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Department of Industry, Science, Energy and Resources

Office of the Chief Economist

Outlook for Selected Critical Minerals

Australia 2021

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Further information

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Project Team

Breanna Gasson, Caroline Lewis and Kate Martin

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Outlook for Selected Critical Minerals: Australia 2021

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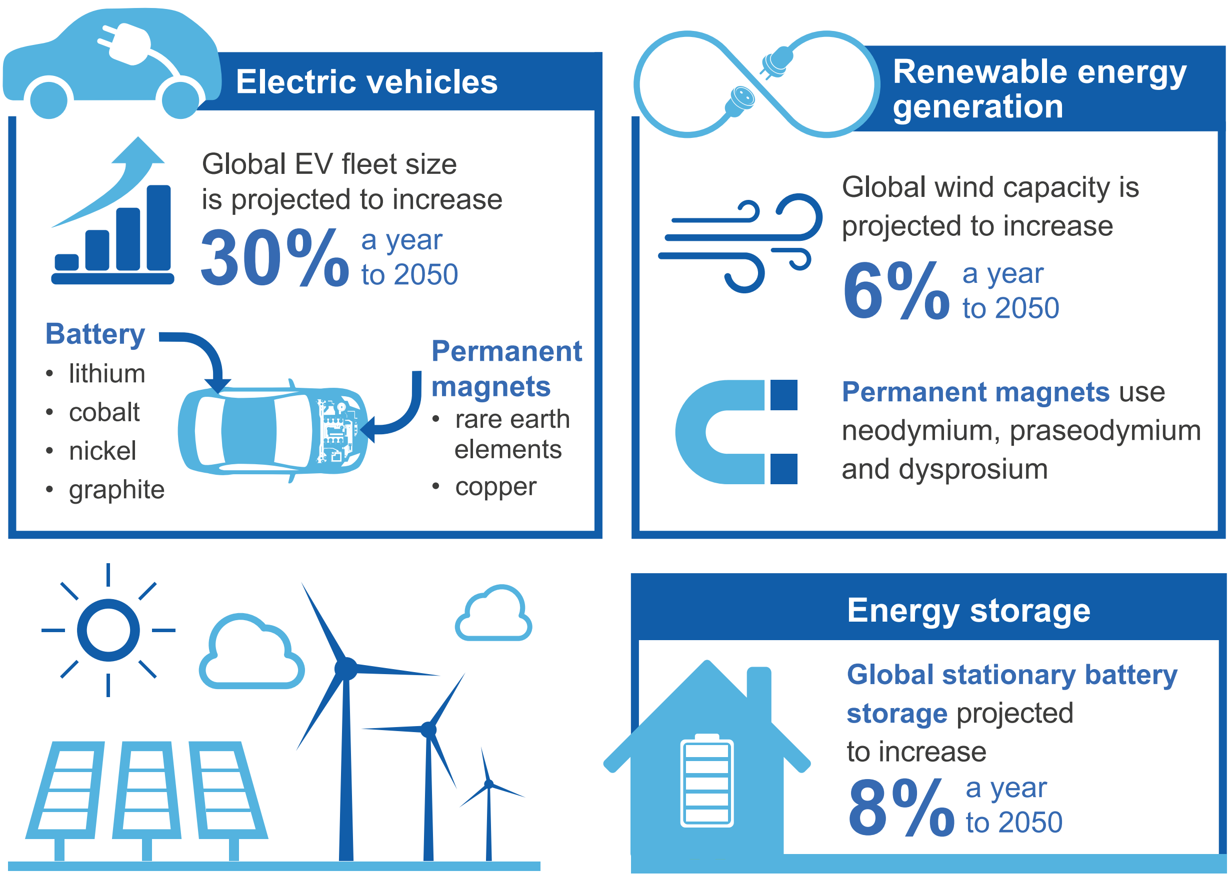
1. Overview

1.1 Critical minerals: strategic interest and growth opportunities

Critical minerals are metals and non-metals that have important economic functions, cannot be easily substituted and face some degree of supply risks. Supply risks can stem from geological scarcity, geopolitical issues, trade policy or other factors, resulting in critical mineral lists differing by jurisdiction.[1]

Critical minerals typically have an important role in industrial applications, but it is their vital role in new technologies that is sparking interest and expectations of faster demand growth.

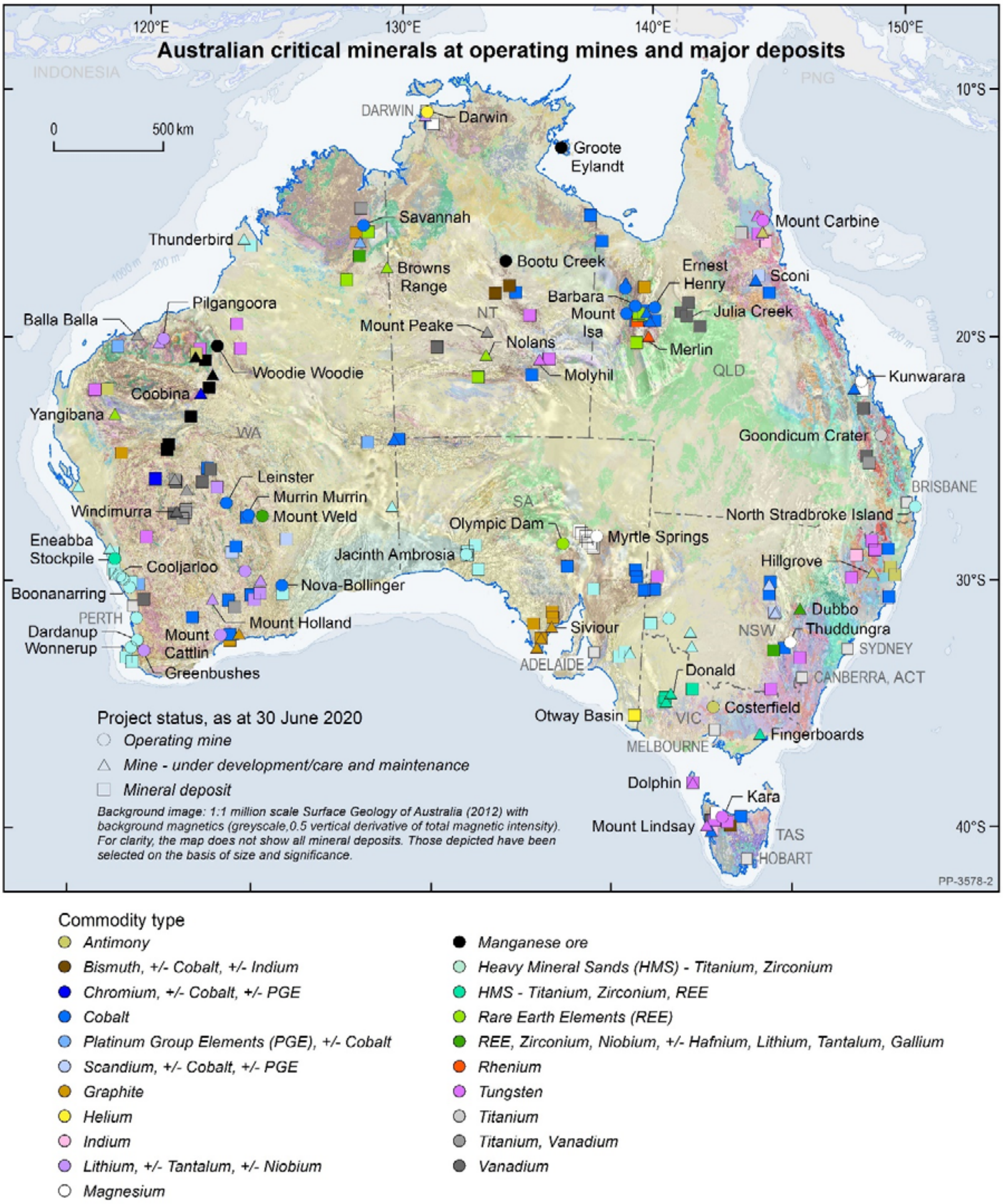
The economic security and supply chain reliability of critical minerals is also gaining attention, as governments look to avoid the negative impacts of trade dependence and related market shocks. Increasing awareness of the need for responsible mineral sourcing, including related environmental and social impacts, is driving further interest in mineral supply chains (e.g. EU battery regulations and industry-led cobalt traceability measures).



1 For example, see lists of US critical minerals and EU critical minerals.

See also Australia's list in Australia's Critical Minerals Strategy. For definition of critical minerals, see Geoscience Australia web-page on Critical Minerals.

Figure 1.1: Critical mineral deposits and major mines in Australia



Source: Geoscience Australia (2020)

1.2 Australia's current and potential role

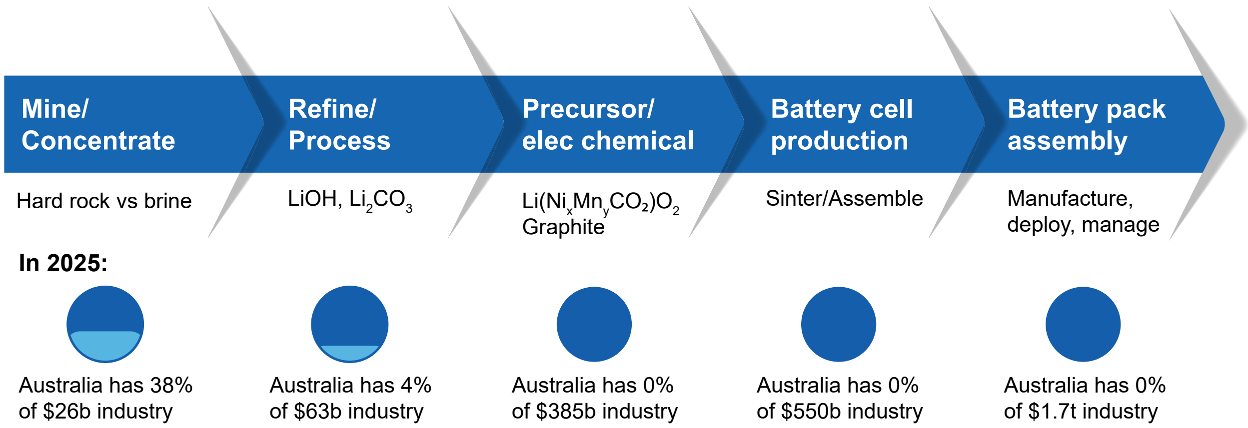
Australia contains a large array of critical minerals and has a history of effective mineral development and integration with world supply chains (Figure 1.1). The development of lithium over the last decade has seen Australia become the world's top producer, with ongoing growth prospects following substantial investment in mine and refinery capacity.

Australia's stable investment environment and governance arrangements (including environmental regulations) make it an attractive choice when considering responsible and secure mineral supply. Manufacturers around the world are increasingly responding to consumer requirements regarding input traceability. Australia supports initiatives for increased transparency of mineral provenance, such as those of the International Organization for Standardization.

Australia's potential in these minerals extends from mine production to downstream investment in value-adding processes. With research and development investment, geographic proximity and complementary infrastructure, investment beyond mining projects is underway. Development of Australia's cobalt, graphite and vanadium resources (as well as lithium) and associated downstream investment could see the battery value-add supply chain expand in Australia: domestic lithium refining is rapidly expanding, while there is potential for domestic manufacturing of vanadium batteries, graphite anodes, and refining of rare earth elements.

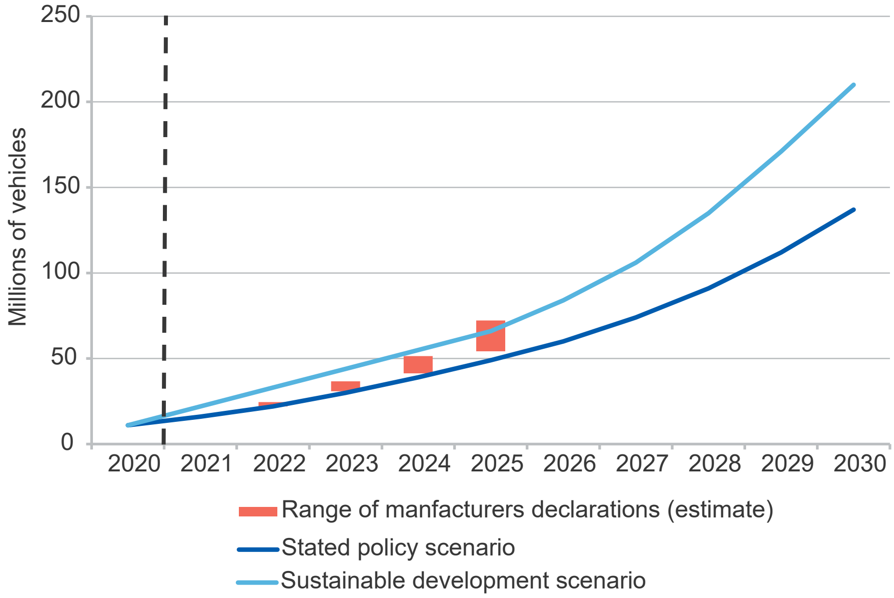
As Australia commences its journey into downstream processing of lithium, cobalt and other commodities, it is worth noting that the value multiplier along these paths is significant (as has been shown for the lithium battery value chain, Figure 1.2). Additionally, auto manufacturers have invested heavily in the transition from internal combustion engines (ICE) to electric vehicles (EV), and therefore it is in their interests to recoup their investment as quickly as possible. Currently, auto manufacturer's planned capacity projections through to 2025 exceed the requirements of announced government policies (Figure 1.3). This available capacity presents an opportunity for accelerating EV production, as well as the demand for minerals used in EV production.

Figure 1.2: Projected value of lithium battery value chain



Source: Porteous et al, Office of the Chief Scientist (2018) *Taking Charge: The Energy Storage Opportunity for Australia.* Department of Industry, Science, Energy and Resources (2021).

Figure 1.3: **Manufacturer announcements compared to EV stock projections in two IEA scenarios**



Source: International Energy Agency, OEMs' announcements compared to electric LDVs stock projections, 2021-2025

1.3 Focus of this report

The 2019 *Outlook for Selected Critical Minerals* publication provided a market outlook for six critical minerals. Since then, markets have progressed (albeit in an interrupted fashion due to COVID-19), digital transformation has accelerated, premiums for low-emissions technologies have continued to decline rapidly, and countries announced 'green' stimulus measures and net-zero emissions targets.

The four critical minerals chosen for this report – rare earth elements, cobalt, graphite and vanadium – have been investigated due to Australia's relatively favourable resource endowment and the prospects for strong market growth. These minerals are featured in the official US, EU and Canadian critical mineral lists, reflecting their importance in terms of future consumption and economic security requirements. While these minerals have important uses in conventional applications such as steel production, catalysts and pigments, they are all used in battery and EV applications, meaning expectations of transport electrification and energy storage advancements could significantly impact the respective markets. This report has an outlook period through to 2030.

This report includes a selected list of Australian critical minerals projects under each of the four critical minerals. For a more comprehensive list of critical minerals projects please refer to the *Critical Minerals Prospectus 2020* available at: https://www.industry.gov.au/news/new-critical-minerals-prospectus-showcases-investment-opportunities.

For further analysis of other minerals in which Australia conducts significant mining activity, such as lithium, copper and nickel, please see the Department of Industry, Science, Energy and Resources quarterly publication, Resources and Energy Quarterly, available at: https://www.industry.gov.au/req.

1.4 Summarised findings

The broad market outlook for these critical minerals is promising – a rapidly transitioning EV and battery storage sector is expected to see consumption growth outpace production growth – elevating prices to the benefit of producers. However, sharp price rises are usually not sustained, as shown by the volatile history in the cobalt price. Instead, the gap between expected and actual consumption growth will pivot on availability of supply, resulting from production uncertainties relating to ore body quality, processing technology, high operating costs and waste management issues.

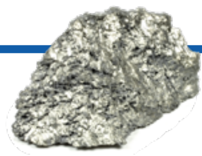
These findings show Australia is well placed to provide raw materials, and potentially refined product, to the world given appropriate market conditions. Across all minerals, consumption growth is dependent on low-emissions technology uptake, which is influenced by policy settings as well as the cost and scale benefits that are becoming apparent in the EV transition. Of the rare earth elements, neodymium, praseodymium, dysprosium, are expected to see consumption growth. Competing against established producers may prove difficult but some diversity of the supply chain could provide strategic advantages.

Of the battery minerals – cobalt, graphite and vanadium – consumption is expected to grow, although this will likely be broadly matched by production growth over the medium term. These production increases may include output from Australia, as well as the rest of the world. Mined cobalt production is expected to more than double by 2030 to meet the increase in consumption. The graphite market is expected to see some market tightness around the middle of the decade, before new production capacity comes online. There is particular upside pressure on vanadium prices in the short-term, which are expected to spike before 2023, and then stabilise amidst rising production.

It is worth noting that the development of the energy storage market is lagging behind the EV market, which may provide upside demand, principally for utility scale storage. Vanadium redox flow batteries are suited to utility scale energy storage because they have a longer life than a lithium battery and more efficient charge cycles, although they are physically heavier than lithium batteries which makes them unsuitable for EVs. Domestic scale energy storage is likely to benefit from bi-directional charging from EVs to dwellings. Bi-directional charging from EVs allows householders to use their car batteries to store electrical energy that may have been gathered by wind or solar and use it domestically. Since an EV may be a sunk cost for many households, this may provide battery storage by default. Such functionality appears to be becoming standard for EV manufacturers, posing upside risk to cobalt demand – depending on evolving battery chemistry.

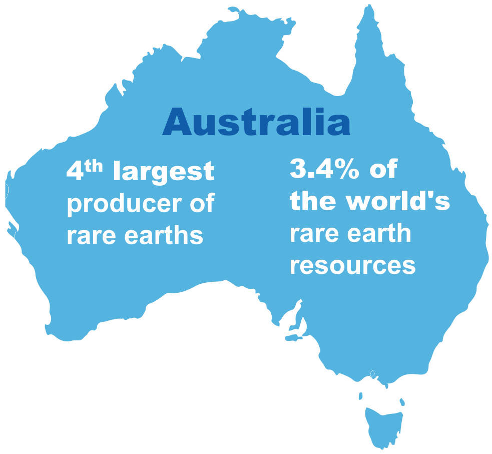
Key critical minerals

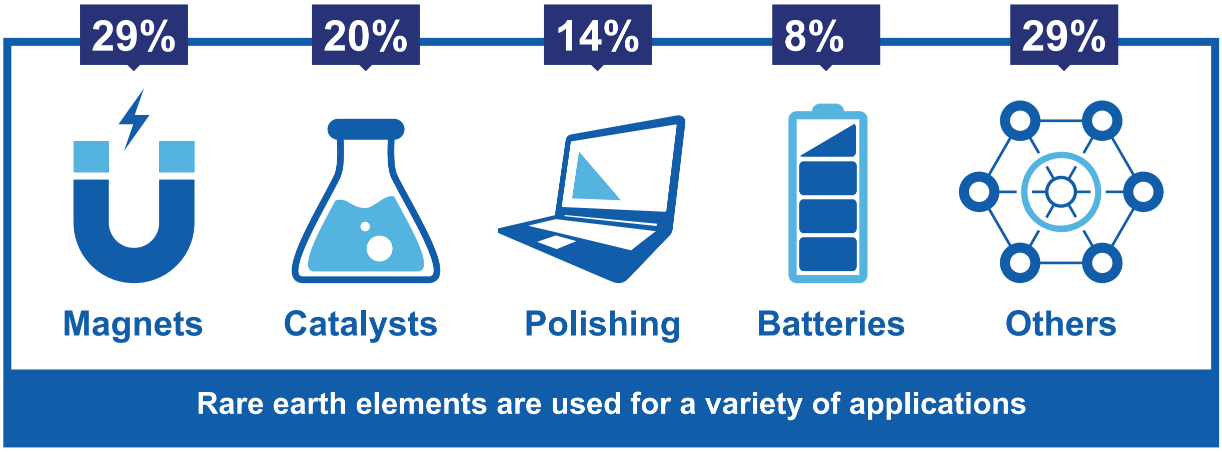
2. Rare Earth Elements



World supply dynamics

Country	2020 production (thousand tonnes rare earth oxides)	Share of world
China	140	57%
US	38	15%
Myanmar	30	12%
Australia	23	9%
Rest of world	18	7%





2.1 Key properties and uses

Rare earth elements (or rare earths) are a group of metals with unique physical and chemical properties. Certain rare earths are primarily used in the production of 'permanent' magnets since they are 'ferromagnetic' and can be magnetised like iron. Rare earth magnets are the strongest permanent magnets available. Generally, these permanent magnets contain numerous rare earth elements including neodymium. Permanent rare earth magnets are used extensively in low-emissions technologies like wind turbines and electric vehicles.

Because rare earth elements are chemically similar, their physical separation can be difficult, time-consuming, costly and environmentally challenging.

Some of the most important rare earth elements used in permanent magnet production are:

- Neodymium (Nd) [light rare earth]
- Praseodymium (Pr) [light rare earth]
- Dysprosium (Dy) [heavy rare earth]

Terbium can also be used in permanent magnet production but its use is not extensive. A more complete list of the rare earths and their uses is presented in Table 2.1.

Table 2.1: Rare earth elements and uses

Rare earth	Uses
Light rare earths	
Lanthanum	Rechargeable batteries, automotive catalysts, television and computer screens
Cerium	Automotive catalysts, glass, polishing powders
Praseodymium	Permanent magnets for EVs and wind turbines, computers, consumer electronic screens
Neodymium	Permanent magnets for EVs and wind turbines, computers, consumer electronic screens
Promethium	Thickness gauges and atomic batteries for spacecraft and guided missiles
Samarium	Magnets for small motors, cancer treatment and nuclear reactors
Europium	Red and blue colours in LCD screens, anti-forgery marks on banknotes
Heavy rare earths	
Gadolinium	LCD screens, used in steel production to improve resistance to high temperatures
Terbium	LCD screens and magnets for EVs and turbines
Dysprosium	Permanent magnets for EVs and wind turbines
Holmium	Nuclear control rods, sonar systems, data storage and laser materials
Erbium	Nuclear control rods, lasers
Thulium	Lasers, as a radiation source in x-ray machines and anti-forgery marks on banknotes
Ytterbium	Portable X-ray machines, lasers, earthquake monitors, strengthening stainless steel
Lutetium	Positron Emission Tomography (PET) scanners for 3D images of cellular activity
Other rare earths	
Yttrium	Consumer electronics, energy efficient lighting, satellites and superconductors

Notes: Scandium is not included as a rare earth element in this list. Promethium does not occur naturally.
Source: Austrade (2019), Geoscience Australia (2013)

2.2 Substitution

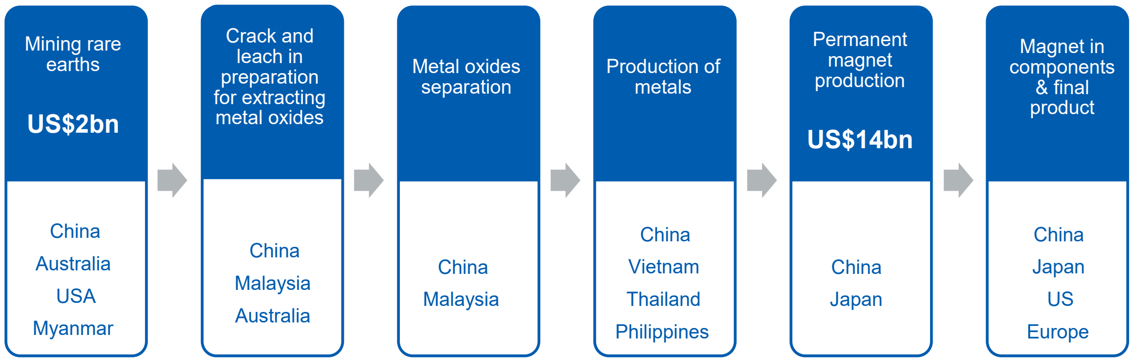
Rare earth substitutes are available in some applications but they tend to be less effective. Users of rare earths have responded to supply issues and price spikes by reducing use in non-essential applications. However, the three important 'magnet' rare earth elements listed above are not easily substituted in the production of permanent magnets. Gadolinium – another rare earth – is sometimes substituted for terbium.

Market supply of the three magnet rare earth elements from recycling was minor in 2020. Although recycling supply is set to grow by 2030, it is not projected to be a significant part of supply and therefore does not provide a substitute for raw material inputs.

2.3 Supply chain analysis

The rare earths supply chain is complex, with processes depending on the end products desired by consumers as well as the type of metals (e.g. magnet metals) or the style of chemicals (e.g. oxide or chloride) (Figure 2.1). China produces about 85% of the world's refined rare earths products, while Lynas Rare Earths Limited ('Lynas'; formerly known as Lynas Corporation) is the largest non-Chinese supplier of refined rare earth products.

Figure 2.1: Rare earths supply chain



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021); IMARC Group (2021)

Whilst China produces rare earth products for its domestic consumption, it also exports to the world – primarily to Japan, Europe and the US. Capacity for further refining is being developed in the US, Australia and Russia. Roskill's projected annual growth rate in end-use demand for rare earths for the world is 4.0% per annum over the next 10 years, with the increasing supply being largely met outside of China as other countries work to regain their earlier expertise that declined due to the environmental issues associated with refining rare earths. In particular, Lynas, in conjunction with the US Department of Defence, is examining refining rare earths in Texas, concentrating on heavy rare earths production.[2]

2.4 World production

China accounts for 57% of the world's mined rare earths output and 85% of refined output

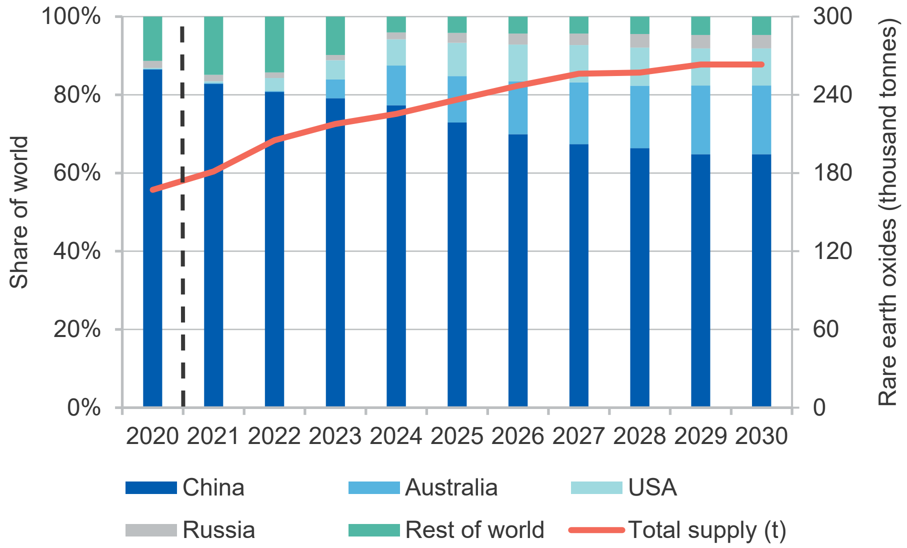
In the rare earths market, China produces approximately 57% of global mined production and around 85% of refined production, with supply largely controlled by six state-owned enterprises.[3] China consumes most of the rare earths that it produces in domestic downstream value-adding. China's capacity utilisation is understood to be only 70% – giving room for increased production from China. In the past, capacity utilisation has been as low as 45%.[4] Although China has extensive rare earths production, it is increasingly reliant on imports from Myanmar, Madagascar, Australia and the US. Having nearby borders with Myanmar and other countries has led to illegal production being unofficially imported to China, evading environmental and social regulations as well as mining quotas.[5]

Global mine supply is projected to grow by 1.5% per year over 10 years to 2030, with growth coming primarily from Australia (Figure 2.2). Refined production is projected to grow by 4.6% per year to 2030, with growth largely driven by Australia and the US (Figure 2.3).

2 Lynas Rare Earths (2021) Quarterly Report for the period ending 30 June 2021
3 Three of the state-owned rare earth producers in China are reportedly merging. Nikkei Asia (2021), China to create rare-earths giant by joining three state companies
4 Yeping, Y (20 Feb 2021) 'China raises rare earth quota as demand shoots up', *Global Times*
5 Roskill (2021)

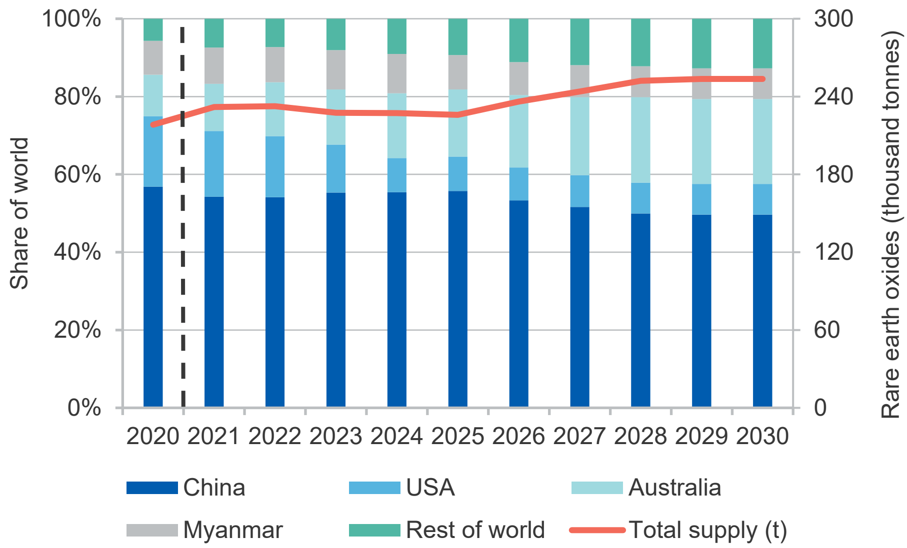
The use of stockpiles makes a comparison of the balance of mined and refined supply more challenging, and is more meaningful for individual element demand and supply. In particular, lanthanum and cerium are in oversupply, while magnet metals are in undersupply – with stockpiles being drawn down. Additional supply of neodymium is due in 2023–24, but the market still faces a deficit from 2028. Australia's mined production of rare earths is forecast to grow by 9.1% per annum over the outlook period (2020-2030), largely as a result of investment by Lynas at their Mount Weld operation, including a possible cracking and leaching facility at Kalgoorlie. Investment in Australia's refinery capacity is also largely attributed to Lynas, although it may take place in a number of geographic locations with the possibility of a refinery based around the processing of Iluka's tailings in Eneabba, WA.

Figure 2.2: Projected rare earths mine production by country



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

Figure 2.3: Projected rare earths refined production by country



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

2.5 World consumption

Growth due to magnet elements

Over the five years to 2020, the consumption of rare earths has grown by an estimated 3.9% per year. Annual growth accelerated to 5% in 2020, despite the impacts of the COVID-19 pandemic.

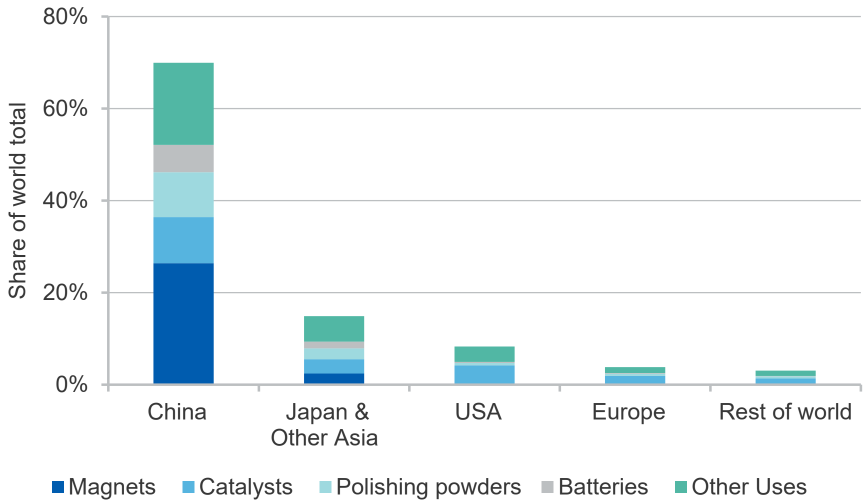
Trade in rare earths can be difficult to elucidate: the statistical codes used for raw materials (in the form of concentrates as well as more refined materials) are often not separate, making it difficult to estimate country trade without back calculations on values. Inconsistent reporting of rare earth elements (for example, as light and heavy rare earths, or by listing individual rare earth elements) across industry further complicates the assessment of trade and production.

In 2020, the largest importers of rare earth compounds (excluding lower value cerium products) were:

- US (20%)
- China (18%)
- Philippines (12%)
- Vietnam (10%)
- Japan (9.7%)
- Germany (9.6%)

China consumes most of the world's rare earths in downstream applications (Figure 2.4). China's main consumption is in magnets, followed by polishing powder and catalysts (with equal shares) and batteries. Japan also consumes rare earths via magnet production, as well as in other applications. Due to the strategic nature of magnet metals supply, stockpiling plays an important part in planning for consumption in the longer term. Many countries are taking a longer term view of the supply chain. Japan in particular, and more recently Germany, have acted to secure the supply of key metals through long term relationships with key producers external to China, as well as securing offtake with promising upcoming producers.

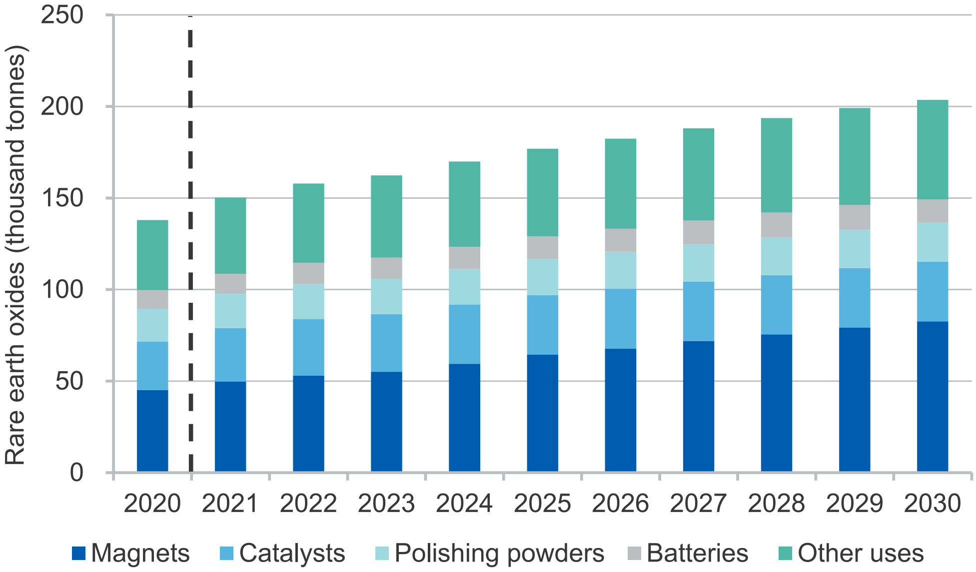
Figure 2.4: Estimated rare earths consumption by use and region, 2020



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

Global consumption is projected to grow at 4.0% per annum over the 10 years to 2030, with magnet production to grow by 6.2% per annum, driven by the strong take-up of low carbon emissions technologies (Figure 2.5).

Figure 2.5: Projected rare earths consumption by end use



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

2.6 Market outlook

Market history shows significant volatility

The rare earths market has had a volatile history, with shortages, oversupply, volatile prices, export restrictions, quotas and 'element specific' behaviour based on whether the element concerned is used in permanent magnet production or in other areas. In the 1990's, with low prices and environmental concerns around the process of separating rare earths, a lot of production relocated away from Australia, India, South Africa and the US towards China. This relocation resulted in a ramp up of Chinese production, including the separation of rare earths and the fabrication of rare earth products, including permanent magnets. In 2009, China introduced export quotas for environmental and resource preservation reasons. Quotas were lifted in early 2015, but subdued prices limited new entrants – unless supported by binding offtake agreements. Emerging low-emissions technologies are dependent on permanent magnets and hence rare earths (especially the magnet metals), and this has led some governments and companies to reclassify these minerals as 'critical', taking measures to support the market in the long term. More recently, in the first half of 2020 prices plummeted to 2010 levels due to the COVID-19 pandemic, followed by a strong recovery in the second half of 2020. These volatile price moves have pushed potential producers to obtain secure offtake agreements, in order to develop projects. Added to this is the emergence of renewables technologies which do not require rare earth permanent magnets, placing additional uncertainty on the outlook for rare earth elements. According to published policies, the International Energy Agency estimates neodymium demand by 2030 to
be similar to projections elsewhere (e.g. Roskill) but notes a significant upside risk for 'sustainable development' and zero emissions.[6]

6 International Energy Agency (2021), The Role of Critical Minerals in Clean Energy Transitions.

Magnet elements in demand

The outlook for rare earth elements varies considerably, depending primarily on the end-use application. Neodymium and praseodymium, in particular, are expected to experience market shortfalls towards the end of the decade, with some relief in 2023–24 as additional supply comes online. Demand-pull factors, including permanent magnet production in China and Japan, are expected to strongly influence the market balance for particular elements.

The outlook for other rare earth elements is more subdued, with much more muted growth prospects. Because a mixture of rare earth elements often occur in each mineral deposit, and they are usually extracted together, oversupply of some rare earths may be exacerbated in areas of low demand. Thus the economics of extraction is increasingly reliant on the 'magnet elements'. The neodymium-praseodymium market is projected to grow by 35% over the outlook period to 2030.

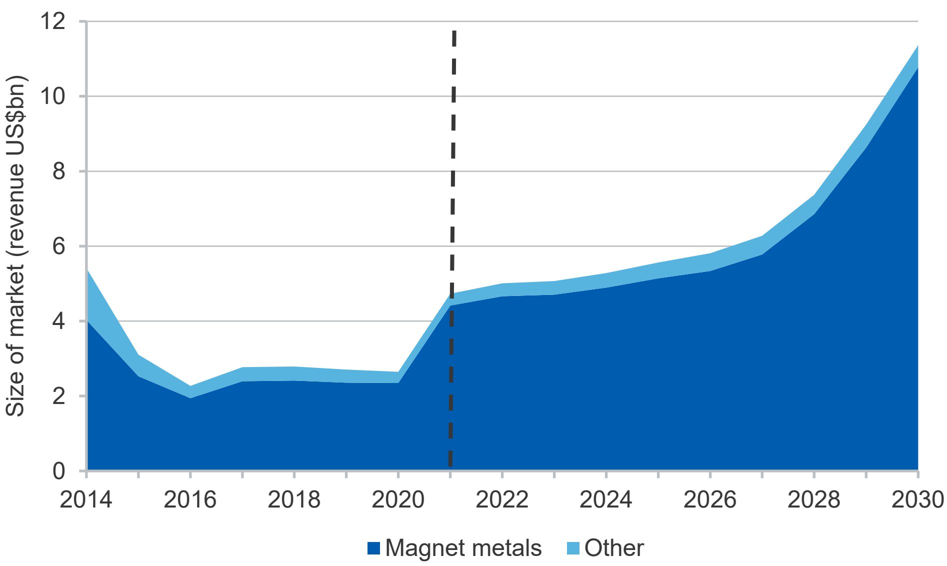
Prices

Neodymium and praseodymium as mixed oxides were trading at around US$40 per kilogram in the first half of 2020, but firmed to over US$55 per kilogram in December 2020. Dysprosium prices were volatile in 2020, falling from around US$260 to US$230 per kilogram by the end of the year. Terbium performed the strongest, increasing from around US$500 per kilogram at the start of 2020 to over US$1000 per kilogram towards the close of 2020. Terbium's price premium makes it less attractive as a magnet metal.

As most producers market a mixed oxide, there is a premium for the separated products. Consequently, producers are looking at ways to extract the most valuable rare earths within their total mine extraction. Meanwhile, explorers are also targeting the more valuable elements.

The compound average annual growth for the price of magnet metals over the next 10 years to 2030 (in real terms) is projected to be 8-9%. The global rare earths market was valued at around US$2 billion in 2020, and is forecast to grow to around US$12 billion by 2030, up an average 16% a year (Figure 2.6).

Figure 2.6: Rare earths market size outlook



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

2.7 Australia

Production and potential production

Australia is ranked sixth in the world in terms of rare earth resources, but fourth in terms of production, largely as a result of output from the Mt Weld deposit. However, the element mix of other deposits makes them attractive for development (Table 2.2). Over the forecast period (to 2030) Australia's mined rare earth element production is forecast to grow by 9.1% annually, driven by increased production planned from Lynas. Additionally, over 2021–2030, Australia's refined rare production is forecast to grow by 69% annually, with increasing production of refined products via the proposed Lynas Kalgoorlie cracking and leaching plant, as well as Malaysian and possible US separation facilities.

Lynas is the largest supplier of refined rare earths (mixed oxide products) outside of China. Processing is currently undertaken in Malaysia, although first stage cracking and leaching may take place in Western Australia by mid-2023. Lynas is are looking at additional extraction of dysprosium and terbium, with testing in a pilot plant in Texas, US. Additionally, Lynas is undertaking production of rare earth metals via toll treatment in Vietnam.[7] Iluka is also developing its Eneabba tailings operation that contains rare earths in the monazite residues. Phase 1 is in production (extraction of old tailings), Phase 2 for 90% monazite concentrate is in construction and Phase 3 (a fully integrated refinery) is undergoing a feasibility study.

ASX-listed producers also include Northern Minerals (currently producing mixed carbonates from a pilot plant). Potential producers are included in Table 2.3.

Table 2.2: Australia's rare earth resources and production

Australia's resources				Australia's production		
Geological potential	Economic Demonstrated Resource	Share world resources	World ranking resources	2020 production	Share of world production	World ranking production
High	4,100 kt	3.4%	6th	23.7 kt	9.4%	4th

Source: Source: USGS January (2021); Roskill (2021); Company reports

7 Lynas Rare Earths (2021) March Quarterly Results - Investor Briefing.

Table 2.3: Selected rare earths development projects in Australia

Company	Project	State	Elements	Status	Production / capacity
Arafura	Nolans	NT	Nd/Pr	Feasibility	Nd/Pr 4kt/year
Astron	Donald	VIC	Rare earths and mineral sands	Feasibility	16 kt/year of mixed rare earths concentrate in Stage 1
Australian Strategic Minerals	Dubbo	NSW	Rare earths, Nb, Hf and Zr	Feasibility	16 kt/year zirconia, 2.2 kt/year rare earth oxides (inc 0.9 kt/year Nd/ 0.2 kt/year Pr, 0.1 kt/year Dy)
Hastings Tech	Yangibana	WA	Nd/Pr	Feasibility	15 kt/year Mixed Conc inc 3.4 kt/year Nd/Pr oxides Site preparation
Iluka	Eneabba (Monazite stockpile)	WA	Nd/Pr Dy/Tb	Feasibility	Fully integrated refinery
Iluka	Wimmera	VIC	Rare earths, mineral sands, Zr, Titanium Oxide	Publicly announced	-
Kalbar	Fingerboards	VIC	Rare earths and mineral sands	Feasibility	8 Mt of heavy mineral concentrate over 15-20 years
Lynas	Mt Weld C&L plant	WA	Nd/Pr Planning to value-add with Dy/Tb.	Committed	12-16 kt/year of mixed rare earth oxides including 5ktpa of mixed Nd/Pr oxides
Murray Zircon	WIM 150	VIC	Rare earths	Feasibility	14.1 kt/year rare earths concentrate
Northern Minerals	Browns Range	WA	Dy/Tb	Feasibility	280 t/year Dy, 3.1 kt/year rare earth oxides for Stage 3
VHM	Goschen	VIC	Nd/Pr/Dy/Tb	Publically announced	-
WIM Resources	Avonbank	VIC	Rare earths	Publically announced	7.5-10 kt/year rare earth concentrate

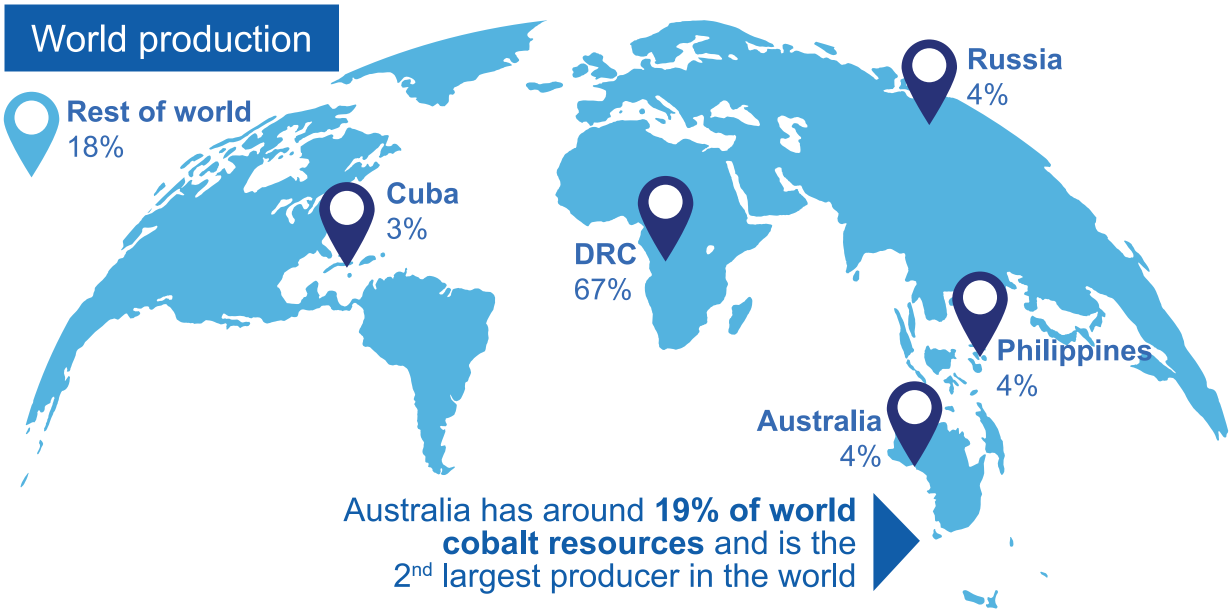
Notes: Nd – Neodymium, Pr – Praseodymium, Dy – Dysprosium, Tb – Terbium, Nb – Niobium, Hf – Hafnium, Zr – Zirconium,

This is a selection of current development projects in Australia and not intended to be an exhaustive list. Projects at feasibility status have undertaken initial project definition work, which can include engineering design, environmental impact studies and regulatory approval, but have not reached the financial investment decision.

Source: USGS (January 2021); Roskill (2021); company reports.

3. Cobalt

World production



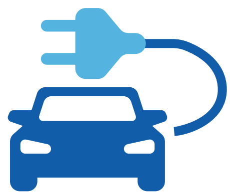
Australia has around **19% of world cobalt resources** and is the 2nd largest producer in the world

Uses

59% of cobalt is used in batteries

Laptops
5-15 grams cobalt

Mobile phones
5-10 grams cobalt



Electric cars
10-20 kilograms cobalt

3.1 Key properties and uses

Cobalt is a ferromagnetic metal that is valued for its stability, hardness, anti-corrosion and high-temperature resistance characteristics.

The main use of cobalt is in the precursors and cathodes of rechargeable batteries (56% of total consumption), followed by nickel-based alloys (13%) which are used extensively in the aerospace industry, tool manufacturing (8%), with smaller amounts used in pigments, soaps and as catalysts. The end-use of cobalt is primarily in portable electronics (36.3% of global consumption), such as smartphones and laptops, however, automotive applications are also large (23%) and growing.

3.2 Substitution

Due to the high price and supply issues associated with cobalt, battery makers have strived to reduce the cobalt content in batteries, instead using nickel-rich cathode chemistries. In late 2020, Tesla Inc. announced that it would move to a cobalt-free battery, although no time frame was given. To date, cobalt substitutes have not been widely adopted, due to inferior performance.

It is expected there will be a considerable increase in the amount of cobalt supplied through recycling over the forecast period. Recycling is already relatively well-utilised, as cobalt can be recovered from a range of secondary sources. Increasingly, growth in cobalt recycling is being driven by battery recycling, as the practice achieves a greater commercial scale with the increased availability of end-of-life batteries. It is forecast that cobalt supply from recycled sources could reach 34 kilotonnes per year by 2030, with over 80% of that volume coming from battery recycling.

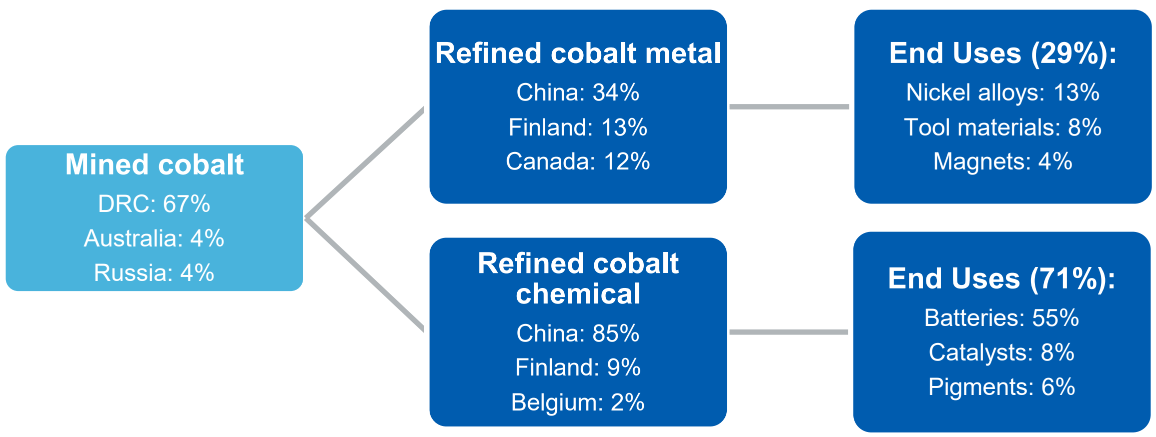
3.3 Supply chain analysis

Cobalt mine production is highly concentrated in the Democratic Republic of Congo (DRC), which accounts for 67% of the global mine production (Figure 3.1). There have been on-going concerns linked to the DRC regarding political stability, labour issues, corruption and transparency, which accentuate the supply chain risk of a highly concentrated market. It is also worth noting that mine ownership in the DRC is highly concentrated between Chinese and Swiss firms.

Cobalt refining is also highly concentrated in a single country. This is especially true for cobalt chemicals, which are expected to experience a surge in demand, while metals tend to have a more diversified refining base, including in Australia. The most significant global trade relationship for cobalt is between the DRC and China.

Another factor to be considered in the cobalt supply chain is that it is typically mined as a by-product. Whilst cobalt itself is not scarce or rare, it typically occurs at relatively low-grade along with other metals, most commonly nickel and copper. As a result, future supply depends on demand for and prices of nickel and copper. Increased battery demand is likely to lead to higher prices for both nickel and copper.

Figure 3.1: Cobalt supply chain



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

3.4 World production

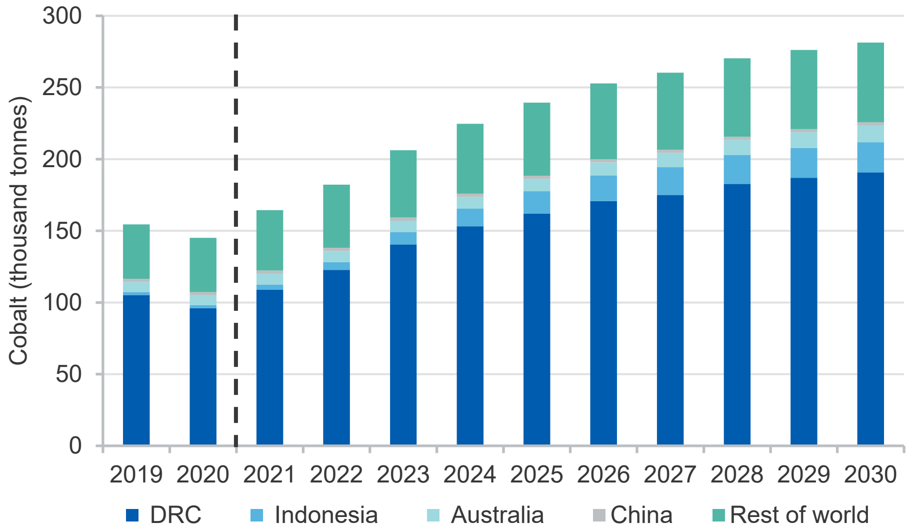
World production of mined and refined cobalt is heavily concentrated

Global production of mined cobalt is highly concentrated, with the DRC accounting for approximately 67% of global production (96,000 tonnes in 2020) (Figure 3.2). Australia is the second largest cobalt miner, accounting for around 4% of global production (5,700 tonnes in 2020). A number of other countries, including Canada, Russia, the Philippines and Zambia, also contribute a smaller share of global production. Global production has decreased recently, due to lower prices; Glencore placed the Mutanda mine – the world's largest cobalt mine – into care and maintenance in 2019 and it is not expected to re-open until 2022. Mutanda tends to be more sensitive to cobalt prices than copper prices, the other major commodity it produces. Typically, the DRC is quite price sensitive due to the prominence of artisanal mining.

Global production of refined cobalt is also highly concentrated. China is the largest producer of refined cobalt products (metal and chemical), accounting for 66% of global refined output, followed by Finland (10%) (Figure 3.3). Both countries rely on imported feedstock from the DRC for their refining operations. Australia accounts for around 3% of the production of cobalt metal and is ranked 6th globally. Figure 3.1 details the major refiners of both mined and refined cobalt.

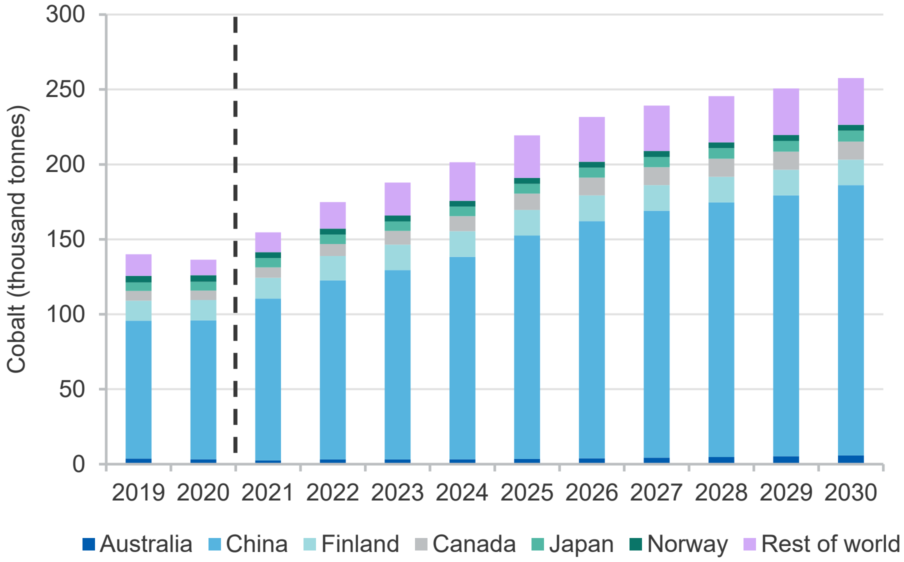
There has been a shift in the type of refined cobalt being produced. Cobalt metal was previously the dominant refined product, however, it is estimated that 65% of refined cobalt is in chemical form in 2020. The production of cobalt chemicals is heavily dominated by China, while the production of cobalt metal is more diversified.

Figure 3.2: Projected cobalt mine production by country



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

Figure 3.3: **Projected refined cobalt production (metal and chemical) by country**



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

3.5 World consumption

Increase in cobalt consumption driven by automotive sector

Global consumption of cobalt has increased significantly in recent years, with growth in consumption across all major uses. The market has grown at an average rate of 4.5% per year since 2013, and total consumption is estimated to have reached 141,000 tonnes in 2020. Most of the growth in consumption has come from cobalt chemicals, due to their use in lithium-ion batteries. Global consumption was somewhat impacted by the COVID-19 pandemic, with a lower year-on-year growth rate of 3.8% in 2020. The reduction was largely driven by the decreased demand for nickel-based alloys in the aerospace industry in 2020, which fell 12%.

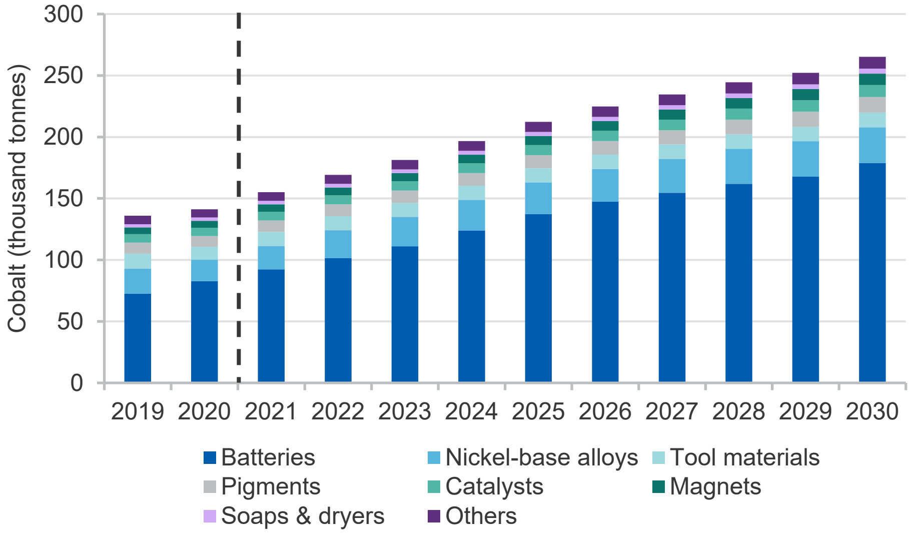
Demand is expected to grow to 280,000 tonnes, more than doubling current consumption, by 2030, at an average growth rate of more than 6% per year. This growth would largely be driven by increased battery demand in the automotive sector (Figure 3.4). The increased demand for EVs is expected to see cobalt use in automotive batteries rise at a rate of 16% per year through to 2030, however advances in battery composition are projected to lead to lower cobalt requirements per unit.

In 2020, the largest importers of cobalt ores and concentrates were:

- China (81% of world total)
- Morocco (14%)
- Finland (2.4%)

The consumption of refined cobalt can be broken down into consumption of cobalt metals and consumption of cobalt chemicals, with the former used in products such as nickel-based alloys and tools, and the latter used in battery production. China is the largest consumer of refined cobalt globally, consuming significant amounts of both the chemical and the metal.

Figure 3.4: Projected cobalt consumption by end-use



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

3.6 Market outlook

Prices likely to recover as consumption picks up

The global cobalt market suffered three consecutive years of over-supply, following a surge in prices in 2016–18. The high prices in mid-2018 triggered a massive supply response in the DRC, leading the market to be in surplus and causing prices to fall significantly throughout the period 2019–2020, to levels under US$30,000 per tonne (Figure 3.5). In early 2021, prices started to recover, rising to over US$45,000 per tonne. Prices are expected to average about US$43,000 per tonne in the period through to 2030.

There is expected to be significant growth in consumption, especially for cobalt chemicals, driven by growth in the battery sector and increased EV manufacturing. Mined cobalt production is expected to more than double by 2030 to meet the increase in demand, however this will require significant additional mine capacity to come online over that period.

Figure 3.5: Cobalt spot price history

Source: S&P Global (2021) Department of Industry, Science, Energy and Resources (2021)
Note: Metal Bulletin price, cobalt metal, standard grade

3.7 Australia

Australia has strong cobalt prospects and a pipeline of cobalt projects

Australia has the 2nd largest resources of cobalt in the world, estimated at around 19% of the world total reserves but only contributing 4% of global mined supply at the moment (Table 3.1). There is significant future potential for Australia's cobalt, with the rising demand for EV batteries, particularly with manufacturers seeking reliable and responsible alternatives sources of supply. Australia's mined cobalt is typically a by-product of nickel laterite resources, while refined cobalt is currently exclusively in the form of cobalt metal. Australia currently produces no refined cobalt chemicals, after production ceased in 2015 with the closure of the Palmer Nickel and Cobalt Refinery (Queensland Nickel).

There are currently four cobalt producing companies operational in Australia: Glencore plc, BHP, First Quantum Minerals Ltd and IGO Ltd, with Glencore being the dominant producer in the Australian market and the only company producing refined material. In March 2021, Glencore announced a temporary reduction in production at its Murrin Murrin facility due to a malfunction. The duration and scale of the reduction is unclear. There are a number of other projects in the pipeline at both early and advanced stages of development (see Table 3.2). In early 2021, Panoramic Resources Ltd announced the restart of the Savannah Nickel Operation, which is expected to have an annual production target of 676 tonnes of cobalt, with first shipments from December 2021. In recent developments, POSCO and First Quantum have announced that they are exploring a partnership to produce battery cathode precursor materials.

Table 3.1: Australia's cobalt resources and production

Australia's resources 2019				Australia's 2020 production		
Geological potential	Economic Demonstrated Resources	Share world economic resources	World ranking resources	Production	Share of world production	World ranking production
High	1399 kt	19%	2nd	5.7 kt	4%	2nd

Source: Geoscience Australia (2020); Roskill (2021)

Table 3.2: Selected cobalt development projects in Australia

Company	Project	State	Status	Capacity
Aeon Metals Ltd	Walford Creek	QLD	Publically announced	22 kt over 11 years
Ardea Resources Ltd	Goongarrie	WA	Publically announced	5.5 kt/year cobalt sulfate
Australian Mines Ltd	Sconi	QLD	Feasible	200 kt of cobalt sulfate over 30 year mine life
Australian Mines Ltd	Flemington	NSW	Publically announced	-
Barra Resources Ltd	Mt. Thirsty	WA	Feasible	1.9 kt over 12 years
Cobalt Blue Holdings Ltd	Broken Hill	NSW	Feasible	3.6 kt/year
GME Resources Ltd	NiWest	WA	Feasible	1.4 kt/year
Queensland Pacific Metals	TECH Project	QLD	Publically announced	3.0 kt/year of cobalt sulfate
Sunrise Energy Metals Ltd	Sunrise	NSW	Feasible	4.4 kt cobalt over 11 years

This is a selection of current development projects in Australia and not intended to be an exhaustive list. Projects at feasibility status have undertaken initial project definition work, which can include engineering design, environmental impact studies and regulatory approval, but have not reached the financial investment decision.

Source: Department of Industry, Science, Energy and Resources (2021); company reports; Roskill (2020).

4. Graphite

Australia's resources

Australia has the 7th largest reserves of graphite

World consumption

Natural graphite

60%

of world consumption

Synthetic graphite

40%

of world consumption

66% of natural graphite consumed in Asia

Uses of natural graphite

Refractories	Batteries	Other	Foundries	Lubricants
44%	22%	17%	12%	5%

4.1 Key properties and uses

Graphite is a black mineral composed of carbon. It occurs naturally in three forms: as crystal flakes in metamorphic rocks, as vein graphite in veins or fractures, and as amorphous graphite in some coal deposits. Most natural graphite is produced as crystal flakes.

Due to key properties such as electrical conductivity, lubrication and thermal stability, graphite is used in a number of industrial applications. Graphite is an excellent conductor of both electricity and heat, and has the highest natural strength and stiffness of any material under extremely high temperatures. Graphite is predominantly used in steelmaking and refractory applications, such as electrodes (32% of total natural and synthetic graphite use in 2020), refractories (18%) and increasing the carbon content of steel by recarbusing (12%). Graphite also has a significant role in low-emissions technologies. Currently, battery applications account for the fourth largest use of total graphite (11% in 2020). Graphite is the largest mineral component in nickel and lithium batteries. Graphite is used in a purified form (spherical graphite) in battery anodes, as a cost-effective and durable way to improve battery conductivity and charging. High-purity graphite is also used in wind and solar technologies.

4.2 Substitution

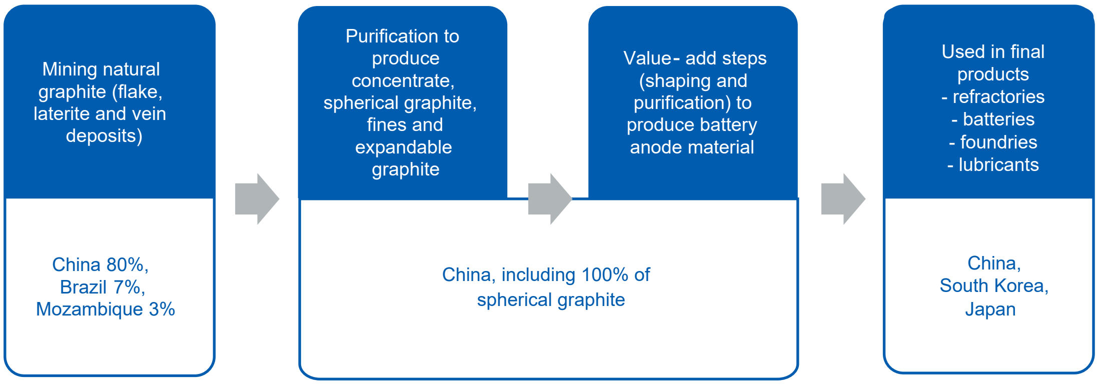
Synthetic graphite is a common substitute for natural graphite in iron and steel production. In battery applications, synthetic graphite powder is a substitute, and silicon anode is under research as another substitute.

While synthetic graphite production is well developed (accounting for 60% of world graphite production) and can produce high quality product, it is more expensive to produce than natural graphite.

Secondary graphite (recycled) is a graphite substitute in industrial applications, which utilises graphite's thermal properties. However, recycling technology is limited, and graphite is currently not recycled on a significant scale.

4.3 Supply chain analysis

Figure 4.1: Graphite supply chain



Source: Roskill (2020); USGS (2021).

Graphite production is concentrated in China at all stages of the supply chain. While China consumes most of its domestic production, in 2019 around 31% of China's natural graphite production was exported. Processing and refinery facilities outside of China are currently limited. China produces all of the world's battery grade (spherical) graphite (Figure 4.1). This is a highly technical process, with associated environmental costs in terms of toxic inputs (hydrofluoric acid) and local pollution.

4.4 World production

China's production dominates world markets

Graphite resources are spread out geographically, and natural graphite is produced in almost 20 countries. Despite this, graphite production is heavily concentrated, with China accounting for around 80% of world production. China is the largest producer of natural graphite in flake (60% of world production) and amorphous forms (20%), and is also the largest producer of synthetic graphite. Other major producers include Brazil (7% share of world production over last five years), Mozambique (3%) and Madagascar (2%).

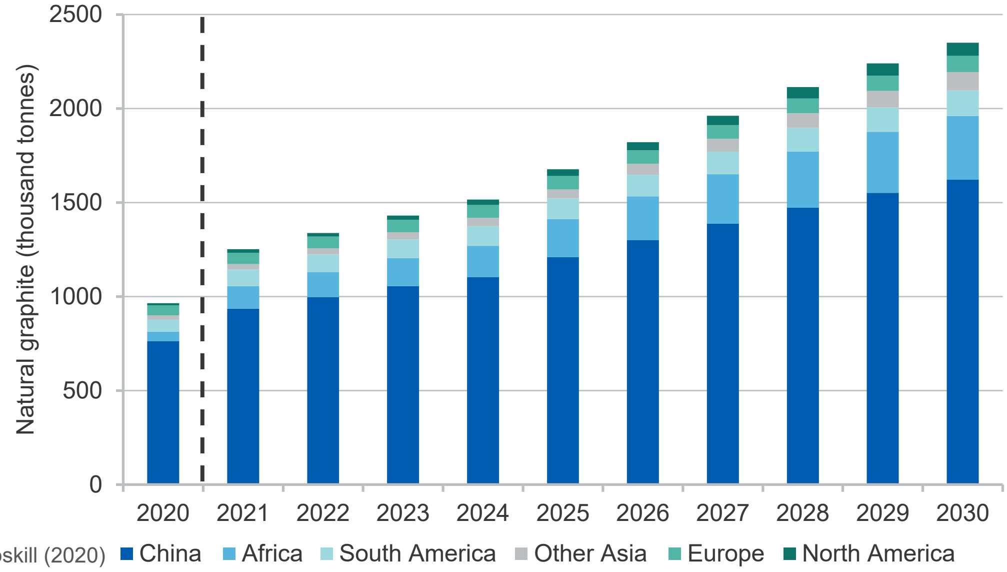
World graphite output fell by 27% in 2020, as producers reacted to a fall in demand due to the COVID-19 pandemic. China produced 787,000 tonnes of natural graphite in 2020, accounting for a higher share of world production (81%) as production from Mozambique declined.

China's graphite production fell in the first half of 2020, due to COVID-19 impacts on consumption and industrial activities, resulting in annual fall of 15% in 2020. China's graphite production has transformed in recent years, as amorphous graphite production has lowered, while production of flake graphite has increased. These changes reflect interruptions to amorphous production (due to enforcing environmental controls) and changing end-use demand, with the rise in flake production closely linked to battery and EV manufacturing.

World production has also been affected by volatility in output from Mozambique. After being the world's second-largest producer in 2018, Mozambique's production fell significantly in 2019 with the temporary closure of Syrah Resources Ltd's Balama flake graphite operation, which accounts for almost all of Mozambique's output. Syrah Resources is an ASX company, and is developing vertically integrated processing facilities in the US. After closing in late 2019 – in response to low prices – production from Balama recommenced in March 2021.

Going forward, production is projected to increase by around 4% annually in the period to 2030 to 2.4 million tonnes, largely driven by the increasing demand from the lithium-ion battery sector (Figure 4.2). The most significant production growth is expected in China, followed by Africa.

Figure 4.2: Projected natural graphite production by country



Source: Roskill (2020)

4.5 World consumption

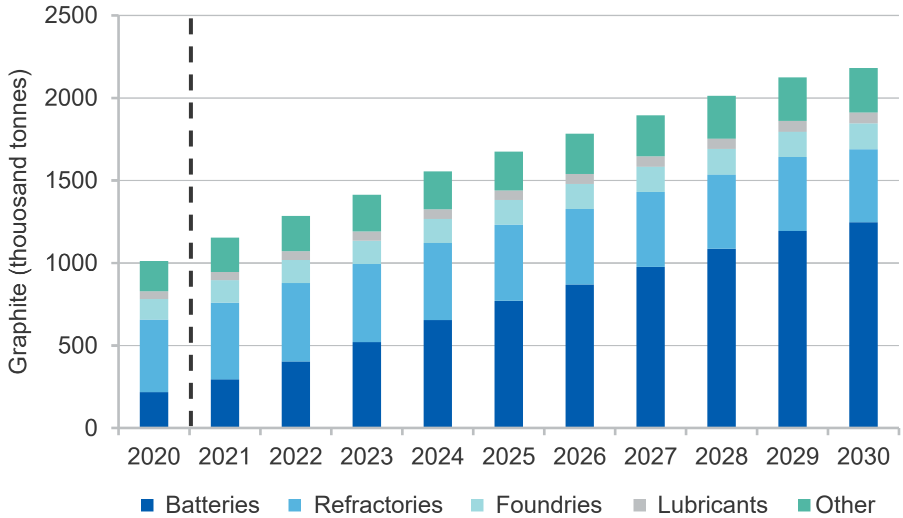
World consumption	Refractories	Batteries	Other
Asia	33%	16%	18%
Europe	4%	1%	6%
North America	2%	1%	4%
South America	2%	1%	5%
Other	1%	2%	2%

Graphite consumption located in Asia in proximity to processing facilities

Around half of world's graphite output is consumed in Asia, primarily in China, followed by Japan and South Korea. In terms of end-use applications, use in refractory applications account for the largest end-use sector (44%), followed by batteries and foundries. Lithium-ion battery manufacturing is concentrated in China, followed by South Korea and Japan, with the US and Europe accounting for a small, but growing share.

After falling in 2020, due to COVID-19 related market impacts, graphite consumption is expected to recover. Going forward, consumption is expected to increase in line with growing battery manufacturing (Figure 4.3). Total graphite consumption is projected to exceed 2 million tonnes in 2030, as the share of graphite used in battery manufacturing almost doubles, up from 217,000 tonnes in 2020. Other economic indicators are positive for graphite used in industrial applications, such as steel manufacturing, though consumption in these sectors is expected to increase at a more moderate rate.

Figure 4.3: Projected graphite consumption by use



Source: Roskill (2020)

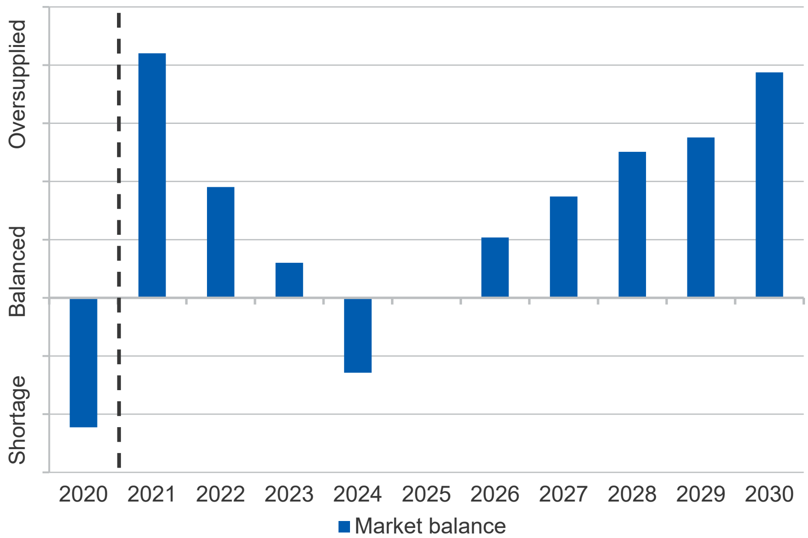
4.6 Market outlook

Graphite in battery use to drive consumption, potentially pushing market into deficit

Positive foreforecasts for battery manufacturing and electric vehicle sales are expected to flow through to higher graphite consumption going forward. However, the exact timing is difficult to predict. End-use demand drivers in China and the rest of the world remain dependent on government policy and subsidies. Even with strong positive consumption growth, the supply side will take some time to adjust.

To optimise battery manufacturing costs, demand for natural graphite is expected to outpace demand for synthetic graphite. Natural graphite can be processed into high purity product suitable for battery use, while remaining cost competitive with synthetic graphite. While the overall graphite market is currently adequately supplied, significant increases in consumption may lead to market tightness for high-quality, battery-grade graphite (Figure 4.4). The adjustment of production and consumption needs is expected to see the graphite market being well supplied over the short-term, which may weigh on prices and subdue production expansions. As battery manufacturing momentum and scale increases, consumption growth could lead to an undersupplied market around the middle of the decade, before new production comes on-line.

Figure 4.4: Projected graphite (natural and synthetic) market balance



Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

4.7 Australia

The only direction for Australia's graphite production is up

There are no producing graphite projects in Australia, however there are a number of development projects underway. The Uley mine in South Australia produced for a year in 2015, before closing due to low prices. In addition to flake graphite mining projects which will produce graphite concentrate, a number of processing facilities, that would produce spherical graphite for battery use, are under consideration. (Table 4.2 and Table 4.3)

Australia has moderate geological potential for graphite and, to date, exploration activity has delineated the world's seventh largest economic resources, mostly in flake form (Table 4.1). South Australia hosts 65% of Australia's economically demonstrated graphite resources, followed by Queensland (17%) and Western Australia (18%).

Table 4.1: Australia's graphite resources and production

Australia's resources 2019				Australia's production		
Geological potential	Economic Demonstrated Resource	Share world economic resources	World ranking resources	2020 production	Share of world production	World ranking production
Moderate	7.97 Mt	3%	7th	0 kt	0%	N/A

Source: Geoscience Australia (2020)

Table 4.2: Selected graphite development projects in Australia

Company	Project	State	Status	Capacity
Hexagon Energy Materials	McIntosh	WA	Publically announced	88 kt/year
Lincoln Minerals	Kookaburra Gully	SA	Publically announced	35 kt/year
Minerals Commodities	Munglinup	WA	Feasibility	52 kt/year
Quantum Graphite	Uley 2	SA	Feasibility	55 kt/year
Renascor Resources	Siviour	SA	Feasibility	80 kt/year (stage 1) 144 kt/year (stage2)

Source: Department of Industry, Science, Energy and Resources (2021); Company reports; Roskill (2020)

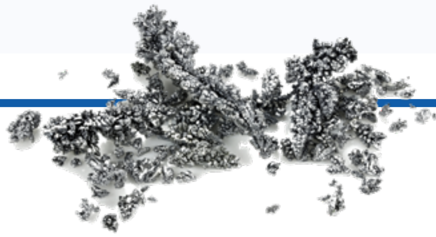
Table 4.3: Selected Graphite refinery/processing facility projects in Australia

Company	Project	State	Status	Capacity
EcoGraf	Kwinana	WA	Feasibility	5.0 kt/year (stage 1) 20.0 kt/year (stage 2)
Hazer Group	Kwinana	WA	Feasibility	-
Mineral Resources, Hexagon Energy Materials		WA	Publically announced	
Renascor Resources	Siviour	SA	Feasibility	80 kt/year (stage 1)

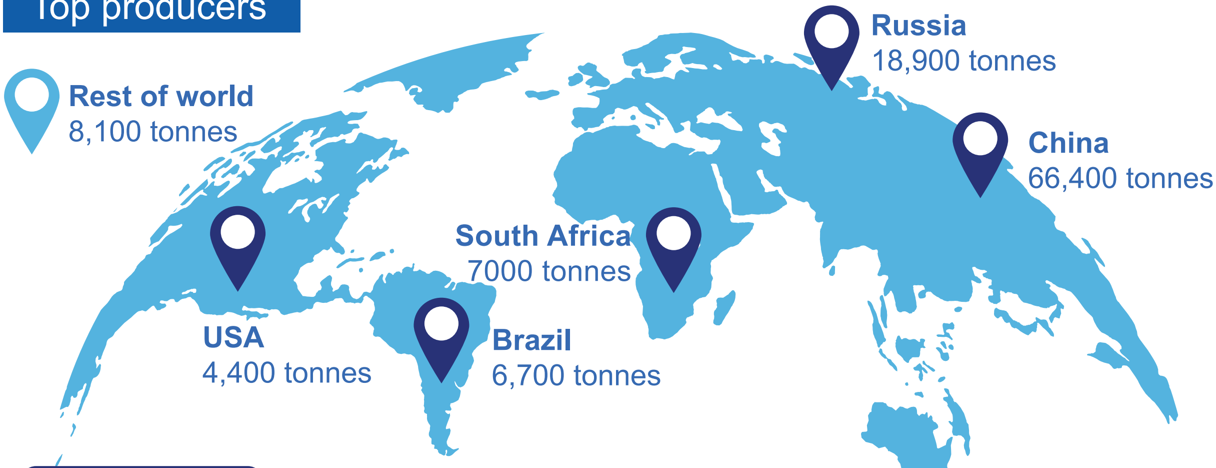
This is a selection of current development projects in Australia and not intended to be an exhaustive list. Projects at feasibility status have undertaken initial project definition work, which can include engineering design, environmental impact studies and regulatory approval, but have not reached the financial investment decision.

Source: Department of Industry, Science, Energy and Resources (2021); Company reports; Roskill (2020)

5. Vanadium



Top producers

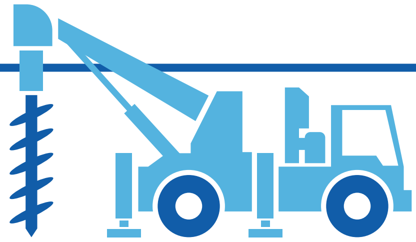


Top consumers

Country	Tonnes
China	62,000
Europe	12,000
North America	10,000

Australia has a number of advanced projects evaluating mining, as well as downstream processing.

Australia's Vanadium resources are the **3rd largest** in the world, accounting for **18 per cent** of world economic demonstrated resources but Australia's current production levels are **negligible.**



5.1 Key properties and uses

Vanadium is used mostly in steel alloys as it adds strength to steel and makes it suitable for applications in tool making, girders and other similar areas. Vanadium also has an emerging role in vanadium redox 'flow' batteries (VRFBs; see below).

Vanadium Redox Flow Batteries

Vanadium redox flow batteries are part of a suite of batteries that are suited to stationary energy storage applications. They are non-flammable compared with lithium batteries and have a longer service life of around 20 years – compared with 10 years for lithium batteries – and can discharge 100% of their stored energy. However, they are much heavier per unit volume making them more suitable for stationary storage applications.[8] Two Australian companies are currently assessing VRFB production in Australia. Whilst the lithium batteries can be reused at the end of life hence the technologies might appear to compete, they can be complementary. Lithium batteries discharge over typically 4-5 hours, whereas the discharge profile for VRFBs is often longer. This complementarity may accelerate the uptake of VRFBs.

8 Energypost.eu (2019), Can Vanadium Flow Batteries Beat Li–Ion Batteries for Utility-Scale Storage?

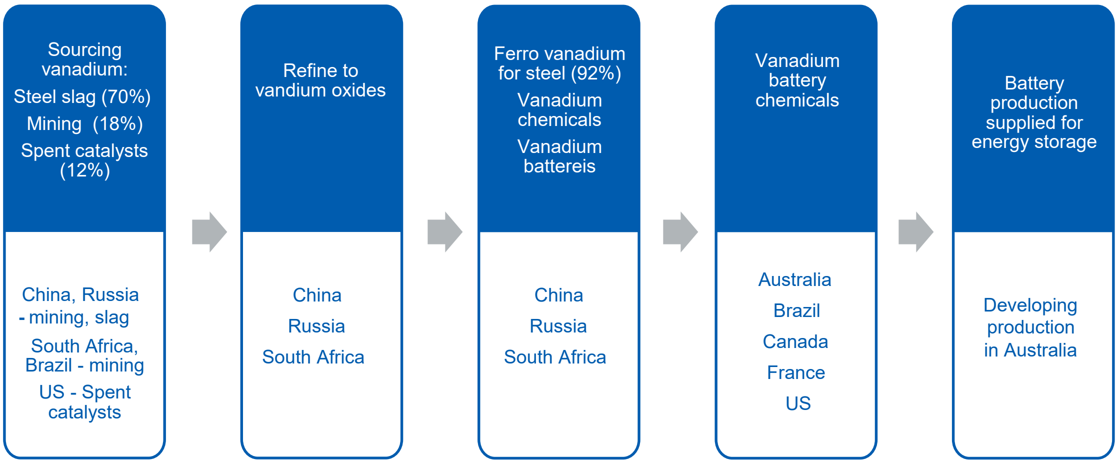
5.2 Substitution

In steel applications, vanadium can be substituted with titanium or, more commonly, niobium; substitution is usually based on moves in prices. Vanadium flow batteries are not unique; zinc flow batteries also exist and therefore potentially compete for market share.

5.3 Supply chain analysis

Seventy per cent of vanadium supply results from smelting iron rich ores containing vanadium to produce pig iron and a vanadium rich slag. Most vanadium (92%) is used as ferrovanadium for steel hardening. The supply of vanadium slag is dominated by China and Russia. Mined vanadium supplies only 18% of the market. Mined vanadium is currently supplied by Brazil and South Africa. The value of the vanadium market is difficult to estimate, since vanadium slag does not have a harmonised customs code. The vanadium battery market is an emerging market whose size is difficult to estimate at this early stage.

Figure 5.1: Vanadium supply chain – battery end product



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

5.4 World production

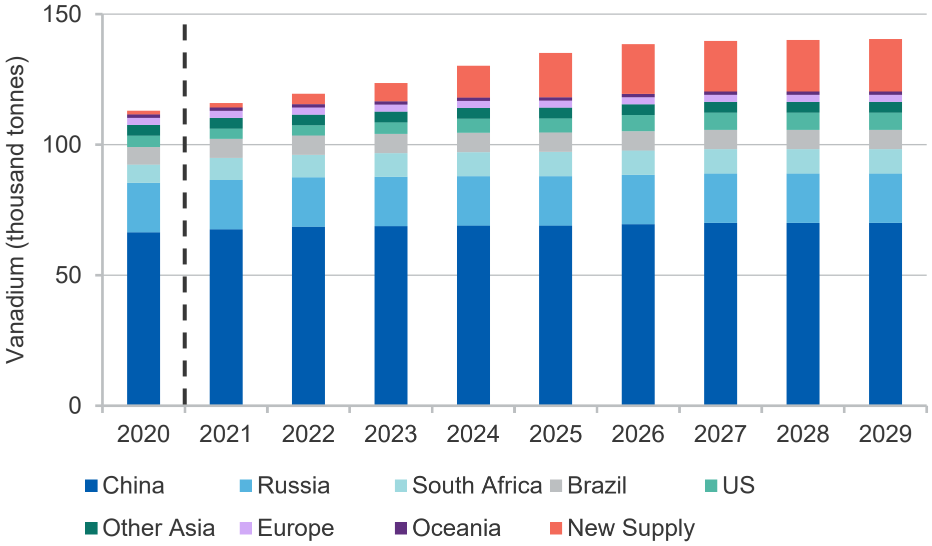
Three major sources

There are three major sources for vanadium production:

- Co-production from ferrovanadium ore, which produces vanadium slag after vanadium-rich iron ore is smelted (>70% of world total)
- Direct mine production (18%)
- Recovery from used vanadium products (often fuel catalysts: 12%)

Production of vanadium from these sources varies by region, with China's production primarily (>85%) via co-production. Russia's production is also co-production. South Africa's production is direct production, centred on the Bushveld Complex. Brazil started direct production from its mines in 2014, and has been steadily increasing output, whilst production in the US is mainly from the recycling of catalysts.

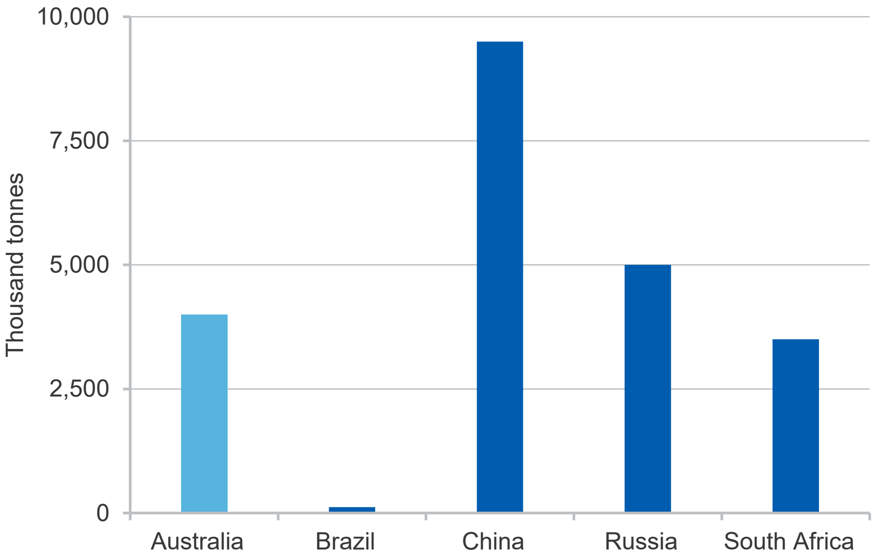
Figure 5.2: **Projected vanadium production by country**



Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

It is worth noting that China holds around 42% of the world's reserves, but produces around 62% of vanadium. By contrast, Australia holds 18% of the world's reserves but currently does not produce vanadium (Figure 5.3).

Figure 5.3: **Vanadium reserves**



Source: USGS (2021); Department of Industry, Science, Energy and Resources (2021)

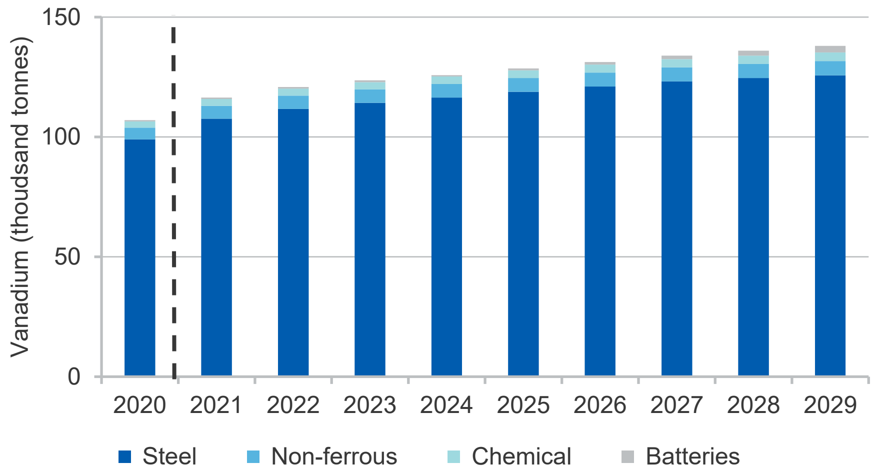
5.5 World consumption

Mature market affected by emerging technologies

The vanadium market is largely driven by steel consumption (accounting for 90% of vanadium use), which is projected to grow by an average 2.9% a year between 2020 and 2029 (Figure 5.4). However, emerging low-emissions technologies are playing an increasing role. Vanadium consumption for batteries is forecast to grow at an average 20.7% a year over 2020 to 2029 (Figure 5.5). The chemicals sector is also due to grow, though by a lesser 3.8% per annum. However, vanadium's use in hardened steel will continue to dominate the market.

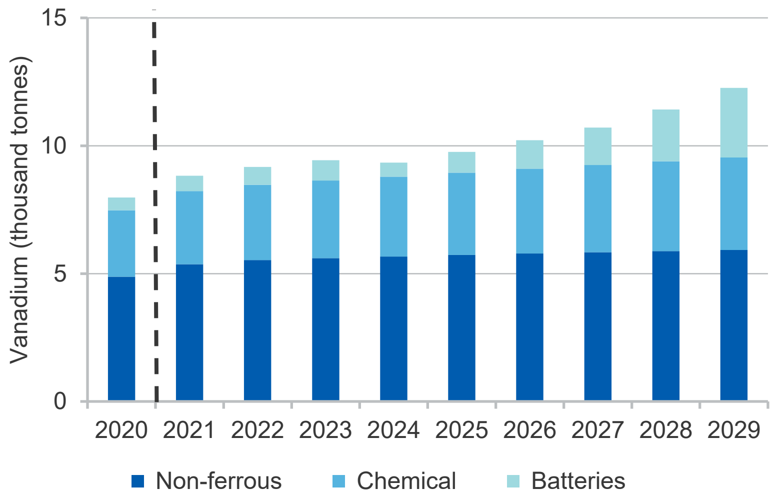
Consumption across regions is forecast to rise in line with consumption by use, with the various regions maintaining approximately the same consumption shares over the outlook period (Figure 5.6).

Figure 5.4: Projected vanadium consumption by end-use – including steel



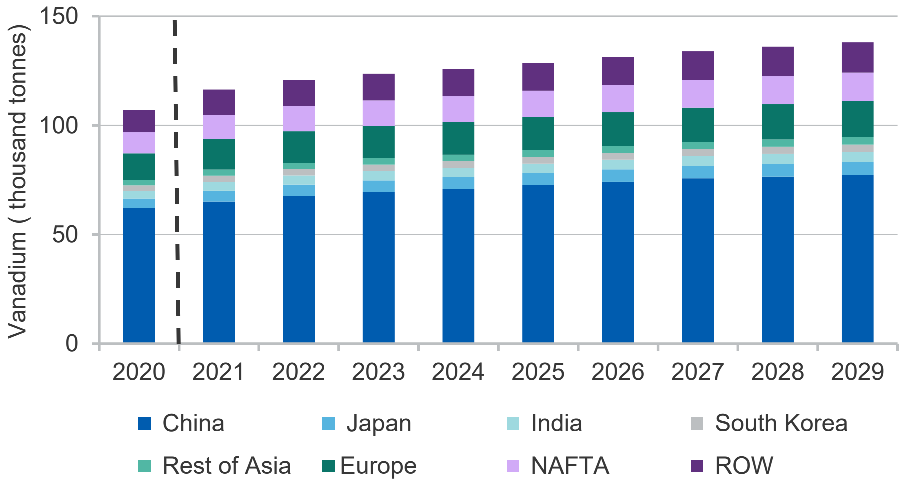
Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

Figure 5.5: Projected vanadium consumption by end-use – excluding steel



Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

Figure 5.6: **Projected vanadium consumption by country**



Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

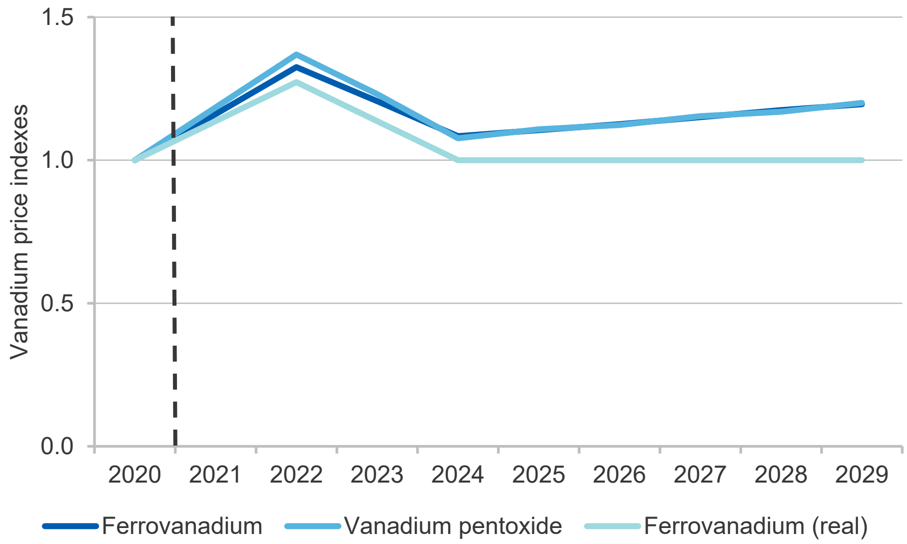
5.6 Market outlook

Prices expected to firm before return to baseline

Market shortfalls may occur over the next couple of years, as Chinese steel production grows. The forecasts assume Chinese slag producers are operating at full capacity. The market shortfalls should result in a tighter market and rising price outlook in the short to medium term. However, as new production enters the market, prices are expected to return to a baseline (Figure 5.7).

Prices for vanadium pentoxide were around US$8 per pound in March 2021, up from US$5 per pound in December 2020. Prices for ferrovanadium were around US$35 per kilogram in early 2021, having appreciated similarly. The size of the market is approximately US$2.4 billion for both ferrovanadium and vanadium pentoxide. This does not include revenue from vanadium slag or recycling.

Figure 5.7: **Vanadium prices outlook**



Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

5.7 Australia

Advanced projects ready for production

Australia does not currently produce vanadium, although it has 18% of the world's reserves (Table 5.1). However, it does have a number of advanced projects, which are pitched towards the energy storage market via vanadium redox flow batteries. Production of vanadium in Australia may also include battery production for the local market. Australia currently produces a similar product: zinc flow batteries via ASX-listed Redflow Limited.

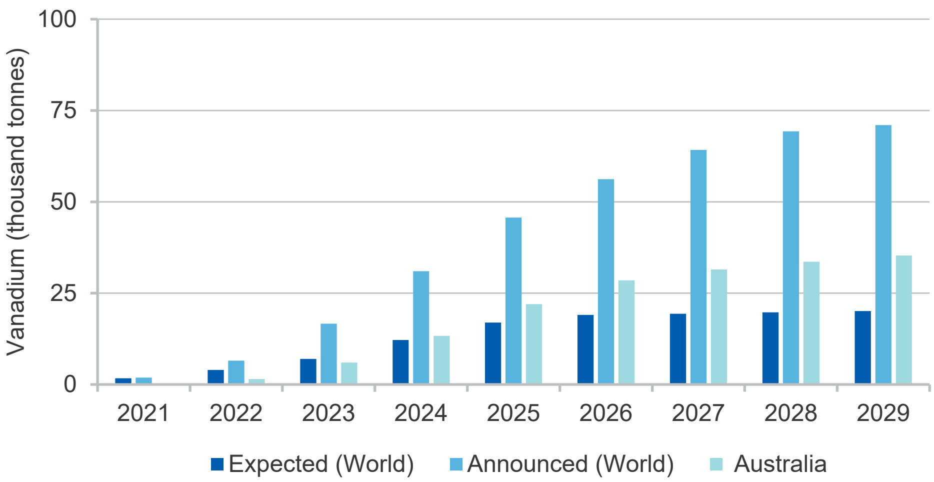
Table 5.1: Australia's vanadium resources and production

Australia's resources				Australia's production		
Geological potential	Economic Demonstrated Resource*	Share world resources	World ranking resources	2020 production	Share of world production	World ranking production
High	4,000kt	18%	3rd	0kt	0%	N/A

Notes: *JORC 1,100 kt; USGS is an estimate and differs from http://www.ga.gov.au/digital-publication/aimr2020/world-rankings
Source: USGS (2021); Department of Industry, Science, Energy and Resources (2021).

Potential projects set to come online to fill a supply shortfall over the next few years are significant. Australia and other countries are well placed to increase supply (Figure 5.8). However, the window for higher prices between 2022 and 2024 may lengthen further into the decade with the implementation of low-emissions technologies such as vanadium redox flow batteries for energy storage, creating higher demand for vanadium over a longer time frame.

Figure 5.8: Vanadium development projects



Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

ASX-listed Technology Metals is investigating downstream processing in Australia, with the aim to produce VRFB's and, in particular, vanadium electrolyte from its proposed Gabanintha Mine (Table 5.2). Meanwhile, ASX-listed, Australian Vanadium is also assessing downstream processing to produce VRFBs for the Australian energy storage market from its proposed Australian Vanadium Mine. It currently sells VRFBs from a variety of manufacturers.

Table 5.2: Selected vanadium development projects in Australia

Company	Project	State	Status	Capacity
Atlantic Vanadium	Windimurra	WA	Feasibility	7.6 kt/year high purity vanadium pentoxide flake
Audalia Resources	Medcalf	WA	Publically announced	-
Australian Vanadium	The Australian Vanadium project	WA	Publicly announced	11 kt/year Vanadium oxide VSUN - Subsidiary focused on Australian energy storage market
Energy Metals	Bigrlyi	NT	Publically announced	-
Multicom	St Elmo	QLD	Publically announced	Initially 10 kt/year vanadium pentoxide
Neometals	Barrambie	WA	Feasibility	At least 275,000 dtpa of vanadium-iron concentrate
Richmond Vanadium Technology/ Horizon Metals JV	Julia Creek	QLD	Publically announced	12.7 kt/year vanadium pentoxide flakes over an initial 20-year mine life
Technology Metals Australia Ltd	Gabanintha	WA	Feasibility	12.8 kt/year Vanadium Oxide 6-10 kt/year under binding offtake
TNG	Mt Peake and Darwin	NT	Feasibility	Offtake agreement in place for 100% of the vanadium oxide (6 kt/year), titanium dioxide pigment (100 kt/year) and iron oxide (500 kt/year) products over 37 years
Vecco Group	Debella Vanadium + HPA Project	QLD	Feasibility	-

This is a selection of current development projects in Australia and not intended to be an exhaustive list. Projects at feasibility status have undertaken initial project definition work, which can include engineering design, environmental impact studies and regulatory approval, but have not reached the financial investment decision.

Source: ASX company announcements; Department of Industry, Science, Energy and Resources (2021)

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