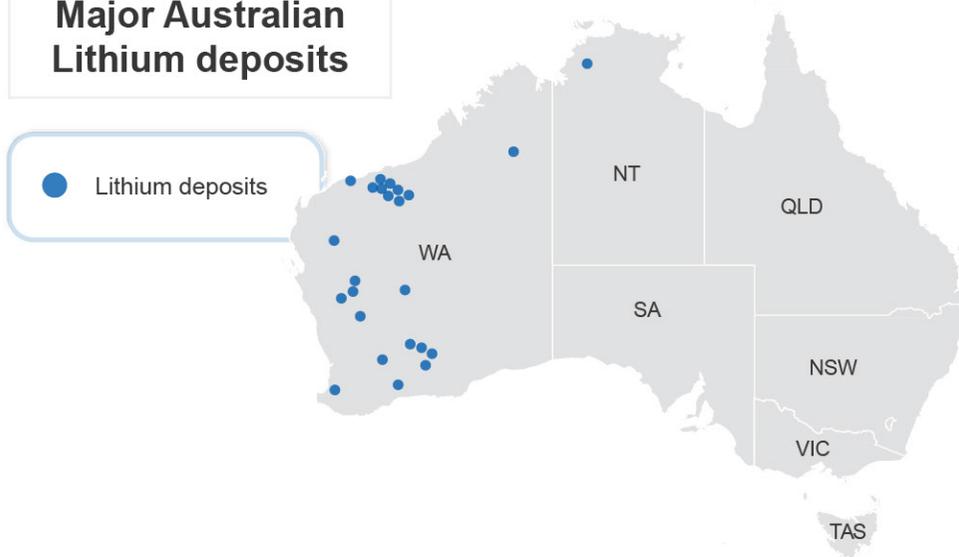




Lithium

Major Australian Lithium deposits



Lithium facts

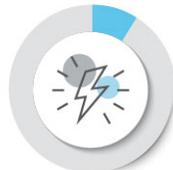


- Lithium metal is so light it floats on water
- Electric vehicle sales are expected to grow tenfold by 2030
- Australian lithium exports will more than double over the next 5 years
- May 2022: Australia's 1st continuous production of lithium hydroxide

World consumption



75%
Rechargeable batteries



8%
Other uses



13%
Ceramics & glass

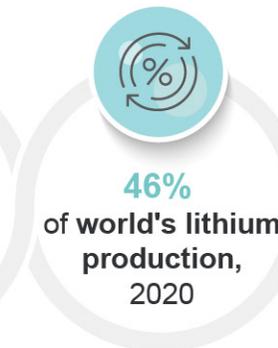


4%
Greases & polymers

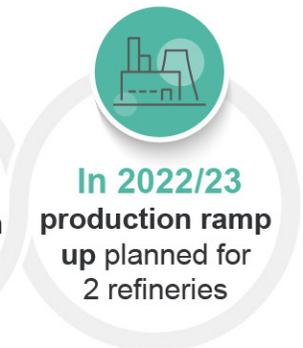
Australia's lithium



Biggest exporter
in the world



46%
of world's lithium production,
2020



In 2022/23
production ramp
up planned for
2 refineries

15.1 Summary

- Spodumene prices are forecast to rise from an average US\$598 a tonne in 2021 to US\$2,730 a tonne in 2022, and US\$3,280 a tonne in 2023 before moderating to US\$2,490 in 2024. We expect lithium hydroxide prices to lift from US\$17,370 a tonne in 2021 to US\$38,575 a tonne in 2022 and US\$51,510 in 2023, and moderate to US\$37,650 by 2024.
- Australia's lithium production is forecast to grow from 247,000 tonnes of lithium carbonate equivalent (LCE) in 2020–21 to 387,000 tonnes in 2022–23 and 469,000 tonnes of LCE in 2023–24.
- Australia's lithium export earnings are forecast to increase by more than ten-fold in just two years from \$1.1 billion in 2020–21 to \$13.8 billion in 2022–23, and ease to \$12.9 billion by 2023–24.

15.2 World demand

Global demand for lithium grows as electric vehicle sales take off

Global lithium demand continued to grow strongly in the June quarter 2022, driven by rising demand for electric vehicle batteries. Despite faltering global economic growth in the June quarter, sales and production of electric vehicles (EVs) continued their rapid growth trend.

Global sales of all types of EVs increased 36% in the year to June 2022 compared with the same period in 2021 — with Chinese sales up 110%, European sales up 6%, and North American sales up 27%.

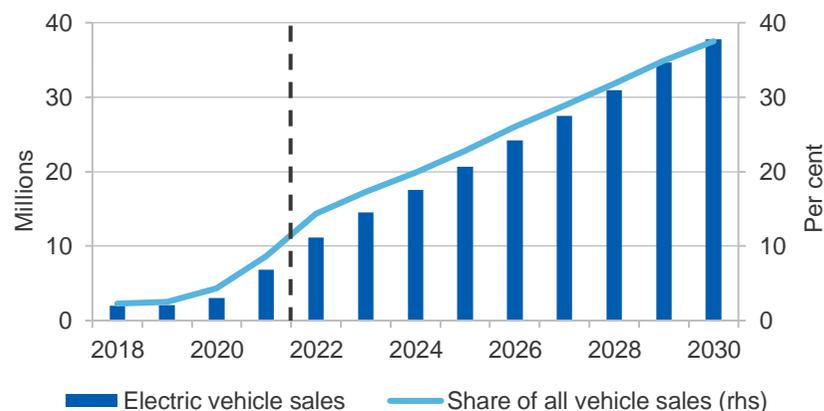
In China, total EV sales have averaged almost half a million vehicles a month so far in 2022, reaching a peak of 650 thousand vehicles in June. Overall, auto production and supply chains in China have now largely recovered from the COVID lockdowns, when EV sales fell to just over 300 thousand vehicles in April 2022.

In May, the Chinese Government cut purchase taxes on some low-emission passenger vehicles by 50%, while some municipal governments have also provided subsidies and incentives to encourage EV purchases. Global passenger EV sales are expected to continue to grow strongly,

albeit at a slower rate than in 2021 — when passenger EV sales more than doubled to an estimated 6.8 million vehicles. Passenger EV sales are expected to hit 11.2 million in 2022 and 14.5 million in 2023 (Figure 15.1).

Key global automakers continue to accelerate plans to transition to EVs by developing new product lines and converting existing manufacturing capacity. The global market share for passenger EVs has quadrupled since 2019, with EV sales representing about 9% of the car market in 2021 (Figure 15.2). Strong underlying demand and EV manufacturers' declarations of further increases in production, imply that EV sales could reach almost 40% of vehicle sales annually by 2030.

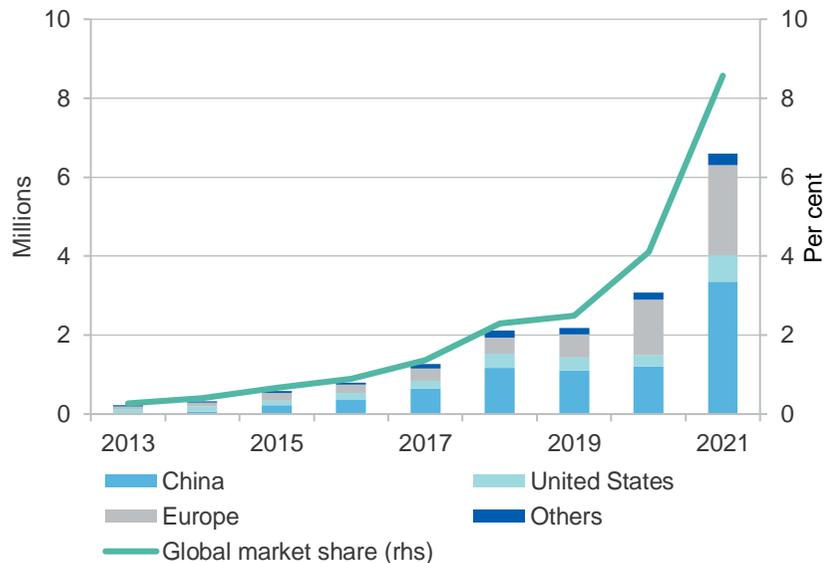
Figure 15.1: Long term electric vehicle sales projections



Source: Wood Mackenzie (2022), Department of Industry, Science and Resources (2022); IEA (2022).

World demand for lithium is estimated to increase from 583,000 tonnes of lithium carbonate equivalent (LCE) in 2021 to 724,000 tonnes in 2022 (Table 15.1). Over the following two years, demand is forecast to rise by over 40%, reaching 1,058,000 tonnes by 2024. Asia remains the major source of demand for lithium, despite the spread of new battery manufacturing capacity into Europe and the US.

Figure 15.2: Electric vehicle sales by country



Source: IEA (2022).

China's EV subsidy program for passenger vehicles, which had been scheduled to conclude by the end of 2021, was extended to the end of 2022 earlier this year. Compared to a similarly priced internal combustion engine (ICE) passenger car model, the Chinese government subsidy provides a saving to customers of about 10,000 yuan. It has been reported that the Chinese government is now looking to continue the incentives next year.

Supply chain issues that plagued EV manufacturers and battery makers late in 2021 and earlier this year have eased somewhat. But supply remains tight, with reports of delivery timeframes for key EV models being pushed well into 2023. Higher prices for lithium as well as other key battery materials (such as nickel, graphite and cobalt) are putting pressure on battery costs.

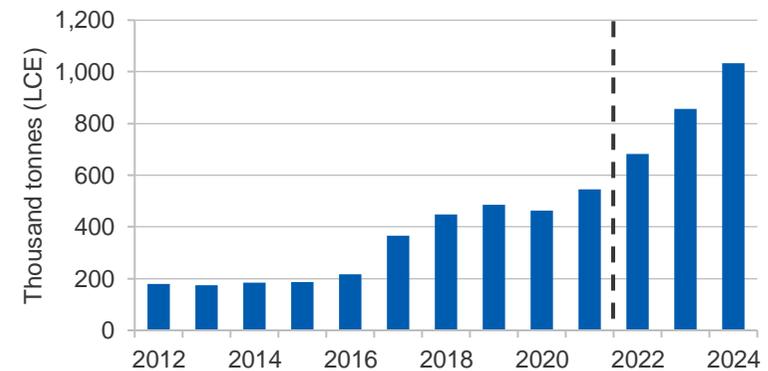
15.3 World production

Global lithium production rising, but supply gap remains

World output was 546,000 tonnes LCE in 2021, and is forecast to reach 682,000 tonnes in 2022 and 1,034,000 tonnes in 2024 (Figure 15.3). This rapid growth — of over 80% in three years — is forecast to be met by gains in output by Australia (see section below), Chile (via expansions to Albemarle and SQM brine operations) and Argentina (via new and expanded brine operations by Livent, Allkem and Minera Exar).

Total supply from mine and brine operations is currently insufficient to meet demand. While new lithium projects are being developed, the supply gap will take time to close. Stockpile size is hard to ascertain, with some estimates of 4-8 weeks for spodumene. Ongoing tight supply conditions are forcing lithium processors and battery makers to pay record prices.

Figure 15.3: Global lithium production



Source: Department of Industry, Science and Resources (2022); Wood Mackenzie (2022).

Global race for new lithium production speeds up

A number of expansions and new projects have been announced in recent months. In addition to ongoing expansions to brine operations in Chile, state-owned mining firm Codelco is undertaking exploration in the Salar de Maricunga, with drilling due for completion early next year.

In Canada, three new lithium projects in Quebec are expected to start production in 2023, with a combined production of over 50,000 tonnes of LCE. Looking further ahead, the reopening of the Whabouchi mine, also in Quebec, is expected to add production of 52,500 tonnes a year from 2025. Mexico has created a state-run company to mine lithium after nationalising lithium resources in April. The company is scheduled to start operations within the next six months. While several companies hold contracts to explore potential lithium deposits, Mexico does not yet produce lithium.

Europe and North America are looking to reduce their dependency on Chinese imports and develop their own lithium production. In August, the US Government's *Inflation Reduction Act of 2022* came into effect. The Act contains provisions to promote the clean energy transition including significant incentives to purchase EVs.

Under the Act, a new EV will only be eligible for tax credits when at least 40% of the battery's critical minerals are extracted or processed from: the US, a free trade agreement partner such as Australia, or recycled in North America. This content requirement applies only to the minerals in the batteries, rather than the entire EV, and includes minerals such as lithium, nickel, cobalt and graphite. The content requirements increase progressively over time, reaching 100% by 2029. From 2024 onwards, the Act also stipulates that eligibility for the tax credits also depends on battery minerals or components not being sourced from 'foreign entities of concern'.

Zimbabwe's Premier African Minerals is expected to start shipping spodumene concentrate from its Zulu lithium mine to China by March 2023, with the long-term goal of producing around 50,000 tonnes a year.

In July, Argentina's Government revealed that Ultra Argentina SRL and China's Zangge Mining have committed \$290 million to explore, develop and process the nation's lithium deposits. The Government expects about

\$4.2 billion of investment in its lithium sector over the next 5 years, which would help double output in 2023, and reach 175,000 tonnes in 2025.

Interest in recycling continues to rise, with recycling projects announced in many nations. However, large scale operations will take time to establish. Stronger lithium prices, combined with rising volumes of used EV batteries, should improve the economics of recycling projects.

15.4 Prices

Record spodumene spot prices rolling into contract prices

Shortages of spodumene, lithium hydroxide and lithium carbonate continue to push spot prices to new records. Spot spodumene concentrate averaged about US\$4,720 per tonne in August 2022 (SC6.0, CIF China).¹ This was up slightly from July, representing a ten-fold increase from the US\$418 a tonne recorded in January 2021.

Spot prices for lithium hydroxide (delivered to China) averaged US\$70,300 a tonne in August 2022, down slightly from the April peak of US\$74,688, but still more than eight times the US\$7,984 average of January 2021.

Supply disruptions in August (due to extended power cuts in Sichuan province, amidst an intense heatwave) added pressure to lithium prices in China. Sichuan produces more than 20% of China's lithium.

As most Australian producers have historically utilised long term contracts, prices received take time to adjust to shifts in spot prices. High average prices reported by Australian producers indicate spot prices are now flowing more rapidly into contract prices. ABS trade data indicate that average realised prices (which reflect a mix of contract and spot priced exports) have increased strongly so far in 2022, as processors seek to ensure supply is sufficient to meet expected demand.

Spodumene prices are forecast to rise from an average of US\$598 a tonne in 2021 to US\$2,730 a tonne in 2022, as record spot prices feed through

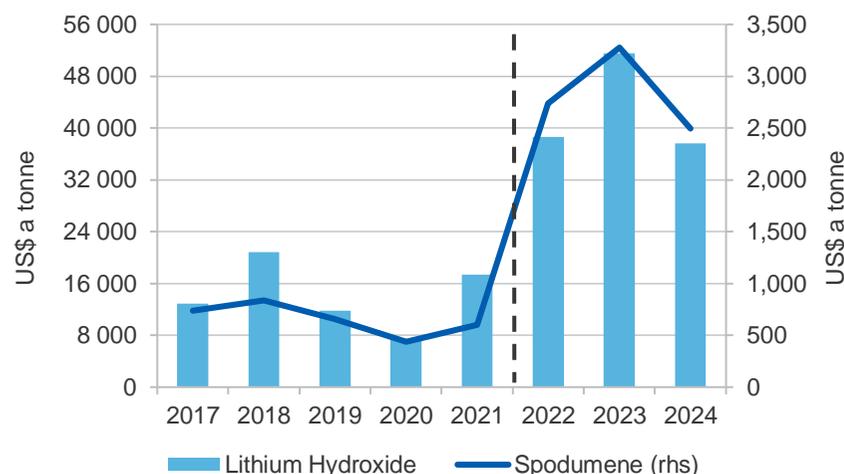
¹ The SC6.0 CIF China price is an industry accepted reference price. The actual spodumene concentrate grade produced and shipped by Australia's lithium producers varies, and is

often lower than the 6% lithium content. Hence, when companies report prices received they adjust the actual price received to generate a 6% 'reference' price.

into contract prices (Figure 15.4). Prices are expected to remain high in historic terms over the outlook, averaging US\$3,280 a tonne by 2023 before moderating to US\$2,490 in 2024.

The lithium hydroxide price is forecast to rise from US\$17,370 a tonne in 2021 to US\$38,575 a tonne in 2022. Prices are expected to peak in 2023 at over US\$50,000 a tonne before moderating to average around US\$37,600 in 2024.

Figure 15.4: Spodumene concentrate/lithium hydroxide prices



Notes: Lithium hydroxide price is for higher-priced battery grade product.

Source: Wood Mackenzie (2022); Department of Industry, Science and Resources (2022).

Rapid price movements and the relative immaturity of the market will likely lead to ongoing uncertainty. Risks to the lithium price forecasts are balanced over the outlook period. While expansions to production are already underway in Australia and overseas, there are long lead times for lithium mine and brine operations. Moreover, the potential for delays in bringing such large volumes of lithium into production, mean risks remain of persistent supply shortages over the next few years.

However, one of the drivers of recent high spot prices appears to be a push by refiners and battery makers to build up inventories, due to

concerns about global supply chains. The lack of data on global lithium stocks makes it difficult to judge how well battery producers have built up stockpiles. If these concerns ease, prices could moderate more rapidly over the outlook period. Prices may also ease if global economic growth slows more rapidly than recent IMF forecasts suggest it will.

15.5 Australia

Lithium set to become a \$10 billion-plus export industry within a year

Record spodumene prices are estimated to have lifted export revenue from \$1.1 billion in 2020–21 to \$4.9 billion in 2021–22. Production from lithium hydroxide refineries is forecast to steadily add to earnings over the outlook period, lifting total annual lithium export revenue to an estimated \$12.9 billion in 2023–24.

The emergence of what is likely to be Australia's newest \$10 billion-plus export industry occurred in three quite distinct stages (Figure 15.5).

From 2013–14 to 2017–18 the industry built capacity. Production volumes and export revenues rose from under \$200 million to \$1.7 billion — a more than eightfold increase.

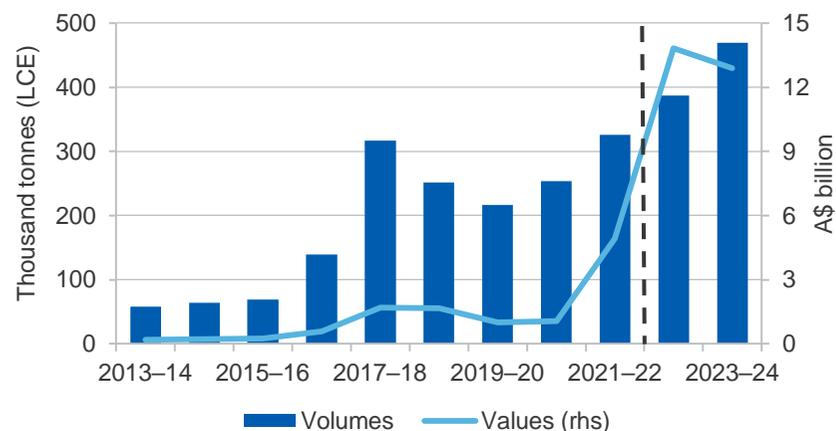
Over the next three years, global demand lost momentum and prices and revenues plunged. This fall tested the resilience of businesses, with some facilities relegated to care and maintenance.

But as global battery manufacturers and automakers reassessed their requirements over the course of 2021, demand for lithium took off again. This third stage holds even stronger growth prospects than the first, with Australia's lithium export revenues forecast to grow from \$1.1 billion in 2020–21 to \$13.8 billion in 2022–23 — a tenfold increase in just two years.

While much of the forecast export growth is price driven, Australia's production capacity is also forecast to grow strongly over the outlook. Expected annual average growth of over 20% a year will see production rise from 247,000 tonnes of LCE in 2020–21 to 387,000 tonnes in 2022–23, and 469,000 tonnes in 2023–24 (Figure 15.5).

Over the forecast period, export volumes of spodumene concentrate are forecast grow by more than one-third. From 2.3 million tonnes in 2021–22, spodumene concentrate exports are forecast to increase to 3.2 million tonnes in 2023–24.

Figure 15.5: Australia’s exports of lithium



Notes: Export values include revenue from spodumene concentrate and lithium hydroxide. Lithium volumes include total exports of spodumene concentrate and lithium hydroxide converted to LCE.

Source: Company reports; WA Department of Mines, Industry Regulation and Safety (2022), Wood Mackenzie (2022); Department of Industry, Science and Resources (2022).

Producers ramp up production and exports

Talison Joint Venture’s three operational plants at Greenbushes produced a combined total of 338,000 tonnes of spodumene concentrate in the June quarter 2022. This was up by 25% from the March quarter 2022. Tailings Retreatment Plant production continued to ramp up following completion of construction in the March quarter. The company has announced that chemical grade plant 2 has also continued to ramp up, with improved throughput, recovery and production. Further ramp up and optimisation is expected in coming quarters.

Pilbara Minerals produced 127,236 dry metric tonnes (dmt) of spodumene concentrate output in the June quarter 2022. This was an increase of 56% from the March quarter (81,431 dmt). The company stated the strong quarterly result was achieved despite being impacted by COVID-19 and associated labour shortages across the mining sector. Total spodumene produced in 2021–22 was 377,902, a 34% gain from 2020–21.

The company states that following completion of the Pilgan Plant improvement project, production capacity is now estimated to be in the range of 360–380 kilotonnes per annum (ktpa) of spodumene. The Ngungaju Plant produced first concentrate from the fines circuit in early June. Ore throughput has continued to increase and ramp up to the planned 180–200ktpa (dmt) concentrate production rate is expected to be achieved during the September quarter 2022.

Final investment decision was taken for a \$300 million incremental 100ktpa capacity increase for the Pilgan plant during the June quarter — which will bring total production up from 580 ktpa to 680 ktpa. The ‘P680’ Project includes \$50 million of pre-investment capital to assist with the proposed next phased expansion – with a targeted production capacity of up to 1Mtpa. FID for the P1000 Project is targeted for late December 2022.

Pilbara Minerals stated that the average realised spodumene sales price achieved in the June quarter 2022 was US\$3,911 per dmt (6% CIF China basis). This was a substantial increase on the March quarter 2022 price of around US\$2,650/dmt. The June quarter average price excludes a 5,000 dmt cargo sold via pre-auction on the Battery Metal Exchange in late June 2022 for just over US\$7,000 dmt (6% CIF China basis), with shipment for this cargo expected in August 2022. Pilbara Minerals sold another 5,000 dmt cargo at auction for around US\$7,700 in September 2022.

IGO states that it expects the chemical grade spodumene concentrate transfer price for the September and December quarters this year to be US\$4,187. This is more than double the price of US\$1,770 a tonne for the March and June quarters.

Output from Mt Marion (owned 50% by Mineral Resources and 50% by Jiangxi Ganfeng Lithium Co. Limited) totalled 128,000 dmt of spodumene concentrate in the June quarter 2022, with an average realised price of US\$2,645 a tonne (up about 35% on the March quarter). In April 2022, the joint venture announced a decision to lift spodumene production at Mt Marion from 450,000 to 600,000 tonnes per annum of mixed-grade concentrate, targeting an annual plant capacity of 900,000 tonnes by end 2022 (equal to 600,000 tonnes of 6% spodumene concentrate).

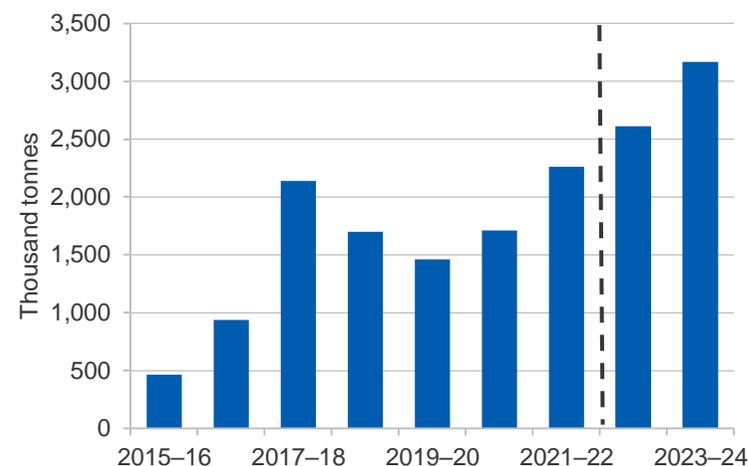
Mineral Resources and Albemarle stated that the restart of Wodgina saw first spodumene concentrate from Train 1 delivered in May, with 20,000 dmt produced in the June quarter. The restart of Train 2 progressed as scheduled, with first spodumene concentrate delivered in July.

Allkem's Mt Cattlin mine produced 24,845 dmt of spodumene concentrate in the June quarter, contributing to the record financial year production of 193,563 dmt in 2021–22. The average spodumene realised price received in the June quarter was US\$4,992 per dmt, more than double the price of US\$2,178 achieved in the March quarter.

Site construction continues at Core Lithium's Finnis Project near Darwin, following receipt of environmental approval for the BP33 underground mine. The project is expected to produce 160 ktpa of spodumene concentrate, and has offtake agreements with Ganfeng Lithium, Sichuan Yahau and a binding term sheet with Tesla. In July, the company reported a 28% increase in the Mineral Resource Estimate following drilling and exploration undertaken in the 2021 drilling season. The company reports that development is on schedule for first export of lithium ore by the end of 2022, and first spodumene concentrate production in 2023.

Liontown's Kathleen Valley deposit near Kalgoorlie received FID in the June quarter 2022. The project is expected to deliver about 500 ktpa of spodumene concentrate in the first year, rising to about 700 ktpa by year 6. Production is expected to start in the June quarter 2024. Offtake agreements are in place for about 90% of Kathleen Valley's start-up capacity, including tier-1 customers Ford, Tesla and LG Energy Solution.

Figure 15.6: Spodumene exports



Source: Wood Mackenzie (2022); Department of Industry, Science and Resources (2022).

Australia's hydroxide refineries on verge of commercial production

Following the key milestone of first production of battery grade lithium hydroxide in May, the Kwinana lithium hydroxide refinery (51% Tianqi and 49% IGO) recommenced production in June after a planned three-week shutdown. IGO stated that production of battery grade hydroxide has allowed the start of the product qualification process with offtake partners, with an expected completion time of 4-8 months.

The company expects Train 1 production to ramp up concurrently with the qualification process over the coming quarters, in anticipation of the plant reaching commercial production during 2022–23. Construction of Train 2 has been partially completed, with the decision for the recommencement of construction to be made by the end of 2022. Each train has a capacity of 24,000 tonnes a year.

First product from Train 1 of the Kemerton lithium hydroxide plant (Albermarle 60%, Mineral Resources 40%) was delivered in early July 2022. Mechanical completion and commencement of production at

Kemerton’s Stage 2 — which will produce an additional 25,000 tonnes a year — is targeted for the December quarter 2022.

Pilbara Minerals’ joint venture with POSCO for the production of lithium hydroxide in South Korea was completed in April. During the June quarter, detailed engineering, procurement, site preparation and road works commenced. The joint venture plans to source over 300,000 tonnes a year of spodumene concentrate from the Pilgangoora operations.

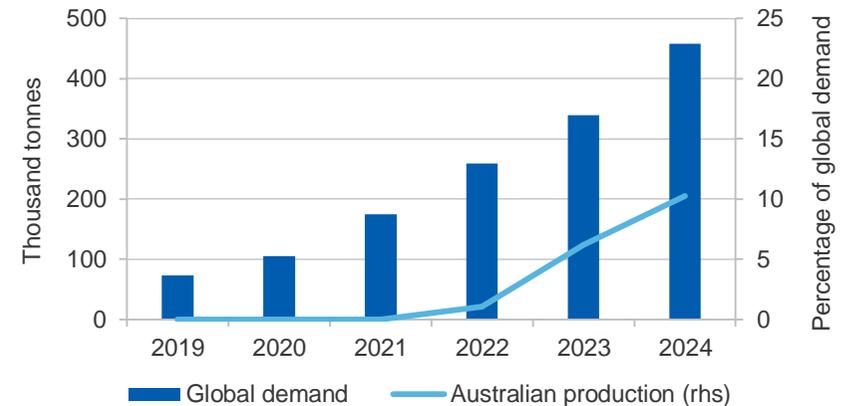
Construction of Covalent Lithium’s (Wesfarmers 50%, SQM 50%) Kwinana lithium hydroxide refinery progressed in the June quarter 2022. The refinery is forecast to start in 2024 — making 50,000 tonnes of lithium hydroxide a year. The refinery will source spodumene from Mt Holland, where construction of the village and aerodrome has been completed, and pre-strip mining and construction of the concentrator is underway.

By 2024, Australia may have about 10% of global lithium hydroxide refining capacity (Figure 15.7), rising to about 20% of global lithium refining by 2027. There are a number of risks to the strong forecast growth for Australian lithium production and revenue over the outlook. Delays to approval and construction of new mine and processing plants, as well as difficulties achieving ramp up to full output, would see slower growth in spodumene output volumes and export values. For Australia’s emerging lithium hydroxide refining sector, more unanticipated delays or technical challenges associated with achieving required product grade, purity and consistency, could delay output and exports.

China dominates the EV battery supply chain, producing three-quarters of all lithium-ion batteries, and holds around 70% of cathode production capacity and 85% of anode production (Figure 5.8). Over half of lithium, cobalt and graphite processing and refining capacity is located in China. This situation is not expected to change rapidly. The IEA states that the majority of the supply chain is likely to remain Chinese through to 2030. In the case of battery production, China accounts for 70% of new global production capacity announced for the period to 2030 (IEA 2022).

Australian businesses are expected to continue their expansion into higher value-added activities over the outlook period. Potential avenues include growth up the battery value chain, from mining and refining into precursor chemicals for cathodes, electrolyte production battery anode plants, battery cell research/production, and battery manufacturing (Figure 15.9).

Figure 15.7: World and Australian lithium hydroxide output

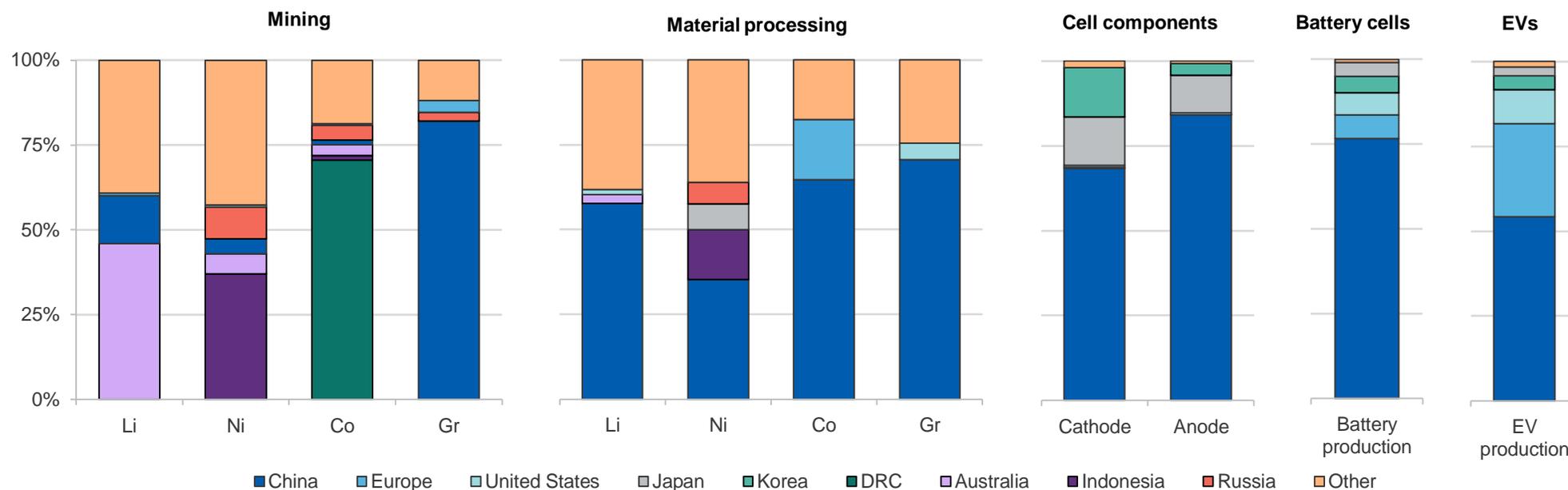


Source: Wood Mackenzie (2022); Department of Industry, Science and Resources (2022)

Revisions to the outlook

Forecast export revenue over the outlook has been revised up substantially. This reflects sustained record prices, faster than expected pass-through of spot prices to contract prices and new Australian production and trade data. Export revenue in 2021–22 has been revised up, from \$4.1 billion in the June 2022 *Resources and Energy Quarterly* to \$4.9 billion. Further out, 2022–23 has been lifted from \$7.8 billion to \$13.8 billion, and 2023–24 from \$9.4 billion to \$12.9 billion.

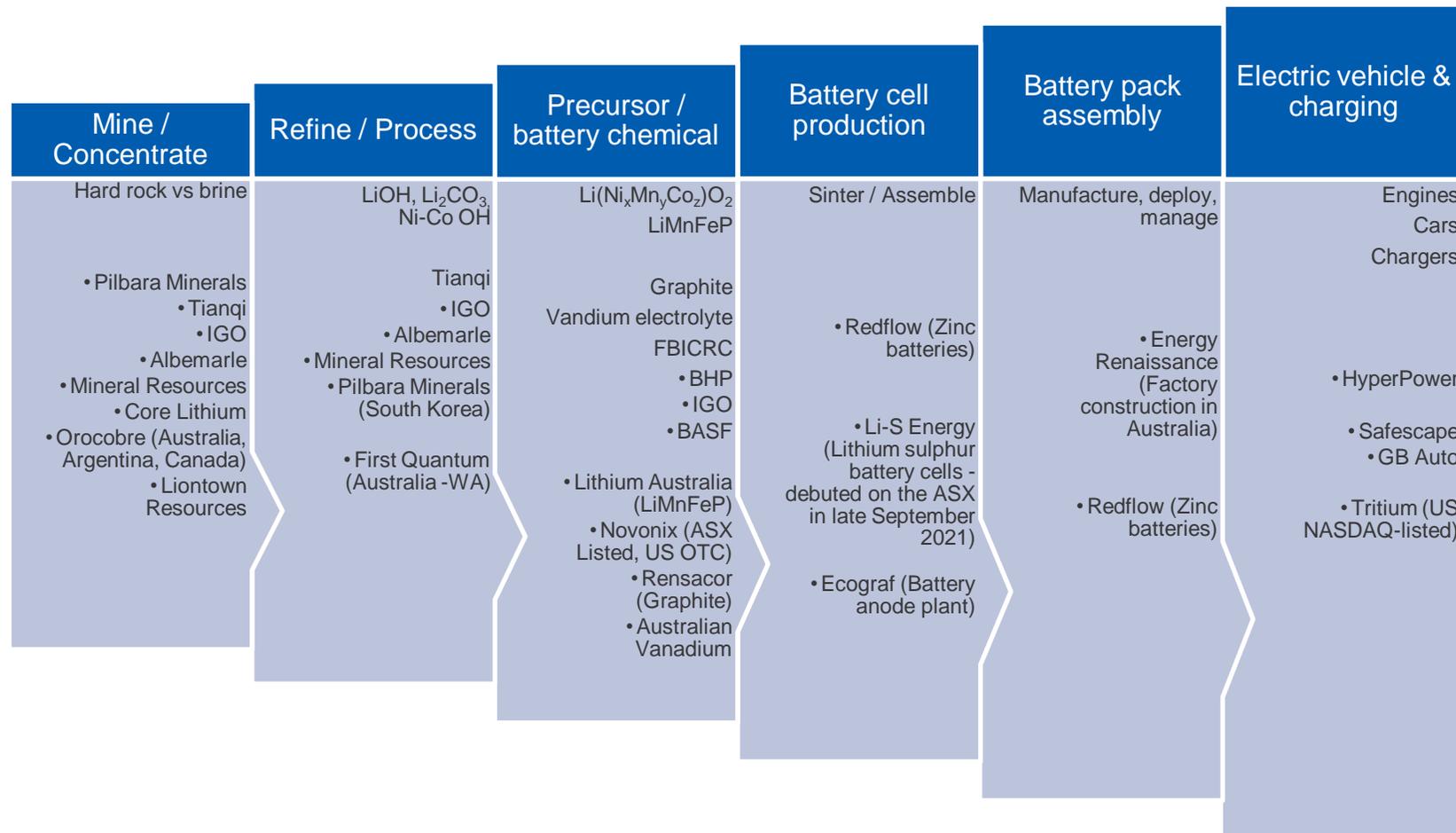
Figure 15.8: Geographical distribution of the global EV battery supply chain



Notes: Li = lithium; Ni = nickel; Co = cobalt; Gr = graphite; DRC = Democratic Republic of Congo. Geographical breakdown refers to the country where the production occurs. Mining is based on production data. Material processing is based on refining production capacity data. Cell component production is based on cathode and anode material production capacity data. Battery cell production is based on battery cell production capacity data. EV production is based on EV production data. Although Indonesia produces around 40% of total nickel, little of this is currently used in the EV battery supply chain. The largest Class 1 battery grade nickel producers are Russia, Canada and Australia.

Source: IEA 2022, *Global Supply Chains of EV Batteries*. DISR 2022 (global lithium mining shares).

Figure 15.9: Global lithium-ion battery value chain (+ zinc and vanadium batteries for large scale storage)



Notes: Redflow is ASX listed and is currently producing zinc batteries offshore. Zinc and vanadium batteries are suitable for large scale storage.

Source: BloombergNEF (2021), Australasian Institute of Mining and Metallurgy: Thought leadership conference, September 2021; Future Battery Industry Co-operative Research Centre (2021).

Table 15.1: Lithium outlook

World	Unit	2021	2022 ^s	2023 ^f	2024 ^f	Annual percentage change		
						2022 ^s	2023 ^f	2024 ^f
Lithium production ^a	kt	546	682	856	1,034	24.9	25.6	20.7
Lithium demand	kt	583	724	864	1,058	24.2	19.3	22.5
Spodumene price								
– nominal	US\$/t	598	2,730	3,280	2,490	357.0	19.8	-23.8
– real ^b	US\$/t	644	2,730	3,180	2,370	324.3	16.3	-25.5
Lithium hydroxide price								
– nominal	US\$/t	17,370	38,575	51,510	37,650	122.1	33.5	-26.9
– real ^b	US\$/t	18,710	38,575	49,990	35,730	106.2	29.6	-28.5
Australia	Unit	2020–21	2021–22 ^s	2022–23 ^f	2023–24 ^f	2021–22 ^s	2022–23 ^f	2023–24 ^f
Mine production ^a	kt	247	335	387	469	35.9	15.3	21.3
Spodumene export volume ^c	kt	1,711	2,264	2,609	3,166	32.3	15.3	21.3
Export value								
– nominal value ^d	A\$m	1,055	4,907	13,836	12,877	365.2	182.0	-6.9
– real value ^e	A\$m	1,179	5,250	13,836	12,355	345.4	163.5	-10.7

Notes: **a** Lithium Carbonate Equivalent (LCE) — a measure of the quantity of refined product; **b** In 2022 US dollars; **c** Includes spodumene concentrates exported — mostly 6 per cent Li₂O concentrate — plus spodumene concentrate used to produce lithium hydroxide for export; **d** Revenue from spodumene concentrate as well as lithium hydroxide; **e** In 2022–23 Australian dollars; **s** Estimate; **f** Forecast.

Source: Company reports; Department of Industry, Science and Resources (2022); Wood Mackenzie (2022); Government of Western Australia Department of Mines, Industry Regulation and Safety (2022).