wollastonite were thought to be slightly lower for primary iron and steel production, which decreased by 3% in the first 7 months of 2022 compared with production during the same period of 2021. The production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, increased by 3% in the first 7 months of 2022. Plastics production was expected to be slightly higher in 2022 than that in 2021.

Globally, ceramics, paint, and polymers (such as plastics and rubber) accounted for most wollastonite sales. Lesser global uses for wollastonite included miscellaneous construction products, friction materials, metallurgical applications, and paper. Several research projects continued in Canada, India, and the United States to evaluate the efficacy of wollastonite in carbon dioxide sequestration. Studies were being conducted to evaluate wollastonite's ability to capture atmospheric carbon dioxide when added to crop fields and its ability to enhance crop productivity. Wollastonite's ability to reduce carbon dioxide emissions in cement production by lowering kiln temperatures needed to produce cement and absorbing carbon dioxide in the process was being evaluated. Global sales of wollastonite were estimated to be in the range of 900,000 to 1,000,000 tons, higher than those in 2021.

World Mine Production and Reserves: More countries than those listed may produce wollastonite; however, many countries do not publish wollastonite production data.

	Mine production[e]		Reserves[1]
	2021	2022	
United States	W	W	World resources of wollastonite are thought to exceed 100 million tons. Many deposits have been identified but have not been surveyed sufficiently to quantify their reserves.
Canada	20,000	20,000	
China	890,000	900,000	
India	110,000	120,000	
Mexico	103,000	100,000	
Other countries	15,000	20,000	
World total (rounded)[2]	1,140,000	1,200,000	

World Resources:[1] Reliable estimates of wollastonite resources do not exist for most countries. Large deposits of wollastonite have been identified in China, Finland, India, Mexico, and the United States. Smaller, but significant, deposits have been identified in Canada, Chile, Kenya, Namibia, South Africa, Spain, Sudan, Tajikistan, Turkey, and Uzbekistan.

Substitutes: The acicular nature of many wollastonite products allows wollastonite to compete with other acicular materials, such as ceramic fiber, glass fiber, steel fiber, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene, in products where improvements in dimensional stability, flexural modulus, and heat deflection are sought. Wollastonite also competes with several nonfibrous minerals or rocks, such as kaolin, mica, and talc, which are added to plastics to increase flexural strength, and such minerals as barite, calcium carbonate, gypsum, and talc, which impart dimensional stability to plastics. In ceramics, wollastonite competes with carbonates, feldspar, lime, and silica as a source of calcium and silica. Its use in ceramics depends on the formulation of the ceramic body and the firing method.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

[2]Excludes U.S. production.

YTTRIUM[1]

[Data in metric tons of yttrium oxide (Y_2O_3) equivalent unless otherwise noted]

Domestic Production and Use: Yttrium is one of the rare-earth elements. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined in 2020 as a primary product at the Mountain Pass Mine in California, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Yttrium was estimated to represent about 0.12% of the rare-earth elements in the Mountain Pass bastnaesite ore. Insufficient information was available to determine the yttrium content of mine production. Monazite, a rare-earth phosphate mineral, was produced as a separated concentrate that includes yttrium-rich xenotime. Both are accessory minerals in heavy-mineral-sand concentrates. There is no commercial separation facility in the United States, and rare-earth concentrates were exported for processing.

The leading end uses of yttrium were in catalysts, ceramics, electronics, lasers, metallurgy, and phosphors. In ceramic applications, yttrium compounds were used in abrasives, bearings and seals, high-temperature refractories for continuous-casting nozzles, jet-engine coatings, oxygen sensors in automobile engines, and wear-resistant and corrosion-resistant cutting tools. In electronics, yttrium-iron garnets were components in microwave radar to control high-frequency signals. Yttrium was an important component in yttrium-aluminum-garnet laser crystals used in dental and medical surgical procedures, digital communications, distance and temperature sensing, industrial cutting and welding, nonlinear optics, photochemistry, and photoluminescence. In metallurgical applications, yttrium was used as a grain-refining additive and as a deoxidizer. Yttrium was used in heating-element alloys, high-temperature superconductors, and superalloys. Yttrium was used in phosphor compounds for flat-panel displays and various lighting applications.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	NA	NA	NA	NA	NA
Imports for consumption, yttrium, alloys, compounds, and metal[e, 2]	450	360	650	670	1,000
Exports, compounds[e, 3]	14	6	1	9	4
Consumption, apparent[e, 4]	400	400	600	700	1,000
Price, average, dollars per kilogram:[5]					
Y_2O_3, minimum 99.999% purity	3	3	3	6	13
Yttrium metal, minimum 99.9% purity	36	34	34	39	43
Net import reliance[6, 7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Insignificant.

Import Sources (2018–21):[8] Yttrium compounds: China,[9] 94%; Germany, 3%; Republic of Korea and Japan, 1% each; and other, 1%. Nearly all imports of yttrium metal and compounds are derived from mineral concentrates processed in China. Import sources do not include yttrium contained in value-added intermediates and finished products.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Rare-earth metals, unspecified:		
Not alloyed	2805.30.0050	5% ad valorem.
Alloyed	2805.30.0090	5% ad valorem.
Mixtures of rare-earth oxides containing yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of rare-earth chlorides containing yttrium or scandium as the predominant metal	2846.90.2082	Free.
Yttrium-bearing materials and compounds containing by weight >19% to <85% Y_2O_3	2846.90.4000	Free.
Other rare-earth compounds, including yttrium and other compounds	2846.90.8090	3.7% ad valorem.

Depletion Allowance: Monazite, thorium content, 22% (domestic), 14% (foreign); yttrium, rare-earth content, 14% (domestic and foreign); and xenotime, 14% (domestic and foreign).

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YTTRIUM

Government Stockpile:[10]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Yttrium	25	25	—	—	—

Events, Trends, and Issues: China produced most of the world's supply of yttrium from its weathered clay ion-adsorption ore deposits in the southern Provinces—primarily Fujian, Guangdong, and Jiangxi—and from a lesser number of deposits in Guangxi and Hunan. Yttrium also was produced from similar clay deposits in Burma.

Globally, yttrium was mainly consumed in the form of oxide compounds for ceramics and phosphors. Lesser amounts were consumed in electronic devices, lasers, optical glass, and metallurgical applications. The average prices for yttrium metal and Y_2O_3 each increased compared with those in 2021. China's Ministry of Industry and Information Technology raised quotas for rare-earth mining and separation to 210,000 tons and 202,000 tons of rare-earth-oxide equivalent, respectively. The yttrium content of the production quota was not specified. Mine production was allocated to 190,850 tons of light rare earths and 19,150 tons of ion-adsorption clays.

In 2022, China's exports of yttrium compounds and metal were estimated to be 2,400 tons of Y_2O_3 equivalent, and the leading export destinations were, in descending order, Japan, the United States, the Republic of Korea, and Germany. In 2021, China's exports of yttrium compounds were 2,100 tons of Y_2O_3 equivalent.

World Mine Production and Reserves:[11] World mine production of yttrium contained in rare-earth mineral concentrates was estimated to be 10,000 to 15,000 tons. Most of this production took place in China and Burma. Global reserves of Y_2O_3 were not quantified; however, the leading countries for total rare-earth-oxide reserves included Australia, Brazil, China, Russia, and Vietnam. Although mine production in Burma was significant, information on reserves in Burma was not available. Global reserves may be adequate to satisfy near-term demand at current rates of production; however, recent high demand of ion-adsorption clay rare earths in Burma and China as well as changes in economic conditions, environmental issues, or permitting and trade restrictions could affect the availability and pricing of many of the rare-earth elements, including yttrium.

World Resources:[11] Large resources of yttrium in monazite and xenotime are available worldwide in placer deposits, carbonatites, uranium ores, and weathered clay deposits (ion-adsorption ore). Additional resources of yttrium occur in apatite-magnetite-bearing rocks, deposits of niobium-tantalum minerals, non-placer monazite-bearing deposits, sedimentary phosphate deposits, and uranium ores.

Substitutes: Substitutes for yttrium are available for some applications but generally are much less effective. In most uses, especially in electronics, lasers, and phosphors, yttrium is generally not subject to direct substitution by other elements. As a stabilizer in zirconia ceramics, Y_2O_3 may be substituted with calcium oxide or magnesium oxide, but the substitutes generally impart lower toughness.

[e]Estimated. NA Not available. — Zero.

[1]See also the Rare Earths chapter; trade data for yttrium are included in the data shown for rare earths.

[2]Estimated from Trade Mining LLC and IHS Markit Ltd. shipping records.

[3]Includes data for the following Schedule B code: 2846.90.2015.

[4]Defined as imports – exports. Rounded to one significant digit. Yttrium consumed domestically was imported or refined from imported materials.

[5]Free on board China. Source: Argus Media group, Argus Metals International.

[6]Defined as imports – exports.

[7]In 2018, 2019, 2020, 2021, and 2022, domestic production of mineral concentrates was stockpiled or exported. For 2018 to 2022, consumers of compounds and metals were reliant on imports and stockpiled inventory of compounds and metals.

[8]Includes estimated Y_2O_3 equivalent from the following Harmonized Tariff Schedule of the United States codes: 2846.90.2015, 2846.90.2082, 2846.90.4000, 2846.90.8050 (2018–2021), 2846.90.8060 (2018–2021), 2846.90.8075 (2022), and 2846.90.8090 (2022).

[9]Includes Hong Kong.

[10]See Appendix B for definitions.

[11]See Appendix C for resource and reserve definitions and information concerning data sources.

ZEOLITES (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2022, seven companies operated 10 zeolite mines in six States and produced an estimated 86,000 tons of natural zeolites. Total production increased slightly compared with production in 2021. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. Small quantities of erionite, ferrierite, mordenite, and phillipsite were likely also produced. The three leading companies accounted for approximately 80% of total domestic production.

An estimated 79,000 tons of natural zeolites were sold in the United States during 2022, 6% more than the sales in 2021. Domestic uses were, in descending order of estimated quantity, animal feed, odor control, water purification, unspecified end uses (such as ice melt, soil amendment, and synthetic turf), pet litter, fertilizer carrier, wastewater treatment, air filtration and gas absorbent, oil and grease absorbent, fungicide or pesticide carrier, aquaculture, and desiccant. Animal feed, odor control, and water purification applications accounted for about 70% of the domestic sales tonnage.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	86,100	87,800	86,700	85,300	86,000
Sales, mill	80,500	77,100	75,300	73,900	79,000
Imports for consumption[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Exports[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Consumption, apparent[1]	80,500	77,100	75,300	74,000	79,000
Price, range of value, dollars per metric ton[e, 2]	50–300	50–300	50–300	50–300	50–300
Employment, mine and mill, number[e, 3]	110	120	120	120	120
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Zeolites used for desiccation, gas absorbance, wastewater cleanup, and water purification may be reused after reprocessing of the spent zeolites. Information about the quantity of recycled natural zeolites was unavailable.

Import Sources (2018–21): Comprehensive trade data were not available for natural zeolite minerals because they were imported and exported under a generic Harmonized Tariff Schedule of the United States code and Schedule B number, respectively, that include multiple mineral commodities or under codes for finished products. Nearly all imports and exports were thought to be synthetic zeolites.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Production almost tripled from 1992 through 2022 owing to increased sales for animal feed, odor control, and water purification applications. Domestic natural zeolite production has remained steady in recent years. However, sales for natural zeolites have waned over the last few years in pet litter and wastewater cleanup applications as a result of competition from other products such as clays and synthetic zeolites. Reported sales of natural zeolites products for the use of synthetic turf, pool filter media, and traction control have become more common within the past 5 years. The increase in sales in 2022 was the result of the expansion of natural zeolites into other applications.

World Mine Production and Reserves: Many countries either do not report production of natural zeolites, report zeolites as part of a pooled group of mineral commodities often listed as “other,” or report production with a 2- to 3-year lag time. End uses for natural zeolites in countries that mine large tonnages of zeolite minerals typically include low-value, high-volume construction applications, such as dimension stone, lightweight aggregate, and pozzolanic cement. As a result, production data for some countries may not be comparable to U.S. production data, which are the quantities of natural zeolites used in high-value applications.

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ZEOLITES (NATURAL)

World reserves of natural zeolites have not been estimated. Deposits occur in many countries, but companies rarely publish reserves data. Further complicating estimates of reserves is the fact that much of the reported world production includes altered volcanic tuffs with low to moderate concentrations of zeolites that are typically used in high-volume construction applications. Some deposits should, therefore, be excluded from reserves estimates because it is the rock itself and not its zeolite content that makes these deposits valuable.

	Mine production[e]		Reserves[5]
	2021	2022	
United States	[6]85,300	86,000	Two of the leading companies in the United States reported combined reserves of 80 million tons in 2022; total U.S. reserves likely were substantially larger. World data were unavailable, but reserves were estimated to be large.
China	52,000	52,000	
Cuba	100,000	100,000	
Georgia	130,000	130,000	
Hungary	27,000	27,000	
Indonesia	130,000	130,000	
Jordan	12,000	12,000	
Korea, Republic of	130,000	130,000	
New Zealand	100,000	100,000	
Russia	35,000	35,000	
Slovakia	150,000	150,000	
Turkey	46,000	50,000	
Other countries	5,500	6,000	
World total (rounded)	1,000,000	1,000,000	

World Resources:[5] Recent estimates for domestic and global resources of natural zeolites are not available. Resources of chabazite and clinoptilolite in the United States are sufficient to satisfy foreseeable domestic demand.

Substitutes: For pet litter, zeolites compete with other mineral-based litters, such as those manufactured using bentonite, diatomite, fuller's earth, and sepiolite; organic litters made from shredded corn stalks and paper, straw, and wood shavings; and litters made using silica gel. Diatomite, perlite, pumice, vermiculite, and volcanic tuff compete with natural zeolites as lightweight aggregate. Zeolite desiccants compete against such products as magnesium perchlorate and silica gel. Zeolites compete with bentonite, gypsum, montmorillonite, peat, perlite, silica sand, and vermiculite in various soil amendment applications. Activated carbon, diatomite, or silica sand may substitute for zeolites in water-purification applications. As an oil absorbent, zeolites compete mainly with bentonite, diatomite, fuller's earth, sepiolite, and a variety of polymer and natural organic products. In animal feed, zeolites compete with bentonite, diatomite, fuller's earth, kaolin, silica, and talc as anticaking and flow-control agents.

[e]Estimated. E Net exporter.

[1]Defined as mill sales + imports – exports. Information about industry stocks was unavailable.

[2]Range of ex-works mine and mill unit values for individual natural zeolite operations, based on data reported by U.S. producers and U.S. Geological Survey estimates. Average unit values per metric ton for the past 5 years were an estimated $125 in 2018, 2019, 2020, and 2021 and $130 in 2022. Prices vary with the percentage of zeolite present in the product, the chemical and physical properties of the zeolite mineral(s), particle size, surface modification and (or) activation, and end use.

[3]Excludes administration and office staff. Estimates based on data from the Mine Safety and Health Administration.

[4]Defined as imports – exports.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]Reported.

ZINC

(Data in thousand metric tons of contained zinc unless otherwise noted)

Domestic Production and Use: The estimated value of zinc mined in 2022 was about $3.2 billion. Zinc was mined in five States at seven mining operations by five companies. Three smelter facilities, one primary and two secondary, operated by three companies, produced commercial-grade zinc metal. Of the total reported zinc consumed, most was used to produce galvanized steel, followed by brass and bronze, zinc-base alloys, and other uses.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Zinc in ores and concentrates	824	753	723	704	770
Refined zinc[e, 1]	116	115	180	220	220
Imports for consumption:					
Zinc in ores and concentrates	([2])	([2])	3	13	6
Refined zinc	775	830	700	702	700
Exports:					
Zinc in ores and concentrates	806	792	546	644	660
Refined zinc	23	5	2	13	10
Shipments from Government stockpile[3]	—	—	—	—	1
Consumption, apparent, refined zinc[4]	868	939	878	908	910
Price, average, cents per pound:					
North American[5]	141.0	124.1	110.8	145.8	190
London Metal Exchange (LME), cash	132.7	115.6	102.7	136.3	160
Stocks, reported producer and consumer, refined zinc, yearend	119	116	120	110	100
Employment, number:					
Mine and mill[6]	2,630	2,470	2,360	2,470	2,600
Smelter, primary	250	250	220	220	220
Net import reliance[7] as a percentage of apparent consumption:					
Ores and concentrates	E	E	E	E	E
Refined zinc	87	88	79	76	76

Recycling: In 2022, an estimated 60% of the refined zinc produced in the United States was recovered from secondary materials at both primary and secondary smelters. Secondary materials included galvanizing residues and crude zinc oxide recovered from electric arc furnace dust.

Import Sources (2018–21): Ores and concentrates: Peru, 71%; Canada, 15%; China, 7%, Taiwan, 4%; and other, 3%. Refined metal: Canada, 66%; Mexico, 16%; Peru, 6%; Spain, 6%; and other, 6%. Waste and scrap (gross weight): Canada, 62%; Mexico, 36%; and other, 2%. Combined total (includes gross weight of waste and scrap): Canada, 66%; Mexico, 16%; Peru, 6%; Spain, 6%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Zinc ores and concentrates, zinc content	2608.00.0030	Free.
Zinc oxide; zinc peroxide	2817.00.0000	Free.
Zinc sulfate	2833.29.4500	1.6% ad valorem.
Unwrought zinc, not alloyed:		
Containing 99.99% or more zinc	7901.11.0000	1.5% ad valorem.
Containing less than 99.99% zinc:		
Casting-grade	7901.12.1000	3% ad valorem.
Other	7901.12.5000	1.5% ad valorem.
Zinc alloys	7901.20.0000	3% ad valorem.
Zinc waste and scrap	7902.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[8]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Zinc	6.46	—	7.25	—	2.27

Prepared by **Amy C. Tolcin [(703) 648–4940, atolcin@usgs.gov]**

ZINC

Events, Trends, and Issues: On February 24, 2022, a final U.S. critical minerals list was published in the Federal Register (87 FR 10381). The 2022 critical minerals list was an update of the list of critical minerals published in 2018 in the Federal Register (83 FR 23295). The 2022 critical minerals list contained 50 individual mineral commodities instead of 35 minerals and mineral groups. The changes in the 2022 list from the prior list were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

U.S. zinc mine production increased by 9% in 2022 compared with that in 2021. Zinc production at the Red Dog zinc-lead mine in Alaska, the largest zinc mine in the United States, increased notably compared with that in 2021 owing to higher mill throughput and zinc ore grades. The owner of the Empire State zinc mine in New York received permitting to begin open pit mining activities. An open pit mine would operate alongside the active underground mine and was expected to contribute to an increase in mill throughput in the first half of 2023. Several other zinc exploration and mine expansion projects were in active development in the United States during 2022. The North American price for Special High Grade (SHG) zinc was estimated to have increased by 30% in 2022 from that in 2021. The North American premium to the LME cash price reached historical highs in 2022 amid decreasing stocks on the London Metal Exchange, reduced production by zinc smelters in Europe because of high energy costs, and the permanent closure of a zinc smelter in Canada. Other zinc smelters in Canada and Mexico reported equipment and operational issues that negatively affected production during the year.

According to the International Lead and Zinc Study Group,[9] estimated global refined zinc production in 2022 was forecast to decrease by 2.7% to 13.49 million tons and estimated metal consumption to decrease by 1.9% to 13.79 million tons, resulting in a production-to-consumption deficit of 297,000 tons.

World Mine Production and Reserves: Reserves for Australia, Bolivia, Canada, China, India, Kazakhstan, Mexico, Peru, Sweden, the United States, and "Other countries" were revised based on company and Government reports.

	Mine production[10]		Reserves[11]
	2021	2022[e]	
United States	704	770	7,300
Australia	1,320	1,300	[12]66,000
Bolivia	500	520	NA
Canada	310	250	1,800
China	4,140	4,200	31,000
India	777	830	9,600
Kazakhstan	194	200	7,400
Mexico	724	740	12,000
Peru	1,530	1,400	17,000
Russia	280	280	22,000
Sweden	234	240	4,000
Other countries	1,960	2,000	30,000
World total (rounded)	12,700	13,000	210,000

World Resources:[10] Identified zinc resources of the world are about 1.9 billion tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; aluminum alloys, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-base alloys are major substitutes for zinc-base diecasting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. E Net exporter. NA Not available. — Zero.

[1]Includes primary and secondary zinc metal production.

[2]Less than ½ unit.

[3]Defined as changes in total inventory from prior yearend inventory. If negative, increase in inventory.

[4]Defined as refined production + refined imports – refined exports ± adjustments for Government stock changes.

[5]Source: S&P Global Platts Metals Week, North American SHG zinc; based on the LME cash price plus premium.

[6]Includes mine and mill employment at zinc-containing deposits. Excludes office workers. Source: Mine Safety and Health Administration.

[7]Defined as imports – exports ± adjustments for Government stock changes.

[8]See Appendix B for definitions.

[9]Source: International Lead and Zinc Study Group, 2022, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 12, [4] p.

[10]Zinc content of concentrates and direct shipping ores.

[11]See Appendix C for resource and reserve definitions and information concerning data sources.

[12]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 23 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2022, one company recovered zircon (zirconium silicate) from surface-mining operations in Florida and Georgia as a coproduct from the mining of heavy-mineral sands and the processing of titanium and zirconium mineral concentrates, and a second company processed existing mineral sands tailings in Florida. Zirconium metal and hafnium metal were produced from zirconium chemical intermediates by one producer in Oregon and one in Utah. Zirconium and hafnium are typically contained in zircon at a ratio of about 36 to 1. Zirconium chemicals were produced by the metal producer in Oregon and by at least 10 other companies. Ceramics, foundry sand, opacifiers, and refractories were the leading end uses for zircon. Other end uses of zircon include abrasives, chemicals (predominantly zirconium basic sulfate and zirconium oxychloride octohydrate as intermediate chemicals), metal alloys, and welding rod coatings. The leading consumers of zirconium metal are the chemical process and nuclear energy industries. The leading use of hafnium metal is in superalloys.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, zirconium ores and concentrates (ZrO_2 content)[1]	[2]100,000	<100,000	<100,000	<100,000	<100,000
Imports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	26,400	22,600	15,600	18,500	35,000
Zirconium, unwrought, powder, and waste and scrap	1,880	1,820	2,030	746	290
Zirconium, wrought	282	289	302	265	300
Hafnium, unwrought, powder, and waste and scrap	42	32	16	23	33
Hafnium, wrought	NA	NA	NA	NA	2
Exports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	77,500	40,500	12,200	10,000	14,000
Zirconium, unwrought, powder, and waste and scrap	556	897	664	589	1,200
Zirconium, wrought	1,150	816	838	966	820
Consumption, apparent,[3] zirconium ores and concentrates (ZrO_2 content)[1]	[2]100,000	<100,000	<100,000	<100,000	<100,000
Price:					
Zircon, dollars per metric ton (gross weight):					
Premium grade, cost, insurance, and freight, China[4]	1,948	1,933	1,843	2,025	2,270
Imported[5]	1,290	1,490	1,380	1,380	1,950
Zirconium, sponge, ex-works China,[4] dollars per kilogram	35	33	21	31	29
Hafnium, unwrought,[4] dollars per kilogram	838	775	750	950	1,900
Net import reliance[6] as a percentage of apparent consumption:					
Zirconium ores and concentrates	E	E	<25	<25	<50
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and (or) from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled. Hafnium metal recycling was limited but could not be quantified.

Import Sources (2018–21): Zirconium ores and concentrates: South Africa, 51%; Senegal, 25%; Australia, 21%; Russia, 2%; and other, 1%. Zirconium, unwrought, including powder: China, 89%; Germany, 8%; France, 1%; Japan, 1%, and other, 1%. Zirconium, wrought: France, 62%; Germany, 19%; Belgium, 6%; Canada, 4%; and other, 9%. Hafnium, unwrought: Germany, 36%; France, 30%; China, 26%; Russia, 3%; and other, 5%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Zirconium ores and concentrates	2615.10.0000	Free.
Ferrozirconium	7202.99.1000	4.2% ad valorem.
Zirconium, unwrought and powder	8109.20.0000	4.2% ad valorem.
Zirconium waste and scrap	8109.30.0000	Free.
Other zirconium articles	8109.90.0000	3.7% ad valorem.
Hafnium, unwrought, powder, and waste and scrap	8112.31.0000	Free.
Hafnium, other	8112.39.0000	4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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ZIRCONIUM AND HAFNIUM

Government Stockpile: None.

Events, Trends, and Issues: Global mine production of zirconium mineral concentrates increased slightly in 2022 compared with that in 2021. Advanced exploration and development projects with planned production of zircon concentrates were ongoing in Australia, Madagascar, Mozambique, Senegal, Tanzania, and elsewhere. In the United States, mining and heavy-mineral-processing operations were expanded near Starke, FL, and at incorporated mobile mining units. Near Camden, TN, a pilot facility was commissioned at the Titan heavy-mineral-sands project to demonstrate mineral separations. U.S. imports and exports of zirconium ores and concentrates increased significantly in 2022. Australia, Senegal, and South Africa continued to be the leading import sources of zirconium ores and mineral concentrates.

The leading global exporters of zirconium mineral concentrates were Australia, Senegal, and South Africa. The leading global importers were China, India, and Spain. Global producers of zirconium sponge included China, France, India, Russia, and the United States. The leading global exporters of zirconium metal including waste and scrap under the Harmonized System code 8109 were China, France, Germany, South Africa, and the United States. Vietnam and the United States led the global importers of zirconium metal.

World Mine Production and Reserves: World primary hafnium production data were not available, and quantitative estimates of hafnium reserves were not available. Zirconium reserves for Australia, Senegal and "Other countries" were revised based on company and Government reports.

	Zirconium ores and zircon concentrates, mine production[e] (thousand metric tons, gross weight)		Zirconium reserves[7] (thousand metric tons, ZrO_2 content)[1]
	2021	2022	
United States	<100	<100	500
Australia	500	500	[8]48,000
China	140	140	500
Indonesia	55	60	NA
Mozambique	100	100	1,800
Senegal	64	70	2,600
South Africa	320	320	5,900
Other countries	150	160	8,500
World total (rounded)	[9]1,300	[9]1,400	68,000

World Resources:[7] Resources of zircon in the United States included about 14 million tons associated with titanium resources in heavy-mineral-sand deposits. Phosphate rock and sand and gravel deposits could potentially yield substantial amounts of zircon as a byproduct. World resources of hafnium are associated with those of zircon and baddeleyite. Quantitative estimates of hafnium resources were not available.

Substitutes: Chromite and olivine can be used instead of zircon for some foundry applications. Dolomite and spinel refractories can also substitute for zircon in certain high-temperature applications. Niobium (columbium), stainless steel, and tantalum provide limited substitution in nuclear applications, and titanium and synthetic materials may substitute in some chemical processing plant applications. Silver-cadmium-indium control rods are used in lieu of hafnium at numerous nuclear powerplants. Zirconium can be used interchangeably with hafnium in certain superalloys.

[e]Estimated. E Net exporter. NA Not available.

[1]Calculated ZrO_2 content as 65% of gross production.

[2]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.

[3]Defined as production + imports – exports.

[4]Source: Argus Media group, Argus Metals International, average of yearend price.

[5]Unit value based on annual United States imports for consumption from Australia, Senegal, and South Africa.

[6]Defined as imports – exports.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 24 million tons, gross weight.

[9]Excludes U.S. production.

APPENDIX A

Abbreviations and Units of Measure

1 carat (metric) (diamond)	= 200 milligrams
1 flask (fl)	= 76 pounds, avoirdupois, or 34.47 kilograms
1 karat (gold)	= one twenty-fourth part
1 kilogram (kg)	= 2.2046 pounds, avoirdupois
1 long ton (lt)	= 2,240 pounds, avoirdupois
1 long ton unit (ltu)	= 1% of 1 long ton, or 22.4 pounds, avoirdupois
long calcined ton (lct)	= excludes water of hydration
long dry ton (ldt)	= excludes excess free moisture
Mcf	= 1,000 cubic feet
1 metric ton (t)	= 2,204.6 pounds, avoirdupois, or 1,000 kilograms
1 metric ton (t)	= 1.1023 short ton
1 metric ton unit (mtu)	= 1% of 1 metric ton, or 10 kilograms
metric dry ton (mdt)	= excludes excess free moisture
1 pound (lb)	= 453.6 grams
psia	= pounds per square inch absolute
1 short ton (st)	= 2,000 pounds, avoirdupois
1 short ton unit (stu)	= 1% of 1 short ton, or 20 pounds, avoirdupois
short dry ton (sdt)	= excludes excess free moisture
1 troy ounce (tr oz)	= 1.09714 avoirdupois ounces, or 31.103 grams
1 troy pound	= 12 troy ounces

APPENDIX B

Definitions of Selected Terms Used in This Report

Terms Used for Materials in the National Defense Stockpile and Federal Helium Reserve

Fiscal year for the U.S. Government is the period from October 1 through September 30. Fiscal year (FY) 2022 is from October 1, 2021, through September 30, 2022. FY 2023 is from October 1, 2022, through September 30, 2023.

Inventory refers to the quantity of mineral materials held in the National Defense Stockpile or in the Federal Helium Reserve. Nonstockpile-grade materials may be included in the table; where significant, the quantities of these stockpiled materials are specified in the text accompanying the table.

Potential disposals indicate the total amount of a material in the National Defense Stockpile that the U.S. Department of Defense is permitted to dispose of under the Annual Materials Plan approved by Congress for the fiscal year. Congress has authorized disposal over the long term at rates designed to maximize revenue but avoid undue disruption to the usual markets and financial loss to the United States. Disposals are defined as any disposal or sale of National Defense Stockpile stock. For mineral commodities that have a disposal plan greater than the inventory, the actual quantity will be limited to the remaining disposal authority or inventory. The Bureau of Land Management will continue to deliver helium from private storage until all Cliffside Field assets are sold or disposed of. It is expected that all Cliffside Field assets will be disposed of in FY 2023.

Potential acquisitions indicate the maximum amount of a material that may be acquired by the U.S. Department of Defense for the National Defense Stockpile under the Annual Materials Plan approved by Congress for the fiscal year.

Depletion Allowance

The depletion allowance is a business tax deduction analogous to depreciation, but which applies to an ore reserve rather than equipment or production facilities. Federal tax law allows this deduction from taxable corporate income, recognizing that an ore deposit is a depletable asset that must eventually be replaced.

APPENDIX C

Reserves and Resources

Reserves data are dynamic. They may be reduced as ore is mined and (or) the feasibility of extraction diminishes, or more commonly, they may continue to increase as additional deposits (known or recently discovered) are developed, or currently exploited deposits are more thoroughly explored and (or) new technology or economic variables improve their economic feasibility. Reserves may be considered a working inventory of mining companies' supplies of an economically extractable mineral commodity. As such, the magnitude of that inventory is necessarily limited by many considerations, including cost of drilling, taxes, price of the mineral commodity being mined, and the demand for it. Reserves will be developed to the point of business needs and geologic limitations of economic ore grade and tonnage. For example, in 1970, identified and undiscovered world copper resources were estimated to contain 1.6 billion metric tons of copper, with reserves of about 280 million tons of copper. Since then, about 650 million tons of copper have been produced worldwide, but world copper reserves in 2022 were estimated to be 890 million tons of copper, more than triple those in 1970, despite the depletion by mining of much more than the 1970 estimated reserves.

Future supplies of minerals will come from reserves and other identified resources, currently undiscovered resources in deposits that will be discovered in the future, and material that will be recycled from current in-use stocks of minerals or from minerals in waste disposal sites. Undiscovered deposits of minerals constitute an important consideration in assessing future supplies. Mineral-resource assessments have been carried out for small parcels of land being evaluated for land reclassification, for the Nation, and for the world.

Part A—Resource and Reserve Classification for Minerals[1]

Introduction

Through the years, geologists, mining engineers, and others operating in the minerals field have used various terms to describe and classify mineral resources, which as defined herein include energy materials. Some of these terms have gained wide use and acceptance, although they are not always used with precisely the same meaning.

The U.S. Geological Survey (USGS) collects information about the quantity and quality of all mineral resources. In 1976, the USGS and the U.S. Bureau of Mines developed a common classification and nomenclature, which was published as USGS Bulletin 1450–A—"Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey." Experience with this resource classification system showed that some changes were necessary in order to make it more workable in practice and more useful in long-term planning. Therefore, representatives of the USGS and the U.S. Bureau of Mines collaborated to revise Bulletin 1450–A. Their work was published in 1980 as USGS Circular 831—"Principles of a Resource/Reserve Classification for Minerals."

Long-term public and commercial planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. Thus, resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions. To best serve these planning needs, known resources should be classified from two standpoints: (1) purely geologic or physical and chemical characteristics—such as grade, quality, tonnage, thickness, and depth—of the material in place; and (2) profitability analyses based on costs of extracting and marketing the material in a given economy at a given time. The former constitutes important objective scientific information of the resource and a relatively unchanging foundation upon which the latter more valuable economic delineation can be based.

The revised classification system, designed generally for all mineral materials, is shown graphically in figures C1and C2; its components and their usage are described in the text. The classification of mineral and energy resources is necessarily arbitrary because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy-fuel resources for the Nation or for specific areas.

Resource and Reserve Definitions

A dictionary definition of resource, "something in reserve or ready if needed," has been adapted for mineral and energy resources to comprise all materials, including those only surmised to exist, that have present or anticipated future value.

Resource.—A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Original Resource.—The amount of a resource before production.

Identified Resources.—Resources for which location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified resources include economic, marginally economic, and subeconomic components. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into measured, indicated, and inferred.

[1]Based on U.S. Geological Survey Circular 831, 1980.

Demonstrated.—A term for the sum of measured plus indicated resources.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.—Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurements are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred.—Estimates are based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Reserve Base.—That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term “geologic reserve” has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.

Inferred Reserve Base.—The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit and for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence.

Reserves.—That part of the reserve base that could be economically extracted or produced at the time of determination. The term “reserves” need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as “extractable reserves” and “recoverable reserves” are redundant and are not a part of this classification system.

Marginal Reserves.—That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technological factors.

Economic.—This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Subeconomic Resources.—The part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Undiscovered Resources.—Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, undiscovered resources may be divided into two parts, as follows:

Hypothetical Resources.—Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources.—Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Restricted Resources or Reserves.—That part of any resource or reserve category that is restricted from extraction by laws or regulations. For example, restricted reserves meet all the requirements of reserves except that they are restricted from extraction by laws or regulations.

Other Occurrences.—Materials that are too low grade or for other reasons are not considered potentially economic, in the same sense as the defined resource, may be recognized and their magnitude estimated, but they are not classified as resources. A separate category, labeled “other occurrences,” is included in figures C1 and C2. In figure C1, the boundary between subeconomic and other occurrences is limited by the concept of current or potential feasibility of economic production, which is required by the definition of a resource. The boundary is obviously uncertain, but limits may be specified in terms of grade, quality, thickness, depth, extractable percentage, or other economic-feasibility variables.

Cumulative Production.—The amount of past cumulative production is not, by definition, a part of the resource. Nevertheless, a knowledge of what has been produced is important in order to understand current resources, in terms of both the amount of past production and the amount of residual or remaining in-place resource. A separate space for cumulative production is shown in figures C1 and C2. Residual material left in the ground during current or future extraction should be recorded in the resource category appropriate to its economic-recovery potential.

Figure C1.—Major Elements of Mineral-Resource Classification, Excluding *Reserve Base* and *Inferred Reserve Base*

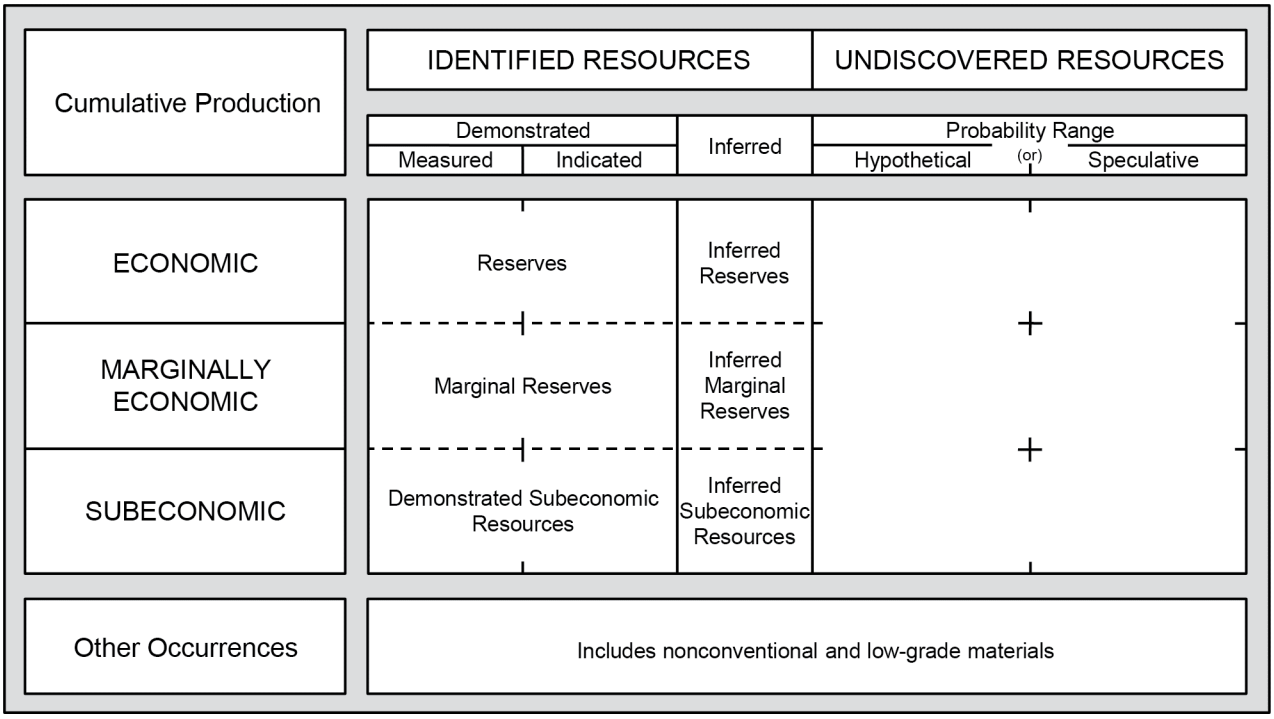
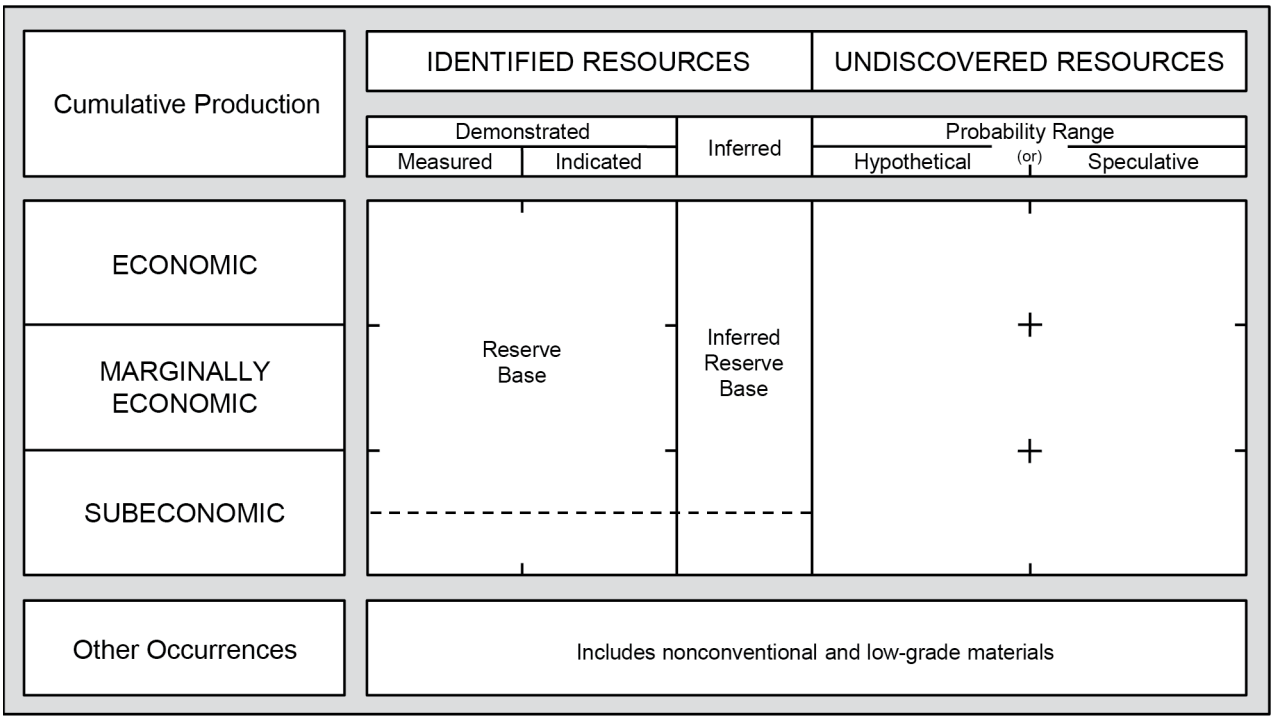


Figure C2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



Part B—Sources of Reserves Data

National information on reserves for most mineral commodities found in this report, including those for the United States, is derived from a variety of sources. The ideal source of such information would be comprehensive evaluations that apply the same criteria to deposits in different geographic areas and report the results by country. In the absence of such evaluations, national reserves estimates compiled by countries for selected mineral commodities are a primary source of national reserves information. Lacking national assessment information by governments, sources such as academic articles, company reports, presentations by company representatives, and trade journal articles, or a combination of these, serve as the basis for national information on reserves reported in the mineral commodity sections of this publication.

A national estimate may be assembled from the following: historically reported reserves information carried for years without alteration because no new information is available, historically reported reserves reduced by the amount of historical production, and company-reported reserves. International minerals availability studies conducted by the U.S. Bureau of Mines before 1996 and estimates of identified resources by an international collaborative effort (the International Strategic Minerals Inventory) are the bases for some reserves estimates. The USGS collects some qualitative information about the quantity and quality of mineral resources but does not directly measure reserves or resources, and companies or governments do not directly report information about reserves or resources to the USGS. Reassessment of reserves is a continuing process, and the intensity of this process differs by mineral commodity, country, and time period.

Some countries have specific definitions for reserves data, and reserves for each country are assessed separately, based on reported data and definitions. An attempt is made to make reserves consistent among countries for a mineral commodity and its byproducts. For example, the Australasian Joint Ore Reserves Committee (JORC) established the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code) that sets out minimum standards, recommendations, and guidelines for public reporting in Australasia of exploration results, mineral resources, and ore reserves. Companies listed on the Australian Securities Exchange and the New Zealand Stock Exchange are required to report publicly on ore reserves and mineral resources under their control, using the JORC Code.

Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources. Because of its specific use in the JORC Code, the term "reserves" is not used in the national inventory, where the highest category is "Economic Demonstrated Resources" (EDR). In essence, EDR combines the JORC Code categories "proved reserves" and "probable reserves," plus measured resources and indicated resources. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term. Accessible Economic Demonstrated Resources represent the resources within the EDR category that are accessible for mining. Reserves for Australia in the Mineral Commodity Summaries 2023 are Accessible EDR. For more information, see table 3 in "Australia's Identified Mineral Resources 2021" (https://doi.org/10.11636/1327-1466.2021).

In Canada, the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) provides definition standards for the classification of mineral resources and mineral reserves estimates into various categories. The category to which a resource or reserves estimate is assigned depends on the level of confidence in the geologic information available on the mineral deposit, the quality and quantity of data available on the deposit, the level of detail of the technical and economic information that has been generated about the deposit, and the interpretation of the data and information. For more information on the CIM definition standards, see https://mrmr.cim.org/en/standards/canadian-mineral-resource-and-mineral-reserve-definitions/.

In Russia, reserves for most minerals can appear in a number of sources, although no comprehensive list of reserves is published. Reserves data for a limited set of mineral commodities are available in the annual report "Gosudarstvennyi Doklad o Sostoyanii i Ispol'zovanii Mineral'no-Syryevyh Resursov Rossiyskoy Federatsii" (State Report on the State and Use of Mineral and Raw Materials Resources of the Russian Federation), which is published by Russia's Ministry of Natural Resources and Environment. Reserves data for various minerals appear at times in journal articles, such as those in the journal "Mineral'nyye Resursy Rossii. Ekonomika i Upravleniye" (Mineral Resources of Russia. Economics and Management), which is published by the "OOO RG-Inform," a subsidiary of Rosgeologiya Holding. Also, reserves data for individual jurisdictions are available on the website of the Federal'noye Agenstvo po Nedropol'zovaniyu (Federal Agency for Subsoil Use). It is sometimes not clear if the reserves are being reported in ore or mineral content. It is also in many cases not clear which definition of reserves is being used, because the system inherited from the former Soviet Union has a number of ways in which the term "reserves" is defined, and these definitions qualify the percentage of resources that are included in a specific category. For example, the Soviet reserves classification system, besides the categories A, B, C1, and C2, which represent progressively detailed knowledge of a mineral deposit based on exploration data, has other subcategories cross imposed upon the system. Under the broad category reserves (zapasy), there are subcategories that include balance reserves (balansovyye zapasy, or economic reserves) and outside-the-balance reserves (zabalansovye zapasy, or subeconomic reserves), as well as categories that include explored, industrial, and proven reserves, and the reserves totals can vary significantly, depending on the specific definition of reserves being reported.

APPENDIX D

Country Specialists Directory

Minerals information country specialists at the U.S. Geological Survey collect and analyze information on the mineral industries of more than 170 nations throughout the world. The specialists are available to answer minerals-related questions concerning individual countries.

Africa and the Middle East

Algeria	Mowafa Taib
Angola	Meralis Plaza-Toledo
Bahrain	Philip A. Szczesniak
Benin	Meralis Plaza-Toledo
Botswana	Thomas R. Yager
Burkina Faso	Alberto A. Perez
Burundi	Thomas R. Yager
Cabo Verde	Meralis Plaza-Toledo
Cameroon	Philip A. Szczesniak
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Congo (Kinshasa)	Thomas R. Yager
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Gabon	Alberto A. Perez
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Malawi	Thomas R. Yager
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Sierra Leone	Alberto A. Perez
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Syria	Mowafa Taib
Tanzania	Thomas R. Yager
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