Critical battery commodities

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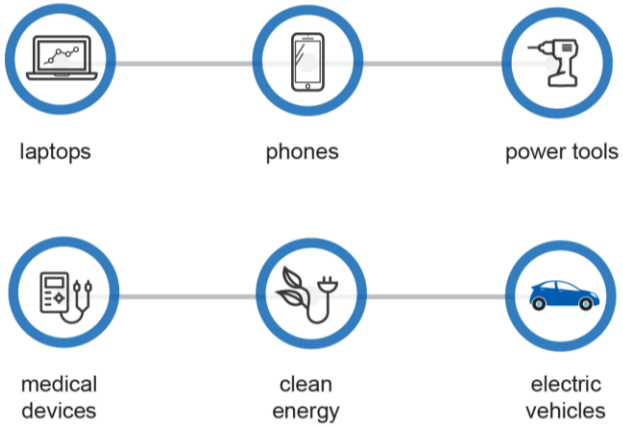
Battery markets and the future



Australia has significant stocks of the three critical battery commodities

Huge advancements in battery technology will have a great payoff for our economy and our standard of living. Australia has three commodities that are used to make batteries.

Lithium

Australia is the world's biggest producer of lithium.

Graphite

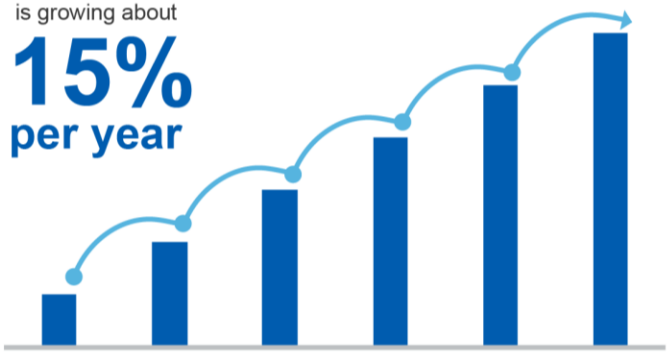
Australia has modest deposits of graphite with new projects currently being progressed.

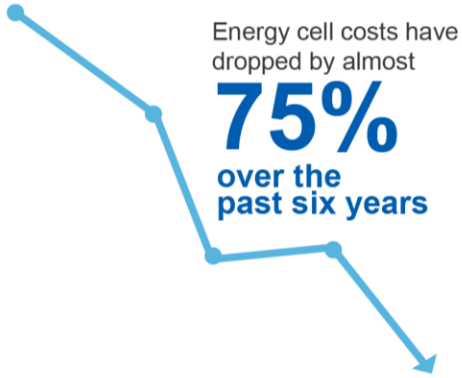
Cobalt

Australia has sizeable reserves of cobalt, and a range of mines are producing it along with other commodities.

The battery market is growing about

15% per year





Energy cell costs have dropped by almost

75% over the past six years

Battery demand has the potential to create **big opportunities** for Australian mineral producers

The potential of battery technology

Global battery markets have entered a period of extremely rapid growth in recent years, and the implications for Australia are potentially highly significant. This is partly due to the potential of battery technology itself, and its capacity to revolutionise clean energy, vehicles, and consumer products. However, battery growth also creates unique opportunities for producers of key commodities, notably lithium, graphite and cobalt.

Australia has major deposits of some of these, and is well placed to capitalise on the opportunities that increased battery demand is creating.

Lithium-ion batteries

Lithium-ion (Li-ion) batteries were first created by an American inventor — John Goodenough — in 1980. The Li-ion battery used the movement of lithium ions between positive and negative electrodes in a way which created more power from a smaller source than any battery before it.

By the early 1990s, Li-ion batteries were being commercially used in electronics such as hand-held video cameras. More recently, Li-ion batteries have become ubiquitous in personal devices and portable electronics.

However, it now appears that we may have barely scratched the surface of the Li-ion battery's potential. It is now clear that lithium-ion transfer — which stores and releases power — can occur in a larger variety of cathode, anode, and electrolyte environments than had been previously understood. Cathodes — an internal mechanism in which ion transfer occurs — are undergoing profound changes. There are many potential combinations of metals a cathode can employ, and new research is unlocking more diverse forms. This is creating more specialised and powerful batteries, unlocking opportunities for new technologies.

The number of potential formulations for ion transfer mean that there are countless types of lithium ion batteries, some of which are shown in the table opposite. Energy density refers to the amount of energy stored per unit of volume, while power density refers to the ability to deliver power.

While there are competing battery types — such as Nickel-Metal Hydride batteries — Li-ion batteries have particular capability in areas, such as energy density, which places them at the forefront of solar energy storage and electric vehicle manufacturing.

The Li-ion market was less than 6 GWh 10 years ago; in 2016, this market is estimated to have surpassed 70 GWh. The number of applications for these batteries is also expanding rapidly, and their market share is rising. In recent years, growth has also been propelled by the use of Li-ion batteries in automotive powertrains for electric vehicles. Companies such as Tesla and Enphase are also developing large-scale residential batteries and solar roofing projects. These batteries can correct the misalignment inherent to rooftop solar, by enabling power generated during the day to be stored and used at night, when power usage peaks.

Roskill are currently forecasting average annual battery market growth of 14 per cent per year out to 2025, when the market is expected to reach 223 GWh.

Batteries classed as Li-ion primarily use three commodities — lithium, graphite and cobalt. Li-ion battery demand has effectively pulled these commodities into a second commodity boom, with demand rising, prices spiking, and investment gathering steam.

Table 15.1: Types of lithium-ion batteries

	End-use products	Characteristics
Lithium Cobalt Oxide	Mobile phones, laptops	High energy density but incurs longer charge times and shelf life of 1–3 years.
Lithium Manganese Oxide	Power tools, medical instruments	Fast recharge and high current discharge, but 1/3 of LCO's energy density
Nickel Cobalt	Electric vehicle powertrains, energy storage	High energy density and long life span; safety and cost were a concern but now resolved.
Nickel Manganese Cobalt	Electric vehicle powertrains, power tools	Can be tailored to high energy or power density; most Japanese and Korean producers sell NMC into the electric vehicle market.
Lithium Iron Phosphate	Electric vehicle powertrains, e-bikes	LFP batteries offer a safe alternative.

Source: DIIS (2017)

Critical battery commodities

Lithium is experiencing rapid growth

Lithium is the lightest, or least dense, elemental metal, being about half as dense as water. It is primarily used for steel making, aluminium smelting, ceramics and glass, greases, and polymer production. Batteries presently account for a small proportion of total lithium demand, but this is set to change significantly over coming years.

The use of lithium in batteries has increased over the past 10 years, as demand for rechargeable batteries in portable devices, electric tools, electric vehicles, and grid/energy storage has risen. Batteries accounted for 35 per cent of all lithium use in 2015, up from 25 per cent in 2007. The major end-uses for batteries in 2015 were electric vehicles (25 per cent), phones (19 per cent) and portable PCs (16 per cent).

The criticality of lithium (a measure used by Geoscience Australia and based on importance in use and availability or supply risk) is rated as 'high'.

The strongest demand growth for lithium over the next 10 years is expected to come from lithium-ion batteries for electric vehicles (including e-bikes) and energy storage applications, with other non-batteries applications growing more slowly. This trend will be supported by the lower cost of batteries and by global efforts to reduce carbon emissions and improve self-sufficiency.

Lithium is the first battery component to face a significant price and investment surge. Prices for lithium carbonate and lithium hydroxide — the two most common forms used in batteries — have generally grown substantially since 2014, though exact details on prices are difficult to track, due to the way lithium is traded.

There are two major lithium deposit types: brine deposits and mineral deposits. Brine deposits occur when lakes, geothermal waters or petroleum brines are enriched with lithium, and are mainly found in South American counties — Chile, Argentina and Bolivia.

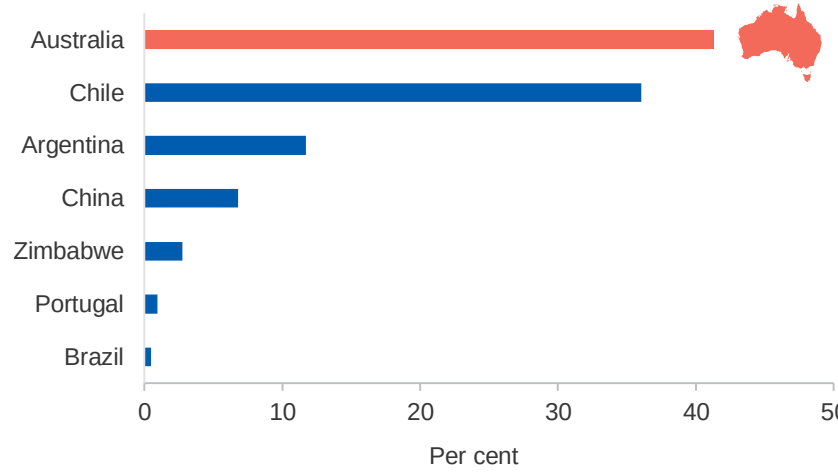
Mineral deposits (spodumene or pegmatite) generally contain a mix of rare metals, including lithium. Extraction from hard rock deposits is expensive, but has the capacity to respond to increased demand much faster than brine operations. As a result, spodumene resources have become the most likely source of new material in the short-term.

Table 15.2: Top five lithium mine reserves

	Reserves (kt)	Production (2016) (kt)
Chile	7,500	12.0
China	3,200	2.0
Argentina	2,000	5.7
Australia	1,600	14.3
Portugal	60	0.2

Source: U.S. Geological Survey, Mineral Commodity Summaries, January 2017

Figure 15.1: World lithium production



Source: USGS (2016) Commodity Summaries

Australia is a key global source for lithium

Australia ranks fourth globally in its lithium deposits — behind Chile, Argentina and China. Most of Australia's economic demonstrated resources (EDR) of lithium occur within hard rock pegmatite deposits in Western Australia, although other deposits have been found in the Northern Territory, and further exploration is underway.

Australia is the largest producer of lithium, and significant resources of spodumene mean Australia is well placed to remain a major producer over the longer term. A host of companies in Western Australia are already targeting near-term concentrate production for sale to Chinese conversion facilities.

The Greenbushes deposit, which is the world's largest and highest grade spodumene deposit, contains around half of Australia's lithium EDR. It accounts for around 30 per of global lithium production. The Mount Cattlin mine also began production in late 2016, while other resources are being developed at Mount Marion and Pilgangoora, with Pilgangoora now regarded as the world's second largest deposit.

There is also a strong prospect of further operations being developed, with positive definitive feasibility studies recently completed by Pilbara Minerals Limited and Altura mining for mines in the Pilgangoora region. The recent increase in the price of lithium has also increased interest in operations where lithium has been produced as a by-product, such as the Bald Hill tantalum mine. In March 2017, Talison Lithium Pty Ltd announced that it had approved the expansion of Greenbushes to double annual production. The expansion will supply a $400 million lithium processing plant to be built at Kwinana, south of Perth.

Lithium exploration continues in other parts of Australia, including the Bynoe pegmatite field near Darwin, where significant lithium-bearing pegmatites have been identified. Australia has a range of salt lakes and groundwater which also hold deposits of lithium, though the potential of these sources has not yet been fully explored.

Australia is not alone in expanding its production. There are plans to increase production in Chile from 48,000 tonnes of lithium to 63,000 tonnes by the end of 2018. Argentina is also planning to undertake big expansions by 2022.

Table 15.3: Australian lithium projects

Project Name	Location	Stage	Approximate Production
Greenbushes	250km S of Perth	Operating	~400 thousand tonnes a year (ktpa) of 6–7.5 per cent spodumene concentrate*
Mt Cattlin	2.2km N of Ravensthorpe	Operating	137 ktpa of 6 per cent spodumene concentrate
Mt Marion	40km SW of Kalgoorlie	Committed	200 ktpa of 4–6 per cent of spodumene concentrate
Pilgangoora Tantalite	150km SE of Port Headland	Feasibility	314 ktpa of 6 per cent spodumene concentrate
Pilgangoora	120km SE of Port Headland	Committed	219 ktpa of 6 per cent spodumene concentrate

Source: DIIS (2017)

Demand for graphite is growing, but not as fast as lithium

Graphite is a naturally occurring mineral that forms when carbon is subjected to heat and pressure in the Earth's crust and in the upper mantle.

Graphite is used for a range of products, including lubricants, foundry operations, brake linings, and steelmaking, though use of graphite in batteries is also on the rise. Advances in thermal technology and acid-leaching techniques that enable the production of higher purity graphite powders, are likely to lead to the development of new applications for graphite in high-technology fields. Innovative refining techniques have enabled the use of improved graphite in carbon-graphite composites, electronics, foils, friction materials, and specialty lubricant applications. Large-scale fuel-cell applications are also being developed, which could consume as much graphite as all other uses combined.

The criticality of graphite is rated as 'medium' by GeoScience Australia.

While China currently dominates production of graphite, it is believed that both Brazil and Turkey have greater reserves. The estimated world total graphite reserve is 230 million tonnes.

New graphite deposits are being developed at various sites around the world, and mines will soon begin production in Madagascar, Mozambique, Namibia, and Tanzania. The global graphite market is expected to lift from just under $14 billion in 2013 to almost $18 billion by 2020.

Australia has modest deposits of graphite

Australia's reserves of graphite are comparatively modest, and there are no operating graphite mining projects. However, a range of projects are currently being progressed, with studies underway at sites in Oakdale and Arno in South Australia, and McIntosh in Western Australia.

Table 15.4: Top five graphite mine reserves

	Reserves (kt)	Production (2016) (kt)
Turkey	90,000	32
Brazil	72,000	80
China	55,000	780
India	8,000	170
Mexico	3,100	22

Source: U.S. Geological Survey, Mineral Commodity Summaries, January 2017

Table 15.5: Australian graphite projects

Project Name	Location	Stage	Production
Mount Dromedary	Queensland (near Cloncurry)	Feasibility	Up to 50,000 tpa
Uley	South Australia (near Port Lincoln)	Care and Maintenance	Up to 64,000 tpa
Campoona	South Australia (near Cowell)	Prefeasibility	140,000 tpa
Oakdale	South Australia (near Port Lincoln)	Prefeasibility	94,500 tpa over three years
Arno	South Australia (near Arno Bay)	Prefeasibility	Unknown
Koppio-Kookaburry Gully	South Australia (near Port Lincoln)	Reserves Development	30-40,000 tpa
McIntosh	Western Australia (near Halls Creek)	Prefeasibility	unknown

Source: DIIS (2017)

Cobalt demand is rising tentatively

Cobalt is a chemical element generally found only in a chemically-combined form. It can be smelted into a hard silvery metal, though it has also been used to create pigments and various ores. Cobalt is also used to create carbides for cutting, superalloys for aircraft engines, and various other metallic and chemical applications.

Cobalt prices have been volatile for years, but appear to have settled somewhat, with only tentative signs of supply issues emerging. Refined cobalt supply is expected to fall below consumption, which is being pushed up by demand from Li-ion batteries and aerospace industries. Offsetting this slightly is a growing shift towards battery technologies which require less cobalt. While this may lower cobalt demand growth in batteries due to substitution, it is still likely that cobalt demand will grow at an average annual rate of around 4 per cent over the next few years. Prices are expected to lift slightly in 2017.

Criticality of cobalt is rated as 'high' by GeoScience Australia.

China is the world's leading producer of refined cobalt, owning 70 per cent of global refinery capacity. The bulk of cobalt is sourced from mines in the Democratic Republic of Congo, though there is increasing concern over the use of child labour (an estimated 40,000 miners are children) and over environmental damage caused by the mines. Primary production is also supplemented by increasing re-use of cobalt from scrap and secondary sources.

Australian cobalt reserves are co-located with other commodities

Although Australia has significant cobalt reserves, there are no dedicated cobalt mines in operation. Most cobalt is mined as a by-product of copper, gold or nickel, and around 40 of Australia's gold and nickel operations are co-located with some form of cobalt deposit. These mines produce varying quantities of cobalt as a secondary commodity. Most deposits are located in Western Australia, though there are small producers in Queensland, New South Wales and South Australia. Australia accounted for 4 per cent of cobalt production in 2011.

With a deficit of 7000 tonnes of cobalt expected by 2020, and with some suppliers facing environmental and human rights concerns, it is likely that there will be emerging opportunities for new suppliers.

Table 15.6: Top five cobalt mine reserves

	Reserves (kt)	Production (2016) (kt)
Congo (Kinshasa)	3,400,000	66,000
Australia	1,000,000	5,100
Philippines	290,000	3,500
Canada	270,000	7,300
Zambia	270,000	4,600

Source: U.S. Geological Survey, Mineral Commodity Summaries, January 2017

Table 15.7: Australian cobalt projects

Project Name	Location	Stage	Outputs
Owendale	New South Wales	Feasibility Started	Scandium, Platinum, Nickel, Cobalt, Copper, Palladium
Syerston	New South Wales	Feasibility Started	Scandium, Nickel, Cobalt, Platinum, Palladium
SCONI	Queensland	Feasibility Started	Cobalt, Nickel, Scandium, Iron Ore
White Range	Queensland	Feasibility Complete	Copper, Cobalt, Gold, Silver, Molybdenum, Rhenium
Mount Gunson	South Australia	Feasibility	Copper, Cobalt, Silver, Gold, Iron Ore, U3O8
North Portia	South Australia	Feasibility Started	Copper, Gold, Molybdenum, Cobalt
Murrin Murrin	Western Australia	Expansion	Nickel, Cobalt
Mulga Rock	Western Australia	Feasibility Started	U3O8, Copper, Zinc, Nickel, Cobalt, Scandium

Source: DIIS (2017)

The future of batteries

Batteries are an important enabler for new technology

Wind and rooftop solar accounted for 41 and 21 petajoules (respectively) of Australia's electricity generation in 2014–15. This amounts to a relatively modest share of Australia's total electricity use, which summed to 908 petajoules over the year. However, solar and wind energy are growing strongly, with solar growing by 60 per cent per year on average over the past 10 years, while wind has grown at an average annual rate of 24 per cent. Wind has reached one-third of total electricity generation in South Australia.

As recent moves towards large battery facilities in South Australia demonstrate, batteries have a significant role to play in supporting emerging energy technologies. Upgrades to interconnectors will also assist, by improving the management of variable generation. Batteries, smart grids and interconnectors, have a mutually supportive function in managing variability and ensuring smooth power provision over time. Batteries are likely to also play an integral part in the potential penetration of electric cars. As improvements to range take effect and prices continue to fall, electric vehicles are forecast to grow in number, from less than 15,000 in 2010 to almost 4 million (or 4 per cent of all cars) by 2020.

The recent independent review into the National Electricity Market (NEM) chaired by Alan Finkel, found that regulatory reform and investment incentives will be important to help battery technology reach its full potential. This potential is significant, with the report noting that "Energy storage technologies can provide solutions to many of the reliability and security challenges facing the NEM as it transitions to a more variable, non-synchronous and distributed generation mix".

Battery markets have some emerging issues, which could affect future trends…

Although growth in demand is likely to pick up, there are emerging challenges to the technology. Battery markets have become somewhat skewed in recent years, with China becoming increasingly dominant across a range of areas. China is now the biggest producer of flake graphite, spherical graphite, lithium-ion anode material, lithium-ion anodes and lithium-ion batteries. China is constructing several large Li-ion factories, which are expected to push the country's share of Li-ion battery production to more than 60 per cent by 2020.

It is not clear yet how far Australia can progress beyond mining and into other parts of the battery supply chain. Lithium concentrates produced from mineral mines need to be further refined into higher purity lithium products before they can be used in batteries. Most lithium concentrate conversion plants are located in China, although two conversion plants have been committed to in Australia. Should Australia attempt to expand its role beyond extraction and further into production and manufacturing of Li-ion batteries, there will be formidable issues around economies of scale and labour cost.

Despite this, the undeveloped state of the supply chain may result in opportunities emerging that are not yet apparent. Battery supply chains are fragile and nascent at present, and improvements to the robustness of these chains would do much to support long-term growth in the battery industry.

… but technological change is a wildcard, and a potential game-changer

Technological change is bringing about significant disruptions and improvements, despite ongoing issues in battery markets. Energy cell costs have dropped by almost 75 per cent over the past six years, as a result of cheaper materials, better manufacturing processes, higher energy densities, better chemical formulations in battery cores, and greater economies of scale.

Already, demand for batteries and associated technologies has changed the game for producers of lithium, cobalt and graphite, turning them into outliers at a time when other commodities are undergoing price falls and declining investment. Time and technological change will show whether the battery boom can drive wider change in global markets and energy models. Investment is being drawn by the promise of electric vehicles, and by the potential for community-generated solar power to displace grid monopolies and fossil fuels. This investor interest is, in turn, generating sizeable funds dedicated to further research and development.

Commodity demand will be strong in the short term, but long-term prospects for battery technology are still in motion. The potential opportunities are vast, and investment and production decisions of today could cast a long shadow into the future.