LITHIUM VALLEY

Establishing the Case for Energy Metals and Battery Manufacturing in Western Australia

MAIN REPORT 2018

About the authors

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1 FOREWORD

This report provides evidence and recommendations for why Lithium Valley could be established in WA just as Silicon Valley happened in California. The rationale is based on the science and engineering realities that show WA has all the basic raw materials, environment and expertise to make it happen. However, WA does not have a history of adding value to its raw materials before export. There are differences with Lithium (and the other battery metals) of the New Energy economy and they are: reliable quality, high value products, security of supply and access to other New Energy metals in a stable political environment. If WA can create global best practice environments that meet or exceed emerging users' demands, this will attract international companies to local specialised industrial regions around the State. That is the context for our report.

The report sets out evidence in support of increasing the value added to New Energy metals prior to export, as the basis of the next stage of industrial development and economic expansion for Western Australia (WA). The transition to a New Energy economy is outlined as a global and local process where WA can help provide leadership and enjoy great benefits from the process. This will require policy support and infrastructure investment coordination from the Commonwealth, WA and local governments. The key enablers are all in place and the time is now otherwise the opportunity will be missed.

WA is home to the world's most accessible abundance of New Energy metals - lithium, rare earths, cobalt, vanadium, tin, tantalum, nickel, manganese and magnesium - essential components in energy storage devices, such as lithium ion batteries. The chemistry of energy storage devices continues to evolve, however the market for these elements is expanding rapidly and will continue to do so for the foreseeable future, due to a range of economic and environmental drivers. The market is for quality battery materials associated with Lithium Ion batteries.

WA has a transparent, western democratic and free market system of governance, offering low sovereign risks to investors. The confidence this inspires has underpinned the development of world-leading mining, petroleum and agricultural sectors, efficient and reliable logistics infrastructure, a high-quality education system and a workforce with diverse and advanced technical competencies and associated professional services. This is a solid foundation for industrial development and growth.

WA has an unmatched array and depth of energy and mineral resources, shares direct ocean access to 2.5 billion people and has a sound long-term growth rate. WA also has abundant renewable energy resources – which are increasingly being harnessed for households and integration into industrial processes to resolve water constraints and reduce energy costs.

WA's location, small population and lack of capital have long stood in the way of greater industrial development. Historically, it was more cost effective to value add closer to large markets or in countries with large, low cost workforces. This is no longer the case. Information technologies, artificial intelligence, automation and new energy systems now favour manufacturing at the earliest point in the value chain where all the input materials can be brought together in a low, cost effective way. WA has this advantage with New Energy metals like no other place in the

world and can offer reliable security of supply to local processing facilities. This is a unique opportunity for the State.

WA also has a special ability to make quality minerals for export as it has developed the smart technologies, software and research capability that allows very precise determination of the mineral quality along the development chain, from discovery through exploiting the resource and transporting it to individualised markets – mostly overseas. With Lithium this can be extracted to create high quality mineral products that can be combined into electrochemical processes that are then made into batteries. There are good reasons why this should be done here.

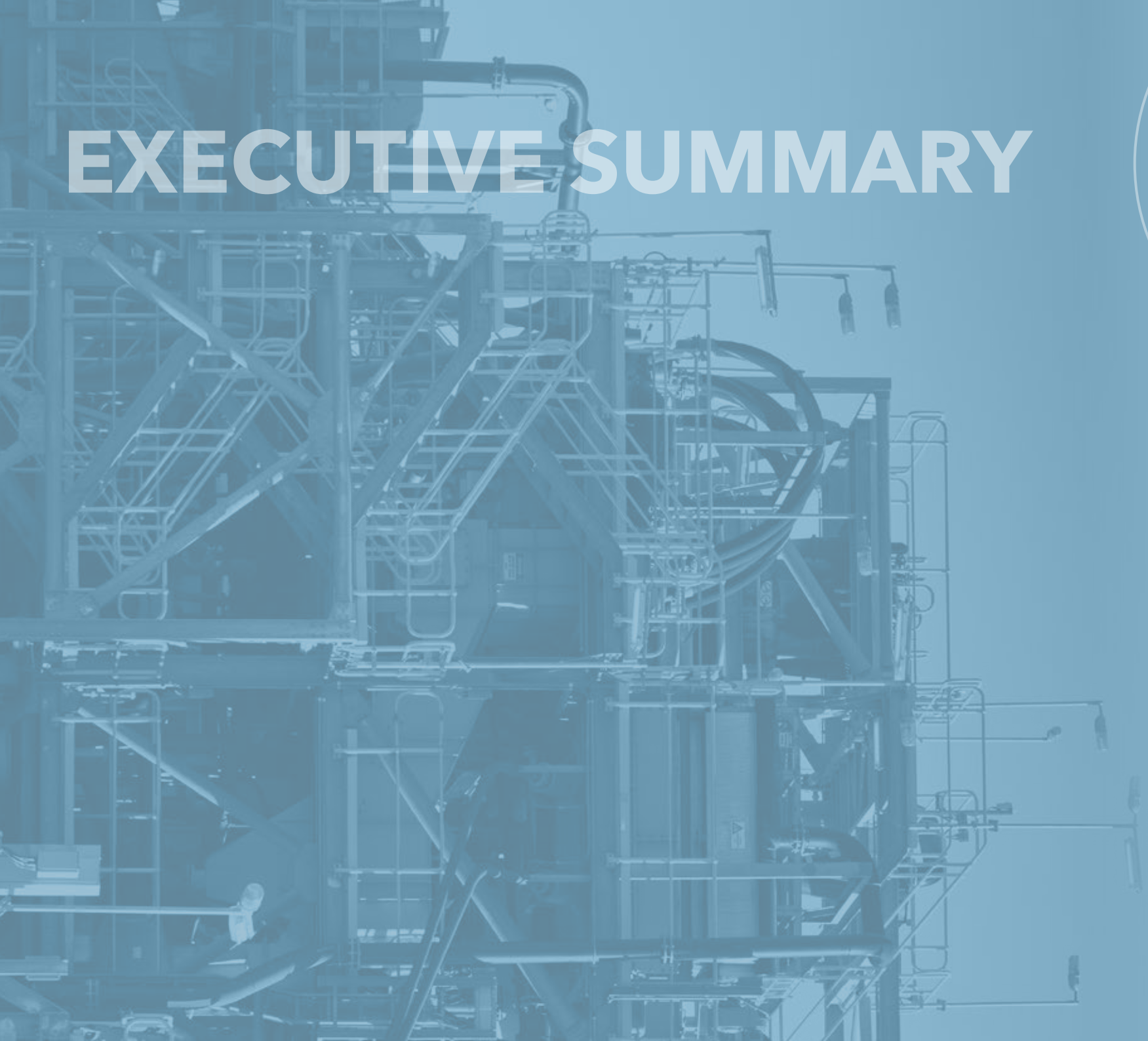
WA is coming of age as an Indian Ocean regional trading power and an important centre for future global trade and security operations. WA's trading partners appreciate the developing strategic role the State has although Commonwealth and State policies do not yet reflect this shift, nor does the political debate suggest a proper appreciation of the scale of the opportunity for the State, Commonwealth and our alliance and trading partners.

The first signs of Lithium Valley are being built with the first 'second stage processing' of Lithium being built at two sites in Kwinana and another under approval at Kemerton. These current investments were based upon business decisions made months or years ago. To build on this momentum a proactive approach is now required to influence further business decisions currently being made internationally and attract additional downstream processing to the State.

This is an opportunity that should now be grasped. We welcome feedback on the ideas in this report on how to make this happen.

Peter Newman, Ray Wills, Cameron Edwards and Colleen Yates

EXECUTIVE SUMMARY



2 Executive Summary

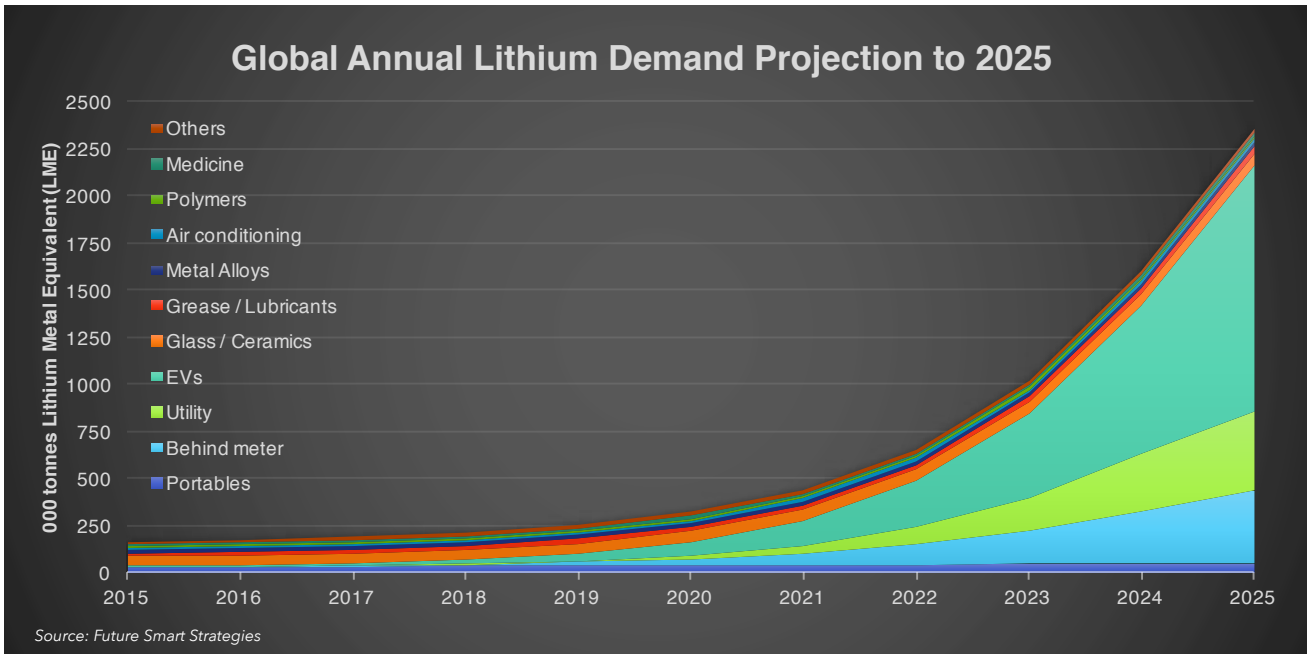
Lithium Valley is a cluster of collaborating and competing New Energy industries that are based around the economy of Lithium Ion-based batteries. This report sets out why WA is the ideal location for Lithium Valley building on the abundance of critical minerals that are now being called New Energy metals. There will be various regional mining and processing locations but this report makes a case for secondary processing primarily in Kwinana, Geraldton, Kemerton with specialised processes in the Pilbara, Kimberley and Goldfields.

New Energy metals are those critical to the manufacturing of batteries that are so critical to future society. These metals include lithium, nickel, manganese, cobalt, vanadium, tin, tantalum, magnesium, rare earths and others. Western Australia (WA) will continue to enjoy competitive advantages as an efficient and reliable supplier of most New Energy metals for the foreseeable future. By contrast, developing and advanced industrial economies have long held competitive advantages across much of the rest of the value chain. This has been a missed opportunity for WA because the economic value of goods increases sharply as they proceed up the value chain. For WA to continue its remarkable growth story it must capture more economic value per unit mined as the basis of future jobs, prosperity and strategic advantages as a trading partner.

2.1 What is the New Energy market?

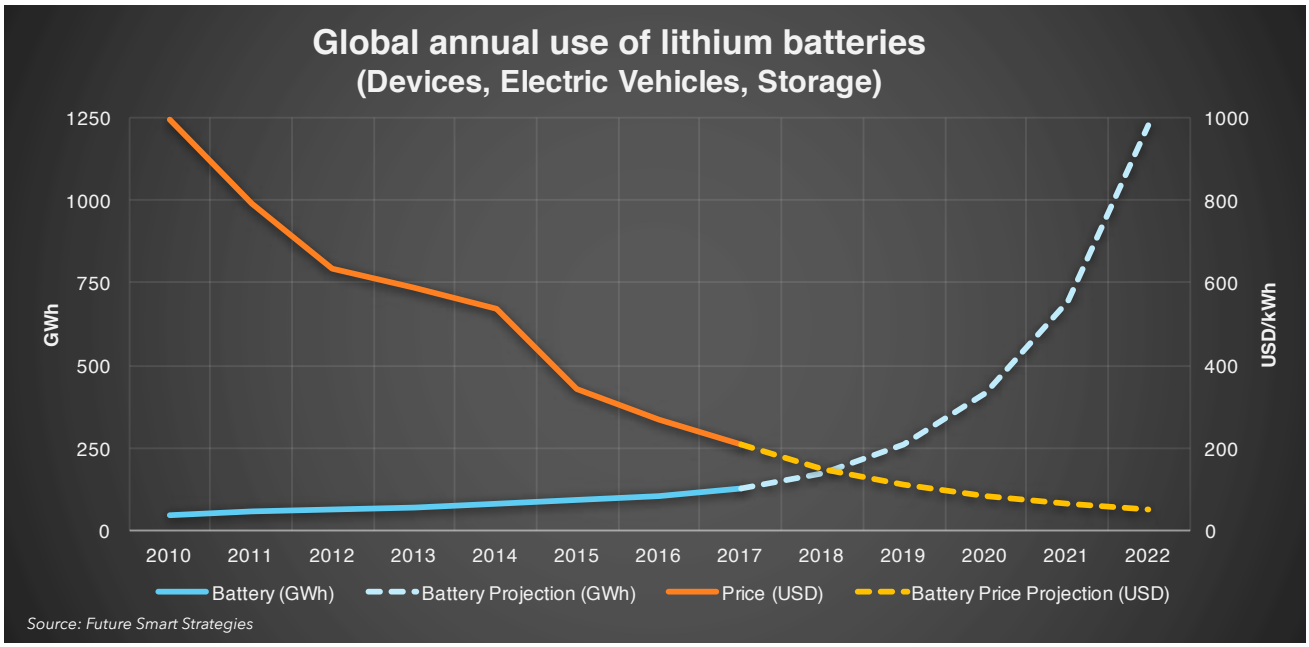
The foundation element of the new energy market is lithium. This metal is now being used in many products but increasingly in batteries for transport and electricity (Figure 1).

1 ***Figure 1:*** *Global Annual Lithium Demand Projection to 2025*



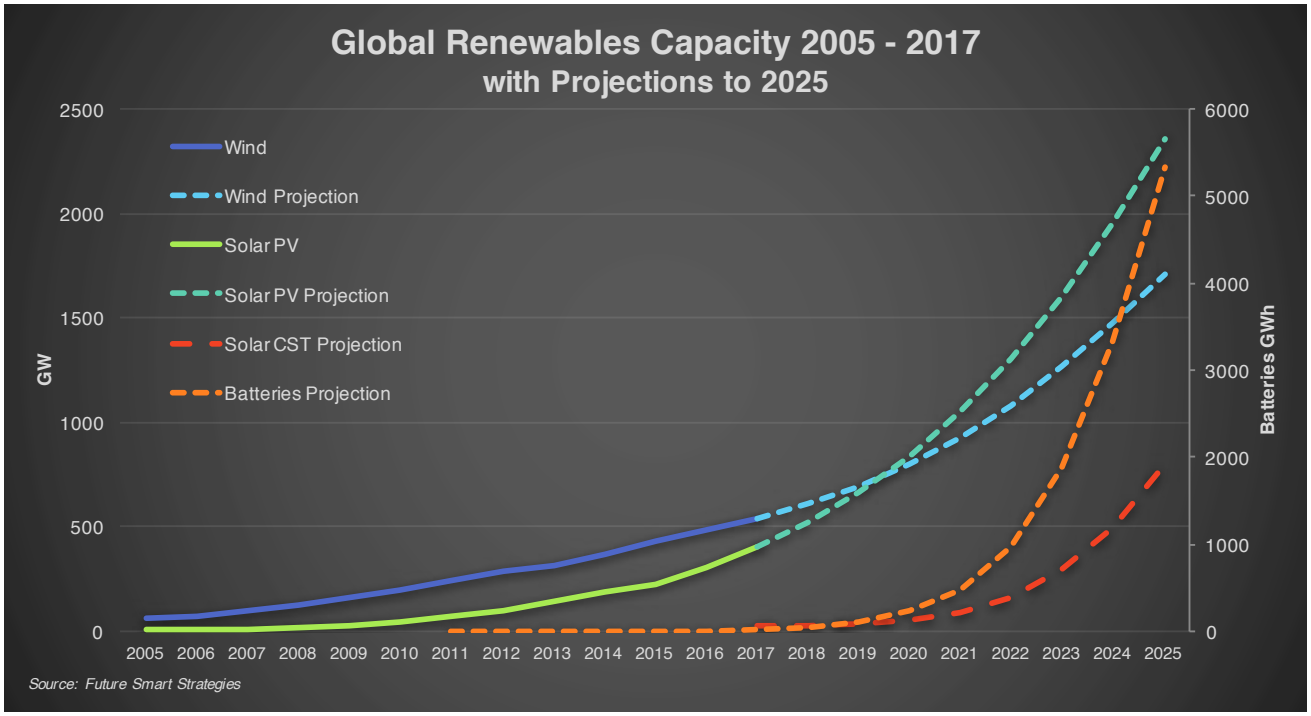
The price of lithium ion batteries has been dramatically reducing as manufacturers gear up for electricity storage and especially electric vehicles (Figure 2).

2 ***Figure 2:*** *Global Annual Use of Lithium Batteries*



Renewable energy from wind and solar requires battery storage. The projected growth in renewable energy and battery storage is shown in Figure 3.

3 ***Figure 3:*** *Global Renewables Capacity Projections*



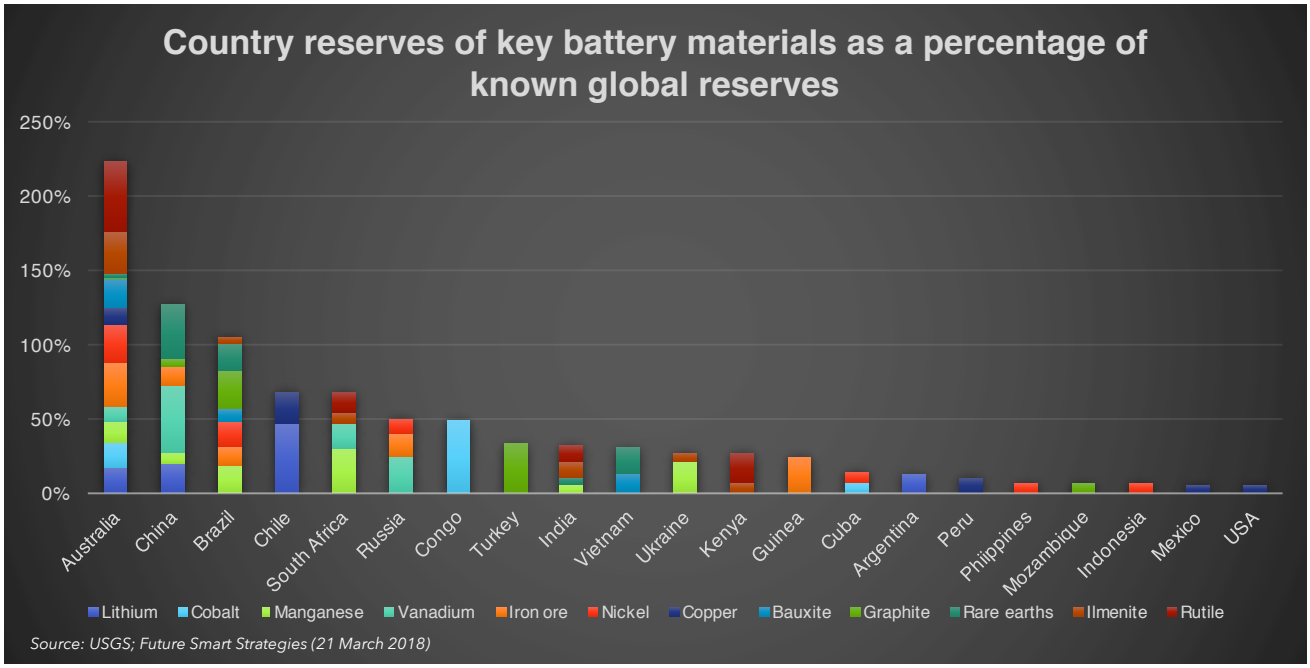
2.2 Why is WA the best place for Lithium Valley?

According to Klaus Schwab, the Founder and Executive Chairman of the World Economic Forum,[1] the world is in the middle of the fourth industrial revolution (the fourth stage). Information technologies, artificial intelligence, automation and new energy systems are the fourth stage technologies that will underpin New Energy metals processing industry in WA, but the term also refers to social media, online communities, gaming, 3-D printing, genetics, breakthroughs in the materials sciences and virtual and augmented reality. Collectively, these technologies are fundamentally altering the way we live, work, and relate to one another. They are also transforming the global economy and WA's position in it.

Fourth stage technologies offer WA the opportunity to develop a much larger industrial base that is complementary to its world-leading resource extraction sector. These technologies shift the competitive advantage of early stage value adding away from low cost labour countries to the earliest point in the value chain where all the input materials can be brought together for highly automated manufacturing processes. Components are then shipped to the major global manufacturing centres for later stage manufacturing where proximity to markets or low-cost labour still afford an advantage. WA is in the unique position of having abundant quantities of almost all the New Energy metals, giving it a large advantage in electro-chemical processing.

The abundance of New Energy metals in Australia, mostly in WA, is set out in Figure 4.

4 ***Figure 4:*** *Country Reserves of Key Battery Materials*



1 Schwabb, K (2015) "The Fourth Industrial Revolution", World Economic Forum, Geneva, https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab.

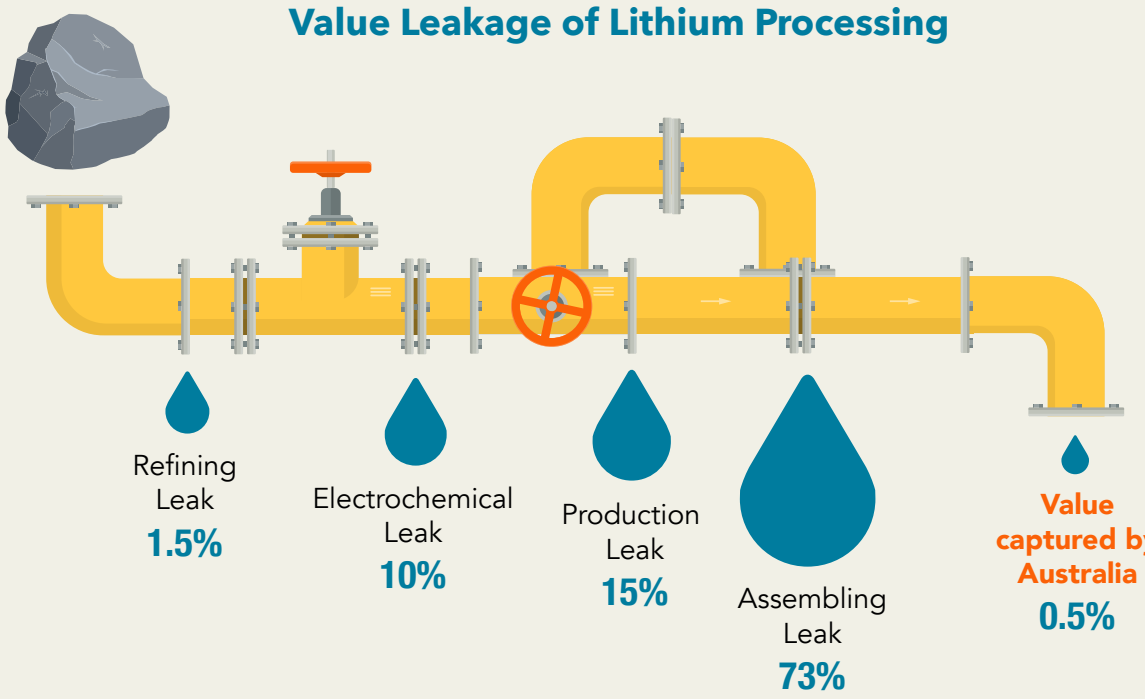


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Figure: 5 *Value Leakage of Lithium Processing*

Source : InfraNomics 2018

Lithium is a critical component of energy storage devices and WA has the largest hard rock reserves of lithium globally and its consistency is most suitable to high quality manufacturing.

Figure 5 shows that almost the entire value of this important strategic resource is captured in other countries and by other processes. Currently Australia captures approximately 0.5% (A$1.1bil) of lithium's ultimate value mainly as simply processed exported ores. 99.5% (A$213bil) of the value of lithium products is paid to Australia's trading partners for value added through electrochemical processing, battery cell production and product assembly by WA's trading partners. Secondary processing in WA alone would capture an additional 12-27% of the value available. This report recommends a review of how royalties are calculated and applied as part of a holistic suite of policies that positively encourages local secondary processing while improving productivity and efficiencies.

WA's Western Trade Coast in Kwinana offers another important advantage. It is one of the most integrated, efficient and productive industrial estates globally. It services world scale oil and gas, resources and agricultural sectors through a concentration of a highly skilled work force, refining, fabrication, chemical, research and innovation, service and supporting companies. The chemical precursors and other requirements for electro-chemical processing are already in place. It has one of the best global examples of industrial ecology with over 158 continuous exchanges between industries. This is based on a strong collaborative approach represented by the Kwinana Industries Council and can be a major building block for creating Lithium Valley as outlined in the governance recommendations below. The availability of the existing synergies to incoming companies enhances their international competitiveness.

Global competition for the emerging New Energy metals market is vigorous. Other countries recognise the importance of New Energy metals and storage devices for future growth and are concentrating significant resources to control these supply chains. WA still has the advantage of being upstream of all of them, but this will erode rapidly if competitors are able to establish long term trading arrangements and attract processing facilities to their shores. Ensuring this does not happen requires an integrated policy and infrastructure response at all levels of government to establish the logistics and industrial infrastructure, the research and development base, as well as the policy levers that will attract proponents to the State.

2.3 What are the benefits for WA?

The cost of missing the New Energy metals industry development opportunity, the New Energy transition, would be high for WA. The direct losses per unit of New Energy metals exported are substantial. The indirect losses through an opportunity forgone to expand WA's industrial and logistics infrastructure for further development by future industries would be much larger. Research conducted as part of this report estimated the following potential employment generation and capital investment from a fully developed New Energy metals industry in WA.

Table 1: ***Estimated Potential Employment Generation and Capital Investment From Developing the WA Energy Metals Industry***

Energy metals - lithium, cobalt, nickel, rare earths and vanadium		
Employment		
Current employment in the New Energy metals sector – 2017	Actual	**7,291**
Expected growth in direct employees until 2025	Estimate	21,480
Forecast employment in the New Energy metals sector - 2025		
Direct – Full Time Employment 2025	Estimate	28,771
Indirect employment 2025– multiplier 2.5	Estimate	71,927
Total New Energy metals sector employment 2025	**Estimate**	**100,698**
Employee wages in 2025	Estimate billions per annum	**A$3.33**
Payroll taxes 2025	Estimate millions per annum	**A$183.30**

Economic contribution from the New Energy metals sector		
Economic contribution of New Energy metals 2016/2017	Estimate billions per annum	**A$2.97**
Potential Economic contribution mine, refining and 10% of electrochemical production per annum 2024/2025	Estimate billions per annum	**A$56.52**

Capital investment for the New Energy metals sector		
Capital investment forecast for new mines, refining facilities	Estimate billions until 2025	**A$13.81**
Capital investment forecast for new mines, refining facilities, secondary processing and recycling	Estimate billions until 2025	**A$34.11**

Source: InfraNomics 2018. All estimates are in nominal values.

In addition, approximately 12,275 construction jobs are expected to be created by 2025.

WA is no longer remote nor positioned at the far end of global supply chains. It is at the beginning of many of them and convenient to the largest global markets. This strategic and economic advantage will likely continue to improve as the economic rise of many nearby nations continues and Indian Ocean Regional economies drive the next global growth super-cycle. The New Energy metals or New Energy industries opportunity is not just about the domestic Australian market, it is almost solely focused on exports to fuel WA's trading partners in a win-win trade deal.

Commonwealth and State policies are yet to reflect WA and Australia's coming of age and its changing strategic role and associated opportunities. There is good reason to redress this oversight urgently. Trade routes are constrained, even as next generation freight vessels are poised to outgrow them. Trade flows are changing as new technologies change where it is best to refine and manufacture. Rising strategic tensions risk disruptions along the most heavily trafficked trade routes. Energy metals are at the centre of this realignment as nations race to secure access to these resources and leverage control of supply chains for economic and strategic advantage.

WA, in addition to its arrival at the centre of current and future trade and development, can service the development of a complementary and comparatively secure southern trade route. WA is one of only a few locations around the world that can guarantee freer trade in New Energy metals while securing supply. This would be transformative for WA and Australia and represents an opportunity for WA's trading partners to participate in and benefit from investments in supporting infrastructure and resulting regional growth if the Federal and State Governments can participate with the necessary urgency.

The need for security of supply is a large strategic issue but so is the need for ethical supply chains which companies today must make part of their business case for location of their investments. WA has the second largest reserves of cobalt in the world. The largest cobalt reserves are in the Democratic Republic of Congo where ongoing social and security issues influence the ethical and sustainable supply. Western Australia, being a highly stable environment can claim to have largely overcome historical ethical issues in mining, processing and manufacturing. The wide spread indigenous employment programs, strong environmental laws and proactive social justice initiatives make New Energy metals from WA, equal to the most ethically mined and processed in the world.

As well as the economic driver in this New Energy metals and industry opportunity there is an element of strategic importance for Australia in the management of these vital resources that are becoming critical for the global economy. These issues are pursued in the report.

2.4 Top priorities **The top priorities identified in this report are:**

1. **Quality** priority in all steps in the value chain – the fundamental driver in bringing value added New Energy-based industries to the state will be the commitment to high quality products. This will require technical and research capability, financial awareness of the opportunities to invest in quality, and governance processes that ensure this outcome.
2. Designation of **strategic resources** – strategic resources are fundamental to the long-term sustainability of WA. Strategic resources must be clearly identified and have additional focus and protection by government.
3. Establishment of a **Specialised Industrial Park** (SIP) in Kwinana – the establishment of a SIP in Kwinana will stimulate broad industry economic activity and generate jobs through the development of New Energy metals manufacturing and processing capabilities, development of secondary supporting industries, trading of goods at lower prices, and improving international competitiveness. It can also be the structure for a series of other governance arrangements including Strategic Environmental Assessment, that can enable the rapid development of New Energy industries on the site and become the base for Lithium Valley.
4. **Branding –** WA has the raw resources of minerals and skilled people to make Lithium Valley a reality. It will require significant support from industry, the community and government but can become a great source of pride and value for the state. It is recommended that the state adopt a branding exercise to position Lithium Valley.
5. **Smart royalties** – It is estimated that Australia loses up to $90B per year in resource royalties.[2] The royalties system must be reformed to capture this value for strategic resources at both the State and Federal levels. Dynamic, rather than flat rate royalties, may also help to incentivise secondary processing and disincentivise (but still permit) the direct export of raw materials. International examples abound of how this can be done.
6. **Domestic reservation** – to ensure a long-term supply of raw materials, a minimum analytically-determined percentage of strategic resources designated for potential local value adding should be reserved. This guarantees local supply security for processing. The minerals should be valued at market price to ensure mining companies are not disadvantaged.
7. **State strategic vision and strategy** - a roadmap with milestones and timelines for up to 20 years to underpin commercial investment decisions. Infrastructure WA could integrate this into its 20-year infrastructure strategy, to help prioritise public and private sector investment linking industrial, logistics and service infrastructure for maximum effect.
8. **Parliamentary Inquiry into New Energy Metals Industry** – all aspects of the development of the Lithium Valley concept as well as how the local energy system can transition into being a model for electricity and transport using the New Energy metals for the transition in electricity generation, transmission and retail as well as the integration of electric vehicles. This can build on the existing Economics and Industry Standing Committee Inquiry into Microgrids and Associated Technologies that is showing the importance of distributed generation.[3]
9. **Regional Lithium Valley** – it is recommended that a globally significant e-waste recycling facility be developed at Geraldton with its port linked to the European, Asian and Indian Ocean markets and its Oakajee Industrial Estate linked by rail to the South West and eastern states. Industrial processing is likely to be viable in Kemerton, the Pilbara, Kimberley and Goldfields if quality New Energy mineral products are created with some potential for the Kimberley across rare earths. All such places need to see their energy as facilitating the solar and battery transition in their own services.

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2 Bagshaw, Eryk (2018), "'Staggering': $90 billion lost in resources tax", The Sydney Morning Herald, March 12, 2018, *https://www.smh.com.au/politics/federal/staggering-90-billion-lost-in-resources-tax-20180305-p4z2uv.html.* (Accessed: 01 May 2018)

3 Economics and Industry Standing Committee (2018), Inquiry into Microgrids and Associated Technologies in WA, 21 February 2018, Legislative Assembly of WA, *http://www.parliament.wa.gov.au/Parliament/commit.nsf/(EvidenceOnly)/8C9FB0B8AA10E88D4825823B0019BAA3?opendocument* (Accessed: 01 May 2018)

2.5 The fierce urgency of Now

Countries around the world, international business and technological innovation are not waiting for WA to take advantage of the New Energy opportunity. Globally, there is intense competition to secure supply chains and dominate the New Energy metals markets. It is difficult to imagine WA capturing more of the benefits of this transformation if government, industry and the community do not collaborate as other countries are doing. Poor advice, the lack of or misguided planning over many years, an absence of a bipartisan vision or strategy now means a solution has to be fast tracked to improve the opportunity to capture these benefits. In the current environment is it questionable whether a traditional departmental planning process is suitable to the fast moving international business developments, competition from other countries or industry timelines. Does the government have sufficient and appropriate resources for this new and demanding role? Are the timings of a government planning process compatible with the speed of international developments in this industry?

This is not about picking winners. It is about the government enabling or facilitating a suitable local business environment (Specialised Industrial Park – Kwinana) that attracts international companies with the critical intellectual property to do further secondary processing in WA. The private sector will do the majority of the planning and provide the financing. This government facilitation and enabling role must occur immediately as the sooner the government engages with industry the higher the likelihood international companies' investment decisions will include Kwinana in the international options available. The alternative is that WA misses the opportunity and unfortunately there are plenty of these examples in recent decades.

The next section sets out the proposed recommendations to maximise the social, economic and environmental benefits for WA, Australia and trading partners.

3

RECOMMENDATIONS

3 Recommendations

3.1 Federal Government

3.2 Specialised Industrial Park (SIP)

Work with the State Government to establish a SIP over the entire Western Trade Coast.

The SIP is a globally developed approach to attract economic development; it is a port or an area of a port in which imported goods can be held or processed free of customs duties before re-export. SIPs have become common in recent years and exist around the world (EU, Middle East, Asia) to increase activity and production within the zone. In Kwinana the main advantages will be to simplify and speed up the approvals processes while also reducing operating costs through greater economies of scale. There is significant evidence that SIPs create increased employment, particularly for higher-skilled personnel, as there is a strong emphasis on value-adding. All quarantine and customs services are provided within the secured zone. The Federal Government can work with the WA State Government to develop an SIP within the Western Trade Coast area.

3.2.1. Encourage the transition from a combustion-driven to an electric economy

Enable Australia to be a leader in the global transition from a fossil fuels-driven economy to a renewable economy through a wide variety of policies, mandates, legislation and regulation.

The global transition to New Energy metals and New Energy industries is driven by a business-based market and by governments through the Paris Agreement that Australia is committed to. Federal leadership in seeing the Lithium Valley opportunity in Kwinana as part of this agenda as well as an economic opportunity, can help place Australia as a world leader.

This would mean integrating agendas for innovation, economic development, strategic and defence planning, as well as climate change. Apart from reducing dependency on imported fuels (mitigating fuel security issues) it would stimulate local renewable industries, generate more local jobs, reduce pollution and move Australia towards a more sustainable economy while increasing national security.

3.2.2. Support the Establishment of a New Energy Industry CRC

Create a New Energy Industry CRC in Perth.

As economies around the world decarbonise the globally burgeoning demand to new energy products produced with Australia's abundant new energy material has been identified as a major and unrealised opportunity for Australian industry as well as research and innovation providers. There is a need to establish a CRC in New Energy Industry in Western Australia to provide the R&D that can link industry to new and emerging markets using Western Australian minerals. WA has some rapidly emerging innovative companies in the use of new energy batteries within cities and regions but does not have sufficient happening in the industry stages between mineral processing and battery use.

CSIRO has several centres of excellence in the energy storage area, in particular the Stored Energy Integration Facility (SEIF) at the CSIRO Energy Centre in Newcastle, NSW, or the Centre for Hybrid Energy Systems (CHES) in Clayton, Victoria. University researchers in WA are also doing work in this area but need a focussed and resourced CRC that can link to industry and to such resources in the east. Facilities associated with the CRC could be established at the Western

Trade Coast (WTC) to maximise research and development, commercialisation and integration in and across key industries. To maximise these facilities, specialist expertise from around the world needs to be encouraged to locate to Kwinana and to set up partnerships for mutual benefit. The core requirement that will attract people and investment to create Lithium Valley in WA is if there is a clear commitment to making the highest quality energy materials along the value chain. Battery manufacturers are already raising their quality requirements beyond what any producer can currently do. This will require world's best technical capability in the industries and universities associated with this venture. It will need smart systems for monitoring in the field and inside industrial processes and constant upgrading to be ahead of the game.

This will give the innovation edge that no other global producer of New Energy metals can provide.

It would provide the basis for local research and development programs to work in parallel with the producers of current-generation production of storage, power and drive components, in order to develop next generation components right through the industry stages to the utilisation of new energy in households and business across the city and regions.

Australia has considerable capability in and utilisation of advanced technology in the processing of metal ores. This capability should be incentivised to extend our technology into the processing of all of the new energy materials, especially those that lead to the production of rare earth magnets, battery precursors (cathodes and anodes) and even the extraction of key materials from complex e-waste mixes. The development of micro-grids and Peer-to-Peer trading of renewable energy is happening in Perth as a global first and can help establish the kind of research centre that will be world-leading.

A Federal Government-funded CRC on New Energy Industry, supported by State Government funds already committed and announced, would be a major step towards establishing Lithium Valley industries in WA.

3.2.3. Commercialization of innovation

Facilitate innovation in New Energy to be commercialised

In order to ensure the highest value return from New Energy metals there is a need to establish innovation support, risk management and procurement processes that can enable these new energy industries to be commercially successful.

A critical factor in the commercialisation of products from innovative or "start-up" customers is having easy access to customers. In 2017, the Queensland University of Technology (QUT) completed a three-year long project to design and produce a lithium-ion battery. The project was funded by a $4M investment from Australian and Malaysian Governments and included construction of a pilot manufacturing plant with a demonstrated battery. This is an admirable accomplishment however, this is not yet a viable commercial operation. Research and development activity is very important but will be most effective when conducted in parallel with established industries.

Government organisations and government trading entities have social and longer-term drivers, in particular new generation power storage and are better able to justify risks against benefits to their stakeholders. The Federal Government's new Infrastructure and Projects Finance Authority is set up to enhance risk management strategies. With this type of government support, a fully functional battery manufacturing operation, can be established, perhaps based on the results of the QUT project or other Australian innovation. However, given the urgency for Australia to rapidly build commercial products, the immediate emphasis should be on attracting technology partners that can immediately deliver manufacturing processes, product designs and global customers. Such a facility could be up and running within one year, producing cells to meet existing commercial demands and developing next generation power storage. This is given as an example of how quickly innovation can be turned into value adding economic activity in the Kwinana SIP of Lithium Valley.

The Federal Government can thus prioritise support of local, emerging and innovative suppliers in purchasing or tendering processes as a risk-manageable means of supporting new products and championing Australian technological innovation. Procurement guidelines in government purchases can be used to help establish markets for new energy innovations and products in Australia and especially WA.

3.2.4. Standards

Set high standards for refined products of New Energy minerals to promote quality and traceability.

As outlined in this report the core attraction for bringing New Energy industries to WA will be whether we have the highest quality product for their batteries in the world. It is therefore recommended that the Federal Government develops new standards for refined products of New Energy minerals such as purity, contaminants and grades that meet the kind of evolving world best requirements from battery producers.

Similar to import locations that require pricing resources on quality, export locations like WA could also codify standards, quality and benchmarks for a global market, such as is the process for pricing Brent crude, TOCOM gold or Iron ore 62% CFR Tianjin. This increases the international importance of products from WA as well as standardising product and increasing jobs in the testing and certification sectors. Currently the market grades for lithium are: as Lithium carbonate, min 99-99.5% Li_2CO_3; large biannual contracts, del continental USA, $/kg or Lithium hydroxide, 56.5-57.5% LiOH; large contracts, packed in drums or bags, del Europe or USA, $/kg or Lithium hydroxide monohydrate min 56.5% $LiOH_2O$; and technical and industrial grades, contract prices DDP Europe and US, $/kg.[4]

The opportunity exists to standardise quality and pricing based upon an Australian standard that will centralise trading around Australian product and lead to greater value-adding local industry as part of the focus on WA as being the Lithium Valley of the world.

3.2.5. Prioritise selection of GST and royalties to take advantage of New Energy industry

Reform the GST model to enable New Energy industry

The current GST system penalises states from developing resources projects as there is an imbalance between the generation of resource royalties and the subsequent redistribution as a result of the Commonwealth's horizontal fiscal equalisation model. The long-term consequences of this policy as it currently stands are unlikely to be beneficial to Australia's long-term development, especially in the resources sectors. In addition, this does not encourage value-adding industries to work with such mineral extraction. Reforms can now happen and the new energy industries opportunity provides the political momentum to adjust the model.

The Federal Government could bring to COAG the reform of royalty systems and the treatment of royalties in the Commonwealth's horizontal fiscal equalisation model as part of the on-going process of adding value in the economy through New Energy industry.

3.2.6. Foreign Investment Review Board – Strategic Resources

Include strategic resources as a new section for Foreign Investment Review Board approval.

Strategic resources should be defined although at a minimum should include lithium, cobalt, rare earths, high purity alumina, graphite, manganese and vanadium. Transactions such as the proposed Altura / Shaanxi investment highlight the opportunity to include a new class of conditions required before approval of foreign investment in this sector. For example, a condition

4 Industrial Minerals (2018), Lithium, http://www.indmin.com/Lithium.html. (Accessed: 01 May 2018)

may be that a minimum amount of investment is made in domestic downstream value-add potentially through to finished battery product. This can only be done as part of a major strategy agreed to by the Federal and State Governments to make the most out of New Energy metals and to ensure that strategic and defence issues are not compromised.

3.2.7. European Union Critical Raw Materials (CRM)

Ensure the EU define Australia as a Critical Raw Materials supplier.

The EU Commission publishes a list of CRM that are important for the EU economy and may have supply risk concerns. In the latest EU Commission report [5]
Australia isn't seen as a major supplier even though Western Australia has all the CRMs.[6]
It is therefore recommended that the Federal Government immediately write to the EU, to note the lack of CRM supplier status. Further, the Government could request that to assist in facilitating diversified supply of these critical materials there should be a commitment for EU companies to seek a better return for investment, technology and secondary processing facilities in Australia. Due to the environmental regulations and restrictions in Europe it may be advantageous to process in WA (where environmental laws are also strong) than export to Europe. As part of a geostrategic agreement with the EU, e-waste from the EU could be reprocessed in WA as part of a long-term concession to justify WA investment.

3.2.8. National recycling policy

Implement a harmonised nationwide recycling approach, potentially using the EU regulations as a guide and using e-waste as the exemplar.

The recent blocking of waste exports to China has exposed a lack of maturity in Australian waste treatment and recycling. e-waste in particular can be considered a resource for manufacturing into raw materials either for domestic usage or export. There are also likely to be synergies with new technology manufacturing and New Energy metals processing. In order to enable e-waste recycling as part of the new SIP area in Kwinana or associated with it somewhere else in WA, there needs to be a national strategy developed.

The choice of sites and management of such a facility would be a state responsibility, hence the focus shifts to WA.

3.3 State Government

3.3.1. Lithium Valley as a WA brand

Establish a branding and information program for Lithium Valley

WA needs to grasp the opportunity provided by the New Energy economy and the extraordinary mineral resources it has to supply this, to establish the brand of Lithium Valley as a clear part of Western Australia's identity and future. By establishing this brand and following through on the more detailed recommendations below the State can be seen to have established a base for companies wanting to be part of the value chain in the New Energy economy. This can be taken around the world and help to show how WA has moved from its major dependence on the boom and bust mineral export economy.

5 European Commission (2017), COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS on the 2017 list of Critical Raw Materials for the EU, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX-:52017DC0490. (Accessed: 01 May 2018)

6 Although natural rubber is not grown commercially in WA, the CSIRO has previously identified the potentially viability of a local industry. http://www.pir.sa.gov.au/aghistory/industries/minor_crops/guayule. (Accessed: 01 May 2018)

To assist companies wanting to relocate or open operations or an office in WA as part of Lithium Valley, it is recommended to produce a database of all local companies already participating in Lithium Valley and associated synergies, across the necessary disciplines required (business case development, approvals submissions) and to make this database publicly available, such as on the main government department websites.

3.3.2. State and Federal Bilateral Approval Process

Establish Federal and State bilateral agreements on the Kwinana, Geraldton and Kemerton sites for the New Energy industries especially Strategic Environmental Assessment.

A common theme from interviews with industry was that companies arriving in WA the first time are unprepared for differences in local regulations, environmental protection approaches, heritages reviews and the approvals process. Often companies from over east or overseas are engaged and valuable time is lost through this misunderstanding. Creation of a local partnership database and capabilities register would save companies time and money in getting the right advice from local companies that understand the local environment but in reality there is a need for a streamlined approvals process.

A Strategic Environmental Assessment (SEA) is the legal process that can enable this in WA. The environmental approvals process covers all areas of potential impact and an SEA is something that is done over a wider area covering a series of potential projects rather than just one project at a time which is not efficient and is highly costly.

It is therefore recommended that bilateral approvals between State and Federal Governments be implemented through an SEA for these strategic Lithium Valley projects. It is important to do more Strategic Environmental Strategies as has been happening on the Perth and Peel 'Green Growth Plan' and a number of others across Australia. These approval processes once completed enable much quicker planning approvals for industries that can show they comply.

Unnecessarily doubling up of approvals processes, especially environmental and planning approvals, at both State and Federal levels has now been demonstrated to have been replaced by these strategic integrated processes. They should be immediately done on the SIP and NIE approvals processes.

As part of the Strategic Environmental Assessment process it is recommended that the State Government completes a checklist or map of all approvals for all industrial parks so that a 'plug and play' environment exists. This good management practice will speed up companies locating to all industrial parks but in particular the ones associated with Lithium Valley. During the interviews, several companies expressed understandable surprise that government approvals processes relating to industrial parks hadn't been completed. The impact has been unnecessary delays, costs, loss of revenues and to the State and Federal Governments, a loss of taxes.

3.3.3. Parliamentary Inquiry into Lithium Valley

A Parliamentary Inquiry to provide a whole of government and community response to Lithium Valley

All government agencies and the broader community need to be brought along with this concept of Lithium Valley. There are various ways to do that but one that enables both mechanisms is a Parliamentary Inquiry. The Parliamentary Inquiry into Lithium Valley should examine all aspects of the development of the Lithium Valley concept as well as how the local energy system can adapt into being a model for electricity and transport using the New Energy metals for the transition in electricity generation, transmission and retail as well as the integration of electric vehicles.

The transition that all global economies are entering can be reviewed to see how WA is managing to compete if not lead. This would then enable the Lithium Valley concept to become

a focus for all agencies and in particular to enable strong and growing public support for this new future. The WA Government Inquiry into Micro Grids is already starting such a process. A Parliamentary Review can assist to gain perspective on this transition and especially to see how the value-added industries are developing. The review would be updated every five years as the transition unfolds.

Another key aspect of a Parliamentary Inquiry could be about how Lithium Valley relates to energy costs. Australia's access to energy resources of both fossil fuels and renewables is world-leading. WA is now showing leadership in the adoption of solar energy and batteries. One of the reasons for this happening is how solar energy companies in Perth have been able to commercialise roof top PV through permitting and financing that is considerably cheaper than in the US. Taking advantage of the New Energy minerals and the solar resources, energy pricing provides opportunities for reliable long-term supply that becomes a major point of difference to competitor nations and provides Australia with significant competitive advantages. The ability to offer long term, reasonably priced energy is essential for manufacturing as it allows companies to continually incrementally improve production. Australia needs to be at the forefront of how New Energy usage, pricing and delivery can stimulate energy-intensive industry growth and value-added energy services. This can be supported and sustained by the ongoing development of locally sourced and cost competitive new generation electricity generation. These matters need to be constantly reviewed.

3.3.4. Domestic reservation across New Energy metals

Following gas policy, set aside key strategic minerals for domestic use.

It is recommended that a domestic reservation scheme be established, based on market valuations, to ensure security of supply for local production and businesses. Security over supply is a major driver of this industry and a domestic reservation policy would encourage local value-added industry.

WA introduced a domestic gas reservation policy in 2006, which requires new gas developments to supply the equivalent of 15% of their gas exports to the Western Australian domestic gas market. The aim of the policy is to maintain domestic gas prices below export parity. Lithium, rare earths and other resources could be subject to similar domestic reservation policies in order to develop and support local business. Although a portion of the income from the resource is foregone the additional value adding from local processing increases the gross return on the original resource. Allowing the export of finite strategic resources, such as rare earths, with minimal domestic processing and without applying suitable taxes or royalties robs WA of the economic and social benefits that should come from the mining of resources that are rare and result in high value/margin products.

3.3.5. Off take agreements and domestic usage

Establish strategic minerals status for all New Energy materials.

Long-term product off-take agreements are usually sought by mine developers in order to underwrite the capital cost of building resource production on-stream. However, the downside of unconstrained agreements is that such agreements effectively exclude any opportunity for domestic value-add to these resources, which in turn results in lost opportunities for domestic industrial growth.

One way of enabling local value-add to be achieved is through recognising 'strategic resources' that are not just like iron ore distributed in many places across the globe but are focussed in WA. Awareness of WA's New Energy metals is rapidly growing. It is therefore recommended that all "new energy" materials should be considered strategic resources. This would need to happen in partnership with the Federal Government. In order to do this it would need:

- All "new energy" materials should be considered strategic resources,
- All such strategic resources to be tracked for their economic reserves and their trade commitments,
- All off-take commitments to be subject to approval to ensure that the ability to satisfy a diversity of domestic and international customers is assured, and
- All off-take agreements to include a domestic value-add requirement.

3.3.6. Smart royalties

Review the royalties scheme in the light of New Energy metals.

This review is needed in order to ensure an equitable return for the State from its New Energy metals, to encourage the supply of strategic resources to Australia and secondary processing in WA, to discourage the exporting of unprocessed resources (especially strategic resources) and to ensure that local job creation is maximized. Resources are finite global commodities and it is further recommended that a review be conducted of comparable jurisdictions to ensure consistency of approach in this rapidly evolving industry as well as to maximize the benefits to the owners of the resources, its citizens.

3.3.7. Incentives

Investigate the provision of direct and/or indirect support to strategic industries using New Energy metals.

Support for mining and resource development is not without precedence in WA as the state geological survey continues to provide information to resource companies and the oil/gas industry was established through the WA Government's West Australian Petroleum Pty Ltd and was supported by the take-or-pay contract that brought natural gas south from the Pilbara. Other incentives can be applied to assist companies that are now wanting to establish value-added processing, for example, South Australia offers interest-free loans, payroll tax holidays, direct bulk buying orders and cheap land as incentives for targeted companies. Other Governments offer many more incentives, such as tax holidays, subsidised utilities and light regulations. WA could be more proactive to be more competitive. This approach is widely used around the world including throughout Asia, Europe and the US for attracting high value industry. It could be argued WA is in the minority by not offering such incentives for priority industries.

Beyond the provision of subsidies, it is recommended that the State Government establish well-capitalised investment funds to focus on investment in priority companies and industries. These investment funds should be commercially run and sit outside of political interference and political processes. This would be a replacement for grant schemes that are often conservative in fund allocation and are inefficient due to government processing costs. There would also need to be an assessment of State and Federal programs to deliver a more coordinated and seamless approach.

3.3.8. Facilitate governance of the Western Trade Coast and SIP.

Establish a dedicated management authority to facilitate development for the WTC and Lithium Valley.

Currently, businesses in the WTC deal with a multiple of government departments each with different approvals, monitoring and reporting regimes. Ideally there should be only one body responsible for the Government interface, especially when an SIP is established with a focus on New Energy Industries. This would speed up approvals while also reducing costs and at the same time it would also be expected to improve compliance with regulations. It is recommended and considered critical that a statutory authority or similar be established for the development, management and marketing of new industries in the Western Trade Coast / Specialised Industrial

Park. It could set the future management of other significant industrial areas such as Oakajee but should begin with a sole focus on the WTC. This would require either:

- A statutory authority be established for the whole of the Western Trade Coast, inclusive of management of the SIP; or
- The Industrial Lands Authority mandate a special purpose vehicle under their restructuring specifically to manage the WTC.

This authority would be responsible for activating, managing and promoting facilitated industrial parks within the WTC such as a Lithium Valley Park inclusive of a plug and play approach covering specifics such as utilities, visas, industrial relation services, and other opportunities to facilitate ease of entry for set up of new companies in both the New Energy metals and ship sustainment space. Professional management with a proactive commercial Business Development focus is critical for a successful industrial park. Activities to be carried out are further described in this document.

3.3.9. Regional Lithium Valley: E-cycling facilities in Geraldton and Minerals processing in Kemerton, the Pilbara, Kimberley and Goldfields

Develop energy metal recycling facilities at Geraldton as part of Oakajee as well as mineral processing in Kemerton, the Pilbara, Kimberley and Goldfields.

E-recycling is a critical new industry required in WA. This will involve significant investment and co-ordination between industry and government, however there are competitive advantages that can be captured if a suitable location can be found. As an international point of differentiation the development should be sustainable and use the maximum amount of renewable energy possible (wind and solar) as can be found in the Geraldton region at Oakajee. Developing the technologies and skill bases to encourage recycling should be prioritised. The facility is linked by rail to the Perth region. This development should be part of Oakajee. Importing e-waste through Geraldton Port is feasible as it is easily accessible to Oakajee.

Currently more than 95% of lithium ion batteries are deposited in landfill. This has a direct impact on the exploitation of scarce resources and unsustainable extraction practices of components such as cobalt, and raises the significant incidence of fires, uncontrolled toxic waste and toxic gas release.

International sanctions on the dumping of e-waste are increasing in response to environmental and social impacts from poorly managed operations combined with under-resourced governance and protection frameworks. In comparison, Western Australia can effectively avoid social or environmental risks.

According to industry participants the demand growth for recycling of energy materials will follow the growth of their virgin components by some 5-10 years. Accordingly, there is a window of opportunity for Geraldton to combine the extractive technology capability of WA's mining industry with its recycling commitments to develop next-generation recycling excellence. The following opportunities could be considered as part of developing the NIE recycling capability:

- Waste stream across the supply chain - both mine site waste dumps, capturing waste stream from domestic and commercial outputs prior to disposal, and recovery from landfill sites.
- Encourage the discovery and commercialisation of comprehensive energy material recycling.
- Material safety standards be reviewed, enhanced as required and enforced for the handling and transport of all e-waste.
- Attract to NIE downstream industries that will reuse recycled materials, combined with virgin materials to produce additional high value-added products.
- Mandating the recycling of all e-waste.
- Phasing out of e-waste exports.

There are new mines for lithium and other New Energy metals in the Pilbara and the Goldfields and the Kimberley. Processing of these minerals to meet the different stages of quality standards may mean it is easier to do such work near to the mines. Being able to participate in all aspects of the Lithium Valley initiative will be an advantage to these industries.

3.3.10. Build the infrastructure needed for the SIP and New Energy initiative

Ensure a timely framework for the transitional development of the new port in Kwinana

The development of the new port at Kwinana is crucial to the long term strategic success of the State of Western Australia. There are four pillars of future economic opportunity that will struggle to meet demand without a port that can accommodate the volumes required for the strategic development of the state above and beyond the existing containerised shipping. These four pillars include:

- Energy Metals and Battery Manufacturing;
- Ship Sustainment both for Defence and Commerce;
- Establishing Western Australia as Asia's Main Source of Proteins; and
- World Class Tourism Development at Fremantle

The new port in Kwinana or Westport as it is now known requires the road and rail links to be upgraded as well as related supporting infrastructure. This should be a priority but would be best done as a PPP project as outlined below.

3.3.11. Western Power access

Renewable power with battery support should be a high priority for the Kwinana region and other parts of the South West Integrated System (SWIS) associated with this New Energy initiative.

With such an obvious recognition of the global transition to using renewables and batteries, the New Energy initiative should also be promoting renewables and batteries as part of any access to the SWIS grid managed by Western Power. The prioritisation of renewable energy access and the uptake of new technologies assists in establishing the system as a dynamic network model that can in itself be part of the New Energy initiative. This means that Western Power should prioritise the access to the grid of renewable projects preferably within a six-month time limit from application to connection, especially anything associated with the major sites in Kwinana and Geraldton.

New technologies such as blockchain systems enabling microgrids and smart grid support through batteries allow greater and more accurate measurement of network usage. These new technologies have the ability to improve financing, network effectiveness, asset utilisation, planning and delivery.

Developing a robust local market for the New Energy metals and batteries can provide a cornerstone for the industry especially when it builds on innovations already underway in WA. The prioritisation of renewable energies fits within this strategy and therefore should be encouraged by fast-tracking access associated with Kwinana and Geraldton. If the Government is committed to attracting secondary processing and electrochemical companies for battery production then a robust local market provides a strong commercial incentive.

3.3.12. Public-private partnerships

Lithium Valley partnerships need to invite private investment

It is recommended that the State Government embraces Public-Private Partnership (PPP) projects to better manage risk, reduce costs and maximise economic benefits in establishing the Western Trade Coast with the New Energy initiative.

In order to assist Lithium Valley the Government needs to develop a framework for the use of PPPs to develop vital WA infrastructure and create the necessary investment opportunities. It is also recommended that the Government implement the unsolicited proposal framework completed by the Department of Premier and Cabinet.

PPPs are an important channel for attracting private investment into a wide range of projects initiated by government in areas like infrastructure and public services and there is much private investment that is needed in the New Energy era. There have only been a few PPPs in WA in recent years though the Perth Stadium project shows they can be very successful. Due to the very limited utilisation of PPPs in WA, private industry will necessarily retain doubts over funding, legal, regulatory and the political environment as long as the possibility remains that arbitrary government intervention might affect the contractual agreement entered into between public and private entities. Hence, development of a PPP framework would benefit industry by providing greater clarity and increased transparency for all parties. The use of such a framework could be trialled on the Kwinana SIP and associated industries as part of the Lithium Valley initiative.

3.3.13. Direct mining investment

Review the involvement of the State Government in New Energy minerals and industries.

The Government should review whether it is in the State's interest to again become directly involved with mining operations either as a majority or minority shareholder in companies that are prepared to enter into local value-added activity in the New Energy arena.

As outlined above the WA Government has a history of direct involvement in mining and resource development. The state should consider partnering in developing resource deposits if the partner companies are committed to developing quality products that would then be processed into Lithium Valley industries and associated value adding activity. The state government could be involved on a short term basis to help capture more of the benefits of these finite resources. This would particularly be to catalyse industrial activity in the SIP. Although this would be a major change from recent government policy, the current budget deficit and the dramatic changes in industry and society resulting from technological advances would justify at a minimum reviewing the risks and rewards to the state. As in the past this involvement would only need to be in the early stages of the transition to a New Energy economy.

3.3.14. Become a model for the circular economy

Develop a program to capture and recycle 100% treated wastewater to the southern groundwater aquifers.

The New Energy economy is also associated with what is known as the Circular Economy where wastes are minimised. Kwinana is globally known for its industrial ecology and waste exchanges that dramatically reduced wastes going into the air and water in the region. The next stage of industrial development in the region needs to take this further and use global best practice waste treatment, especially on wastewater.

It is recommended that discharges of wastewater into the sea be scaled down and eventually prohibited as soon as practically possible to enable the local development of alternative wastewater uses for agriculture and industry and maximise the economic and social benefits for the region, especially the value of Cockburn Sound. Treated wastewater with reduced dissolved

salt content is a valuable but expensive commodity. The treated wastewater presently being recycled by industry from the sewage pipe passing through Kwinana is a good example of how the area can treat its waste. WaterCorp has its Managed Aquifer Recharge project that is now taking 100% treated sewage and recycling it back to the northern groundwater aquifers. The New Energy initiative in Kwinana can be used to ensure any water needed for the site is treated wastewater and any wastewater created is returned to the system as 100% treated groundwater recharge for the southern aquifers or used by agriculture or industry as part of a Circular Economy program with considerable value to the state.

3.3.15. State strategic plan and objectives

Provide industry with a clearer view of how Lithium Valley industries fit into its strategic objectives.

There are many reasons why the State Government needs to clarify the WA Vision of industry, employment, the environment and the economy over a 5 and 10-year period. The Lithium Valley initiative is a very good example of how a clear and committed strategy and vision of industry, employment, the environment and the economy for at least the next five to ten years, can help provide the certainty industries need for investment and the community needs to provide the political capital for government programs. Such a Strategy would then help bring all agencies and government bodies to assist with the Lithium Valley agenda.

It is considered essential that the State has a clear and committed strategy and vision of industry, employment, the environment and the economy for at least the next five to ten years. This is to provide guidance to society and industry about the desired direction for the State. For instance, the Government should:

- Clarify the short, medium and long-term strategy for energy. For instance, the EU's strategy is structured around five closely interrelated and mutually reinforcing dimensions addressing (i) energy supply security, (ii) a fully-integrated energy market, (iii) energy efficiency, (iv) decarbonising the economy and (v) research, innovation and competitiveness. Perhaps WA could have a similar strategy and execution plan.
- Create a term-limited project directorate with the authority and support to drive cooperation, collaboration and completion of the roadmap towards the WA Vision.
- Prioritise and enhance overseas efforts by WA Government resources such as WA's Agent General to the UK, and where possible orient all diplomatic missions by Western Australian Ministers in 2019 to ensure these are well informed, well integrated, well resourced, and well managed to provide the highest level of Export policy framework

The lithium sector is critical for the new energy economy. Other jurisdictions, such as Chile, around the world have imposed significant conditions on lithium extractors including term licenses, downstream investment demands, export limits and commitments to in-country value add. Australia has a significant amount of new energy resources, although it has a restricted range of customers for value added industries, yet. These can be opened up by a concerted State Government plan starting with a Strategic State Plan.

It is recommended that for all "new energy" materials, an export policy framework should be established that:

- Supports reservation of materials for local value-add;
- Supports commitments for local investment in local value industries; and
- Supports global diversification of customers.

3.3.16. Finite resources and intergenerational allocation

Review intergenerational revenue allocations.

It is recommended that the Government reviews the process of the intergenerational allocation of the benefits from finite royalty revenues, with a particular focus on implementing a scheme that is modelled on the Norwegian sovereign wealth fund approach. Although Western Australia is currently blessed with abundant natural resources, there is a debt owed to previous generations who were custodians of the land and also to future generations who inherit the land. At the time of writing, all royalties are included in current yearly revenue totals and it could be argued that little is saved or invested. In addition, there has been an increase in unsustainable debt, an increase in government deficits and a growing government reliance on royalties from unsustainable finite resources (18% in 2017; 15% in 2016). The Norwegian Government's approach to the equitable allocation of finite resource royalties across the generations is widely seen as world's best practice.

The aim is to incentivise secondary processing and therefore royalty holidays or royalty reductions for mining companies are unlikely to achieve this goal. The focus needs to be on incentivising high technology processing companies to locate processing facilities in WA. Based on interviews these companies are sensitive to operating costs like energy, logistics, chemicals, water, staff costs as well as supply security, not royalties.

3.3.17. State Government policy on electric vehicles

State Government review phasing out petrol and diesel vehicles by 2030, especially in metro areas.

Global Governments in nations and cities are regulating and incentivising to phase out petrol and especially diesel in favour of electric vehicles. This can be seen as a help to the environment but it also helps facilitate the New Energy transition.

The WA power network is preparing for a significant increase in electric vehicle (EV) usage. The Government of Norway has incentivized EVs and seen 40% of new cars sold in Norway being EVs. Several European Governments are discussing banning petrol and diesel engines over the next fifteen years: The Netherlands by 2025, Paris by 2030 and even Germany is investigating phasing out petrol and diesel engines in favour of EV and gas around 2030. Eighty per cent of WA's light vehicles could be accommodated on the network without significant investment and this would increase electricity usage (approximately 8-11%) and increase revenues to the State Government. Greater numbers of EVs for the local market would increase the demand for batteries and assist to underpin local battery production. Other benefits would be reduced pollution, improved fuel security, new industries and jobs, cheaper vehicle purchase and maintenance costs, health and safety benefits and reduced imports of foreign petroleum products.

Most importantly the policy would provide a strong signal to the world that WA is taking seriously the New Energy economy and wants to play a big part in its development locally.

3.3.18. European Union Critical Raw Materials (CRM)

WA initiate EU support over Lithium Valley through CRM status.

As outlined above the EU Commission publishes a list of CRM that are important for the EU economy and may have supply risk concerns. In order to assist WA's minerals being placed on this list it is recommended that the State Government assist in facilitating diversified supply of these critical materials with WA companies in return for investment, technology and secondary processing facilities. As part of a geostrategic agreement with the EU, e-waste from the EU could be reprocessed in WA as part of a long-term concession to justify WA investment. Thus this approach can be part of the branding and promotion of Lithium Valley to the EU and its companies that may be interested in investing here. Due to the emphasis on quality that is expressed through standards, environmental regulations and strong technical and transparent monitoring of products, the Lithium Valley brand can be something for WA to use as a major means of creating our future.

4

MAIN REPORT

4 Energy Metals and Power Storage: A Global Perspective

4.1 Why Are Energy Metals So Important?

Globally, the energy sector is undergoing major transformation driven by a range of push and pull factors including:

- **Global climate agreements**
- **Urbanisation**
- **City air pollution**
- **Functionality**
- **Costs**
- **Technology developments**
- **Resource scarcity**
- **Energy portability**

As populations grow, there is increasing energy demand for electronic devices including phones and mobile devices, computers, power tools, air-conditioning, water pumping, electric vehicles and other industrial applications. Technological advances in renewable energy generation combined with the dramatic increase in the number of portable devices has increased the demand for batteries while also improving distributed generation, usage and network synchronisation of electricity. Battery technology innovation and improvements in economies of scale promise to deliver cost-competitive stationary storage. A virtuous technology and market development spiral has taken hold, which is rapidly transforming how we generate, use and manage energy.

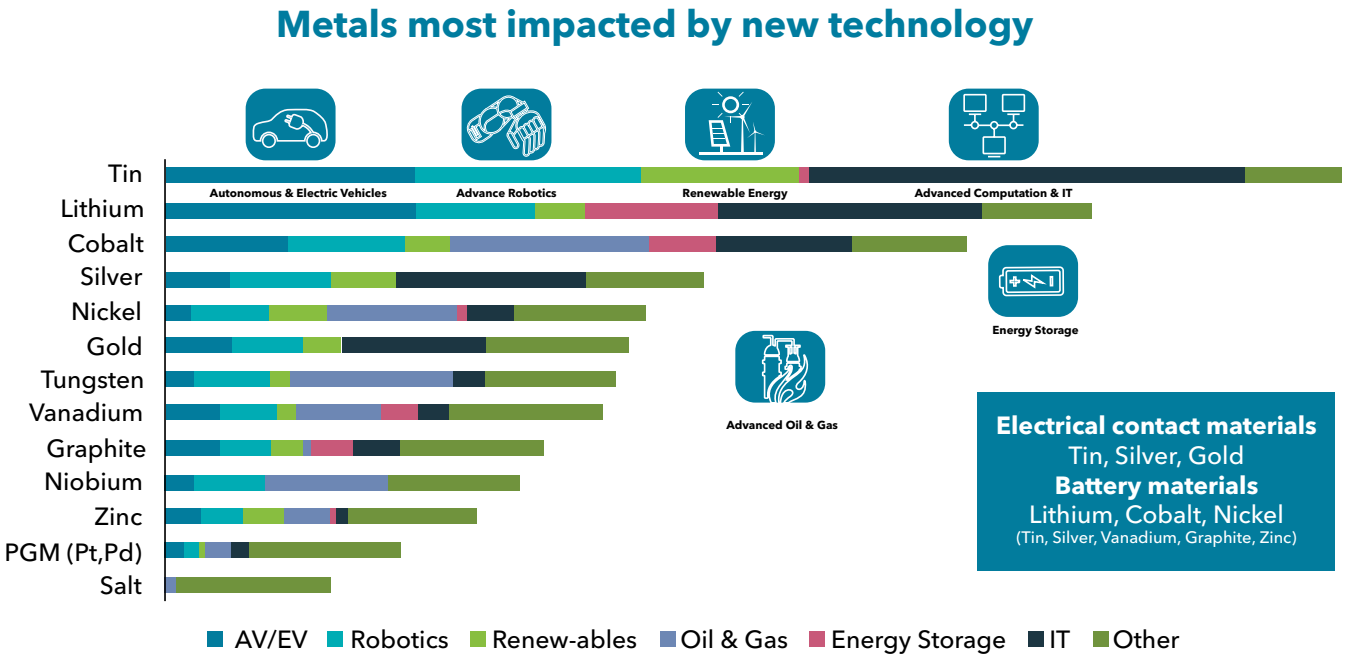
Key pillars of this transformation include:

Power generation	Energy storage and consumption	Power consumption for transport, industry and trading
Rare earth elements (in combination with iron and boron) become the permanent magnets that convert kinetic energy from turbines (driven by wind, gas combustion, water flows, steam, etc) into electrical energy.	"On demand" – energy materials, primarily lithium, that are chemically and physically assembled into battery cells for recharge and discharge on demand.	Converting electrical energy into kinetic energy is the reverse of generation and uses the same principals – using more rare earth based permanent magnets.

Research undertaken by MIT show the metals most impacted by new technology (Figure 6). As can be seen, tin, lithium and cobalt are the main metals affected across all new technologies while current battery storage technologies most impact lithium, cobalt, vanadium and graphite. As will be shown later, the most significant growth is seen to be associated with lithium-ion batteries due to electric vehicles and power storage.

Lithium hydroxide currently commands a premium to lithium carbonate primarily due to its importance for high-grade battery storage. In batteries, lithium hydroxide has a large storage capacity and a long life between charges. Lithium hydroxide also provides the first solid state battery that improves efficiency and safety as well as being relatively cheap and light.

6 ***Figure 6:*** *Energy metals most impacted by new technology*

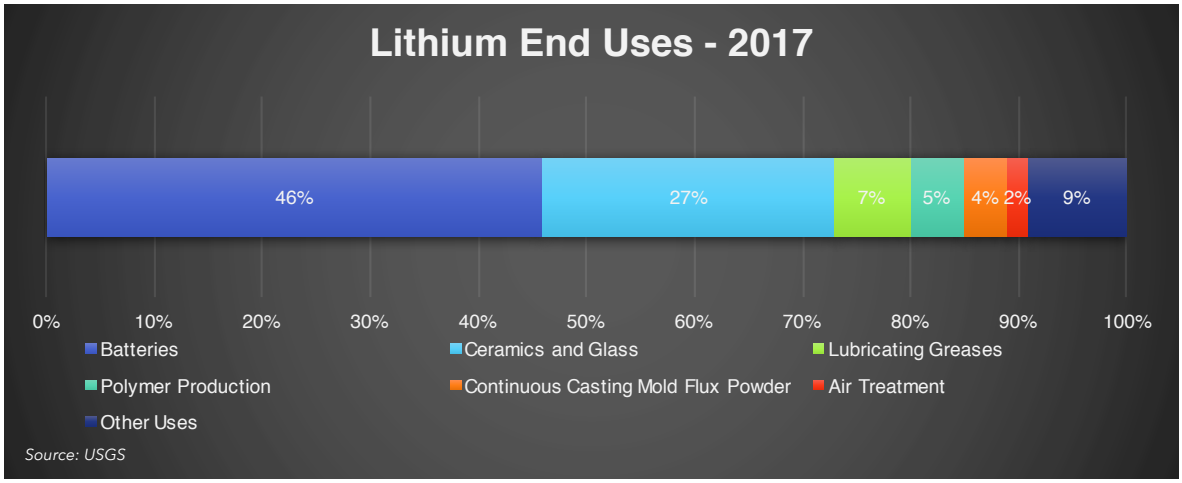


Source: MIT

Lithium hydroxide currently commands a premium to lithium carbonate primarily due to its importance for high grade battery storage. In batteries, lithium hydroxide has a larger storage capacity and a longer life between charges. Lithium hydroxide also provides the first solid-state battery that improves efficiency and safety as well as being relatively cheap and light.

4.2 Batteries, Storage and Lithium: Understanding the Value Chain

Lithium has several uses, including glass and ceramics, lubricants, flux additives for metal alloys, lithium batteries, and lithium-ion batteries (Figure 7). These uses currently consume more than three quarters of lithium production.

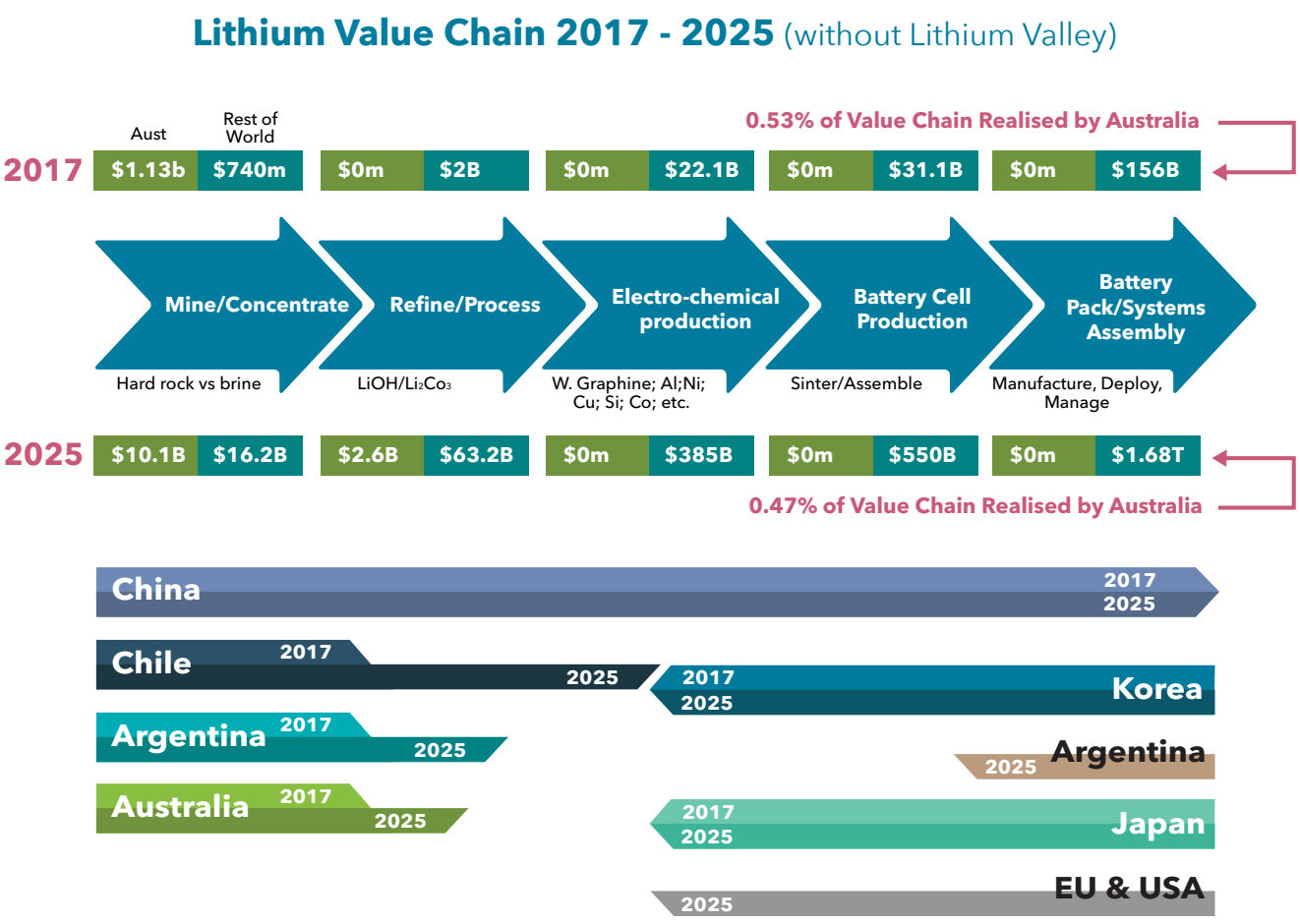


7 ***Figure 7:*** *Lithium 2017 consumption by end use*

Nickel has been the primary base element in rechargeable batteries for decades and most people have heard of nickel cadmium (NiCd) or nickel metal hydride (NiOH) batteries. As battery technology advances the composition of rechargeable batteries is changing and the proportion of New Energy metals in batteries is increasing. As nickel is ubiquitous as the primary metal in rechargeable batteries, it is these New Energy metals that tend to take naming rights.

Figure 8 shows the actual lithium value chain in 2017 and the estimated value chain in 2025. There are significant value capture opportunities across the entire New Energy metals processing spectrum. The important questions are 'where?' and 'by whom?' will this value will be created and captured. While Figure 8 only refers to lithium, it is illustrative of other New Energy metals such as cobalt, vanadium, nickel, etc, which also have similar value chain profiles.

8 ***Figure 8:*** *Lithium value chain in 2017 – 2025 Without Lithium Valley (AUD)* [7]



Source: Association of Mining and Exploration Companies (AMEC); Future Smart Strategies (FSS)

The annual consumption of lithium for batteries is already significant (Figure 9) and demand is accelerating. Similarly, the rise in the demand for rare earth elements has been driven by the high technology sectors such as smartphones, televisions, decentralised energy generation, renewable energy and the growth in electric transport. It is expected that the demand increase for rare earths will follow a similar trajectory as lithium.

7 Association of Mining and Exploration Companies (2018), A Lithium Industry in Australia: A value chain analysis for downstreaming Australia's lithium resources, *https://amec.org.au/Public/Media/AMEC_Publications/A_lithium_Industry_in_Australia.aspx*. (Accessed: 01 May 2018)

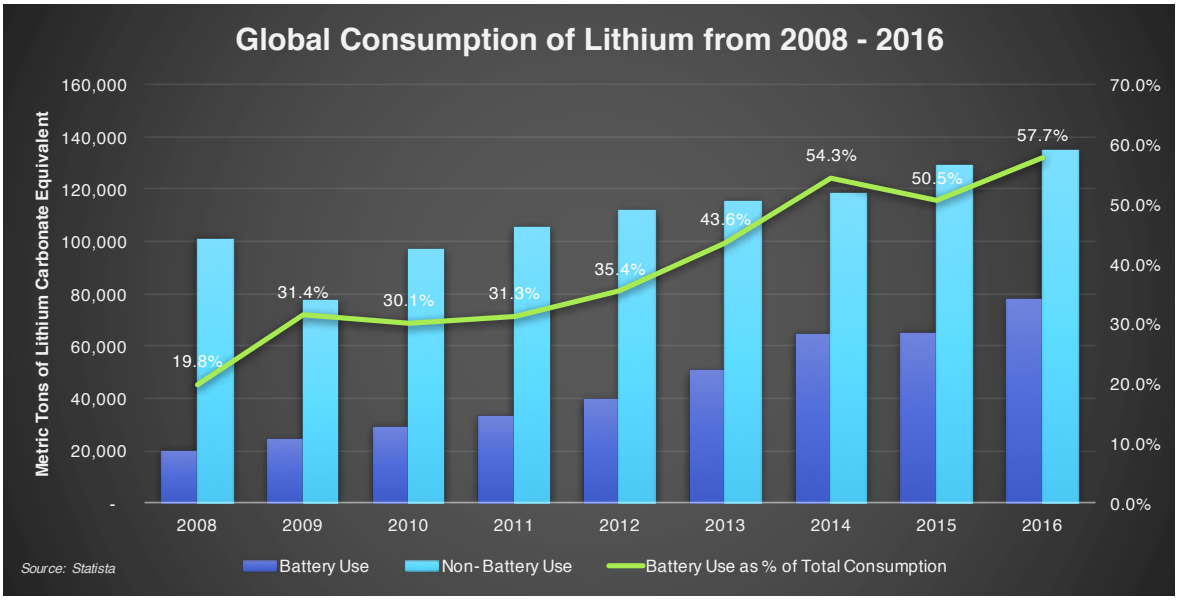


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Figure 9: *Global Consumption of Lithium from 2008 - 2016*

Global battery production has reached the tipping point where further exponential growth is forecast for lithium and other energy storage related materials. The industry is now benefiting from the economies of scale, the learning curve effect (the more of a product that is manufactured, the cheaper the product becomes), greater resource access and increasing applications of the products (Figure 10). These New Energy industries, as they are collectively referred to in this report, are all growing rapidly.

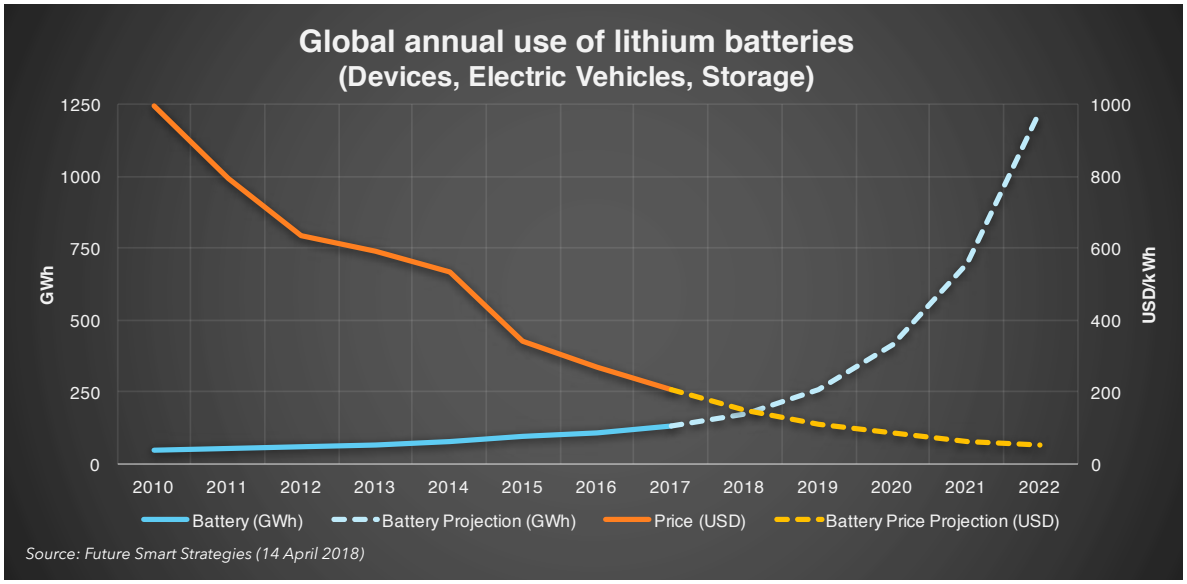

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Figure 10: *Falling price and increasing cumulative volume of batteries*

An indicator of these demand drivers is that in 2014 global production of lithium batteries totalled approximately 30GWh. In 2018, there is approximately 350GWh of new lithium battery manufacturing capacity being planned and demand estimates by some industry analysts suggests that this needs to be closer to 500GWh by 2025.[8]

8 Ferris, R. (2017), "Electric vehicle demand leads to skyrocketing number of lithium-ion battery factories around the world", 11 December 2017, CNBC, *https://www.cnbc.com/2017/12/11/electric-vehicle-demand-leads-to-jump-in-number-of-lithium-ion-battery-factories.html*. (Accessed: 01 May 2018)

Based on Benchmark Minerals estimates, 600GWh would require approximately 300kt of lithium hydroxide, 84kt of cobalt and 400kt of spherical graphite.[9] At a briefing to the Association of Mining and Exploration Companies (AMEC) members on 6th March 2018, McKinsey and Co forecast that lithium hydroxide requirements for 2025 could be over 550kt.

A 2017 meta-analysis of global lithium forecasts determined low- and high-range forecasts for lithium hydroxide requirements in 2025 to be 553kt and 2,076kt respectively. A consumer demand analysis conducted at the same time indicated that the 2025 demand for lithium may even be as high as 3,570kt, including power tools (161ktpa), electronics (68ktpa), distributed energy storage (DER) (1.1Mtpa) and electric vehicles (EV) (1.7Mtpa).[10] In 2018 the world produced around 250ktpa of lithium so there is little doubt that the world is entering a new economic transformation. This growth will also impact the other battery metals.

There is a growing trend towards centralisation of material processing and materials that has led to a number of responses internationally. Unlike Australia, Chile is the world's second largest supplier of lithium and has been conscious to avoid the total export of potential downstream value-adding of its lithium resources. Chile has created a series of integrated policies specifically to encourage the creation of domestic value-adding industries (Figure 8). To this end, Chile has been focusing on a domestic lithium reserve, similar to WA's gas reserve, that will only be made available to domestic value adding industries. This domestically reserved lithium is also discounted to export prices as a further incentive for local production.

9 Benchmark Mineral Intelligence (2016), "Tesla faces raw material reality with expanded gigafactory", http://benchmarkminerals.com/tesla-faces-raw-material-reality-with-expanded-gigafactory/. (Accessed: 01 May 2018)
10 Future Smart Strategies internal analysis (2018).

"Batteries are at the heart of the ongoing industrial revolution. They represent a key enabling technology in the context of the Energy Union. Their development and production play a strategic role in the ongoing transition to clean mobility and clean energy systems. Batteries embody our ambition, as set out in President Junker's State of the Union, to help our industries remain or become world leaders in innovation, digitisation and decarbonisation.

"As was recalled by the actors in our meeting, we are at a critical juncture. The lack of a domestic, European cell manufacturing base jeopardises the position of EU industrial customers because of the security of the supply chain, increased costs due to transportation, time delays, weaker quality control or limitations on the design."

Vice-President or Energy Union, Maros Sefcovic, October 11, 2017

To reinforce their lithium manufacturing credentials, Chile undertook a global roadshow targeting major battery component manufacturers, essentially offering security of supply, favourable production environment and discounted lithium chemical prices. The effect of this policy so far has resulted in commitments that should see the commencement of production in Chile of about 58ktpa of battery cathode material within two years by two South Korean and two Chinese companies with an investment cost of approximately US$758 million (A$985 million).[11]

Currently, the key players that dominate supply of lithium carbonate equivalent (LCE) are: North Carolina-based Albemarle Corp. as the market leader, with an 18% share of the total market, followed by Jiangxi Ganfeng Lithium Co 17%; Soc. Quimica & Minera de Chile SA (SQM) 14%; and Tianqi 12%. Other minor players produce the residual volume, the largest among them being FMC Corp. (5%), which is soon to offer its shares in a planned initial public offering.[12]
Several of these companies have substantial off-take agreements with China.

The EU Commission has established an EU Battery Alliance with the intended purpose of avoiding reliance on Asia for supply of batteries. The working group has set out to identify existing European expertise in all segments of the battery supply chain. Australia has an opportunity to develop its own policy approaches to deliver similar outcomes as well as being a reliable, diversified and responsive source of supply to the global customers such as the EU.

In the past three years China has been leading the way in investment for battery megafactories with 49% of production capacity, followed by the EU with 23% of planned capacity and 15% in the USA. It is worth noting that both Europe and the USA are dependent on securing resource supplies in order to support their own value-add industries.

China controls 89% of the lithium refining and processing market, 75% of the electrochemical market and 50% of the cell production market by value. This is a significant concentration of critical processes in one country for this strategic material especially when Chinese companies also are vertically integrated with miners, battery producers, assembling and distributing.[13]

As this industry progresses, there is a growing trend for companies to develop and implement 'responsible sourcing' policies in line with the Organization for Economic Co-operation and Development (OECD) Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. As an example, Tesla reports to the US Securities and Exchange Commission on their sourcing of 'conflict materials' for products used in their vehicles.[14]

Australia can benefit from resolving these challenges through rebalancing the current concentration of control over traceable supply chains in this sector, without compromising the economic development of its trading partners.

11 Reuters (2018), "Chile says companies to invest $754 million in lithium industry", Reuters, *https://www.reuters.com/article/us-chile-lithium/chile-says-companies-to-invest-754-million-in-lithium-industry-idUSKCN1GL2UA*. (Accessed: 01 May 2018)
12 Fickling, David (2018), "The Lithium Cartel Should Be Stopped", Bloomberg, 18 May 2018, *https://www-bloomberg-com.cdn.ampproject.org/c/s/www.bloomberg.com/amp/view/articles/2018-05-18/time-to-block-the-lithium-cartel*. (Accessed: 01 May 2018)
13 Association of Mining and Exploration Companies (2018), A Lithium Industry in Australia: A value chain analysis for downstreaming Australia's lithium resources. *https://amec.org.au/Public/Media/AMEC_Publications/A_lithium_Industry_in_Australia.aspx*. (Accessed: 01 May 2018)
14 Lambert, Fred (2018), "Tesla releases 'Conflict Minerals Report', increases minerals tracking and reduces cobalt use", Electrek, 30 May 2018, *https://electrek.co/2018/05/30/tesla-conflict-minerals-report-battery-cobalt/*. (Accessed: 30 May 2018)

4.3 Types of lithium ion batteries

The battery test centre in Canberra has been testing a variety of lithium-ion batteries to simulate 'normal' daily cycling of the batteries and mimicking 'real world' conditions. The batteries being tested are:

Table 2: ***Battery Chemistries by Company***

Product	Country of Origin	Chemistry	Total Installed Capacity (kWh)
Alpha ESS	China	Lithium Iron Phosphate (LFP)	9.6
Ampetus Super Lithium	China	Lithium Iron Phosphate (LFP)	9
Aquion Aspen	USA	Aqueous Hybrid Ion (AHI)	17.6
BYD B-Box	China	Lithium Iron Phosphate (LFP)	10.24
GNB Lithium	Germany	Lithium Iron Phosphate (LFP)	13.6
LG Chem RESU HV	Korea	Nickel Manganese Cobalt (NMC)	9.8
Pylontech	China	Lithium Iron Phosphate (LFP)	9.6
Redflow Zcell	USA	Zinc-Bromide Flow (ZNBR)	10
SimpliPhi	USA	Lithium Iron Phosphate (LFP)	10.2
Tesla Powerwall 2	USA	Nickel Manganese Cobalt (NMC)	13.2

Source: ITP – Battery test centre report 3 – November 2017 (http://batterytestcentre.com.au/wp-content/uploads/2017/07/Battery-Testing-Public-Report-3-November-2017.pdf)

The point is that there is no single standardised lithium ion battery and the chemical composition and physical characteristics are regularly changing. The reason for these different combination of battery elements is to find the most economical composition of materials, lighter and more efficient power, reduce the usage of rarer elements and improve safety issues.

Figure 11 shows the energy metal composition of a 18-650 lithium ion battery cell as used in a Tesla vehicle. The Tesla Model S runs on 16 battery packs with each pack made up of 444 18-650 battery cells, for a total of 7,104 battery cells per vehicle. The key New Energy metals in this battery cell are lithium and cobalt, yet there are a wide variety of different battery chemistries that all require different New Energy metals in differing proportions.[15] A 70kWh Tesla Model S battery contains an estimated 63kg of lithium. [16] The new Tesla 3 series uses a new battery design called the 21-70 that has less weight and greater energy. This is an example of the ongoing evolving battery chemical and design market.

15 Alvarez, Simon (2018), "Dissecting Tesla Model 3's 2170 lithium ion battery cell, what's inside?", Teslarati, 12 February 2018. https://www.teslarati.com/inside-tesla-model-3-2170-lithium-ion-battery/. (Accessed: 01 May 2018)
16 Lambert, Fred (2016), "Breakdown of raw materials in Tesla's batteries and possible bottlenecks", Electrek, 10 November 2016. https://electrek.co/2016/11/01/breakdown-raw-materials-tesla-batteries-possible-bottleneck/. (Accessed: 01 May 2018)

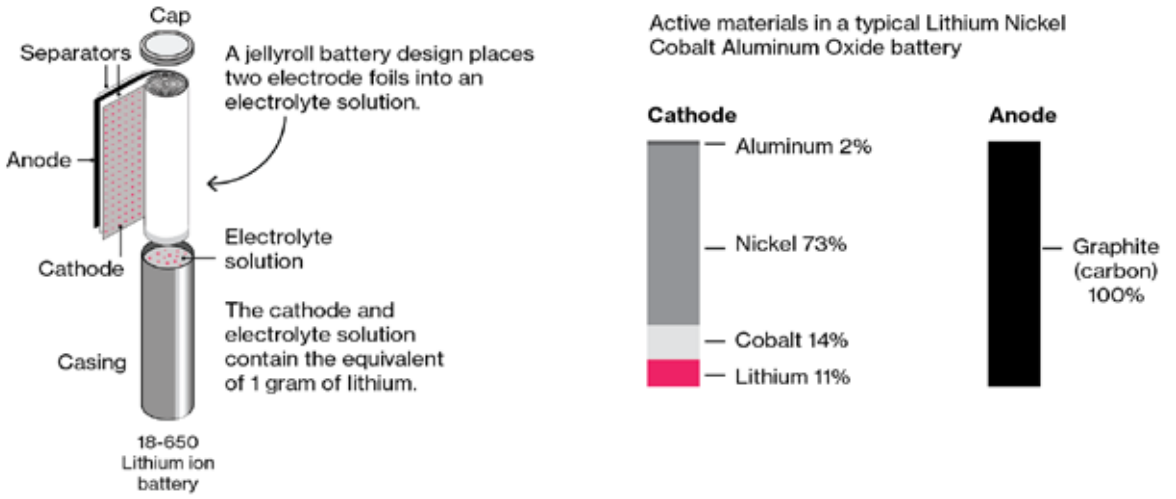

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Figure 11: *Materials and Components for a Tesla 18-650 Lithium Ion Battery Cell*

Source: Bloomberg New Energy Finance [17]

4.4 The Importance of Rare Earth Elements to the Future of Power Storage

Geoscience Australia suggests rare earth elements (REE) to consist of 17 elements.[18] REEs commonly occur together in differing proportions in ore bodies. When purified, these elements have a range of uses including lighting, TV screens, steel production, catalytic convertors, magnets, lasers, smartphones and nuclear reactors. Growing demand from high technologies has fuelled the growth over the last two decades. However, two recent dynamic factors are currently driving a major growth in demand for the particular rare earth elements dysprosium, neodymium and terbium:

- The global growth and efficiency improvement of wind turbines (Figure 12)
- The global growth of electric vehicles (of all types) (Figure 13)

These rare earths are critical components of the specialised magnets that enable these new turbine and motor systems to work more efficiently, more economically and for longer than any existing alternatives. According to some sources, it is unlikely that there will be effective substitutes for these rare earth materials due to their unique properties.[19]

Based upon forecasts for electric vehicles sales and wind turbine generation installations, the 2025 global demand for these key rare earths is expected to be approximately 150,000 tonnes.[20]

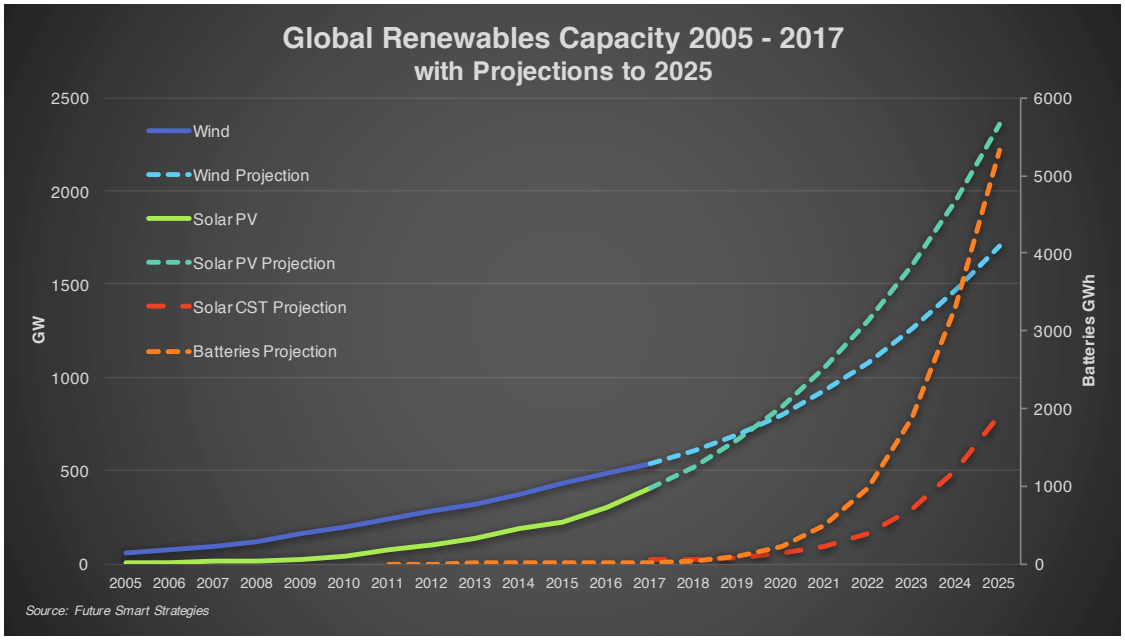
This represents more than 20 years' worth of production from a current single, efficient processing facility.

17 Shankleman, Jessica, Biesheuvel, Tom, Ryan, Joe, Merrill, Dave (2017), We're Going To Need More Lithium, Bloomberg, 07 September 2017. https://www.bloomberg.com/graphics/2017-lithium-battery-future/. (Accessed: 01 May 2018)

18 Geoscience Australia (2016), Australia's Identified Mineral Resources 2016, 20 December 2016. https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search?node=srv#/metadata/e893e4ff-e366-4132-867e-e041044a9041. (Accessed: 01 May 2018)

19 Graedel T. et al. (2015), "On the materials basis of modern society", Proceedings of the National Academy of Sciences of the United States of America (PNAS), May 19, 2015. 112 (20) 6295-6300. http://www.pnas.org/content/pnas/112/20/6295.full.pdf (Accessed: 01 May 2018)

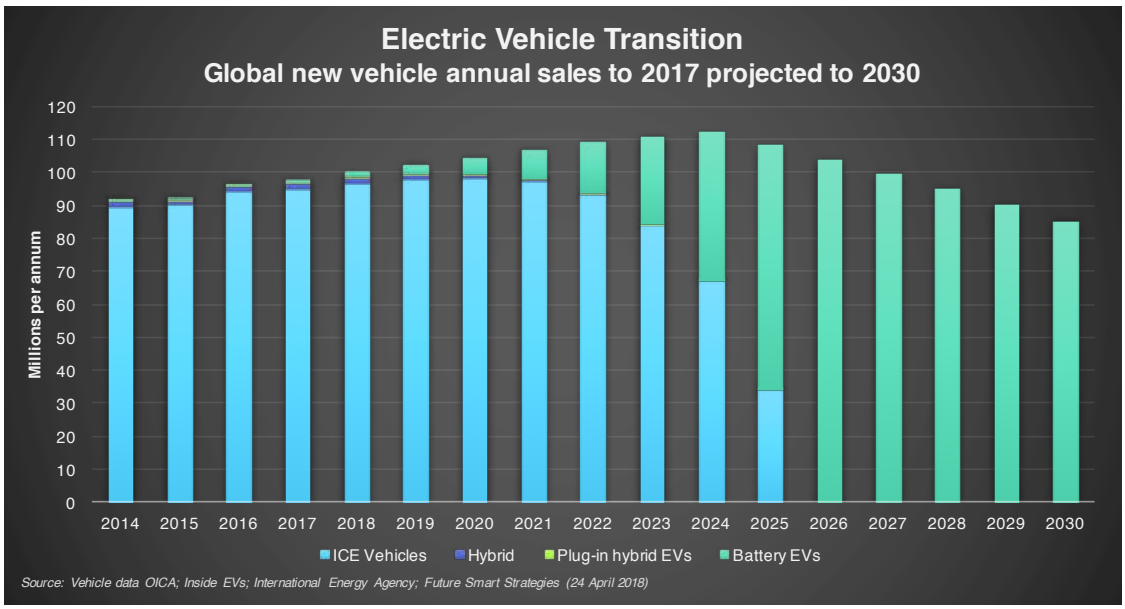
20 Future Smart Strategies internal analysis (2018)



12

Figure 12: *Growth of wind and solar capacity, and projected growth including storage to 2025*

Rare earths account for approximately 30% of the materials (by weight) in a permanent magnet. A modern, high-powered turbine uses approximately 650kg/MW of permanent magnets.[21] This means that the permanent magnet for a 5MW high-powered turbine will include approximately 975kg of rare earth material. This is almost ten times the mass of rare earths used in older turbines, due to a redesign that dramatically simplifies the turbine manufacture, reduces the number of components, overall weight and significantly improves wind turbine reliability.[22]



13

Figure 13: *Global projection annual car sales and transition to electric vehicles including Hybrids, PHEVs and BEVs to 2030*

Similarly, the rapid growth in electrically powered transportation vehicles (e.g. scooters to ferries,

21 Pavel C., Lacal-Arantegui R., Marmier A., Schuler D., Tzimas E., Buchert M., Jensiet W., Blagoeva D., "Substitution strategies for reducing the use of rare earths in wind turbines", Resources Policy, Vol 52, p349-357, https://reader.elsevier.com/reader/sd/408E915E7B100F83057CB4E05E82E172424426566191347390 5CF84F9E6C36D01CCC24B8EEA13A35FE0F7BB5F7AFA4E8. (Accessed: 01 May 2018)

22 Hart K, McDonald A, Polinder H, Corr E, Carroll J, IMPROVED COST OF ENERGY COMPARISON OF PERMANENT MAGNET GENERATORS FOR LARGE OFFSHORE WIND TURBINES, https://repository.tudelft.nl/islandora/object/uuid:10d2436b-f0f0-436c-999f-9bdff4600182/datastream/OBJ. Accessed: 01 May 2018)

> **"In 2010 the Chinese government blocked exports of rare earths to Japan over a dispute when Japan detained a Chinese fishing trawler. This immediately impacted critical industries in Japan including hybrid cars, wind turbines and guided missiles as there was no alternative supply."**

cars to airplanes) has led to a similar demand growth for high performance electric motors, all using large amounts of rare earth materials.

Currently standard vehicles have more than 40 magnets and 20 sensors that use REE and hybrid vehicles use about 1.25 kilos of REE magnetic material. It is expected that EV's will use around three times more.[23]

China is currently the world's largest rare earth mining nation with estimates of China's accounting for 79% of annual global extraction in 2017. Facing diminishing domestic reserves, China also imports rare earths for refining and reselling domestically and internationally. In 2017, 78% of US rare earth imports were sourced from China.[24]

This lack of supply diversity presents a global commercial risk to companies and countries. It is China's dominance that helps keep rare earths at the top of the 'risk list' compiled by the British Geological Survey that assesses the importance of minerals needed "to maintain our economy and lifestyle".[25] China has methodically implemented a holistic policy strategy approach that has inhibited the entry of rival producers and the development of new technologies to process rare earths. China also acts to invest heavily in rare earth mines globally, maintaining continued fears of a Chinese monopoly of these strategic materials.

Through its "Made in China 2025" blueprint and integrated policy and investment framework, China's Government aims to move the country up the manufacturing value chain and dominate advanced technologies such as robotics, artificial intelligence, semiconductors and biomedicine.[26] This has been far sighted with a holistic approach that is also being applied to water and agriculture. China's enormous and relatively closed domestic

23 https://investorintel.com/sectors/technology-metals/technology-metals-intel/high-strength-permanent-magnets-an-untapped-source-of-critical-rare-earth-metals-but-can-the-metals-be-economically-recovered/ (Accessed 19 March 2018)
24 United States Geological Survey 2018, Mineral Commodities Summaries 2018, 31 January 2018, https://minerals.usgs.gov/minerals/pubs/mcs/2018/mcs2018.pdf. (Accessed: 01 May 2018)
25 Minerals UK (2015), Risk list 2015, British Geological Survey Centre For Sustainable Mineral Development, http://www.bgs.ac.uk/mineralsuk/statistics/risklist.html. (Accessed: 01 May 2018)
26 The State Council of the People's Republic of China, Made in China 2025, http://english.gov.cn/2016special/madeinchina2025/. (Accessed: 01 May 2018)

market, a capacious budget for supporting preferred industries, and a technocratic government facing no organized domestic opposition, means China's trading partners face a unique environment where the strategies and tactics of the past are no longer as relevant.

Australia, with considerable identified reserves, is a much smaller but politically important supplier of rare earth concentrate such as Hastings-WA and Arafura-NT (Lynas-NT is already 100% exported to Malaysia). Rare Earths have also been found in the Kimberley, see section 4.7. Australia's current advantage is due to its ability to rapidly and transparently bring resource extraction on stream. Europe is arguably the most vulnerable trading bloc so there is an opportunity for a substantial deal between WA and the EU to the mutual benefit of both.

Japan has been instrumental in developing WA over the last fifty years and is one of WA's closest and most important trading partners and investors. Japan is also highly vulnerable to strategic supply of resources incentivising Japanese companies to relocate production facilities to WA, building upon the long and mutually beneficial relationship.

Finally, it has recently been reported that the United States and Australia have agreed to work together on strategic minerals exploration, extraction, processing and research and development of rare earths and high-performance metals to sustain the jobs of today and develop the jobs of tomorrow. [27]

4.5 Rare Earth Permanent Magnets

Permanent magnets are the key technology in modern wind turbines as they eliminate the need for gearboxes and allow the turbine to produce electricity at lower rotational speeds. Also, permanent magnet wind turbines do not require an external electricity source to power the induction generator used by previous generations of wind turbine. In 2016, 61% of the global permanent magnet production by value was in "NdFeB" rare earth magnets.

Approximately 90,000 tonnes of NdFeB magnets were produced globally,[28] containing around 27,000 tonnes of REE. Driving investment in this industry is both the increased demand for magnets, as well as the value-add to be captured by producing magnets from source materials. Using recent prices, the per kilo cost of typical NdFeB magnet raw materials is around $22.50 (Table 3).

27 Gottliebsen, Robert (2018), "Trump seeks Australia help to loosen China's grip on rare earths", The Australian, 27 February 2018, https://www.theaustralian.com.au/business/opinion/robert-gottliebsen/trump-seeks-australian-help-to-loosen-chinas-grip-on-rare-earths/news-story/f459c0140aed356c806ece0f69b41c97 . (Accessed: 01 May 2018)

28 Benecki, Walter (2017), *More Than You Ever Wanted to Know About the Permanent Magnet Industry!*, January 2017, http://www.waltbenecki.com/uploads/more_than_you_ever_wanted_to_know.pdf. (Accessed: 01 May 2018)

Table 3: ***Input value of typical NdFeB magnet***

Element	% of magnet	Price $/kg	$ value/kg magnet
Neodymium (Nd)	29% - 32%	60.00	17.40 – 19.20
Iron (Fe)	64.2% – 68.5%	1.00	0.648 – 0.685
Boron (B)	1.0% - 1.2%	0.70	0.007 – 0.008
Aluminium (Al)	0.2% - 0.4%	2.00	0.004 – 0.008
Niobium (Nb)	0.5% -1%	41.00	0.205 – 0.410
Dysprosium (Dy)	0.8% -1.2%	350.00	2.800 - 4.200
Total			**21.064 – 24.511**

Source: Future Smart Strategies

The selling cost of the completed magnet is close to $100 per kilo, a more than four-fold value increase.

Considering the growing rate of global wind power and overall benefits of the permanent magnet synchronous generator (PMSG) wind turbines, the future demand for high-performing NdFeB magnet and its constituent elements is likely to rapidly increase. Any associated supply shortages or disruptions may have a dramatic impact on price rises of critical rare earth elements.

The vehicle industry, both EV and internal combustion engines, is expected to be the fastest growing end-use industry segment in the global permanent magnet market over the next 5-10 years, not only due to the rising permanent magnet demand in the drive motors but also the increase in on-board actuators (autonomous steering, regenerative braking, drive-by-wire systems, etc).

The power units on most mainstream EVs are designed around REE permanent magnets due to their motor's cost and efficiency. Long term supply concerns continue to drive efforts to reduce the reliance on these magnets, however the efficiency and price advantages of REE permanent magnets continue to advantage them over alternatives.

Domination of rare earth raw material supply has given China an enormous advantage in this growing magnet market. China is the largest producer of permanent magnets in the world, though a significant proportion is from non-Chinese owned companies or joint ventures.

Processing and recycling these rare earth materials in WA is essential for participation in the New Energy metals global economy.

4.6 Lithium Ion Battery Recycling

The recycling of lithium ion batteries provides an opportunity for Australia to physically retain battery metals and will therefore reduce the overall energy and resources required to produce new batteries, as the lithium in batteries is 100% recyclable. This has a direct impact on the exploitation of scarce resources and unsustainable extraction practices of components such as cobalt,[29] and reduces the health and environmental impacts from mining

29 Sanderson, H (2017), "LME's cobalt inquiry highlights ethical issues for industry", 24 November 2017, Financial Times, https://www.ft.com/content/930846c2-d047-11e7-b781-794ce08b24dc. (Accessed: 01 May 2018)

and beneficiation of metals such as nickel.[30]

Lithium ion batteries are classified as a ***Class 9 Dangerous Good*** for transport where Class 9 denotes miscellaneous dangerous substances and articles.[31] If not properly managed, Class 9 goods pose a health, safety, fire and explosion risk to resource recovery and landfill infrastructure.[32] There have been a number of reports of lithium ion battery fires during waste handling,[33] and in the event of a fire or exposure to moisture, toxic fluorine gases are released.[34]

The safe disposal of lithium ion batteries in a sustainable and environmentally suitable way will become increasingly important as the adoption of electric vehicles and stationary energy storage rises.[35]

Currently the Australian recycling rate of batteries, including lithium ion batteries, remains around 3%.[36] This represents an untapped source of raw battery metals. However, the high reactivity of lithium requires specialised processes to ensure safe handling. Established industrial processes to recycle lithium ion batteries exist in the EU, Japan and North America. The main industrial techniques to extract battery minerals are mechanical, hydrometallurgical and pyrometallurgical.[37]

The mechanical process includes crushing and shredding the battery before sorting and separating the battery metals. Due to the high reactivity of the lithium compounds (that can produce hydrogen and toxic fluoride gases), mechanical processes require additional precautions to handle larger battery volumes, such as inert gases or cryogenic cooling.

The hydrometallurgical process uses mechanical pre-treatment before utilising acids or bases to leech the battery metals into a solution that is then concentrated, precipitated and recovered. The process allows the recovery of the majority of battery metals including lithium at high purities.

The pyrometallurgical process smelts the batteries (without pre-treatment) to produce a metal alloy and molten slag. Leeching is applied to the metal alloy to recover cobalt, nickel, copper and iron. The remaining minerals in the slag, namely lithium, aluminium and manganese, are currently not cost effective to recover.[38]

The hydrometallurgical process offers the highest recovery efficiency, while the pyrometallurgical process does not require mechanical pre-treatment and has the additional benefit of being able to process Nickel Metal Hydride (NiMH) batteries. The economic value from each of the battery

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30 Opray, M (2017), "Nickel mining: the hidden environmental cost of electric cars", 24 August 2017, The Guardian, https://www.theguardian.com/sustainable-business/2017/aug/24/nickel-mining-hidden-environmental-cost-electric-cars-batteries. (Accessed: 01 May 2018)

31 United Nations Economic Commission for Europe (2016), European Agreement Concerning the International Carriage of Dangerous Goods by Road Volume 1, ECE/TRANS/257 (Vol.I), https://www.unece.org/fileadmin/DAM/trans/danger/publi/adr/adr2017/ADR2017e_web.pdf. (Accessed: 01 May 2018)

32 Randell, P (2016), Waste lithium-ion battery projections, Prepared for the Department of the Environment by Randell Environmental Consulting, http://www.environment.gov.au/protection/publications/waste-lithium-ion-battery-projections. (Accessed: 01 May 2018)

33 Fattal, A, Kelly, A, Liu, A and Giurco, D (2016), Waste Fires in Australia: Cause for Concern?, Prepared for the Department of Environment by University of Technology Sydney Institute for Sustainable Futures, http://www.environment.gov.au/protection/publications/waste-fires-australia. (Accessed: 01 May 2018)

34 Larsson, F, Andersson, P, Blomqvist, P and Mellander, BE (2017). "Toxic fluoride gas emissions from lithium-ion battery fires", Scientific Reports, Vol. 7, Article No. 10018, http://www.nature.com/articles/s41598-017-09784-z.pdf. (Accessed: 01 May 2018)

35 Randell, P (2016), Waste lithium-ion battery projections, Prepared for the Department of the Environment by Randell Environmental Consulting, http://www.environment.gov.au/protection/publications/waste-lithium-ion-battery-projections. (Accessed: 01 May 2018)

36 Clean Up Australia (2017), Battery Recycling Fact Sheet, November 2017, http://www.cleanup.org.au/PDF/au/clean_up_australia_battery_recycling_factsheet-2017.pdf. (Accessed: 01 May 2018)

37 Boyden, A, Soo, VK and Doolan, M, (2016), "The Environmental Impacts of Recycling Portable Lithium-Ion Batteries", Procedia: Social and Behavioural Sciences, Volume 48, pp. 188–193, Presented at the 23rd CIRP Conference on Life Cycle Engineering, https://doi.org/10.1016/j.procir.2016.03.100. (Accessed: 01 May 2018)

38 Lebedeva, N, Di Persio, F and Brett, L, (2016), "Lithium ion battery value chain and related opportunities for Europe", Publications Office of the European Union, https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/lithium-ion-battery-value-chain-and-related-opportunities-europe. (Accessed: 01 May 2018)

metals strongly influences the choice of the recycling process, and the metals that are ultimately recovered. Currently recycled lithium ion batteries (early generation) contain less than 2% of lithium by weight [39] with much higher percentages of cobalt and nickel. Due to the high commodity prices of cobalt and nickel, global industrial lithium ion battery recycling processes prioritise cobalt and nickel recovery over lithium. As a result, lithium is typically not recovered.

Australia also has competitive advantages in the recycling of e-waste due to the ability to provide ethical, sustainable and environmentally robust processes and documentation. This can be a point of differentiation and part of the WA branding approach.

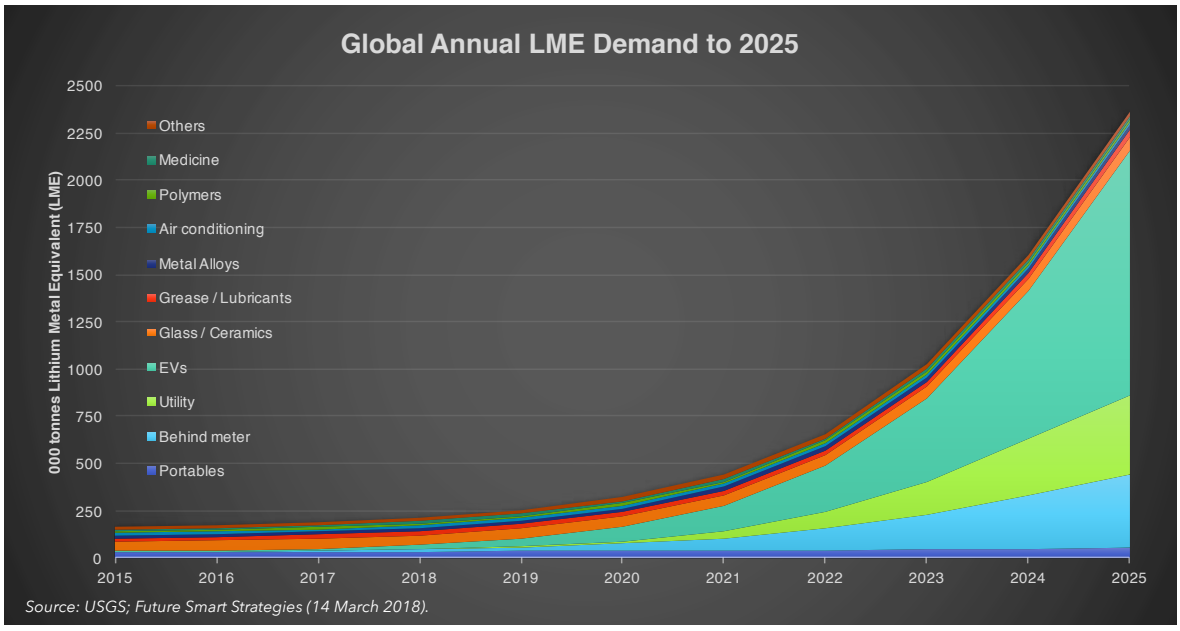
4.7 The current profile of the New Energy metals sector in Western Australia

The primary raw materials consumed in current leading lithium-ion battery chemistries are lithium, nickel, cobalt, manganese, copper, aluminium, iron and graphite. Detailed analysis and availability of these can be found in Appendix A.

WA has reserves of all the base battery materials including graphite and was one of the main suppliers of lithium for 2017. WA is also adding lithium supply capacity faster than any other country with two new spodumene mines increasing capacity by 34% in 2017.[40]

Even so, the future lithium demand forecasts are increasing exponentially (Figure 14). The main drivers are forecast to be electric vehicles, distributed generation and utility scale storage.

WA also has over one hundred recorded graphite mineralisations in the state, as well as domestic development of technology to produce synthetic graphite. In 2013, Australia's Economic Demonstrated Resources (EDR) of graphite were estimated to be 969.59kt, almost 20% of which is in WA (176.77kt). [41]



14

Figure 14: *Cumulative impact of electrification on lithium metal consumption*

39 European Li-Ion Batteries Advanced Manufacturing (ELIBAMA) (2014), Li-ion Battery Recycling, https://elibama.files.wordpress.com/2014/10/v-d-batteries-recycling1.pdf. (Accessed: 01 May 2018)

40 United Stated Geological Survey (2018), Mineral Commodity Summaries 2018, https://minerals.usgs.gov/minerals/pubs/mcs/2018/mcs2018.pdf. (Accessed: 01 May 2018)

41 Geosciences Australia (2013), Graphite, http://www.ga.gov.au/scientific-topics/minerals/mineral-resources/graphite. (Accessed: 01 May 2018)

The supply of Western Australian lithium has certainly fuelled the acceleration of the battery revolution that is taking place around the world. Even with WA's ability to bring new materials to market, demand is still outpacing supply. As a result, there has been a significant growth in lithium carbonate equivalent (LCE) prices from a multiyear base of approximately US$8k/t to around US$16k/t. Cobalt's growth has been more spectacular rising from approximately US$22k/t to current prices over US$80k/t (see further information in Appendix C – Current and Planned Energy Metals Investment).[42]

WA has the potential to remain a major global supplier by continuing to expand supply. Another advantage for WA is the customer preference for lithium hydroxide (as opposed to lithium carbonate) as a supply material for battery cells. Since lithium hydroxide is best produced from hard rock spodumene (as found in WA), WA has a material and technological advantage when compared with less-valued lithium carbonate despite carbonate's lower production cost when extracted from brines such as those found in South America.

Hard rock mining has a number of distinct advantages over brine production. Brine production requires an evaporative process through the use of ponds that are dependent on weather conditions to extract lithium salts that can be extracted for a profit, averaging around 200 to 1,400 milligrams per litre producing a 1% to 2% lithium concentrate. Hard rock extraction relies on traditional methods of drilling and processing which can take place near mine or near market and can deliver anywhere between a 1% to 6% concentrate.[43]

Currently 100% of WA's low value lithium concentrate (spodumene) is exported to China for processing. This is in the process of changing with lithium refining plants like Tianqi, SQM/ Kidman and Albemarle. China's early recognition of the battery and power industry transformation resulted in the adoption of a holistic policy approach including investing in operating mines and establishing long-term production off-takes. At present, the vast majority of future lithium extraction in WA is already committed to foreign buyers. As miners are capital constrained this has often been necessary to underwrite the development of mines, however, it restricts the opportunities for local "value add" in future, unless concessions are secured or government policy is changed to encourage investment towards local downstream processing and battery cell production.

With WA's extensive resources of rare earth materials, combined with reserves of boron and other minerals, there is the potential to process these minerals domestically. This also allows for the further downstream domestic manufacture of permanent magnets for turbines and motors with the potential to expand manufacturing further downstream.

Outside of China, rare earths production is primarily undertaken by Australian producer Lynas Corporation as a significant non-Chinese supplier, though their main off-take agreement is with China. Lynas' refining plant is in Malaysia. There are several other Australian-based resource REE projects that could assist Australia solidify its position as the main commercial alternative to China in the production of REE.

Expected to go into production in mid-2018, Northern Minerals' Browns Range REE project, located 160 kilometres south-east of Halls Creek in WA's East Kimberley region, will produce 573 tonnes of total rare earth oxides per year, of which 50 tonnes will be dysprosium.[44] Although only a portion of the

42 Department of Mines, Industry Regulations and Safety (2017), 2017 Major Commodities Resources File, *http://www.dmp.wa.gov.au/About-Us-Careers/Latest-Statistics-Release-4081.aspx*. (Accessed: 01 May 2018)

43 LePan, Nicholas (2018), "Hard Rock Lithium Versus Brine: 4 Juniors to Play This Space", Smallcap Power, 18 May 2018, *https://smallcappower.com/community-contribution/community-articles/hard-rock-lithium-deposits/*. (Accessed 29 May 2018)

44 Australian Financial Review (2018), "Northern Minerals eyes role in global EV boom", Australian Financial Review, 30 May 2018, *http://todayspaper.smedia.com.au/afr/shared/ShowArticle.aspx?doc=AFR/2018/05/30&entity=Ar03502&sk=74292D9E&mode=text*. (Accessed: 30 May 2018)

increasing demand for rare earths around the world, this represents an important alternative source for local manufacturing opportunities.

According to the report *'Australia's Identified Mineral Resources 2017'* in 2016, Australia's Economic Demonstrated Resource (EDR) of rare earths was 3.43Mt.[45] This accounts for approximately 3% of the world total of 120Mt (USGS estimate), of which China holds the greatest proportion of any country (>36%). China also dominates world production (>83%). Australia is the second largest producer at 11%.

Another critical resource material for batteries is cobalt and WA is also one of the leading producers of cobalt outside of the Democratic Republic of Congo.[46] In 2018, the Democratic Republic of Congo has declared cobalt, tantalum and niobium as strategic mineral resources: *"We need to make enough money before we run out of these minerals so that is why they are strategic to the country"* Jean Nkunza, Advisor to Prime Minister Ponyo.[47] It would be prudent for WA to also declare cobalt a strategic mineral and ensure maximum value for finite resources.

4.8 Rare Earth Processing

The ore containing rare earth elements is typically crushed and then concentrated at (or near) the mining site to remove the rock material. This leaves a Mixed Rare Earth Carbonate product (MREC) that is supplied to refining plants. Due to the nature of individual ore deposits, the proportions of each specific rare earth element in the concentrated MREC varies significantly from site to site.

The refining stage adds considerable value by producing separate stable compounds for each REE. These compounds (usually as powder) are then supplied to downstream manufacturers, such as permanent magnet producers.

4.9 Solution to the strategic fuel supply issue

Australia is not in compliance with International Energy Agency guidelines for minimal strategic fuel reserves. This is even more acute in Australia as there are no international fuel lines, fuel supplies geographically close and the Australian economy is highly reliant on fossil fuels. State and Federal Governments are consistently mute on this point even though industry bodies and specialists from defence continue to highlight this strategic weakness. WA is further isolated from the rest of Australia in relation to fuel security and therefore WA is the most vulnerable State in the most vulnerable country to fuel security issues. This issue does not need to continue into the New Energy economy.

If Australia was to prioritise the transition to the electric economy, more transport would be electrified thereby reducing the demand for imported fuels. It also improves the local demand for batteries and local resources while creating new industries. The focus is to replace diesel with electric alternatives as soon as possible as one solution to the strategic fuels issue. Other strategic initiatives are also needed and comparative examples like Norway's holistic approach could be considered.

45 Geoscience Australia, (2017), Australia's Identified Mineral Reserves 2017, http://www.ga.gov.au/__data/assets/pdf_file/0005/58874/Australias-Identified-Mineral-Resources-2017.pdf. (Accessed: 01 May 2018)

46 United Stated Geological Survey (2018), Mineral Commodity Summaries 2018, https://minerals.usgs.gov/minerals/pubs/mcs/2018/mcs2018.pdf. (Accessed: 01 May 2018)

47 Reuters (2018), "Cobalt to be declared a strategic mineral in Congo", Reuters, 15 March 2018, https://www.reuters.com/article/us-congo-mining-cobalt/cobalt-to-be-declared-a-strategic-mineral-in-congo-idUSKCN1GQ2RX. (Accessed: 30 May 2018)

5. ENERGY METALS & POWER STORAGE

5 Strategic Geo-Political Importance of Locating an Energy Metals and Power Storage Value Chain in Western Australia

WA is a western democracy with a strong, transparent legal system, robust property rights and intellectual property protection. WA has a long history of stable government and being industry and mining friendly. Apart from being a major source of lithium, WA also has an abundance of complementary resources, including energy, for the power storage industry. By locating more lithium-ion and advanced materials processing in WA, WA can position itself as a politically neutral, reliable and ethical supplier of Critical Raw Materials (CRMs) to the world. The larger the industry grows the greater the economies of scale that drives further investment and processing.

Local processing can reduce supply chain costs and access to the wide variety of complementary raw materials makes WA an ideal cluster location for production. Along the Western Trade Coast (WTC) are concentrated fabrication and reagent facilities, a highly qualified and experienced workforce, cutting edge processes, affordable energy and reliable utilities while being in close proximity to universities. There are few places in the world that have all these advantages in one location while also being a globally connected export centre capable of supplying any country. As production grows greater economies of scale will further benefit local production.

Traditionally, Australia has focused on a Harvest/Mine/Concentrate approach and limited refining processes. WA could instead focus on attracting companies that specialise in electro-chemical processes and further down-stream processing technology. WA already possesses the foundations of technological commercialisation upon which this additional processing capacity can be built.

> **"The potential for Western Australia to provide a secure, vertically integrated supply chain for lithium-ion and advanced materials industries in a neutral country is of great strategic significance, which is a tremendous competitive advantage over countries that only have downstream production capabilities."**

There is an opportunity to bring all these elements together with WA's lengthy experience as an export economy to become a major export centre for a variety of products and processed goods in this New Energy industry sector. There are a great number of advantages of being an export centre in a

neutral location with diverse supply chain optionality and a strong export focused economy. WA can also offer an ethical supply chain that is growing in importance to end-user consumers worldwide. The New Energy metals value-adding industry can create significantly more value and jobs compared to the traditional limited mining approaches. The strategic and economic importance of Australia will grow creating further opportunities for a West Coast trading, manufacturing and maritime security hub.

5.1 European Union assessment of Critical Raw Materials

Countries around the world are increasingly emphasising the importance of Critical Raw Materials due to market influences, security and governance issues and the increasing demand for new elements.

In February 2018 the US Government published a list of 35 CRMs that "Any shortage of these resources constitutes a strategic vulnerability for the security and prosperity of the United States."[48] WA has the majority of these CRMs.

48 Volcovici, Valerie and Taylor, Susan (2018), "U.S. seeks to boost output of 35 minerals, reduce import reliance", Reuters, 17 February 2018, *https://af.reuters.com/article/drcNews/idAFL2N1Q61KS*. (Accessed: 30 May 2018)

"The question is "do we have the hardness for this?" Firstly, beyond perhaps a little secondary processing the miners have no interest in this and the ownership structure is keyed in part to where processing is done. Secondly - this is an area of jealousy guarded patents. Those who hold them are every bit as nationalist as ourselves. They will be prone to emotionalism as well as rational decision. Thirdly - though decisions can't be made by companies alone. This effort requires close government engagement. Necessary not to pick winners here but to back all players to be here."

Honourable Kim Beazley AC Governor of Western Australia - 24th May 2018

Europe's economy is perhaps more vulnerable for a variety of reasons and the EU recognises that the reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe.[49] In 2017, the European Commission created a list of CRMs for the EU that combine raw materials of high importance to the EU economy and of high risk associated with their supply (Table 4).

Table 4: ***Critical Raw Materials Identified by the EU***

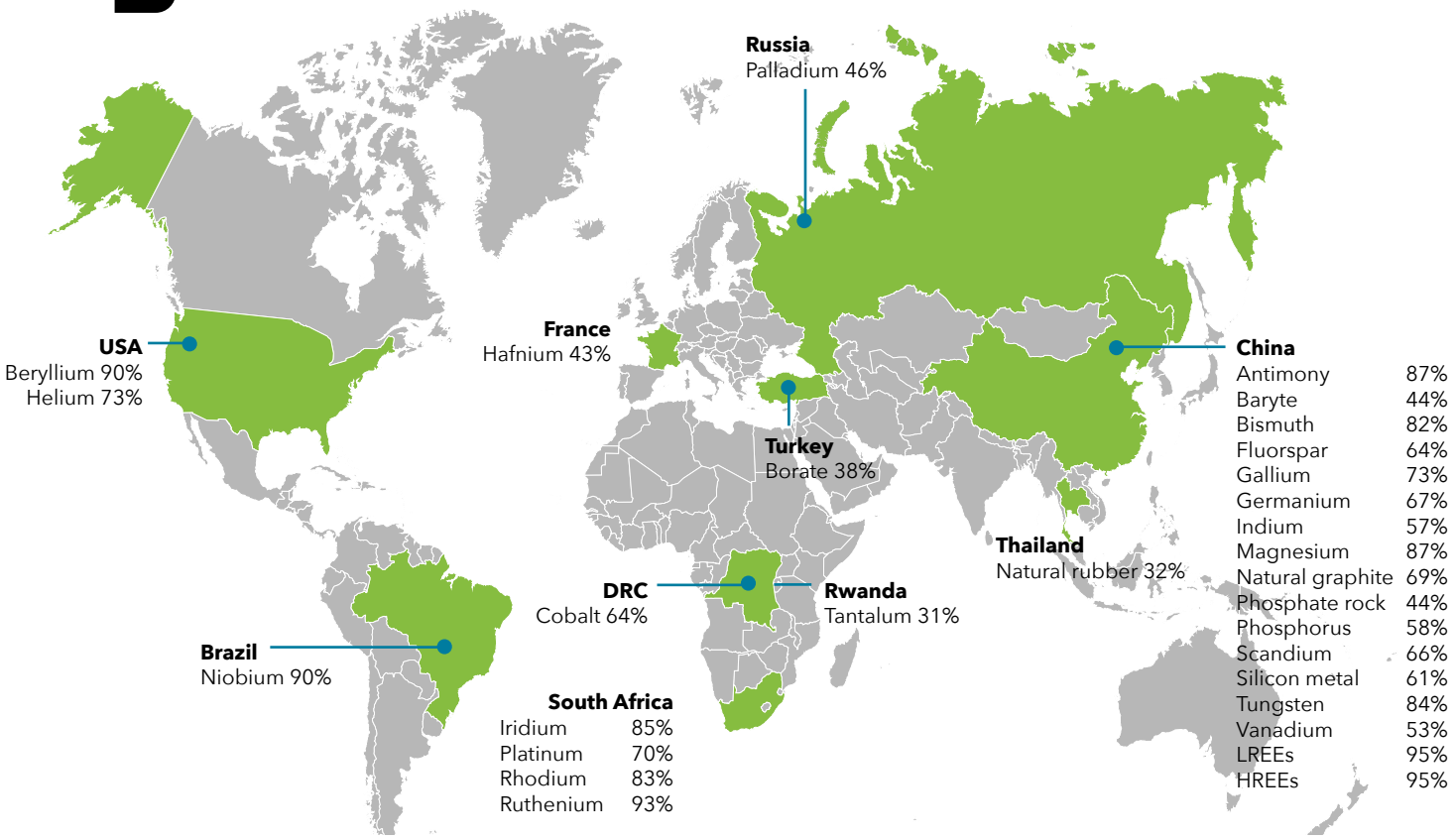
Mineral	Deposit Location	Mineral	Deposit Location
Antimony	Local WA deposits	Beryllium	Local WA deposits
Borates	Local WA deposits	Cobalt	Local WA deposits
Coking Coal	Australian deposits	Fluorspar	Local WA deposits
Gallium	Local WA deposits	Germanium	Local WA deposits
Indium	Australian deposits	Magnesium	Local WA deposits
Natural Graphite	Local WA deposits	Niobium	Local WA deposits
Phosphate Rock	Local WA deposits	Silicon Metal	Local WA deposits
Tungsten	Local WA deposits	Platinum Group Metals	Local WA deposits
Light Rare Earths and Heavy Rare Earths	Local WA deposits	Baryte	Local WA deposits
Bismuth	Local WA deposits	Hafnium	Local WA deposits
Helium	Local WA deposits	Natural Rubber	CSIRO studies supported developing a local industry
Phosphorus	Local WA deposits	Scandium	Local WA deposits
Tantalum	Local WA deposits	Vanadium	Local WA deposits

Source: European Commission (http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en)

Supply risk reflects the risk of a disruption in the EU supply of the material. It is based on the concentration of primary supply from raw materials producing countries, considering their governance performance and trade aspects. Modern technology depends upon many of the CRMs such as solar panels, wind turbines, electric vehicles, and energy-efficient lighting. These CRMs are essential for many industries across the entire supply chain.

49 European Commission (2017), COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS on the 2017 list of Critical Raw Materials for the EU, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017DC0490. (Accessed: 01 May 2018)

15 ***Figure 15:*** *Countries accounting for the largest share of the global supply of CRMs*



Source: European Commission (http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en)

Figure 15 maps out the active sources of supply of CRMs as understood by the EU.[50]

As of 2017, the EU does not recognise Australia as a major supplier of CRMs (to the EU) although United States Geological Survey data recognise the importance of Australia is a significant supplier globally of CRMs. This is intriguing considering WA has commercial reserves of almost all of the CRMs. Clearly there is an opportunity for WA to provide a secure and diverse supply of CRMs to the EU and in return receive offtake revenues and investment in local secondary production facilities. Having EU investment in WA can act as a passive form of defence in times of security uncertainty. There are advantages to WA of having a broad and diverse investment community. The EU can benefit from local expertise and processing costs, affordable energy and water costs and a reliable, ethical and environmentally sensitive supply of all CRMs. The EU recently established a European Battery Alliance (EBA) to focus on securing access to raw materials for batteries. This Alliance incorporates active membership from across industry to drive the technological changes required for the EU. Interestingly in a recent presentation [51] from the EBA, the assumption is that the EU can acquire all the raw materials they need from the market without making strategic investments in mines or local processing facilities. As other countries aim to control the entire supply chain originating from the mine it remains to be seen whether sufficient resource volumes actually reach an open market. There is the incentive for European companies to invest more upstream to secure sufficient resources for the future.

50 European Commission (2017), COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS on the 2017 list of Critical Raw Materials for the EU, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017DC0490. (Accessed: 01 May 2018)

51 InnoEnergy (2018), "EIT InnoEnergy plays pivotal role within the European Battery Alliance", InnoEnergy, 03 May 2018, http://www.innoenergy.com/eit-innoenergys-role-within-the-european-battery-alliance/. (Accessed: 30 May 2018)

> **"If cobalt falls into the hands of the Chinese, yeah you won't see EVs being produced in Europe etc. They are waking up too late... I think it's because the car industry has never had a supply chain problem before."**
>
> *Ivan Glasenberg - CEO Glencore told the FT Commodities Global Summit in Lausanne, Switzerland. March 2018*

5.2 EU and Western Australia Supply Agreements

The EU seeks to ensure the supply of identified Critical Raw Materials. Western Australia can provide these materials and much more. Not only is WA a reliable supplier from a neutral country, WA has strong environmental laws that are consistent with EU principles. A potential win-win deal for both parties could be:

1. A strategic materials supply arrangement to the EU in accordance with World Trade Organization rules.
2. Additional high technology manufacturing plants based in Western Australia supporting EU companies where energy costs are lower, quality is high and environmental standards are comparable.
3. An exclusive, long-term agreement to reprocess all of the EU e-waste, including batteries, potentially for up to 50 years.

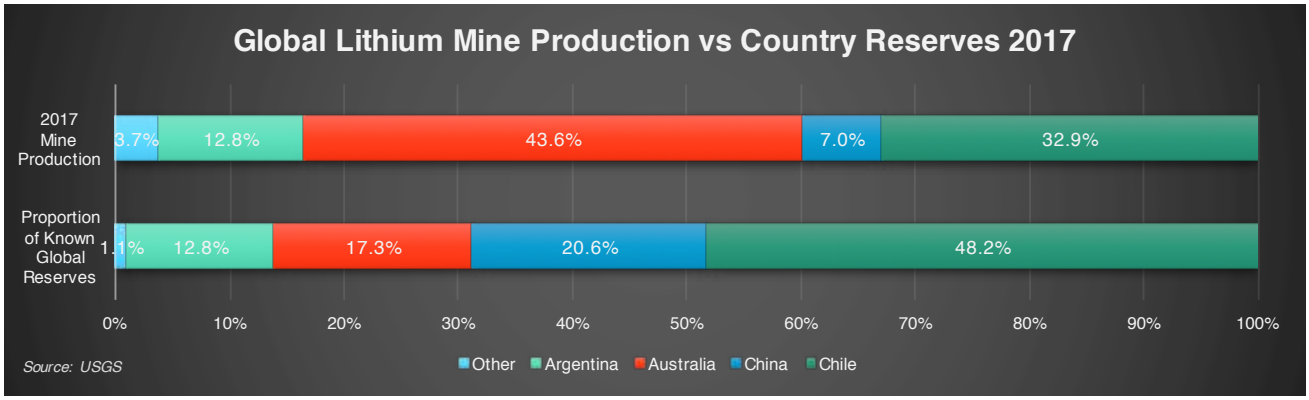
This could be facilitated between the respective governments, which is the approach proposed by the Indian Government.

5.3 Western Australia as the Preferred Supplier of Strategic Resources

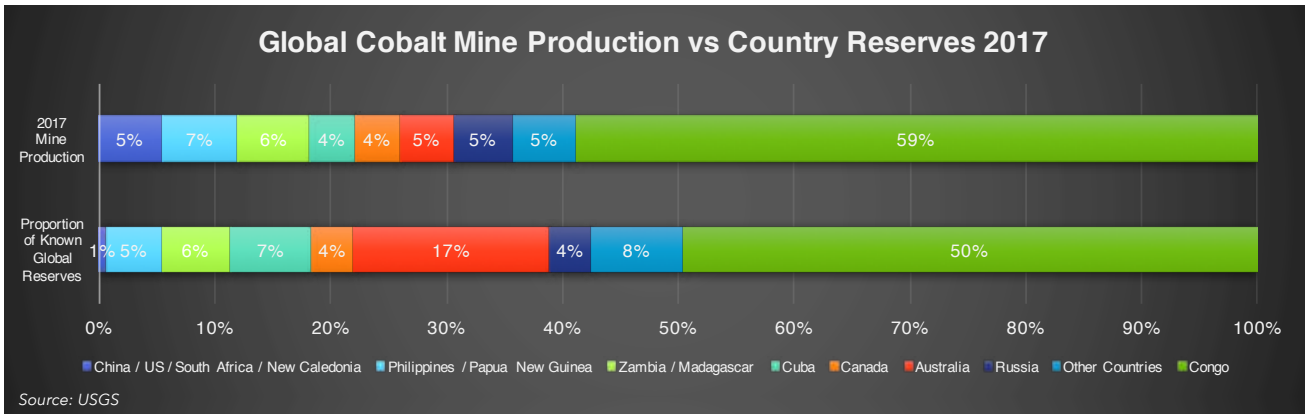
WA is endowed with enviable economic reserves of most of the materials required for this new energy transformation. According to research compiled for this report, WA currently supplies 44% of the world's lithium, 5% of the world's cobalt, 14% of manganese, 16% of alumina, 9% of nickel, and 5% of copper. Not only is WA already a leading supplier to current markets, but WA also has substantial reserves of most of the critical materials to be a key global supplier in the future (Figure 16, Figure 17, Figure 18).

> **"The European Commission has identified 27 critical raw materials. Western Australia has significant commercial reserves to supply almost all of them and yet WA's current contribution to world supply is considered negligible. WA has an outstanding opportunity to become the preferred independent supplier of critical raw materials to the EU and the rest of the world."**

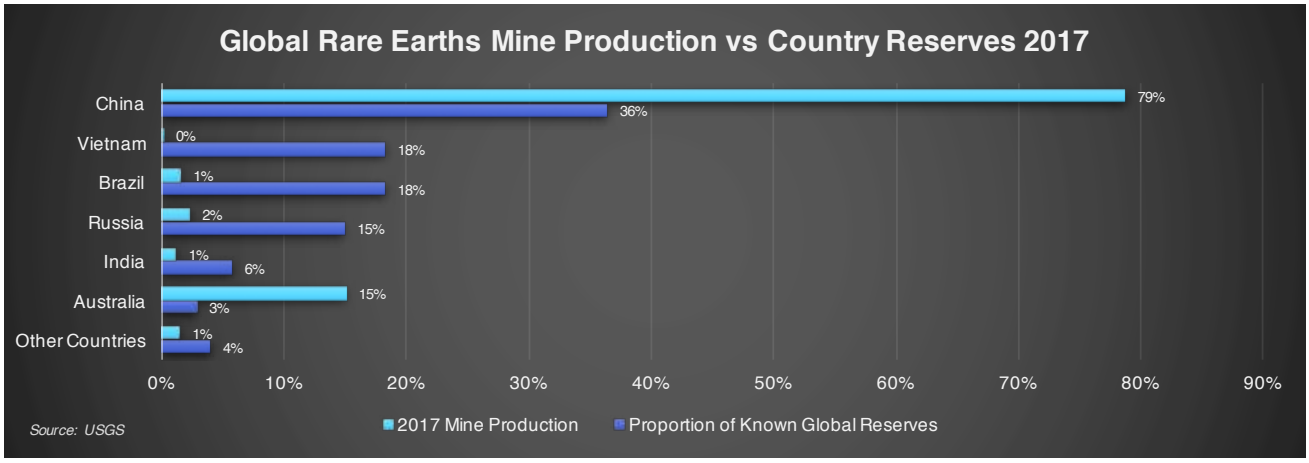
16 ***Figure 16:*** *Global Lithium Mine Production vs Country Reserves 2017*



17 ***Figure 17:*** *Global Cobalt Mine Production vs Country Reserves 2017*



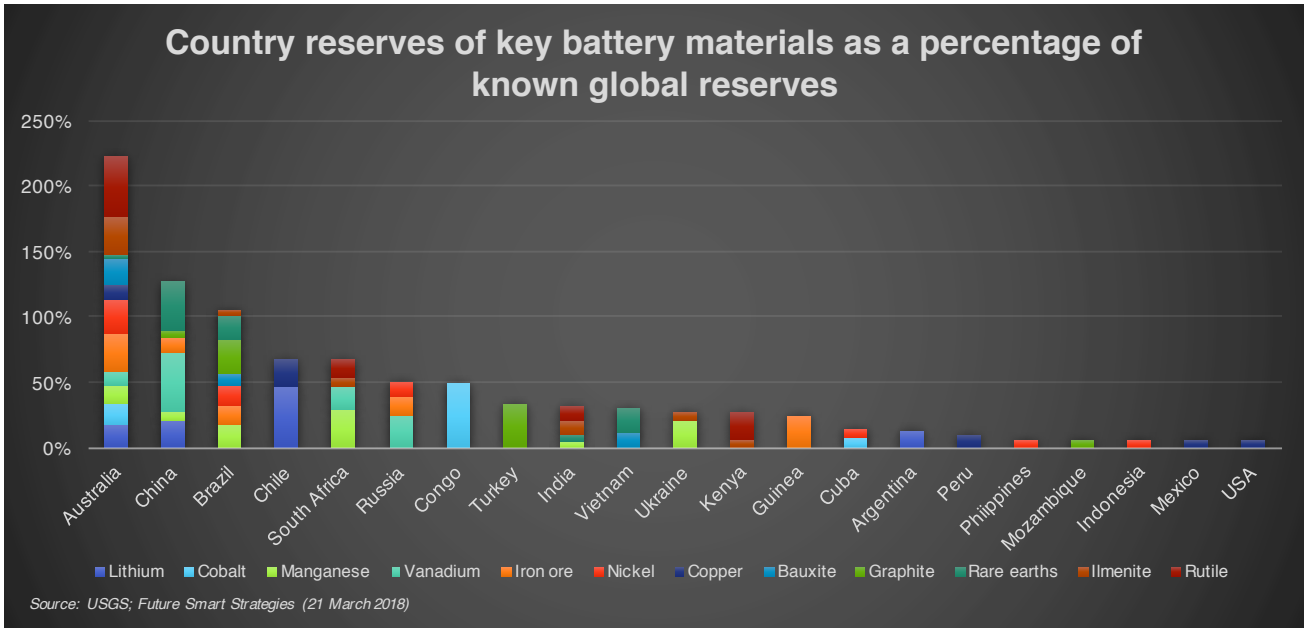
18 ***Figure 18:*** *Global Rare Earths Mine Production vs Country Reserves 2017*



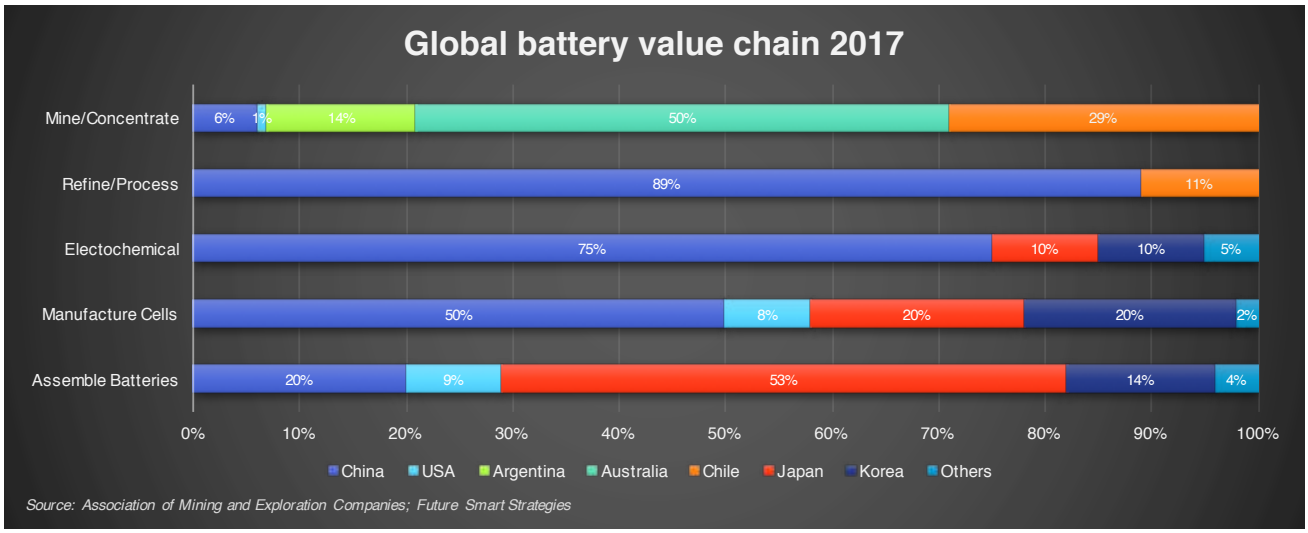
Currently WA is mostly a crusher of rocks, and the main value-adding Australia undertakes is making big rocks into smaller rocks, with little or no activity in the far higher value-adding downstream processes (Figure 8). Globally, Australia dominates reserves of battery resources in both diversity and depth (Figure 19). The main sources of the materials for battery production and

New Energy metals are Australia, China, Brazil, Chile, Argentina, Bolivia and South Africa although no other nation matches Australia's unique depth and diversity of materials. When considered with the other advantages mentioned in this report, this puts WA into a unique position for developing high technology industries. These higher margin, lower volume, value adding industries are better suited to local Australian processing.

19 ***Figure 19:*** *Global reserves of key battery materials*



20 ***Figure 20:*** *Global battery value chain 2017*



From a strategic perspective, WA can explore trade alliances with countries such as with the EU, US, Brazil, Chile, India, Korea, Japan, Indonesia and South Africa in relation to New Energy metals and processing. For this to be realised, Kwinana Bulk Terminal and the local supply chains would need to be upgraded and modernised. The current facility excludes importing more bulk materials from other countries that would potentially support further industrial growth in the surrounding region. Greater imports and processing generates greater economies of scale creating a positive feedback loop. Mineral processing can also be a service WA provides to African countries that builds on the long and positive relationships in the region due to the mining industry.

The recent review of Kwinana Bulk Terminal conducted by the Fremantle Port Authority limited the consultants to 'suitability for current use', which not only limits the potential for the port but also the State and the development of new industries. Private sector investment and operations allowing vertically integrated supply chains connected into world markets could drive the development of the Kwinana region as the private sector is highly motivated to innovate and maximise commercial benefits.

WA also has other benefits to be the global preferred supplier of strategic resources, these are:

- Competitive energy costs,
- Competitive water costs,
- World class environmental protection framework,
- Commitment to sustainability,
- Concentration of global companies in a variety of industries providing a deep pool of professional expertise, well trained work force and well- respected universities,
- Independent country, secure location, western legal system, robust intellectual property rights,
- Well trained and experienced workforce and strong university research and technologies,
- The potential for a Specialised Industrial Park to drive efficiencies and international competitiveness, and
- Flexibility in supply delivery.

"If WA targets and successfully attracts highly strategic investment, then the State will harvest significant economic benefits from the projects, products and processes that will be associated with this new energy transformation. These benefits will continue well beyond 2030, delivering thousands of jobs and many billions in state revenue. Only the government can facilitate or enable the development of these local industries. As has been demonstrated for years, if left to pure market forces, then ores would likely be exported to other countries for further processing benefiting the mineral extractors rather than the original mineral owners. "

Resources executive - Perth

> **"The gas boom came and went with few residual benefits apart from royalties. The significant engineering expertise, research and development and manufacturing was mainly completed overseas. We need to be smarter to avoid repeating "the North West Shelf - A sea of lost opportunities?" findings. WA needs a plan and strategy otherwise the long term benefits of the current New Energy metals boom will be lost."**
>
> *Marine engineering executive - Perth*

WA is perfectly positioned to capitalise on its natural bounty. There have been missed opportunities to better maximise the North West shelf, the Australian Marine Complex, the iron ore boom and most recently the natural gas projects. The chances of maximising more of the value from WA's finite resources will improve with greater collaboration between government, within government, industry and the community as well as articulating a clear vision and strategy.

In June 2018 the Indian government mandated all State-owned mineral-based companies to pool their resources to acquire lithium and cobalt assets overseas. This is a high profile example of a democratic government seeking to lead bi-lateral international negotiations to secure Critical Raw Materials. Australia and WA are ideally placed to enter into bi-lateral negotiations with India to formulate a mutually beneficial deal.

http://www.miningweekly.com/print-version/indian-state-owned-firms-mandated-to-acquire-overseas-lithium-and-cobalt-assets-2018-06-22

> **"It should be recognised that the Chinese-owned Tianqi Lithium chose Kwinana as a refining facility for lithium hydroxide from a variety of worldwide options. This highlights that sovereign risk issues now outweigh commercial issues as Tianqi aims to be a reliable global supplier."**
>
> *Industry executive - Innovate Australia's Advanced Minerals Forum - May 2018*

STRATEGIC SITES FOR ENERGY, METALS, POWER & RECYCLING

6 Strategic Sites for Energy Metals, Power Storage and Recycling

This section proposes a model and supporting evidence for developing a New Energy metals value adding industry in WA. Key considerations include:

- Primary processing (spodumene production) can be done anywhere;
- Secondary processing requires an array of chemical and other inputs that favour the Western Trade Coast; and
- Battery components can be manufactured anywhere, but will benefit from proximity to export facilities and refined New Energy metals.

The section describes the strengths, weaknesses, opportunities and threats of developing a New Energy metals industry in WA.

6.1 Primary Processing of Lithium and Rare Earths

Lithium deposits are spread across WA and initial processing and beneficiation of the spodumene rock into a spodumene concentrate is likely to occur close to the mine site to reduce logistics costs. Currently, this spodumene concentrate is then exported overseas for further processing. There exists an opportunity to identify strategic locations in WA, such as Kemerton, Geraldton, Pilbara and the Kimberley for the primary processing of spodumene concentrate into carbonate or hydroxide. Similarly, these strategic locations could also be developed to process rare earths into oxides. After primary processing, the carbonates, hydroxides and oxides can be easily transported and either be exported or undergo domestic secondary processing.

To further refine lithium and rare earths into higher value commercial outputs, such as metal alloy ingots, electro-chemical processes require ease of access to a range of chemicals and other unique inputs at a low distributed cost.

The Western Trade Coast at Kwinana is already a significant refining area as nickel and cobalt are already refined at Nickel West. Rare earths are not currently refined in WA although there are opportunities for doing so, particularly in Kwinana or possibly Geraldton. This depends on the company and government policy. In addition, there are all the reagents, raw materials, fabrication companies and testing/processes/project companies available within a concentrated area.

The assembly of power storage units are less constrained than alloys and electro-chemical processes and can take place in a number of areas. However, there are usually sound commercial benefits to locate assembly facilities close to demand domestically or close to ports to export finished products.

There are some issues with some of WA's industrial sites from a marketing perspective as companies encouraged to locate within them are under the assumption that all base environmental approvals (such as flora and fauna assessments) have been completed. To move this industry forward, it is recommended to check all strategic industrial sites that are being marketed to industry against this assumption, and to clearly articulate up front what has to be done and how long it will take to get to construction. The best way forward would be to conduct a strategic Environmental Assessment that can enable industries to 'Plug and Play' if they can show they can meet the already assessed conditions.

6.2 The Western Trade Coast

The Western Trade Coast (WTC) is an approximately 6,000-hectare industrial region that has been designed as a gateway to global industry wanting to access the growing economy, secure infrastructure and skilled workforce in WA. Located approximately 40km south of Perth at Cockburn Sound, the WTC has direct links to air, sea, road and rail network making it the ideal place to locate for strategic business. The location, facilities and infrastructure make it the perfect international export option for business collaboration with Asia, Africa, the Middle East and Europe.

The four primary estates within the WTC are known as Kwinana Industrial Area (KIA), Latitude 32 Industry Zone, Rockingham Industry Zone and the Australian Marine Complex (AMC). The WTC:

- Is a significant contributor to the WA economy with direct sales of $14.7 billion per annum;
- Employs approximately 11,400 people directly, of which 64% live locally within Cockburn, Kwinana or Rockingham local government authorities (LGAs);
- Pays $953 million in wages and salaries directly to workers employed within the WTC;
- Has indirect inter-industry flow-on effects amounting to an estimated $10.3 billion in output, $800 million in wages and salaries paid, and approximately 18,000 jobs;
- Makes a positive social contribution to local communities with over $1.8 million in donations reported by industries participating in the study for 2010/11;
- Has an extensive and highly integrated network of industrial symbiosis with approximately 158 synergies mapped between Kwinana cluster industries within the WTC, making the WTC a global leader in this area;
- Is a skills development centre and provides the state with a uniquely skilled workforce, making the local

"The WTC provides the opportunity for businesses to be part of WA's strong economic growth. With world-class infrastructure, export facilities and significant government partnerships, the WTC is one of the fastest growing trade and industry regions in Australia, supplying businesses with all they need to support major operations."

workforce highly valued by resource industries in the north of the State; and

- Is committed to managing the environmental impacts of industry. Environmental issues including noise, air quality, societal risk, groundwater and the marine environment of Cockburn Sound are being well managed by industry and government, with improvement in the local environment continuing over time.

One of WA's strategic advantages is the concentration of oil and gas, agriculture, defence, petrochemicals and resources industries all in one location. In this concentrated cluster lies the necessary expertise in metal fabrication, infrastructure, electrical trades, project management, chemical analysis, monitoring processes/ training, etc, that has developed symbiotically with these global industries. The economies of scale, collaboration and competition this allows makes the region highly competitive. Other regions in Australia and the Indian Ocean do not have these advantages and is another reason why Perth is an ideal location for secondary manufacturing of New Energy metals.

A further rational for focusing on the WTC is the need for high quality New Energy metals for battery production. Electric vehicle manufacturers are requiring much higher quality of refined metals for their batteries. In order to enable this, industries need to locate where they can to access the workforce, the technologies, and the research capabilities that enable higher technology production. Locating in the WTC would enable this and hence Lithium Valley industries would be attracted there. A Co-operative Research Centre (CRC) for the New Energy industry would greatly assist such as goal ensuring quality products to international standards.

The WTC is geographically isolated from other major Australian industrial centres and resource hubs and has developed independently into a unique industrial cluster with a wide variety of activity and industries. The number of connections in the WTC makes it one of the most intense industrial synergy regions in the world and comprises a range of by-product and utility exchanges. For instance, in the 2014 *Western Trade Coast Integrated Assessment* report it identified over 158 synergistic industrial exchanges compared to 30 in Kalundborg, Denmark. [52] Kalundborg is regularly cited as an example of a world-leading industrial cluster.

52 SKM and REU (2014), Western Trade Coast Integrated Assessment – Environmental, Social and Economic Impact, September 2013 (Reissued 2014). Document prepared for the Western Trade Coast Industries Council, *https://www.kic.org.au/library/reports-submissions/242-integrated-assessment-executive-summary/file.html*. (Accessed: 01 May 2018)

21

Figure 21: *Western Trade Coast – Reference - Kwinana Industries Council*

6.3 Specialised Industrial Park

It is recommended that a Specialised Industrial Park (SIP) is established over the entire WTC. A SIP is a port or an area of a port in which imported goods can be held or processed free of customs duties before re-export. SIP's have become common in recent years after the first one was established in Ireland in 1959. They exist around the world (EU, Middle East, throughout Asia) and highly incentivise increased activity and production in the zone. The China economic miracle started with their first SIP in Shenzhen in 1980. There is an abundance of evidence that SIPs create increased employment, particularly higher skilled staff, as there is a strong value adding emphasis. All quarantine and customs are provided within the secured zone. There is a positive knock-on effect for logistics and operations due to the increases in throughput and volume movements – from which Fremantle Port Authority and LandCorp receive a fee.

> **Despite innovations in automation in recent years, over the last decade Australia has fallen from 23rd to 95th in the World Bank's rankings for trade across borders. On these rankings, Australia is now trading behind Albania, Nicaragua, and Swaziland.**
>
> *Infrastructure Partnerships Australia 2018*

SIPs are located within a country's national borders, and their aims include: increased trade, increased investment, job creation and effective administration. To encourage businesses to set up in the zone, financial and regulatory incentives are usually introduced. For instance, the authorities act as a one-stop shop, cutting related red tape and simplifying administrative procedures. There are other incentives provided by governments, such as foreign ownership rules, special labour laws and fiscal incentives. The SIP should target a wide assortment of economic sectors, including commercial and manufacturing activities and professional services, such as warehousing and trans-shipment. Additionally, companies may be offered tax holidays, where on establishing in a zone they are granted a period of lower taxation.

The creation of a SIP by the host country may be motivated by the desire to attract foreign direct investment. The benefits a company gains by being in a Specialised Industrial Park may mean it can produce and trade goods at a lower price, aimed at being globally competitive.

An underrated aspect of SIPs is that they allow local companies to sell freely to other countries, as once the threshold into the Port precinct is crossed, goods are effectively exported, simplifying many of the procedures and paperwork. This expands local companies' customer bases and leads to new products and services and the viability of investing in innovation. This is particularly true for small businesses as they no longer have to worry about absorbing the costs of tariffs and other barriers to market entry and can sell their products freely. Based on recent studies completed by InfraNomics the compound annual growth rate (CAGR) of SIPs is typically in the range of 10-14% over a 10 year period. This is approximately double the CAGR of an unfacilitated industrial park and approximately 2-3 times the current growth rate of the Kwinana Industrial Area.

SIPs allow:

Increased:	Reduced:
• Economic activity	• Regulation
• International competitiveness	• Costs
• Manufacturing and jobs	• Bureaucratic interference
• Diversity and synergies	• Approval times
• Quality infrastructure access	• Urban encroachment
• Productivity	• Customs interfaces
• Integrated transport	

6.4 Western Trade Coast Industrial Park

Within the SIP there is a proposal for a 'Plug and Play' (PnP) Industrial Park. Targeting a minimum 500 Hectares (ha) and adjacent to the new port facilities, the Industrial Park has the potential to attract New Energy metals and battery industries. In a PnP industrial park, all utility infrastructure would already be in place, strategic assessment clearances would already be granted to enable quick decisions for companies committing to the area, and the option to lease tailored facilities would be available. Benefits of an industrial park include:

- Prime location in WA's premier economic zone;
- Plug and Play can result in up to 20% CAPEX reduction;
- Existing development cluster providing a multitude of synergies;
- Access to five universities providing technical knowledge as well as the CRC tailored to their needs;
- An industrial environment that is well experienced with scaling up new technologies; and
- All feedstocks, utilities, industrial services, gases and chemicals available in bulk, providing industrial park residents the economic benefits of economies of scale.

Five hundred hectares is a small industrial park by world standards. For example, European industrial parks are usually around 1,200ha; one of the largest industrial parks in the world can be found in Shanghai, China is 3,800ha. These industrial parks are considered highly strategic assets and as such are always placed in strategic locations allowing easy access to logistics, raw materials, close to population centres, etc. Japan, Germany and The Netherlands are recognised worldwide leaders in the specialist area of industrial park development and many lessons can be learned from these locations.

The industrial park would be integrated into the new port in Kwinana project scope, similar to other locations such as Rotterdam and Singapore, thus providing the export infrastructure for raw materials that have already undergone domestic secondary processing. With up to 4,000Ha of land available according to the City of Kwinana, Indian Ocean Gateway report, there remains ample room for expansion. With a new port and supply chain upgrade it is expected that additional investment into the region will occur.

In comparative industrial parks around the world there is a dedicated management team, similar to the Australian Maritime Complex (AMC) in Henderson. This dedicated management team proactively identifies and aims to attract industry both domestically and internationally to the industrial park. With

the current WA State Government setup, this function would be performed by the WA Department of Jobs, Technology, Science and Innovation (JTSI). Consultations with industry has revealed that businesses do not consider JTSI to be the right party to develop an Industrial Park. Business considers a dedicated, commercially focused and experienced team of key experts, like the AMC, would be suitable to develop a facilitated Industrial Park. Successful Industrial Parks elsewhere in the world typically have dedicated management, usually independent from government, business development focused and proactive.

It is no longer possible to build comparable industrial parks in Sydney or Melbourne as suitable land has already been sold or developed for other uses, so the opportunity is lost in these cities. Urban encroachment has significantly impacted the Port Botany industrial park precinct in Sydney, costing tens of thousands of ongoing jobs and losing tens of billions per year in economic earnings. Sydney's main airport is now in danger of becoming a stranded asset due to urban encroachment and the lack of surrounding industry. Gladstone, Queensland, has a heavy industrial precinct although uses of this precinct are limited. The Eagle Farm Industrial area near the Port of Brisbane is the only other comparable site for potential industrial development, however it lacks some of the advantages of the WTC and its focus is logistics. Ergo, the WTC is the premier location in Australia for development of a world-class industrial park and unlike elsewhere in Australia is perfectly suited for the export market.

The first stage of the Industrial Park could include the land parcel where the Motorplex is located and is bordered by Abercrombie Rd in the East, Anketell Rd in the North, Thomas Road in the South and Rockingham Road in the West.

Ideally the Industrial Park should be providing a higher level of service and support compared to competitor facilities elsewhere in the world. This means potentially providing or facilitating specialist advice on:

- Health and safety
- Customs and clearance services
- Labour and industrial relations
- Government advisory
- Instrumentation, control and automation techniques
- Laboratory, testing and analytical support
- Literature, information, learning and teaching aids
- Materials technology and testing
- Mechanical processes
- Pharmaceutical, packaging and storage techniques
- Shipping
- Research and Innovation

Ultimately, it is about supporting companies operating within the Industrial Park in a cost-effective way. The importance of management being flexible to changing conditions should not be under-estimated.

A comparative analysis with successful international industrial parks could be completed with identified strengths implemented into the new park and identified weaknesses improved upon.

6.5 Industrial Parks, Local Government and State Government

Industry is restricted to certain specific locations that offer utilities, infrastructure and market access. These restrictions are not a concern for the overwhelming majority of residential development and zoning. It is well understood that urban encroachment on industrial areas severely hampers or restricts economic activities and protection of industrial land for development and expansion will be necessary for Lithium Valley.

Industrial parks are powerhouses of industrial activity and job creation. Apart from generating billions of dollars of revenues per year each new job created in the industrial area or around the port has a positive indirect multiplier impact of approximately 2.5 new indirect jobs being created. Residential developments can assist in creating knowledge economy centres and sub centres; however industrial areas provide a wider diversification of job opportunities especially for higher paying jobs. Industrial Parks naturally attract people wanting to live near their employment and centres of activity and it is critical that industrial and residential zoning is managed better in the future than in the past. In extreme situations residential encroachment can force the closure or relocation offshore of affected industries.

Only the State Government is able to make strategic decisions about what is best for the State. In strategically important areas like the Western Trade Coast interviews with industry leaders stated that local government does not have the resources, experience, competencies or overview to appropriately govern these areas, although a local perspective is always necessary to be involved. This is why this report proposes a Specialised Industrial Park to protect the region for future generations as well as transferring planning powers to a specialist government body for strategically important areas like the Western Trade Coast. This will hopefully ensure that there is sufficient industrial land in the future and that the region operates for the benefit of the State and Nation whilst working in partnership with local government and the community.

"The Western Trade Coast is a cornerstone of the WA economy and one of the most interconnected industrial precincts in the world. It is an unrecognised global leader in industrial symbiosis and an Australian economic gem. "

"Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving the physical exchange of materials, water, power, by products, infrastructure, people etc. The key to industrial symbiosis is the collaborative approach to maximising synergies offered by geographic proximity."

Chertow 2000.

6.6 Strengths, Weaknesses, Opportunities and Threats for Lithium Valley at the Western Trade Coast

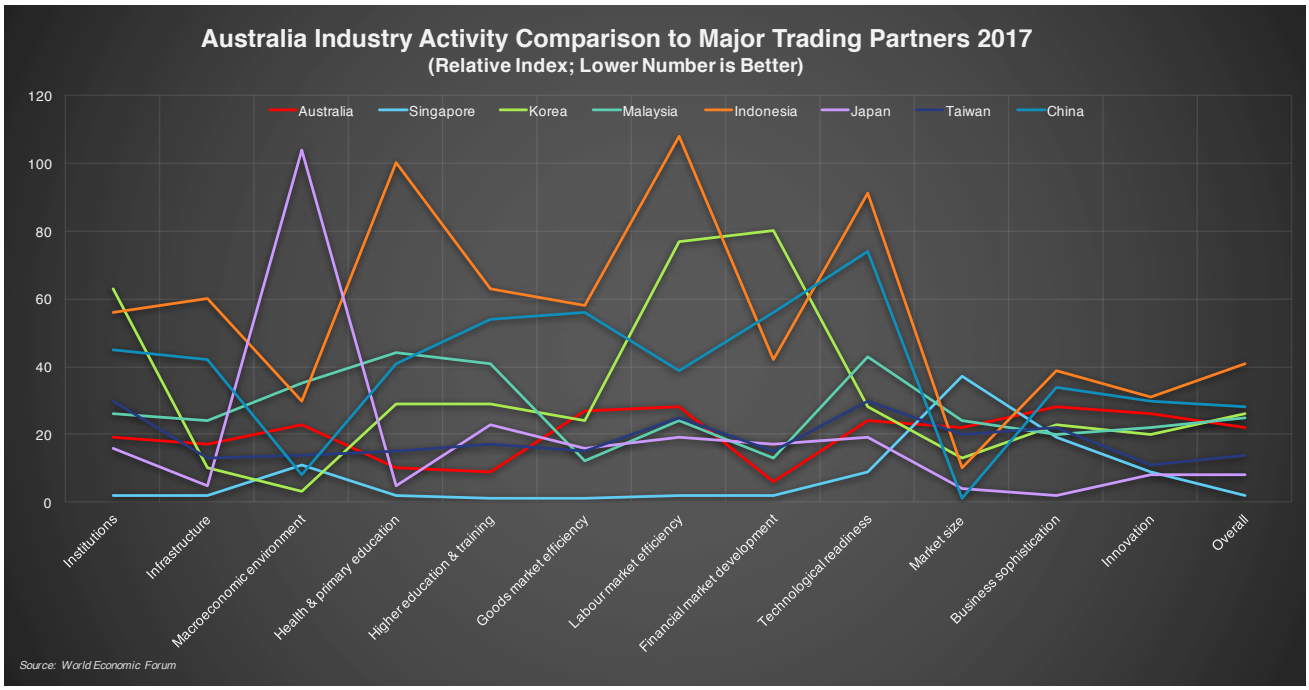
6.6.1. Strengths

In addition to the unique benefits of the WTC, additional strengths for creating the leading global hub for New Energy metals includes:

1	Business Friendly environment – One of the world's leading industrial clusters with a wide variety of raw materials and resources, reagents, a new modern port being developed, land to expand and all utilities.
2	Geopolitically stable location – WA is a politically stable region with few direct threats.
3	Reliable supplier – WA has a long history of being a reliable supplier of high quality resources.
4	Western legal system – Strong property rights and robust intellectual property protection.
5	Environmental regulations – WA has stringent environmental regulations protecting producers and consumers.
6	Industry concentration – Including oil and gas, resources, defence, agriculture and petrochemical production.
7	Government – Dedicated government department (JTSI) reporting to the Premier to facilitate approvals and establish businesses in WA.
8	Speed to Vertical – Fast tracked approvals, rapid integration with existing industry, export ready containers or air freight.
9	Logistics – International quality logistics available through Qube, Toll, DP World, FedEx etc.
10	Infrastructure – Water, power, sewerage, Wi-Fi, gas, roads etc are all available.
11	Supporting industries – Surrounded by a wide variety of established fabrication, testing, reagents, chemicals, health and safety companies, all supporting existing businesses and industries.
12	Community and Education – Internationally recognized universities, with a potential CRC specifically focused on New Energy Industries. Highly qualified workforce. Close to a major city. Regularly voted one of the world's most attractive cities to live. Outstanding arts, cultural attractions and community events.
13	Lower manufacturing costs – Abundant raw materials locally available, lower logistics costs and with an industrial park, lower operational costs.

These strengths require appropriate marketing to foreign companies that most likely are unaware of the advantages of Kwinana, especially the competitive advantage of access to raw materials and symbiotic companies that support high value production and strategic energy metals support.

22 ***Figure 22:*** *Australian corporate governance compared to major trading partners 2017*



The corporate governance comparison to major trading partners (Figure 22) highlights that Australia performs adequately across most categories although there is room for improvement. *The Global Competitiveness Report 2016-17*,[53] prepared by the World Economic Forum, is considered an objective review of the foundations of a country's efficiencies and sophistication. Australia's performance is consistent with strengths in health, education, training and financial development. However, although Australia has made gains in the labour market in recent years, Australia continues to lose competitiveness in innovation and business sophistication.

As Australia is considered to be an innovation-driven economy, the importance of being more involved in new economy products (as opposed to just supplying materials) cannot be overstated. As

53 Schwab, K (2016), The Global Competitiveness Report 2016–2017, World Economic Forum, http://www3.weforum.org/docs/GCR2016-2017/05FullReport/TheGlobalCompetitivenessReport2016-2017_FINAL.pdf. (Accessed: 01 May 2018)

"WA has plenty of domestic gas. It is affordable and at competitive prices in huge contrast to the east coast. This is an underplayed story that WA has a stable energy market for business development. It is a massive advantage for WA to offer affordable, long term gas/energy contracts to international manufacturing companies."

Mark Pownall – CEO WA Business. Mark My Words - 5 May 2018 – Soundcloud

Australia's trading partners continue to improve, ongoing domestic reforms to improve competitiveness need to be prioritised.

6.6.2. Weaknesses

Based on recent interviews, industry highlighted a lack of departmental focus and a lack of understanding of business commercial drivers as obstacles to industry growth and development. There is heavy competition between regional industrial parks with different parts of government favouring regional sites at Kemerton, Geraldton, Pilbara, Goldfields-Esperance and the Kimberley. However, while there is a strong need to deliver economic development to these sites and their communities, significant investment needs to be considered, or at least, clearing the basic environmental approvals to make them viable and attractive for companies to move there. In the meantime, the WTC has the necessary approvals, infrastructure and workforce to kickstart the Lithium Valley concept.

According to industry, the greatest weakness that has impacted the WTC region for decades has been a lack of a coherent focus from both the State and local governments. Inconsistent planning has allowed increasing urban (residential) encroachment around industrial areas, blocked and curtailed investment, reduced international competitiveness, stunted supply chains and impacted operations. A more co-ordinated government approach is required to allow the region to grow and develop more effectively.

Moving the focus of regulations from prescriptive to objective could result in a transfer of the risk from the government to the private sector. This may be through reducing monitoring costs, improving risk management as the private sector is better equipped and resourced to manage the risks, and the refocusing of government staff from routine compliance monitoring to the proactive development of sensible regulation frameworks.

Industry and WA in general often has a customer concentration risk, that is, relying upon one or a couple of key countries for sales. With New Energy metals and downstream processing there is the opportunity to mitigate country concentration risk and diversify across a wider range of global customers, which is why the EU is important.

Additional weaknesses include supply chain capacity and costs, limited vacant land, lack of exports, and capacity issues at the existing berths. These are all symptoms of the same issue, which is the lack of international competitiveness. WA is suffering from a lack of scale. In the past the domestic population has been the main demand driver for Kwinana infrastructure development, apart from the big international developments like Alcoa, BP, Tronox, Nickel West, etc. This domestic focus has meant smaller-scale supply chains and facilities resulting in lower volumes and higher costs. The delivery of greater volumes of products requires new production, supply chains and operational facilities. How this can be developed is a critical part of the development process for the industrial park.

Industry consultation has highlighted the lack of government incentives compared to other States like Victoria or South Australia, or other countries such as Malaysia and Singapore. WA needs to be more proactive and potentially offer incentives for strategic companies and industries and generally be more proactive and aggressive. Because of the importance of New Energy metals, other countries and even other Australian states will make every effort to entice companies away from WA if the State Government continues to be complacent and underestimate the competition.

6.6.3. Opportunities

New Energy metals and battery manufacturing are set to become one of the largest and most important technological waves in human history. The impact of the developing technologies will change every corner of the globe. WA has a major initial advantage with the sourcing of the majority of the key elements locally. In addition, the WTC, the legal and political system and reliable history of exporting only add to WA's competitive advantage in this arena. The opportunity is to inform and attract companies with the necessary intellectual property for secondary processing to WA.

Sixty percent of the world's population lies due north, in the same time zone as WA. This region, including China and South East Asia, has the highest economic growth in the world. As growth shifts to India and Africa as expected, WA and the WTC is ideally positioned to service and support this growth. These countries need the resources and products that WA can and has the opportunity to produce.

The WTC is a major economic zone with an international specialisation in the refining of bulk products. Due to the availability of critical raw materials, energy supplies, technical expertise and the other benefits previously mentioned, WA has a suite of strong competitive advantages for secondary processing. Some of these sectors can be expanded, while others developed into a full collection of New Energy industries associated with Lithium Valley.

> **"Business networks continue to become more complex and organisations more and more integrated. It is not organisations that are competing but international supply chains to meet ever more demanding customers."**
>
> *Christopher 1996*

6.6.3.1. Port Infrastructure Development and Governance of the WTC

The development of the new port at Kwinana is important for the development of the New Energy metals industry as it will provide high capacity, modernised port facilities, greatly improving import and export capability. In turn, the expected improvement of the logistics in the WTC allows for greater efficiencies to be captured across the entire supply chain.[54]

The port operations can be a way of increasing the value of the real estate, as the new port would generate development of the WTC. That is where the real money and value is, in the development of the land. In addition, the establishment of a SIP within the WTC would make access to a port attractive to new investment but it has to be integrated with land parcels because that is where the value is. The Government continues to own the land on which the port and industrial development occurs and grants leases or long term concessions over parcels including transport, land and port access to maximise vertical integration options and supply chain efficiencies. Ideally, there should be only one body responsible for the Government interface, especially when a SIP is established with a focus on New Energy Industries. This would speed up approvals while also reducing costs and at the same time it would also be expected to improve compliance with regulations. It is recommended and considered critical that a statutory authority be established for the whole of the WTC or the Industrial Lands Authority mandates a special purpose vehicle under their restructuring specifically to manage the entire WTC.

This statutory authority may zone a portion of the WTC for Lithium Valley and mandate a professional dedicated management team (similar to AMC) to develop, manage and market to local and foreign companies. There is a strong incentive for this to occur as quickly as possible due to the speed of international developments in the New Energy metals industry. Services would include providing a plug and play solution covering specifics such as approvals, utilities, visas, industrial relation services, and other opportunities to facilitate companies locating to region. Professional management, appropriately incentivised with a proactive commercial Business Development

54 Christopher, Martin (2015), "Supply chains compete, not companies", husdal.com, 02 October 2015, http://www.husdal.com/2008/04/22/supply-chains-compete-not-companies/. (Accessed: 30 May 2018)

"If Albemarle, Tianqi and SQM realise their projections for 2022 in terms of lithium metal equivalent (LME), that means there will be around 240,000 tonnes of LME, which would fill approximately 12,000 TEU going from Kwinana into the Fremantle Port. If all by train, that's the same as around 126 additional train movements over a year (each train at the maximum allowable of 95 TEUs), or if all by road, anywhere between 6,000 – 12,000 (dual or single) additional trucks. Per week, that's 115 - 230 trucks or 2.5 train movements. This assessment does not include any other input or output (including waste materials) necessary to manufacture the LME. These volumes and future volumes are not included in current State Government trade or freight forecasts although they were included in the Kwinana Industries Council Trade flow forecasts 2017."

Infranomics 2018

focus is critical for a successful industrial park.

Following the establishment of Lithium Valley, the statutory authority may grant a lease on land within the WTC and or/ grant long-term concessions that provides a steady upfront revenue stream and growing capital for expansion as was done with the Perth Airport. The parcels for lease, owned by Government, should be large; for instance all the WTC should be one or two parcels to maximise development and expansion opportunities. The zoning would allow the concession or lease holders to consolidate smaller privately owned parcels so that the operations and efficiencies within the industrial park are maximized. The zoning and variety of government authorities needs to be simplified to derisk the region for investors. Ideally, concessions should be granted to Australian Superannuation funds that have the funds, governance and operational expertise to manage these types of assets. The concessions should be long, for instance 50 years as a minimum, to justify the infrastructure investment needed. The land becomes a long-term asset, generating long-term revenue back to the State and appropriate regulatory control over the lessee. Failure to uphold the quality standards set by Government, or agree suitable business plans, allows the option to cancel the lease. Government sets the regulations and the rules, thus maintaining control, while generating upfront cash and increasing revenues. The concession or lease holder would regularly have to submit strategic plans, such as every 5 years, to demonstrate suitable growth and development of the industrial park and surrounding region. This is a common approach around the world and therefore there are plenty of examples to refer to, for instance Perth Airport.

The development of the Lithium Valley and the new port at Kwinana has the potential to spur a massive economic surge that can drive down state debt. As the ultimate landlord, the Government retains control over the lessees.

State infrastructure planning has suffered from having no overarching long-term strategy as agencies, such as Fremantle Port Authority, LandCorp or Department of Transport each have different areas of focus and therefore risks misaligned objectives. It is hoped that

Infrastructure Western Australia is tasked to resolve this issue as part of a strategic infrastructure plan.

While there may remain incremental capacity and efficiency improvement opportunities at Fremantle Port, the Fremantle Port effectively reached its optimal economic capacity years ago and is strategically limited by rail access and stranded by urban encroachment, both of which cannot be reversed. What remains are higher costs, diminishing returns and lower international competitiveness. Most of all, Fremantle no longer has the industrial land available to enable an initiative like Lithium Valley or any other large scale industry to develop. It is imperative that the State looks forward to the modern, fully integrated, internationally competitive new port in Kwinana.

6.6.3.2. Develop Western Australia's soft power

Soft power is the ability to influence the behaviour or thinking of others through the power of attraction and ideas. This is vital to WA's international policy. A defining feature of soft power is that it is non-coercive; the currency of soft power is culture, political values and foreign policies. WA's democracy, rule of law, strong economy, quality education, cutting-edge science, food and agricultural standards, multiculturalism, and environmental protections are all sources of influence.

These facets underpin WA's ability to attract capital and talent from around the world. This is especially important considering WA has the complete list of Critical Raw Materials published by the EU (apart from coking coal and natural rubber, which can be grown in WA). The State Government has the opportunity to build a greater presence in Europe, Africa and India so that WA becomes an international supplier of choice that will help both parties to diversify.

There is an opportunity to build upon WA's soft power advantages so that exporters can develop new markets or expand existing ones. The notion of Lithium Valley can become part of WA's branding and hence part of this soft power approach.

6.6.3.3. Development of Intellectual Property

Local universities and institutes are widely praised for their research and technology. The application of this research and development into local industry to maximise the benefits locally is not as successful as it could be.

There is an opportunity to integrate universities and industry into a business cluster, serviced by universities and a CRC focusing on the New Energy Industry. This will assist in the process of technology transfer between academic and industrial parties while ensuring high quality and evolving products are produced.

There is currently a lack of information on New Energy metals and related products particularly in the processing and application markets. Without sufficient information gathering and analysis, then decision making by government and industry will be sub-optimal. If greater emphasis is placed on information gathering and analysis this will enable better decision making and resource allocation.

There is also an opportunity for Australian Bureau of Statistics and Geosciences Australia to prioritise exploration research, enhanced data assemblies, identified economic reserves, extraction rates, processing rates, export rates and all prices and incentives to better identify, capture and manage WA's finite strategic resources for domestic reservation.

6.6.3.4. Increased Mining Investment

WA has many local advantages including supply reliability, logistics, local skills, local research and development, access to domestic and international markets, rapid approvals, transparent regulatory system and more. However, WA does not have any existing operations that deliver key value-add to new energy components such as batteries or permanent magnets.

Building on the work of this report, there is an opportunity to identify and engage with the prospective key processing companies at the most senior level possible. This engagement includes clearly summarising the offering of WA, how WA can assist the companies to grow and surpass their competitors while also mitigating supply chain, geopolitical or raw material sourcing risk. Particular attention

should be made to break down information silos and work towards shared goals. A commercial approach should be taken rather than a political process approach.

WA has the opportunity to aggressively target local investment from international companies that already have commercially successful intellectual property and production processes in WA's value-chain gaps and foster long-term links between these strategic companies and local research and development organisations to build the next generation of intellectual property in the sector.

As JTSI is the lead agency for economic development, international trade and investment as well as reporting to the Premier, it is the obvious government department to be responsible for the development of a strategic resources industry.

6.6.3.5. Wastewater capture and re-use

Treated wastewater with reduced dissolved salt content is a valuable and expensive commodity. Yet, much of the treated water in WA is being pumped back out to sea. WaterCorp is part of the Managed Aquifer Recharge study process that has demonstrated that treated water can be safely injected into aquifers. In a land where water is a limited resource there are obvious economic, social and environmental benefits of reusing this water.

The Kwinana Wastewater Recycling Plant (KWRP) is the cornerstone initiative in WaterCorp's plan to reduce the amount of scheme water consumed in the Kwinana Industrial Area. There is an opportunity to increase KWRP's current nameplate capacity by 60%, to produce recycled water that could be used within WTC, which is an essential resource for the manufacture of New Energy metals. There is the potential for the cost of additional recycled water to be funded by industry if policy can be developed where treated wastewater leaving the Woodman Point Waste Water Treatment Plant is further recycled to specific industry standards onsite where a company is located. This option could reduce the cost and open up similar opportunities in agriculture.

6.6.3.6. Threats

All countries that have high technology aspirations are devoting immense resources towards controlling the New Energy metal supply chain. Recent reports from the EU and the US show that China has been methodically executing a long-term strategy in this field for a number of years. Korea, China, Japan, Taiwan, Singapore, Malaysia all seek to control the supply chain as it is fundamental to products that underpin their economies and security. Other countries and regions have New Energy metals, but no other region has the abundance and variety of resources such as in WA.

A major threat highlighted in industry interviews was the siloed approach across departments and the inability for bureaucracy to be nimble and proactive compared to other jurisdictions. Companies have no sovereign loyalties and will move to whichever jurisdiction offers the best commercial terms. WA needs to demonstrate that it offers the best overall commercial terms and risk profile while ensuring strategic risks are managed by local suppliers of New Energy metals.

Industry feedback indicated that the greatest threat to economic development is failing to improve the competitive efficiency of the supply chains, of which the Kwinana port is a fundamental requirement. The new port at Kwinana provides the greatest opportunity to expand scale, reduce costs, develop new businesses or become more internationally competitive.

Additional major threats are continued urban encroachment, technological obsolescence, inconsistencies between local and state planning, security, transfer of production facilities to other states or countries, and bureaucratic process and approval delays. Recently South Australia has been seen as very proactive toward industry. Without exception, companies interviewed said it is easier to gain necessary approvals in SA than compared to WA.

Without continual reduction in capital or operational costs and improvement in local infrastructure, companies in the region will risk falling behind their international competitors. This in turn threatens the on-going operations of companies in the region, with the consequent risk of either relocation or closing down of their operations.

6.7 Private Sector Investment and Public Private Partnerships

It is expected that a development of this scale will only happen if it can involve a significant amount of investment from the private sector. Most projects will involve private sector investment and potentially a portion of government land and there is likely to be several opportunities to engage in Public Private Partnerships (PPP). This is not only true for the New Energy metals sector but also the development of the new port at Kwinana and any access routes that may be needed.

In recent years PPPs have emerged as the preferred model to harness greater private investment participation in infrastructure development and most importantly, to access specialised skills, innovation, new technologies associated with infrastructure development, operations and maintenance. The increasing technical, systems and financial demands have been driven by the increasingly prominent role of the private sector, both as a source of finance and provider of services required for the successful operation of ports. This has had an impact on ownership and operating structures.

Well known examples of PPPs in WA are the Fremantle container terminal and the AMC, where the State Government is the 'landlord' and private companies are the stevedores or industrial park management. This landlord model approach is widely recognised as being an effective method of managing port operations or industrial parks around the world. Different management structures are used worldwide, but in the majority of large and medium sized industrial parks the landlord port model is used. For instance, 85–90% of global ports are landlord ports, which account for about 65–70% of global container port throughput. In this model, management responsibilities are delegated to the private sector, while the title in the land and assets remains with the Government. These industrial parks benefit from the operational expertise of the private terminal operators, experience of staff, and access to capital, systems, processes and customers.

In a typical landlord model, the Government or State-owned body owns and manages the land and basic infrastructure, including common facilities such as roads, transmission lines, water pipelines etc. The private sector usually has a term concession and is responsible for industrial park operations and related investments such as buildings, common user facilities etc. Concessions are generally awarded on a leasehold basis for 20 to 50 years (plus option) to justify the private sector investment and may include the rehabilitation or construction of infrastructure by the concessionaire. Concessions enable governments to retain ultimate ownership of the land, control over operations on the land, as well as safeguarding public interests. At the same time, they relieve governments of the substantial operational risks and financial burdens. Private investments tend to range from minimum stakes of 20% through to full financing, depending on the host country.

There is usually significant legal complexity associated with PPPs, as a number of operational issues and procedures are involved, requiring an understanding of local conditions by the private sector however these issues are justified by the long terms benefits. Therefore, if the industrial park is developed under a PPP model, the Government may need to conduct a comprehensive review of the legal and regulatory framework governing the port sector in order to determine whether amendments to existing laws may be necessary or whether new legislation is required.

Achieving efficiency gains, a key objective of PPPs, depends on how risks and responsibilities are transferred between the public sector to the private sector, according to the principle that risks should be borne by the party best able to manage them. Detailed risk analysis and appropriate risk allocation between the public and private sectors are paramount to achieving a win-win partnership for both parties.

The Perth Airport model is another example of a PPP. The Government owns the land, with all land and operations being regulated by the Airports Act. This could be a suitable model for the WTC as superannuation funds manage the facilities and contribute capital. The investors ensure companies have their own facilities to ensure vertical integration. The superfunds are incentivised to maximise throughput, which is required at the WTC as well. Although this SWOT analysis has been primarily focused on the WTC, there exists opportunities to replicate these processes across other strategic industrial areas identified by the state as well as their ports for Lithium Valley to expand state-wide.

6.8 Oakajee: Future e-cycling Facility for the Indo-Pacific Region

Oakajee is located approximately 23km north of the major regional centre of the City of Greater Geraldton in Western Australia. Geraldton is located 420km north of Perth (approximately 4.5-hour drive) and has freight rail access. The future Oakajee Port and the surrounding Strategic Industrial Area (SIA) has been identified in the past by previous State Governments as an international gateway to service the Mid-West region. The port and SIA would cover approximately 6,400ha and have the potential to service and support many existing and future industries in the Mid-West region, including export-orientated mineral resources and heavy industrial activities in the 1,100ha industrial core. The Oakajee Port development was suspended for a variety of reasons.

In 2018, there is virtually no global recycling of lithium or other New Energy metals as the industry has only recently developed and most batteries end up in landfill. However, as industry grows the volume of end of life batteries will force countries to recycle, especially as there are a variety of New Energy metals in a battery that would yield additional value through the process.

There is an opportunity to develop an international battery recycling business in WA to target this long-term problem of modern society as well as developing a new industry for processing the materials. Oakajee could be the location for this processing. This would allow WA to provide a 'cradle to grave' strategy for all New Energy metals allowing greater supply and hedging options. As well there is the potential to create a whole new industry in regional WA with private sector funding and government enabling the development. The catalyst is securing long term e-waste contracts to underpin the development.

The advantages of recycling in Geraldton - Oakajee are:

- Excellent port import/export access as the batteries will be sourced internationally and the converted materials sold internationally.
- Access to reagents and chemicals for processing. These can be sourced from Kwinana or imported as already occurring in regional mineral processing.
- Available technical and specialist staff. There are critical processes requiring specialised chemical engineering and processing skills available locally.
- Support from local fabrication, testing, training, process and other related industries.
- An opportunity to recycle all the batteries from the Square Kilometre Array and other space related programs. This will provide an initial base load of product.
- Potentially processing of raw ores to increase the scale and diversity of the operations.

To develop this a long-term supply of e-waste needs to be secured to justify the investment in the Industrial Park facilities. In the deal with the EU proposed in Section 5.2, a long term, say 50-year, supply agreement for e-waste is proposed as this provides the cornerstone agreement for long-term materials supply.

In recent years, hi-tech waste has been exported to China for recycling or sent to landfill in developing countries in Africa. Dumping e-waste in Africa is often unethical and environmentally unsustainable and China has recently blocked importing waste so Australia will soon be forced to find alternative solutions to processing locally produced waste. Hi-tech recycling in Australia is an under-developed industry, relying on a history of largely voluntary recycling programs, combined with bulk export of e-waste for overseas processing.

Some overarching drivers impact the sector:

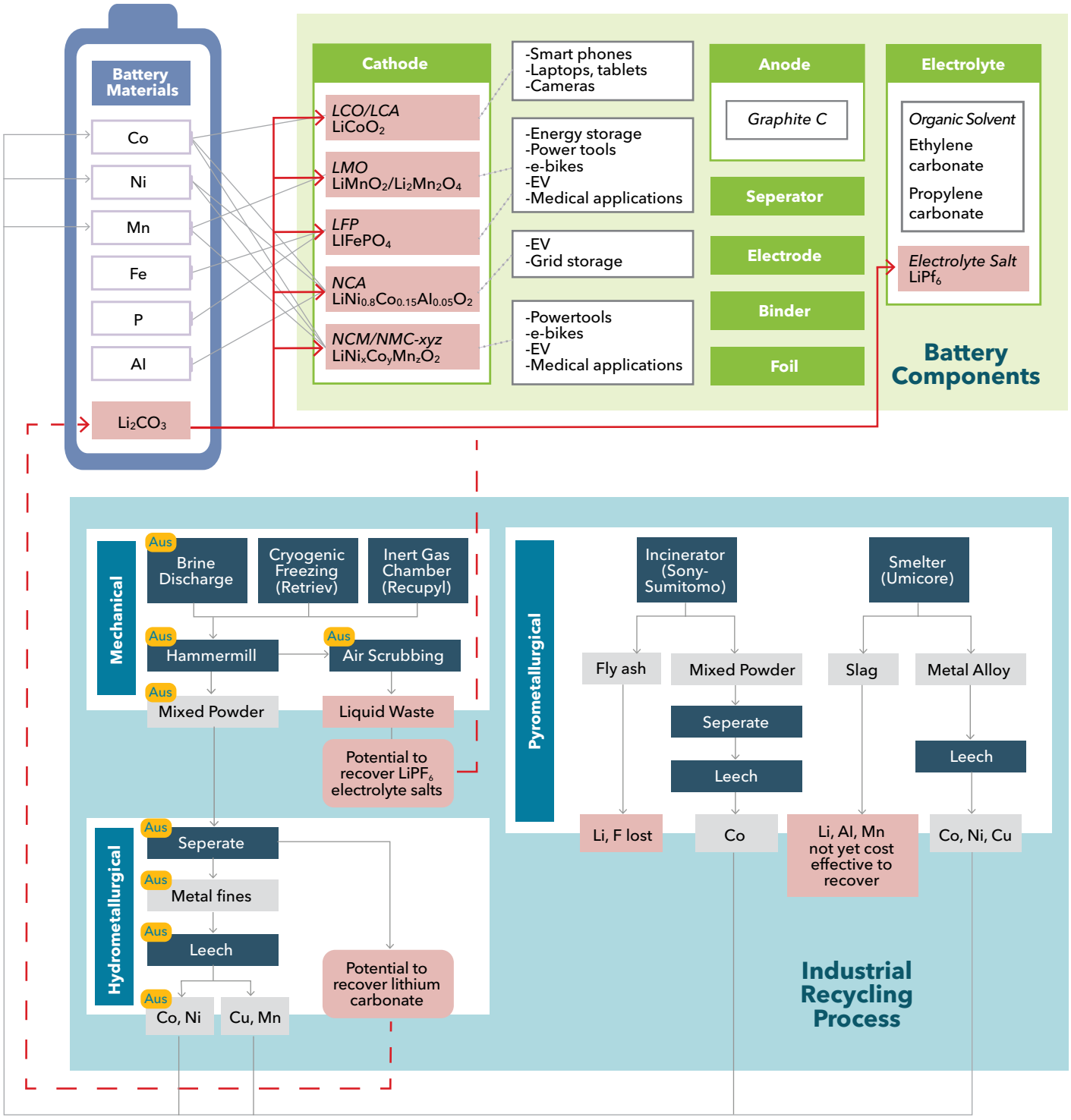
- The difficulty (mechanical and chemical) of extracting individual high-value materials from a complex manufactured end-of-life product (Figure 23);
- The low concentration of high-value materials;
- The vast range of embedded materials;
- The hazardous, reactive and/or toxic nature of many of these materials;
- The low profitability of unsubsidized broad-based recycling;
- The significant push-back from e-waste destination countries against future processing;
- The exponential increase in e-waste volumes as the global energy economy transitions;
- Landfill charges are low and do not reflect environmental, zoning or social impacts.

Early recognition of these issues came from the United Nations, resulting in the development of governance positions on the practice of international "trade" in e-waste.[55] The principles of this Basel Convention on the movement and disposal of hazardous wastes supports the safe domestic recycling of all Australian (and imported) waste, including e-waste.

It is important that waste is reframed from being a negative and useless product to a source of raw materials and of value. New technologies have transformed the entire waste process spectrum and there is the opportunity to capture this value locally. Figure 23 sets out the value chain where recycling can be conducted.

55 United Nations Environment Program (2014), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, *http://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf*. (Accessed: 01 May 2018)

23 ***Figure 23:*** *2018 status of global and Australian industrial-scale LIB recycling technologies*



Source: Future Smart Strategies (2018)

Australia has one of the lowest battery recycling rates in the world with only three percent of waste batteries recycled in 2017 with lithium batteries being sent offshore for recycling.[56]

Currently there is only one company that recycles lithium ion batteries domestically, using a hydrometallurgical process to recover cobalt and nickel.[57]

To encourage the recycling of all types of lithium ion batteries (rather than only high cobalt or nickel battery chemistries) the economic and regulatory conditions have to improve to create a cost incentive for recycling. To develop a self-sustaining recycling industry, assurance of recycling volumes is required. This would require importing from overseas, the establishment of a national collection network and recycling scheme to facilitate a centralised collection process and to redistribute battery waste to various battery recycling companies. A CRC for New Energy metals would also be expected to increase recycling opportunities.

Due to the serious environmental, health and safety risks, and government deadlines for banning e-waste from landfill, the acceptance of lithium ion batteries in landfills needs to be discouraged.[58] Many such schemes are already in place in other countries, most notably in the EU [59] and Japan [60] where all producers of batteries are required to fund battery collection schemes, that covers both the cost of the collection network and the cost of recycling their batteries. In Australia, the *National Television and Computer Recycling Scheme* and *National Tyre Product Stewardship Scheme* can be used as policy frameworks for an Australian battery stewardship scheme. The Australian Battery Recycling Initiative (ABRI) are currently negotiating with State and Federal Ministers for Environment to establish a national stewardship program for handheld batteries.[61]

There is an opportunity to reduce both the funding costs of a national battery recycling scheme and the cost of battery metals, by integrating a domestic recycling industry with domestic lithium ion battery manufacturers. Establishing the means to develop a circular economy in the lithium sector would provide a competitive advantage for Australian clean energy exports. Importing e-waste and extracting the minerals also positively supports local industry and concentrates the knowledge locally.

The development of specialised battery resource facilities will require significant State Government investment to address some of the short comings of the location. A clear strategy and business plan with a detailed project plan should be developed. Ideally, this should be led by experienced commercial people with complimentary industrial knowledge. The quantum of this financial assistance would need to be determined as part of the Business Case.

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56 Energy Matters (2018), "Australia's first lithium battery recycling plant opens in Victoria", 02 May 2018, Energy Matters, https://www.energymatters.com.au/renewable-news/australia-lithium-battery-recycling-victoria/. (Accessed: 07 May 2018)

57 Waste Management Review (2018), "Australia's first lithium battery recycling plant opens", 27 April 2018, Waste Management Review, http://wastemanagementreview.com.au/australias-first-lithium-battery-recycling-plant-opens/. (Accessed: 01 May 2018)

58 Victoria State Government (2018), Waste Management Policy (e-waste) 2018 (Policy), Engage Victoria, https://engage.vic.gov.au/application/files/2515/0837/0565/Draft_WMP_E-waste_FINAL.pdf. (Accessed: 01 May 2018)

59 European Union, (2013), DIRECTIVE 2006/66/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, Amended 20 November 2013, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006L0066-20131230andrid=1. (Accessed: 01 May 2018)

60 Ministry of the Environment (2001), Law on the Promotion of Effective Utilization of Resources, Government of Japan, https://www.env.go.jp/en/laws/recycle/06.pdf. (Accessed: 01 May 2018)

61 Australian Battery Recycling Initiative (2015), ABRI urges Environment Ministers to support battery stewardship, 13 July 2015, http://www.batteryrecycling.org.au/wp-content/uploads/2015/07/150713-Call-for-Ministers-to-Support-Battery-Recycling.pdf. (Accessed 01 May 2018).

7

ECONOMIC BENEFITS

7 Economic Benefits of Establishing Lithium Valley

When capturing economic benefits for the State from the New Energy metals value chain, there are three (3) distinct stages of economic and social development that need to be considered:

- Mining operations;
- Refining operations; and,
- Secondary processing.

Secondary processing is by far the most important due to synergies with other industries, the higher value capture and the social benefits generated. Specifically, the economic contributions were computed for lithium battery manufacturing in terms of employment, wages and benefits and investment.

7.1 Results of Economic Analysis

The focus is the development of projects and facilities in relation to the New Energy metals market in WA including construction, mining operations and secondary processing facilities.

The results of the analysis in Table 5 are based on actual figures from 2017 and forecasts are until 2025.

Lithium Mine Processing Plant Western Australia.

Table 5: ***Estimated Potential Employment Generation and Capital Investment from Developing the WA Energy Metals Industry***

Energy metals - lithium, cobalt, nickel, rare earths and vanadium		
Employment		
Current employment in the energy metals sector - 2017	Actual	7,291
Expected growth in direct employees until 2025	Estimate	21,480
Forecast employment in the energy metals sector - 2025		
Direct - Full Time Employment 2025	Estimate	28,771
Indirect employment 2025 - multiplier 2.5	Estimate	71,927
Total energy metals sector employment 2025	Estimate	100,698
Employee wages in 2025	Estimate billions per annum	A$3.33
Payroll taxes 2025	Estimate millions per annum	A$183.30
Economic contribution from the energy metals sector		
Economic contribution from the energy metals 2016/2017	Estimate billions per annum	A$2.97
Potential Economic contribution mine, refining and 10% of electrochemical production per annum 2024/2025	Estimate billions per annum	A$56.52
Capital investment for the energy metals sector		
Capital investment forecast for new mines, refining facilities	Estimate billions until 2025	A$13.81
Capital investment forecast for new mines, refining facilities, secondary processing and recycling	Estimate billions until 2025	A$34.11

Source: InfraNomics 2018. All estimates are in nominal values.

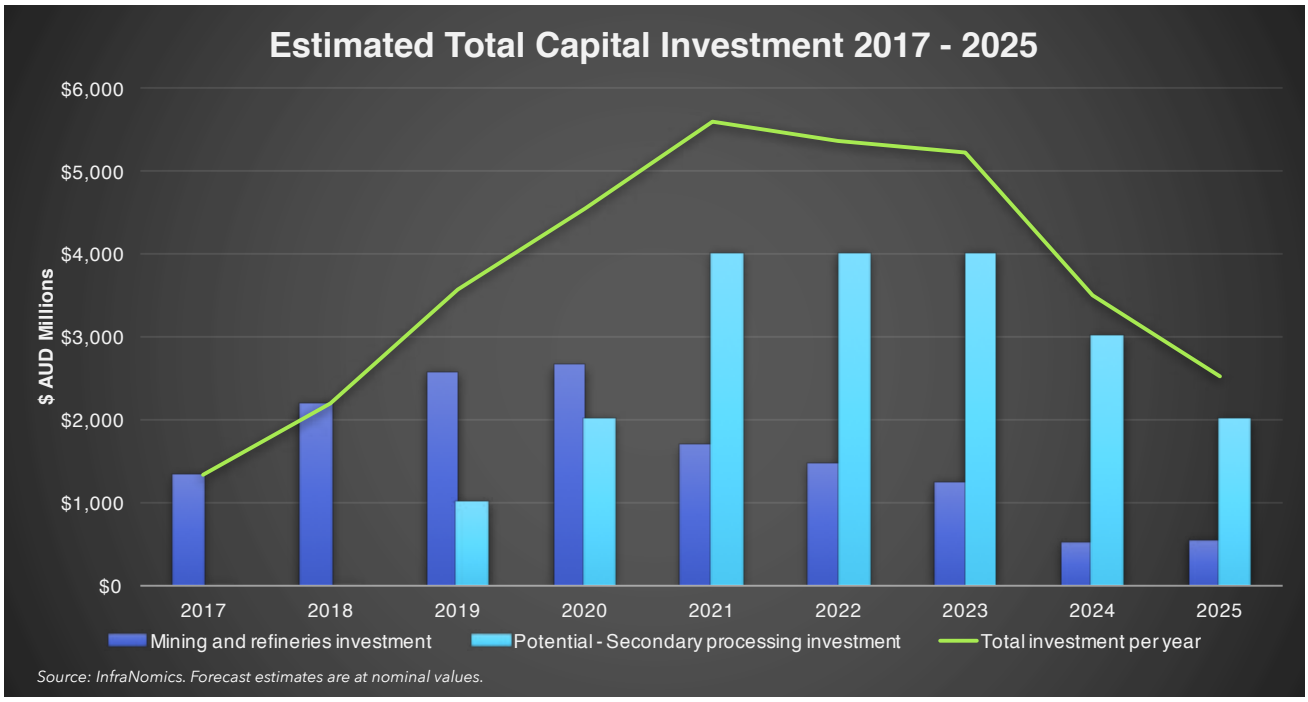
According to researchers at Sanford C. Bernstein and Co the total investment globally in new lithium mines will likely range from US$350 billion to US$750 billion.[62] The forecast shown in Table 5 assumes investment into mines and basic refining in WA will be approximately A$13.8 billion which represents between 3% and 1.4% of the total global investment in this area and

62 PR Newswire (2018), Breakthrough Technology Could Unlock $84 Billion Worth Of Trapped Lithium, CISION PR Newswire, 19 March 2018, *https://www.prnewswire.com/news-releases/breakthrough-technology-could-unlock-84-billion-worth-of-trapped-lithium-677259183.html*. (Accessed: 01 May 2018)

this indicates that there is potential for significantly more investment in WA. If only 10% of this investment forecast range is invested in Australia then this would amount to A$45 – A$97 billion. In turn this would substantially alter the forecasts in this report in a positive manner. In addition to lithium there are investments into other minerals to support the industrial transformation currently underway.

According to the Lithium Value Chain diagram in Figure 8, over US$297 billion (A$385 billion), of value will be created in the electro-chemical processing industries. Western Australia has the potential to capture approximately 10% of this market (A$38.6 billion) and would be in addition to the normal mining and refining. These cell components include the production of cathode materials, anode materials, electrolytes, separators and other battery related materials. The forecast is estimated to be up to A$20 billion into these cell components until 2025 and follows the availability of raw materials from the refineries being built.

24 ***Figure 24:*** *Estimate of capital investment 2018 – 2025*



> **"The investment in mining and refineries is already underway based on decisions made several years ago. It is this second wave of secondary processing investment that is starting and is currently in this investment decision window that WA needs to target. Companies and countries are currently making multi-billion decisions on where to locate secondary processing and assembly plants around the world. It is these plants that WA needs to target in 2018 as the investment decision window will likely close sometime in 2019. Without the WA government, industry and community working together in the most competitive of global markets, the opportunity will be taken elsewhere."**

25 ***Figure 25:*** *Energy Metals Industry Development Full Time Employee Forecast*

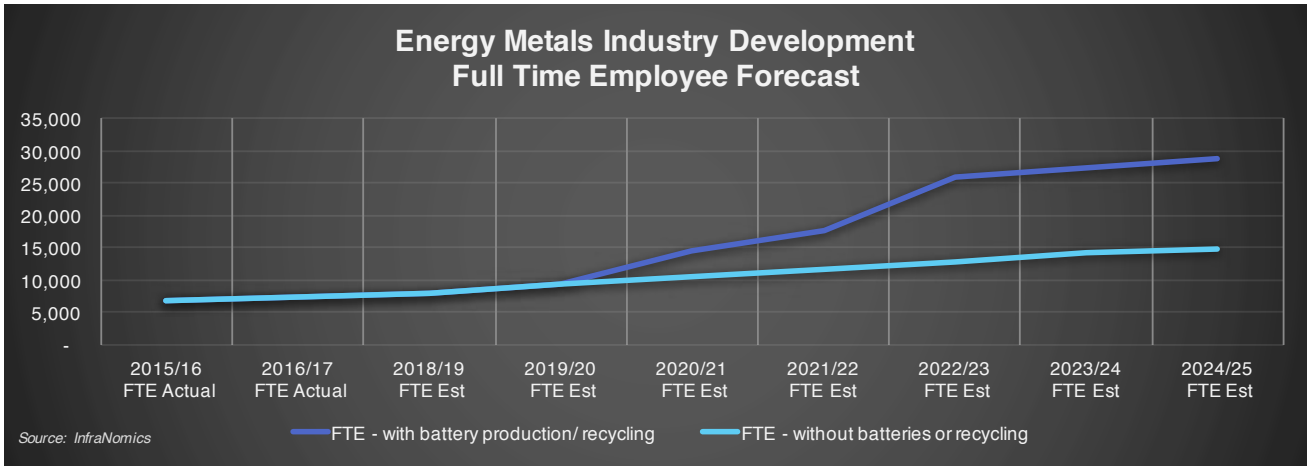


Figure 25 is a chart showing estimated growth of employment in the New Energy metals industry including if batteries are produced and recycled in WA. The impact of battery production is significant to WA but globally this is minor. As secondary processing are higher paying jobs than normal mining operations then there is a positive multiplier effect throughout the community.

In addition to the existing projects in WA and the forecast projects there is also the opportunity to secure battery production facilities focusing on the export market. Building upon WA's ability to secure supply for raw materials, advantageous supply chain location, industrial hubs and other advantages there is a very real prospect of battery facilities being located in WA. The capital investment forecasts are referenced to existing and planned local projects, new projects in Chile and the EU as well as estimates for new plant costs in the future.

In this economic impact assessment, the focus has been on employment, wages, capital expenditure and government tax revenue. The impact on the wider community or synergies with other sectors or companies was outside the scope of this report and has thus been omitted. The modelling of indirect (flow-on) economic impacts arising from estimates of direct economic impacts have been considered at State level. However, due to

> **"Instead of just digging it up and shipping it out, the plan is to do a lot of minerals processing in Australia, which would produce a rare earth composite product that's high in purity. We really think there's much more value-add to be had by doing downstream processing, and Australia is the perfect place to do that."**
>
> *Gavin Lockyer - Arafura Resources*
> *ABC News*

New Energy metals concentration in regional areas, there will likely be a profound impact upon regional communities, especially where primary processing is localised.

During the review we have considered input-output (I-O) modelling, partial equilibrium analysis and computable general equilibrium analysis where information is available or can be reliably forecast and the results are included in this report.

7.2 Current and estimated future contribution to gross domestic product

WA is in the enviable position of having an abundance of New Energy metals. The New Energy metals found in WA that will be discussed in the economic analysis include, but are not limited to the following:

- Lithium
- Cobalt
- Nickel
- Manganese
- Vanadium
- Rare Earths

The Department of Mines, Industry Regulation and Safety WA (DMIS) provides export data for a number of energy metal commodities. Table 6 outlines the quantity and value based on this data:

Table 6: ***Export data: Energy metal commodities***

Commodity	Qty 2015/16 (kt)	Value 2015/16 (A$m)	% of value	Qty 2016/17 (kt)	Value 2016/17 (A$m)	% of value
Lithium (Spodumene)	417,286	$242.0	9%	866,422	$601.5	20%
Cobalt	5,479	$174.8	6%	4,732	$237.5	8%
Nickel	175,752	$2,202.7	80%	157,429	$2,081.1	70%
Manganese Ore	425,303	$146.2	5%	236,470	$57.0	2%
Total	**1,023,820**	**$2,765.7**	**100%**	**1,265,053**	**$2,977.1**	**100%**

Source: Department of Mines, Industry Regulation and Safety, WA

As can be seen in Table 6, the importance of lithium is increasing dramatically and this is only the low grade, low value spodumene. Higher grade lithium carbonate and hydroxide will be of significantly higher value.

The economic contribution from Section 7.1 is based on actual known projects and likely projects should the industry develop in WA.

7.3 Actual and forecast employment in WA mineral sector - New Energy metals

Construction jobs are expected to increase sharply in the coming years due to the new lithium industry developments. The potential processing factories are likely to be battery manufacturing facilities focussing primarily for the export market. All the New Energy metals are expected to see growth in employment although the main employment growth will be in the lithium sector. Permanent employees are expected to earn a minimum 12% higher wages than construction workers in the New Energy metals industries, and secondary processing is expected to be over 31% higher than construction workers salaries. Based on published data, executive salaries for energy metal companies are higher than comparative resource company salaries on a cash basis.

InfraNomics' analysis forecasts employment generation until 2025 to be approximately 21,480 new full-time positions. Based upon research into employment multipliers, the indirect employment multiplier is expected to be 2.5 and equates to an estimated 53,700 indirect jobs may be created. This brings the total jobs creation opportunity in the sector to 75,180. If this is added to existing direct and indirect jobs this equates to an estimated 100,698 jobs related to this New Energy metals sector by 2025.

The wages paid on the full-time positions are forecast to increase by approximately A$2.45 billion until 2025, from an estimated A$845m in 2016/17, to over A$3.3 billion in 2025. In Western Australia, the payroll tax rate is 5.5%. From 1 July 2016, the annual threshold is $850,000 and the monthly threshold is $70,833. The estimate is that payroll tax collections will increase by approximately A$134 million per annum until 2025, from A$46.5m in 2016/17 to be approximately A$181 million per annum by 2025.

Capital investment in the following New Energy metals lithium, manganese, nickel, rare earths, tin, tantalum and lithium, vanadium, cobalt and titanium is forecast to be a minimum A$13.8 billion until 2025 based upon existing or in development projects. Capital investment in this sector has increased substantially in the last 12 months and is expected to continue as new projects are publicly announced. In addition, if new secondary processing factories were built the total capital investment is forecast to be approximately an additional A$20.3 billion and employ up to 13,000 people. Total forecast potential capital investment of A$34.1 billion also includes the A$13.8 billion for mines and refining as well as A$300 million for recycling facilities which could be developed in Geraldton.

Table 7 highlights employment data, as provided by the Department of Mines, Industry Regulation and Safety, of the proportion of employment of individuals in the energy metal sector.

> **"And we also have a great skill set here in Australia, so let's take it right through to its logical conclusion, which is make the batteries here."**
>
> *Vincent Algar - Australian Vanadium*
> *ABC News*

Table 7: ***Average annual employment in WA mineral sector - New Energy metals***

Mineral	2016-17 NoI*	2016-17 FTE*
Total employed	106,652	84,711
Manganese	0.07%	0.07%
Nickel	5.53%	6.88%
Rare Earths	0.16%	0.15%
Tin, Tantalum and Lithium	1.02%	1.48%
Vanadium - Titanium	0.01%	0.01%
Total - Energy metal	**6.79%**	**8.61%**

*Source: Department of Mines, Industry Regulation and Safety, WA *(NoI = Number of individuals, and FTE = Full time equivalent)*

Although direct energy metal employment in WA makes up a small proportion of overall employment the percentage is expected to rise from approximately 8.6% to approximately 11-13% in the coming years. This percentage may actually be higher depending upon the impact of automation in the traditional resource sector.

7.4 Indirect employment and multipliers

Indirect employment is important when considering the effect differing industries have on wider society and that some industries create more jobs than others. To do this, industry multipliers are often used however it is important to highlight that there are limitations. For instance, multipliers are high level and at best summaries of industries. As well, multipliers assume unlimited supply and stable environments. The Australia Bureau of Statistics discontinued the use of multipliers because of the ongoing debate about how the results were used. The multipliers presented in this report are for information purposes to demonstrate the relative importance of differing parts of the supply chain.

According to the Minerals Council of Australia and Deloitte Access Economics the multiplier for indirect employment in the mining sector is quite low at .677 and .99 respectively. [63] As there are few reference points in Australia for secondary processing of materials like the New Energy metals and rare earths, international comparative analysis of similar projects has been conducted.

High-technology industries such as New Energy metals processing and battery production are seen as having particularly large multipliers. Enrico Moretti's [64] research on US cities suggests that each additional job in high-tech industries demonstrated a multiplier of 4-5 as employees have high salaries and a disproportional local impact. Ian Hathaway Bay Area Council Economist, [65] explains the two reasons behind this multiplier effect are that "High tech workers earn high salaries and therefore have higher levels of disposable income which can be

63 Deloitte Access Economics (2017), Mining and METS: engines of economic growth and prosperity for Australians, Report prepared for the Minerals Council of Australia, https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-mining-mets-economic-growth-prosperity-engines-170317.pdf. (Accessed: 01 May 2018)
64 Brokaw, L (2012), The Multiplier Effect of Innovation Jobs, 06 June 2012, MIT Sloan Management Review, https://sloanreview.mit.edu/article/the-multiplier-effect-of-innovation-jobs/. (Accessed: 01 May 2018)
65 Kawa, Lucas (2013), "Every New High Tech Job Translates To 4.3 More New Hires", Business Insider Australia, 05 January 2013, https://www.businessinsider.com.au/high-tech-job-multiplier-2013-1?r=US&IR=T. (Accessed 03 June 2018)

spent throughout the local economy; and secondly, because high tech firms tend to cluster around one another, it draws in businesses that support high tech in their normal business operations." Increased downstream processing of New Energy metals will require higher skilled and experienced workers that will have a higher impact upon the local economy compared to standard extraction mining and export.

In the UK, a detailed analysis of multipliers in similar chemical and metal manufacturing suggested a multiplier of approximately 2.4. Research undertaken by InfraNomics on industry multipliers for the Western Trade Coast indicated that businesses around the port can expect a multiplier of approximately 2.3.

The 2016 *Bunbury Geographe Regional Growth Plan*[66] identified multipliers for downstream metal processing for lithium and alumina to generate a multiplier of approximately 2.4. A report by Syme Marmion and Co on the Kemerton Strategic Industrial Area in 2012 indicated a multiplier of 5.71 for indirect employment core industry manufacturing.

Taking these and other reference sources together, this report will use a multiplier of 2.5 as representative of the region, the type of manufacturing and the industry.

Based upon a detailed analysis of existing and future projects (disclosed and not disclosed) as well as international comparable projects and forecasts, if the opportunities are captured and additional secondary processing does occur in WA, employment is expected to increased from 2017 : 7,291[67] direct jobs to approximately 2025 : 28,771 direct jobs. Including indirect employment using a multiplier of 2.5 this equates to 2025 : 71,927 indirect jobs or total employment in 2025 : 100,698 direct and indirect jobs.

"The problem with growing the industry, and value adding, was a lack of political will. It's not only business. Governments should be asking how do we maximise the value for Australia?

How do we do what the Chinese did, set up an industry downstream to make sure we capture as much value as possible? We've got the product, now we need the collaboration and the political leadership and look beyond existing systems and look to the future."

George Bauk - Northern Minerals, ABC news

66 Bunbury Geographe (2016), Regional Growth Plan Part One Strategy, December 2016, http://bwea.com.au/wp-content/uploads/sites/190/2017/01/Bunbury-Geographe-Growth-Plan-STRATEGY-FINAL-Dec-2016.pdf. (Accessed: 01 May 2018)

67 Department of Mines, Industry Regulation and Safety - Resources Safety Division, 2017

7.5 WA royalties and sovereign wealth funds

"Western Australia's royalty system was designed to return to the community about 10% of the mine-head value of the ore, regardless of the commodity or the level of processing."[68] It could be argued that the royalty scheme is from a different era when there was greater direct employment and local processing as well as higher social contributions. With automation, direct exporting of low processed ores and regional Australia contributions the net financial contribution to the State is lower than in the past. It is recognised that royalties are a highly complex and emotive area and there have been significant developments even since the 2015 Government report [69] on this topic. As the Hon Ben Wyatt stated on Twitter, 11 Jan 2018 *"Royalties are not a tax but a price paid by mining companies to exploit a resource owned by the public."*

Another incentive to restructure the royalty system is the GST mechanism that indirectly transfers the vast bulk of royalty benefits to the other states, perversely penalizing resource development. A smart royalty scheme, that is a royalty scheme that encourages domestic downstream processing through a variety of incentives and penalties, may be considered more appropriate in the future than a flat percentage tax.

As well both the State and Federal Government are eerily mute on the Norwegian Sovereign Fund approach, widely seen as world's best practice. Although Western Australia is blessed with abundant natural resources, there is a debt owed to previous generations who were custodians of the land and also to future generations who inherit the land. At the time of writing, all royalties are included in current yearly revenue totals and it could be argued that little is saved or invested. In addition, there has been an increase in unsustainable debt, an increase in government deficits and a growing government reliance on royalties from unsustainable finite resources (18% in 2017;15% in 2016).

There is a strong moral argument that current governments should not be spending all royalty revenues. The Norwegian Government is limited to spending just 4% of their sovereign wealth fund each year, with the rest hoarded for future disasters that may befall the Scandinavian country. As WA has always lacked local capital for infrastructure investment, establishing a proper sovereign wealth fund, with proper corporate governance, separate from political control could provide this necessary capital for future generations. The current record extraction and export of finite resources could provide this base for the future.

In the New Energy metals industry, there is expected to be little need to boost demand due to ongoing market pressures. Secondary processing of New Energy metals in Australia is a function of attracting foreign processing companies to Australia that currently hold the Intellectual Property over these critical downstream processes. These companies will come to Australia not because of lower cost ores but because of supply security issues, stable environment, diversity of supply and export options, quality, access to a broad spectrum of New Energy metals, greater economies of scale, logistics costs, ethical supply chains, affordable energy etc. Therefore, there is no incentive to offer local miners royalty relief or royalty holidays as local miners are not the target companies for secondary processing. On the contrary there are strong economic, social and environmental arguments to increase royalties to incentivise secondary production in Australia while at the same time discourage the export of unprocessed raw materials.

68 Department of State Development and Department of Mines and Petroleum, Mineral Royalty Rate Analysis Final Report 2015, http://www.dmp.wa.gov.au/Documents/Minerals/Mineral_Royalty_Rate_Analysis_Report.pdf. (Accessed: 01 May 2018)

69 Department of State Development and Department of Mines and Petroleum, Mineral Royalty Rate Analysis Final Report 2015, http://www.dmp.wa.gov.au/Documents/Minerals/Mineral_Royalty_Rate_Analysis_Report.pdf. (Accessed: 01 May 2018)

8

DRIVING THE RENEWABLES DEBATE

8 Driving the Renewables Debate

The State wants more secondary processing of energy materials and the best way to achieve this is to develop and incentivise the local market. This can be done by increasing the use of batteries particularly through renewable energy but also through encouraging electric vehicles, industrial power storage or local distributed generation.

One key area to focus on is growing renewable energy however for larger scale installations grid interconnection issues are the main obstacles. Germany is often seen as a model for developing and growing renewable energy, which has developed a complex and sophisticated local industry. Germany is recognised as being very renewable energy proactive and has developed a wide compliment of incentives and penalties to encourage renewables. This is especially important in WA to reduce long term power costs, reduce the dependence on imported fuels, increase national security, increase power reliability and reduce transmission costs. Section 8.1 is a summary of the German interconnection situation.

8.1 Residential scale interconnection in Germany

European Union (EU) law governs Germany's interconnection process. Under EU law, member states may prioritize the interconnection of renewable energy generators. Germany passed the Renewable Energy Sources Act (EEG) in 2000 and subsequently updated it four times to 2017. The EEG requires that utilities prioritize connecting renewable energy projects to the grid. However, without a legislated timeframe for responding to interconnection requests, there is the argument that the law still allows utilities to unnecessarily delay PV projects (GSIA 2010). Further, the exact requirements for establishing interconnection, including technical interconnection criteria, vary by utility. Overall there is a strong political mandate to prioritise and interconnect renewables as it fits within the German and EU energy strategy. WA lacks a strategy for energy, but if it did, then renewables would likely be prioritised too, for similar reasons as the EU.

The interconnection process in Germany follows the same general process as in WA, including the application, utility review, and commissioning. In Germany grid infrastructure upgrades for interconnection are paid by the utility, in Australia the generator can be liable for all the upgrade costs.

8.2 Commercial- and Utility-Scale Interconnection in Germany

In Germany, commercial and utility scale projects basically follow similar interconnection procedures as residential-scale projects. However, there can be delays in grid connections and high fees for installations over 30kWp as there is no legally defined preferred interconnection and this allows transmission operators to obstruct the interconnection process. In addition, larger sources (up to 5MWp) require two additional steps such as determining the capacity of the existing infrastructure to support the project and the location of the interconnection point. Both of these can result in delayed connections.

Overall there is the regulatory pressure to prioritise the interconnection of renewable energy projects as this is part of the wider strategy to reduce dependency on foreign fossil fuels, develop a local industry, reduce long term costs, reduce pollution and improve the sustainability of society.

Developing a robust local market for the New Energy metals and battery can provide a cornerstone for the industry and therefore the prioritisation of renewable energies fits within this strategy and should be encouraged by fast tracked interconnection.

8.3 New Energy sector in WA

The New Energy sector is transformative in that some simple innovations are driving a hugely disruptive change in WA's industrial base. WA is ideally geographically positioned with the right minerals, logistics and capability to benefit with the appropriate engagement.

The New Energy sector is characterised by:

- Decentralised energy generation;
- Electrification of transportation;
- Ready storage and portability of electrical energy;
- Elimination of State utility monopolies;
- Energy trading between users; and
- The net functional cost reductions of all of these.

The opportunities for WA include:

- Fabrication sector – electric motors or expansion into designing, constructing and supplying electric vehicles;
- Marine sector – continued development of shipbuilding as well as potentially improving on Norway's example of designing and building electrically powered vessels;
- Renewable energy sector – construct and deploy charging systems, edge-of-grid systems, behind-the-meter storage, utility stabilisation systems;
- Construction and real estate – Reduce build costs and take direct ownership of utilities by a citizen utilities;[70]
- Technologists and economists – design, build and deploy energy trading systems that dynamically optimise price, source and use of electricity.

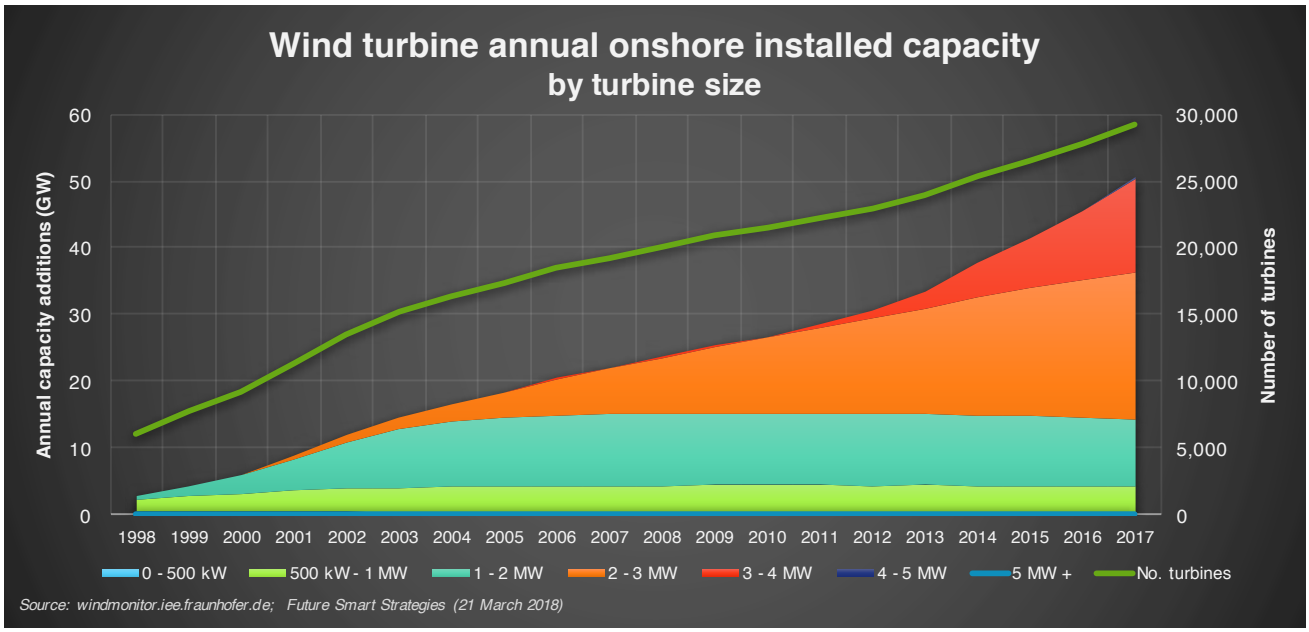
Some of these opportunities are already being developed – an energy trading system created in Perth using blockchain software; edge of grid system designed and built in Bibra Lake; electric ferry built in Perth; smart charging systems designed and built in Queensland. What all of these have in common is that they are importing all key components of their systems, most of which are originally dependent upon WA's own mineral resources.

70 Green, J and Newman, P (2017), "Citizen utilities: The emerging power paradigm", Energy Policy, August 2017, Volume 107, p283-293.

8.4 Global New Energy

The following figures illustrate some of the global trends that will involve WA's New Energy metals. Wind turbines are important to highlight, not only due to the continuing growth of renewables but mainly due to the large and increasing volume of rare earths required for their magnets. This increase in demand for rare earths enhances the New Energy metals trends discussed throughout this report.

26 ***Figure 26:*** *Growth of onshore wind turbine size and numbers*



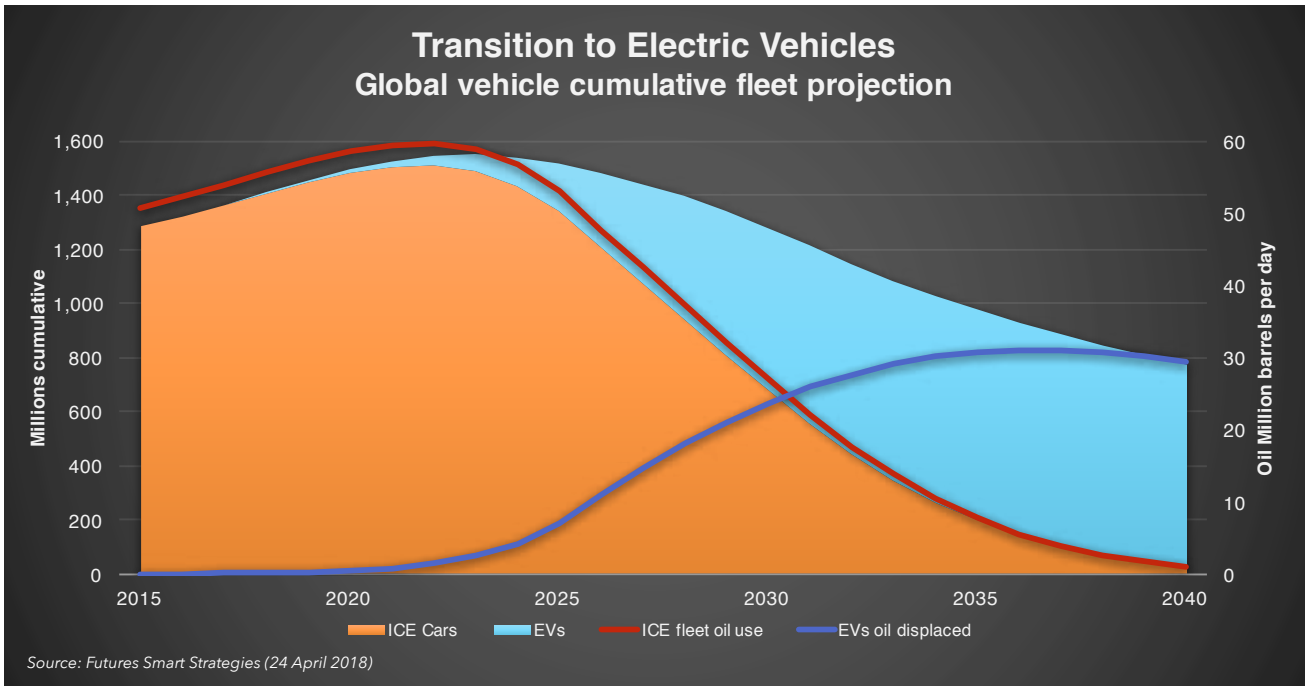
The global growth of the number of wind turbines first slowed as wind turbines have increased in turbine size, but numbers are accelerating again as turbines move offshore and projects get larger.

Offshore of Scotland, 6-megawatt wind turbines with 90m blade tips are already operating atop a 90-meter-high substructure ballasted with 5,000 tons of iron ore. By 2021, GE expect to be commissioning 12MW of offshore wind turbines.[71] These turbines require tones of specific New Energy metals.

In the motor vehicle industry, the potential of electrification is not only an opportunity to reduce costs, use renewable energy to power motor cars but also reduce air pollution, especially in cities. The change is also about the coincident changes in connectivity, the role of artificial intelligence in bringing about self-driving vehicles, the subsequent impact this may have on flexible shared use and changing ownership models (Figure 27), and ultimately the impact that will have on global vehicles fleets.

71 Gerdes, J. (2018), GE to Deploy the World's Most Powerful Offshore Wind Turbine in 2021, 02 March 2018, Green Tech Media, https://www.greentechmedia.com/articles/read/ge-to-deploy-the-worlds-most-powerful-offshore-wind-turbine-in-2021#gs.MytRSqw. (Accessed: 01 May 2018)

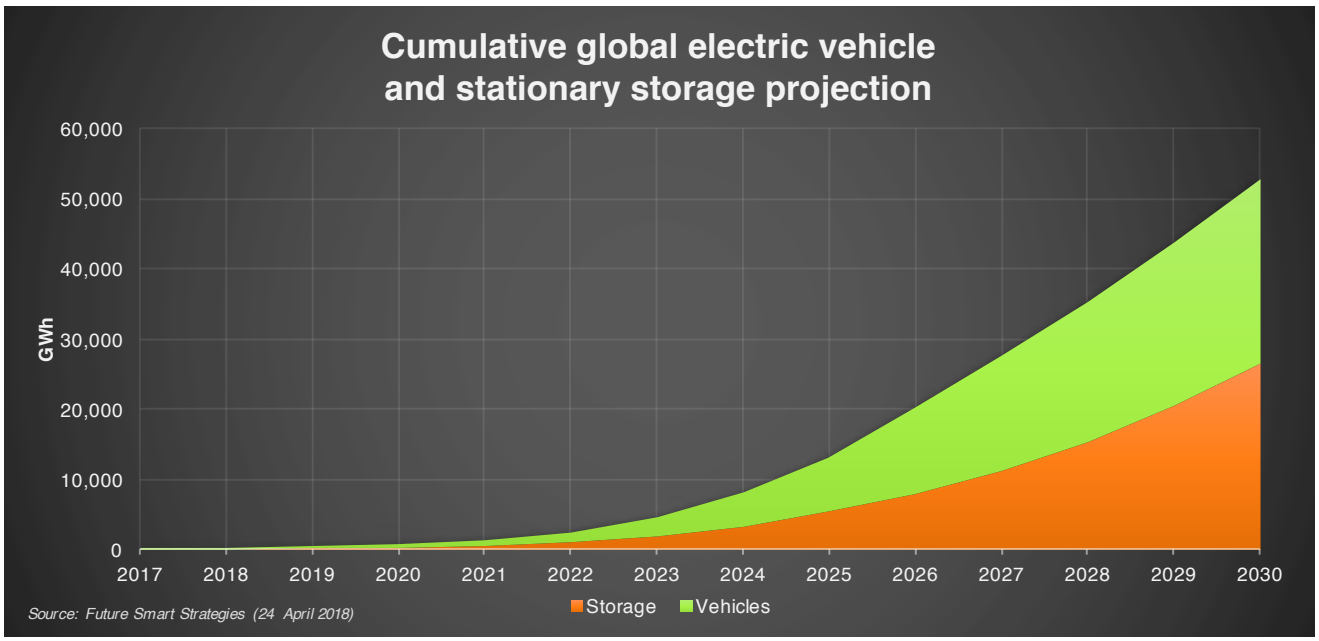
27 ***Figure 27:*** *Projected change in global vehicle fleet to 2040 with transition to electric vehicles*



Economic implications – As electric vehicles (EV) cars are now comparable or cheaper than traditional vehicles over a whole of life analysis, there are strong commercial and strategic reasons to focus on a combination of renewable energy and new EVs.

The projections forecast that the majority of batteries are likely to initially be used in EVs, where the available electricity as a portable power source is more valuable. This however is likely to change over the next decade with increasingly strong demand from stationary storage both behind the meter and utility scale uses (Figure 28).

28 ***Figure 28:*** *Cumulative impact on battery use for electric vehicles and stationary storage*

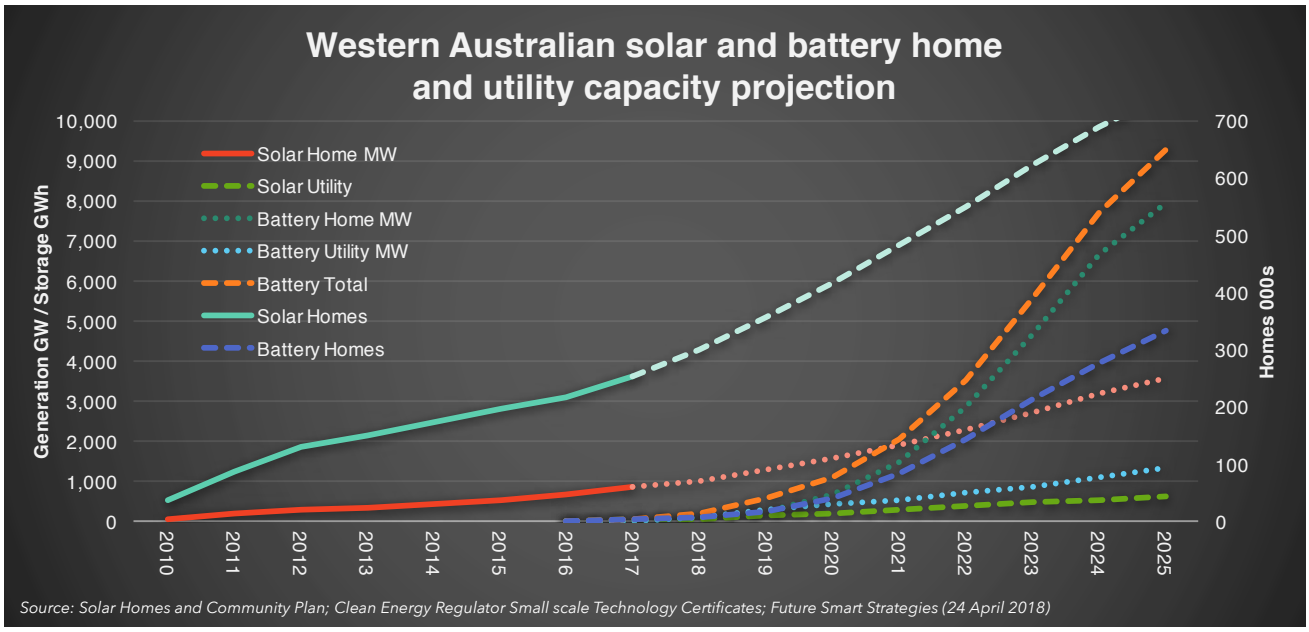


8.5 The long-term values for WA

There are many advantages for WA to continue the support and development of renewable energies such as:

- Comprehensive, major, long-term and socially responsible economic growth;
- Foundation for a major strategic research and development sector based upon New Energy metals, relatively unaligned, with subsequent international value;
- The opportunity to enhance product range and value by introducing new economic values due to the paradigm change of portable energy.

29 ***Figure 29:*** *Comparing actual and projected demand for solar with projected battery storage demand in the Western Australian market*



CONCLUSIONS AND RECOMMENDATIONS

9 Conclusions and recommendations

Lithium Valley is the opportunity for WA to take hold of its economic future. At stake is over 100,000 jobs and greater than $50 billion of annual revenue that would transform the WA economy. As a contribution to the global economy it has significant economic, social and environmental value. This will require the following:

9.1 Federal Government

9.1.1. Work with the State Government to establish a Special Industrial Park (SIP) over the entire Western Trade Coast.

9.1.2. Enable Australia to be a leader in the global transition from a fossil fuels-driven economy to a renewable economy through a wide variety of policies, mandates, legislation and regulation.

9.1.3. Create a New Energy Industry Co-operative Research Centre (CRC) in Perth.

9.1.4. Facilitate innovation in New Energy to be commercialised

9.1.5. Set high standards for refined products of New Energy minerals to promote quality.

9.1.6. Reform the GST model to enable New Energy industry

9.1.7. Include strategic resources as a new section for Foreign Investment Review Board approval.

9.1.8. Ensure the EU defines Australia as a Critical Raw Materials supplier.

9.1.9. Implement a harmonised nationwide recycling approach, potentially using the EU regulations as a guide and using e-waste as the exemplar.

9.2 State Government

9.2.1. Establish a branding and information program for Lithium Valley

9.2.2. Establish Federal and State bilateral agreements on the Kwinana and Geraldton sites for the New Energy industries especially Strategic Environmental Assessment.

9.2.3. A Parliamentary Inquiry to provide a whole of government and community response to Lithium Valley

9.2.4. Following gas policy, set aside key strategic minerals for domestic use.

9.2.5. Establish strategic minerals status for all New Energy materials.

9.2.6. Review the royalties scheme in the light of New Energy metals.

9.2.7. Investigate the provision of direct and/or indirect support to strategic industries using New Energy metals.

9.2.8. Establish a dedicated management authority to facilitate development for the Western Trade Coast (WTC) and Lithium Valley.

9.2.9. Develop energy metal recycling facilities at Geraldton as part of Oakajee as well as mineral processing in Kemerton, the Pilbara and Goldfields.

9.2.10. Ensure a timely framework for the transitional development of the new port in Kwinana

9.2.11. Renewable power with battery support should be a high priority for the Kwinana region and other parts of the South West Integrated System (SWIS) associated with this New Energy initiative.

9.2.12. Lithium Valley partnerships need to invite private investment

9.2.13. Review the involvement of the State Government in New Energy minerals and industries.

9.2.14. Develop a program to capture and recycle 100% treated wastewater to the southern groundwater aquifers.

9.2.15. Provide industry with a clearer view of how Lithium Valley industries fit into its strategic objectives.

9.2.16. Review intergenerational revenue allocations.

9.2.17. State Government review phasing out petrol and diesel vehicles by 2030, especially in metro areas.

9.2.18. WA initiate EU support over Lithium Valley through CRM status.

APPENDIX A - GLOSSARY OF KEY TERMS

10 Appendix A - Glossary of Key Terms

Industry 4.0 - The fourth industrial revolution where technology will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before

Lithium – The third element on the periodic table, is a highly reactive metal that which is never found in its natural state. To support supply chain and production logistics, is usually refined into either lithium carbonate or lithium hydroxide. There are two major sources for lithium production.

- spodumene – a pegmatite (hard rock) based mineral containing lithium in the form of a lithium aluminium silicate compound. Spodumene is Western Australia's primary source of lithium. As lithium is not available as a metal, the grade of the mineral is based upon the lithium oxide (LiO2) content. With respect to lithium, spodumene is generally considered to:
- be the most expensive to extract;
- is able to produce product very quickly;
- produces the quality most suitable for battery use (the major demand growth area)
- is typically concentrated to a 6% lithium oxide content (2.8% lithium)
- Lithium Brine deposits – majority of world's economic reserves of lithium are contained in lake beds, much of these in South America. Lithium from these sources have:
- lowest concentration costs (evaporation);
- lower purity product;
- slow production cycle time.
- there is the potential for exploiting sedentary deposits – which contain less than 10% of known lithium reserves, but no significant production expected in the near (5 year) term.

Lithium Carbonate – a compound (LiCO3) that can be refined from any of natural sources of lithium (pegmatite, brine, clay). It contains approximately 18.8% lithium by weight.

Lithium Carbonate Equivalent (LCE) is a common term to define the tradeable commodity that contains a known proportion of lithium.

Lithium Hydroxide –a refined compound (LiOH) containing approximately 16.5% lithium by weight. It is often preferred as a compound for conversion into suitable electrochemical compounds.

Lithium Metal Equivalent (LME) – a measure of the lithium actually contained.

- 1 kg LCE contains 188 grams of lithium
- 1 kg lithium hydroxide contains 165 grams of lithium
- 1 Tonne spodumene 6% concentrate contains 27.9kg of lithium

Lithium-ion – A lithium atom that has an electron removed, leaving the atom in an electrically positive charged state. The size of the lithium ion allows it to readily migrate though the cell's electrolyte and between electrodes – its travel direction based whether it is being charged or discharged.

Lithium-ion (Li-ion) cell – any storage system that depends on this lithium ion storage and transport principal which supports repeated energy charge, store, discharge and recharge.

Li-ion cells: Chemistry – there are many (patented) chemistries and nanostructures, broadly identified by nomenclature describing the cathode electrode's dominant active component - where the Anode is typically graphite (carbon) based. The exception is the LTO (below) where the name defines the anode, the cathode usually being one of the other materials described.

- Lithium nickel cobalt aluminium oxide (NCA)
- Lithium nickel-manganese-cobalt oxide (NMC)
- Lithium cobalt oxide (LCO)
- Lithium manganese oxide (LMO)
- Lithium iron phosphate (LFP)
- Lithium titanate (LTO)

These chemistries offer different price-performance options (including temperature sensitivity, internal resistance, storage density, charge/discharge rates, longevity, stability…). This makes generalisations about their use problematic, especially as various users of these batteries (Tesla, Toyota, etc). However, some examples are:

- Tesla use NMC and NCA (EVs and storage) cylindrical.
- BYD (EVs and buses) use LFP cylindrical.
- Chevrolet EVs use NMC/LMO hybrid pouch.

Li-ion battery Cells: Structure – two separated electrodes (cathode and anode) are embedded in an electrolyte. These electrodes act to transport the electrical current into and through the electrolyte to provide storage and discharge. Lithium is in the electrolyte as a lithium salt. There are many cell architectures that are designed to meet specific functional requirements. These include:

- Cylinder – similar to traditional "disposable" batteries, these combine structural integrity and energy storage in one device by (effectively) rolling ribbons of cathode, separator, electrolyte and anode into a "swiss roll" and sealing it in a container (Panasonic);
- Prismatic – Instead of rolling the ribbons of cathode, separator, electrolyte and anode into a cylindrical shape, they are structured into a "flat pack" allowing them to be designed to fit particular installations. This flat design may be achieved by folding continuous electrodes (i.e. Samsung) or multiple layering of electrodes (LG Chem).
- Button – a sandwich of electrodes, separator and electrolyte into a standard shape device suitable for watches, remotes, etc.
- Pouch cell (often called lithium polymer) – the evolution of a layered design into a lightweight package enabled by improvements in production technology.

Lithium Ion Battery pack – A combination of cells, packaging and electronics. A single battery cell is a simple device that individually stores and discharges relatively low amounts of energy. To deliver meaningful performance for energy storage or transport requirements, many individual cells (often many thousand) are required to allow significant energy consolidation. This then requires a method for distributing power, monitoring cell status, managing charge/discharge and condition reporting. These packs also need to be in a format "fit for purpose" (size, weight, shape, capacity, strength, etc. A storage device or an Electric Vehicle may contain many "packs", not necessarily the same size (due to "space and shape" design constraints), nor necessarily with the same number of cells. The assembly of cells into packs also supports simpler downstream integration into storage systems and electric vehicles.

Western Trade Coast (WTC) - is located 30 minutes south (approximately 40km) of Perth at Cockburn Sound and has direct links to air, sea, road and rail network. It is an approximately 4,000-hectare industrial region and consists of four primary estates Kwinana Industrial Area (KIA), Latitude 32 Industry Zone, Rockingham Industry Zone and the Australian Marine Complex (AMC).

APPENDIX B - AN ANALYSIS OF ENERGY METALS

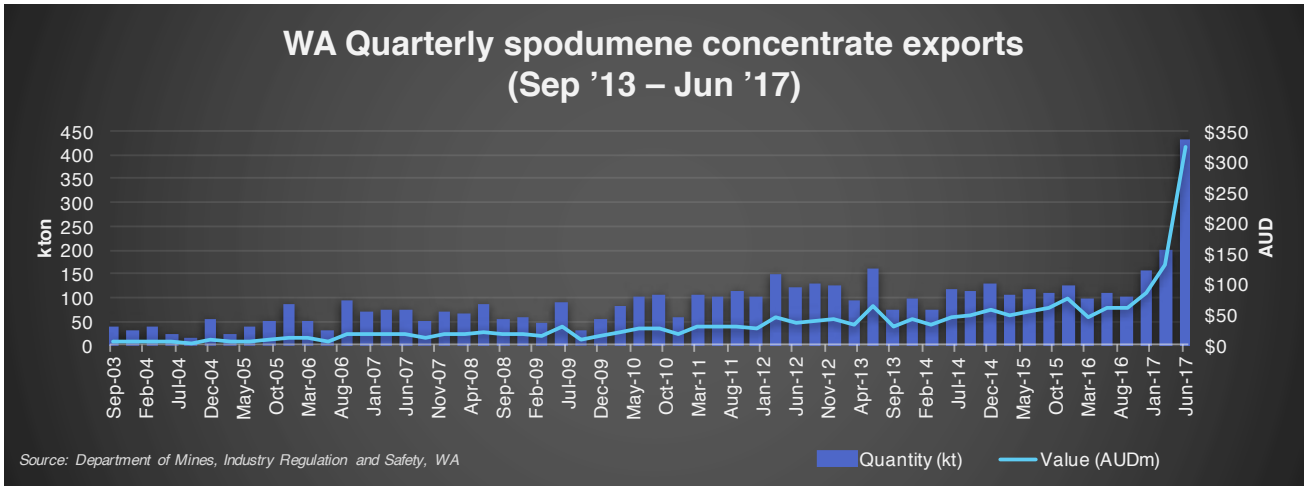
11 Appendix B – An Analysis of Energy Metals

11.1 Lithium

There are currently 50 active lithium projects in the State.[72] There are four (4) operating mines which include; Greenbushes, Mt Marion, Mt Cattlin and Wodgina. All lithium is currently exported as concentrate. Other advanced mining projects include; Pilgangoora, Earl Grey (Mt Holland) and Bald Hill.

Figure 30 and Table 8 illustrate both the total quantity (kilotons, kt) and value (AUD millions) of lithium spodumene concentrate exports in WA:

30 ***Figure 30:*** *WA Quarterly spodumene concentrate exports (Sept '13 – Jun '17)*



The growth of demand in power storage, particularly electric vehicles is a massive industrial transition. Currently power storage is dependent on lithium and demand is expected to continue to have strong growth in the coming years.

72 Beardsmore, T (2018) Western Australia: Battery Metal Powerhouse, Geological Society of Western Australia, 23 February 2018, http://www.dmp.wa.gov.au/Documents/Geological-Survey/09-Western%20Australia%20a%20battery%20metal%20powerhouse-Trevor%20Beardsmore.pdf. (Accessed: 01 May 2018)

Table 8: ***WA Quarterly spodumene concentrate export growth (Mar'15 – Jun '17)***

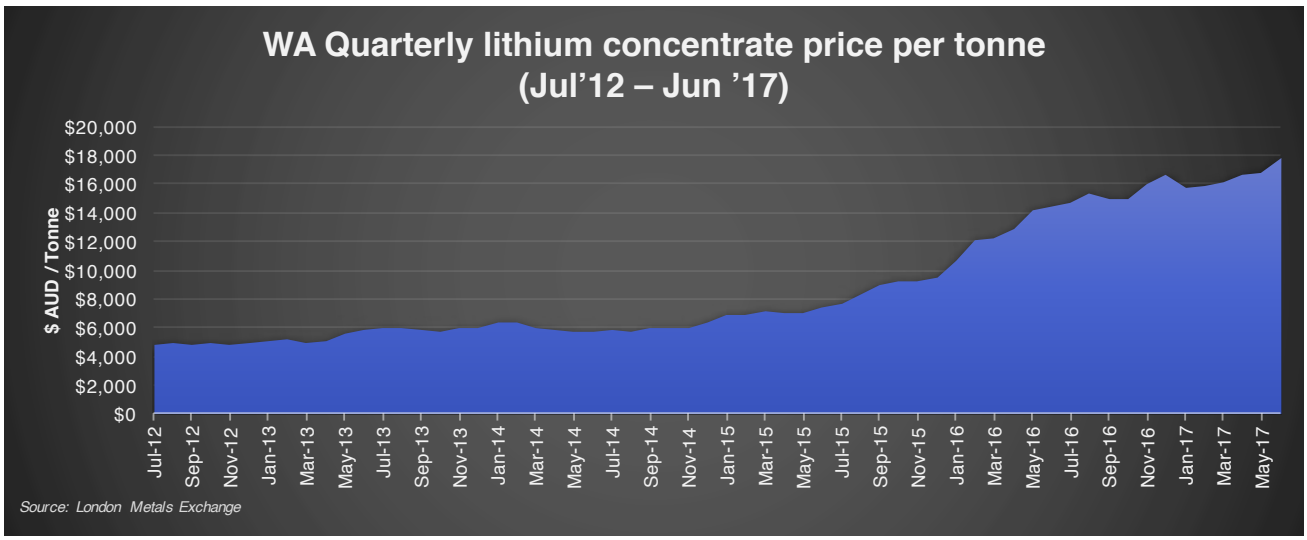
Quarter	Quantity (kt)	Month on month growth (kt)	Month on month growth (%)	Value ($Am)	Month on month growth ($Am)	Month on month growth (%)
Mar-15	98.99			47.96		
Jun-15	112.63	13.64	13.77%	55.83	7.87	16.41%
Sep-15	103.90	-8.73	-8.81%	59.97	4.14	8.63%
Dec-15	118.32	14.41	14.56%	76.45	16.48	34.36%
Mar-16	91.25	-27.07	-27.35%	44.99	-31.46	-65.59%
Jun-16	103.82	12.57	12.70%	60.58	15.59	32.51%
Sep-16	95.77	-8.04	-8.12%	60.73	0.14	0.30%
Dec-16	149.69	53.91	54.46%	84.38	23.66	49.32%
Mar-17	194.98	45.29	45.75%	132.06	47.68	99.42%
Jun-17	425.98	231.00	233.35%	324.27	192.21	400.77%

Source: Department of Mines, Industry Regulations and Safety

Figure 30 and Table 8 highlight the increased export volume and overall sales value of spodumene concentrate in WA. In the financial year 2016-17, some 866.4kt were exports at a value of $A601m.

Figure 31 illustrates the lithium concentrate price movement, in AUD, between July 2012 and June 2017.

31 ***Figure 31:*** *WA Quarterly lithium concentrate price per tonne (Jul '12-Jun '17)*



Price increases have been notable since early 2016. This correlates with the increase in the volume of spodumene concentrate exported from WA over the same period. Average price per tonne in FY 2016/17 was $A15,946 per tonne, peaking at $A17,764 per tonne in June 2017 from a low of $A14,704 per tonne in July 2016 (20.8% increase over the financial year).

Some forecast demand for lithium carbonate equivalent (LCE) range from between 495 – 600ktpa in 2025, up from 200ktpa in 2016.[73] This is driven largely by the increase in lithium-ion battery update for storage and EVs. As mentioned earlier this is considered a conservative demand forecast, with other estimates suggesting growth in demand could exceed 2,000ktpa by 2025 (driven primarily by the battery sector). The table below from 2015 shows the forecast demand for major lithium-ion applications:

Table 9: ***Forecast global growth rates – LCE kpta***

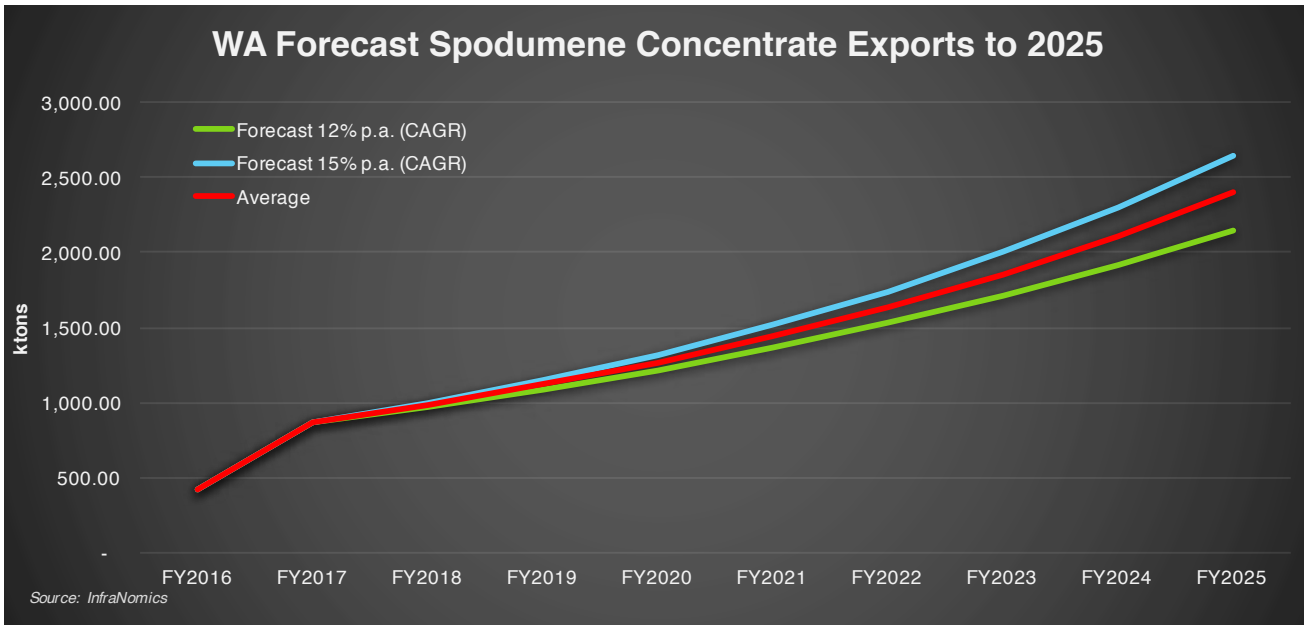
Application	Lithium Products	Demand kpta LCE 2015	Demand kpta LCE 2020	Demand kpta LCE 2025	Growth rate
Batteries	Lithium hydroxide and carbonate	60 – 70	150 – 170	350 – 400	**15 – 25% p.a.**
Glass / Ceramics	Spodumene / petalite concentrates Lithium carbonate	40 – 50	45 – 55	55 – 65	**2 – 4 % p.a.**
Greases / Lubricants	Lithium hydroxide	15 – 20	20 – 25	30 – 40	**4 – 8% p.a.**
Metal Alloys	Lithium metal and alloys	10 – 15	12.5 – 20	15 – 25	**3 – 5% p.a.**
Air Conditioning	Various	5 – 10	7.5 – 12.5	10 – 15	**3 – 5% p.a.**
Polymers	Various	4 – 8	7.5 – 12.5	10 – 15	**2 – 4% p.a.**
Medicine	Specialty organo-compounds	4 – 8	7.5 – 12.5	10 – 15	**2 – 4% p.a.**
Others	Various	10 – 15	12.5 – 20	15 – 25	**3 – 6% p.a.**
CAGR		**150 - 170**	**265 - 340**	**495 - 600**	**12 - 15% p.a.**

Source: Dakota Minerals

As is very clear, the main growth is in batteries, in particular EVs and renewable energy. Applying the compound annual growth rate (CAGR) assumption as calculated by Dakota Minerals (now Novo Litio Ltd) in Table 9, a forecast demand range of the spodumene concentrate export for WA has been derived.

73 Dakota Minerals (2017), Lithium supply and demand, *https://www.dakotaminerals.com.au/lithium/lithium-supply-demand*. (Accessed: 01 May 2018)

32 ***Figure 32:*** *WA Forecast Volume of Spodumene Concentrate Exports to 2025*



The forecast of export spodumene concentrate shown in Table 10 utilises Department of Mines, Industry Regulations and Safety (MIRS) data as a basis. All other assumptions, such as WA's share of global spodumene exports, potential for new and unplanned operations, have been left unchanged. With more refining capacity it is expected that the amount of spodumene exports will decrease. The purpose of this graph is to estimate the volumes available either for processing or export. Table 10 sets out a number of key volume increase outputs from the analysis.

Table 10: ***WA Key forecast volume changes for Spodumene Concentrate Exports***

	FY2017	FY2020	FY2025
Export volume (ktpa)	866.4	1,217.3 – 1,317.7	2,145.2 – 2,650.4
Export volume increase (ktpa) – previous period	n/a	350.8 – 451.3	928.0 – 1,332.7
Export volume increase (%) – previous period	n/a	40% - 52%	76% - 101%

Source: InfraNomics

Expanding on the methodology as set out above, a forecast of the value of spodumene concentrate exports has been calculated. Figure 33 outlines the forecast trend of export value ($Am):

33 ***Figure 33:*** *WA Forecast Value of Spodumene Concentrate Exports*

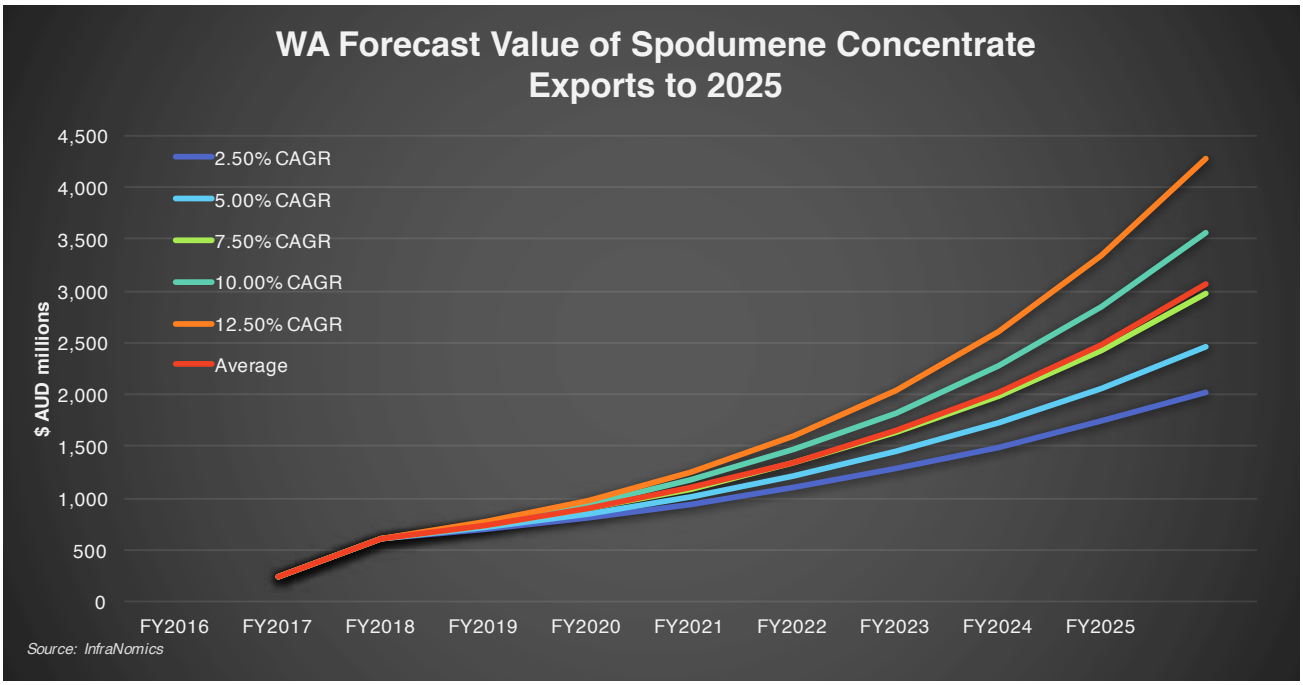


Table 11 applies a CAGR range on export value per tonne in addition to the increases in WA export volume. Table 11 sets out a number of key outputs from the analysis.

Table 11: ***WA Key forecast export value changes for Spodumene Concentrate***

	FY2017	FY2020	FY2025
Export value ($Am)	$601.5m	$947.5m - $1,252.8m	$2,028.0m - $4,270.8m
Export increase ($Am) – previous period	n/a	$346.1m – $651.3m	$1,080.5m – $3,018.0m
Export increase ($Am) – previous period	n/a	58% - 108%	114% - 241%

Source: InfraNomics

Spodumene concentrate is the lowest level of processing of lithium and the incentive is to value add locally and reduce exports of spodumene in the future.

> **"Exporting lithium as spodumene really means that WA is exporting 972kg of waste product and 28 kg of lithium in every tonne shipped. That in itself is justification to only export refined products."**

There have been a number of key reports on lithium price forecasts in recent months. In February 2018, Morgan Stanley issued a report suggesting lithium prices could reduce by as much as 45% by 2021. This is based on forecasts of a coming supply glut as lithium miners race to meet market demand.[74] However, this analysis has largely been discounted by industry experts and other analysts.

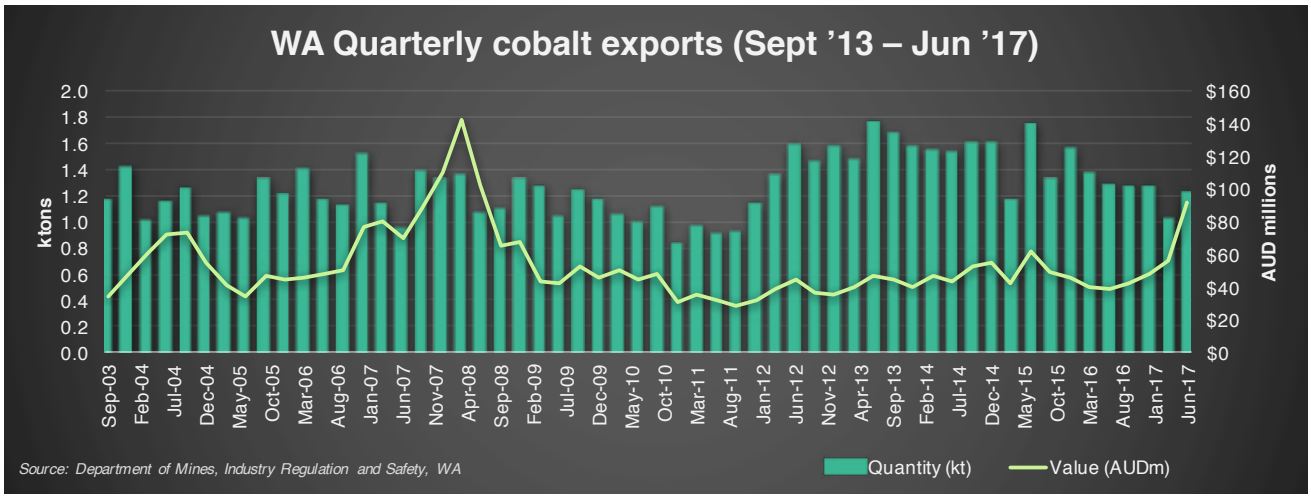
It has been suggested that Morgan Stanley's forecast of oversupply fails to take into account that few lithium processors have the capacity and ability to produce the very high-grade lithium compounds that batteries need. Therefore, supply pressure will continue until lithium processing capacity is expanded.[75]

11.2 Cobalt

Cobalt is an essential element in the production of battery storage devices, due to its ability to provide high energy density. Cobalt's demand is forecast to increase dramatically over the coming decades, with its use in EV and other lithium-ion based batteries set to increase more than 6-fold, from marginally higher than 50,000 tonnes per annum in 2017 to approximately 325,000 tonnes by 2030 based on projections from Darton Commodities.

Figure 34 and Table 12 illustrate both the total quantity (kt) and value ($Am) of cobalt exports in WA.

34 ***Figure 34:*** *WA Quarterly cobalt exports (Sept '13 – Jun '17)*



74 Jacobs, S (2018), Morgan Stanley predicts a 45% fall in lithium prices by 2021, 27 February 2018, ***Business Insider***, https://www.businessinsider.com.au/lithium-prices-45-fall-by-2021-2018-2. (Accessed: 01 May 2018)

75 Mordant, N (2018), Lithium glut? No way, say industry executives eyeing demand, 28 February 2018, ***Reuters***, https://www.reuters.com/article/us-mining-bmo-lithium/lithium-glut-no-way-say-industry-executives-eyeing-demand-idUSKCN1GB2ZA. (Accessed: 01 May 2018)

Table 12: ***WA Quarterly cobalt export growth (Mar'15 – Jun '17)***

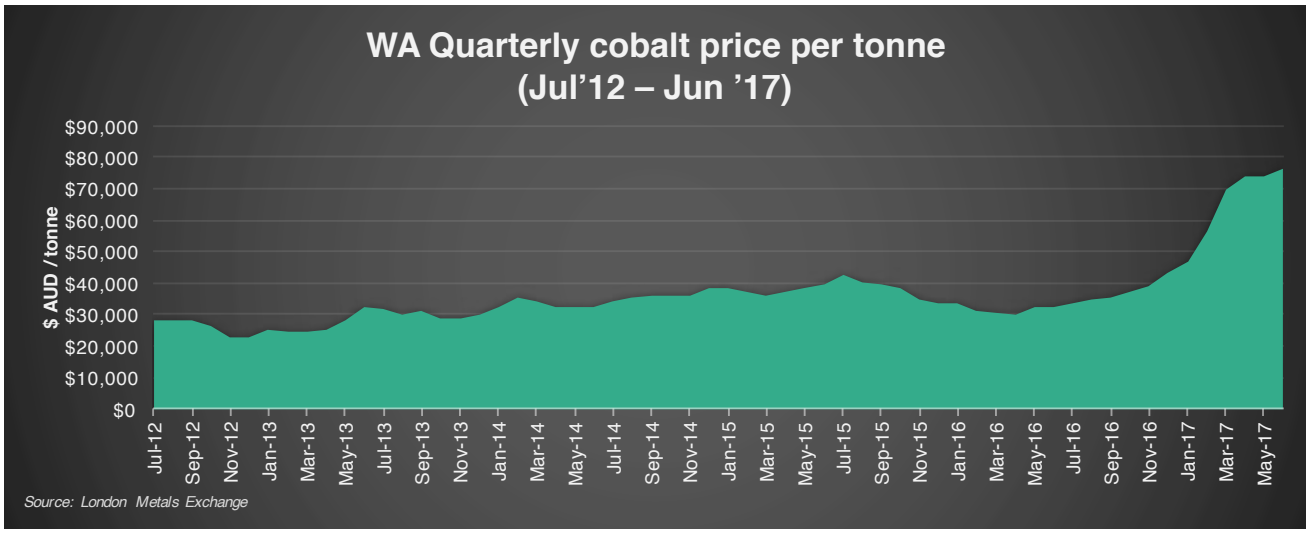
Quarter	Quantity (kt)	Quantity growth (kt)	Quantity growth (%)	Value ($Am)	Value growth ($Am)	Value growth (%)
Mar-15	1.15			41.79		
Jun-15	1.72	0.58	0.58%	61.67	19.88	41.45%
Sep-15	1.31	-0.42	-0.42%	49.77	-11.90	-24.81%
Dec-15	1.54	0.24	0.24%	46.25	-3.52	-7.35%
Mar-16	1.36	-0.19	-0.19%	40.26	-5.98	-12.48%
Jun-16	1.27	-0.08	-0.08%	38.57	-1.70	-3.54%
Sep-16	1.25	-0.02	-0.02%	41.81	3.24	6.76%
Dec-16	1.26	0.01	0.01%	48.43	6.62	13.81%
Mar-17	1.01	-0.25	-0.25%	56.16	7.73	16.12%
Jun-17	1.21	0.19	0.20%	91.13	34.97	72.91%

Source: Department of Mines, Industry Regulation and Safety, WA

Figure 34 and Table 12 highlight the stagnant export volume, but there is an upward trend in overall sales value of cobalt in WA, particularly towards the end of FY2016-17. This is a reflection of the rapid increase in price per tonne towards the end of FY2016-17. In the financial year 2016-17, some 4.3kt were exports at a value of A$237.5m.

Figure 35 illustrates the cobalt price movement ($A per tonne), between July 2012 and June 2017:

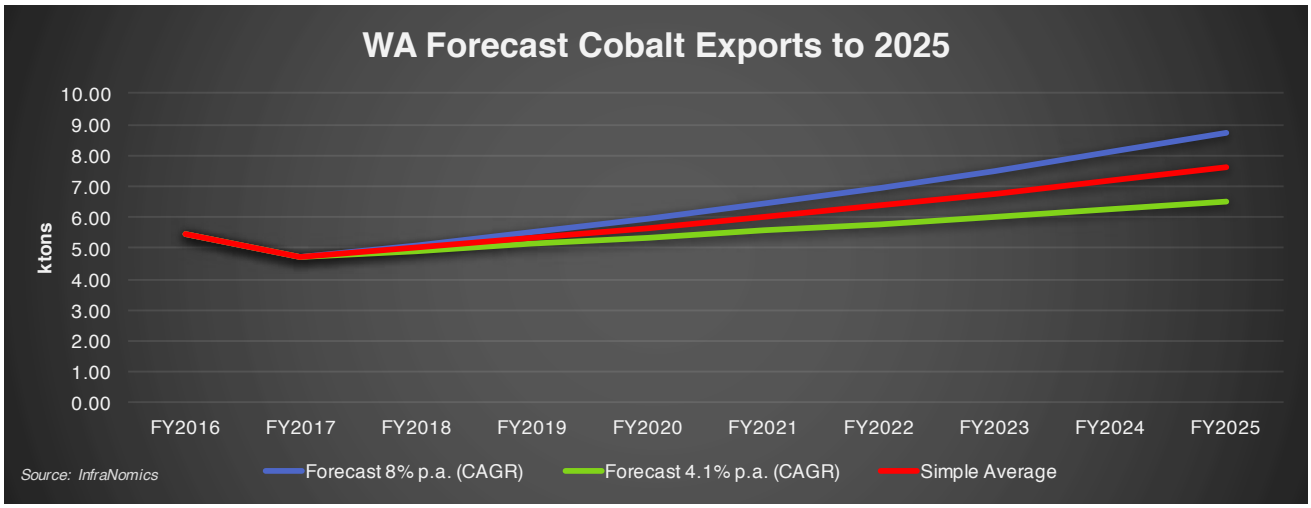
35 ***Figure 35:*** *WA Quarterly cobalt price per tonne (Jul'12 – Jun '17)*



Price increases have been notable since early 2017. This correlates with the increase in the overall value of cobalt exported from WA at the end of FY2016-17. Price per tonne in FY 2016/17 was A$51,669 per tonne, peaking at $A76,311 in June 2017 from a low of A$33,525 per tonne in July 2016 (127% increase over the financial year).

Similar to Lithium, Cobalt demand is forecast to grow considerably over the coming decade. Gindalbie Metals, a Perth-based cobalt miner, forecasts an 8% per annum growth in demand to 2020 to meet the needs of the battery storage industry.[76] Canadian-based investment bank Eight Capital is slightly less bullish on the global demand for cobalt. However, Eight Capital predicts that supply growth will increase 4.1% per annum to 2025.[77] Figure 36 utilises these growth assumptions as a basis for forecasting WA cobalt exports to 2025.

36 ***Figure 36:*** *WA Forecast Volume of Cobalt Exports to 2025*



The forecast export of cobalt in Table 13 utilises MIRS data as a basis. All other assumptions, such as WA's share of global cobalt exports, potential for new and unplanned mining operations, have been left unchanged. Table 13 sets out a number of key volume increase outputs from the analysis.

Table 13: ***WA Key forecast volume changes for Cobalt Exports***

	FY2017	FY2020	FY2025
Export volume (ktpa)	4.73	5.33 – 5.96	6.53 – 8.76
Export volume increase (ktpa) – previous period	n/a	0.61 – 1.23	1.19 – 2.80
Export volume increase (%) – previous period	n/a	13% - 26%	22% - 47%

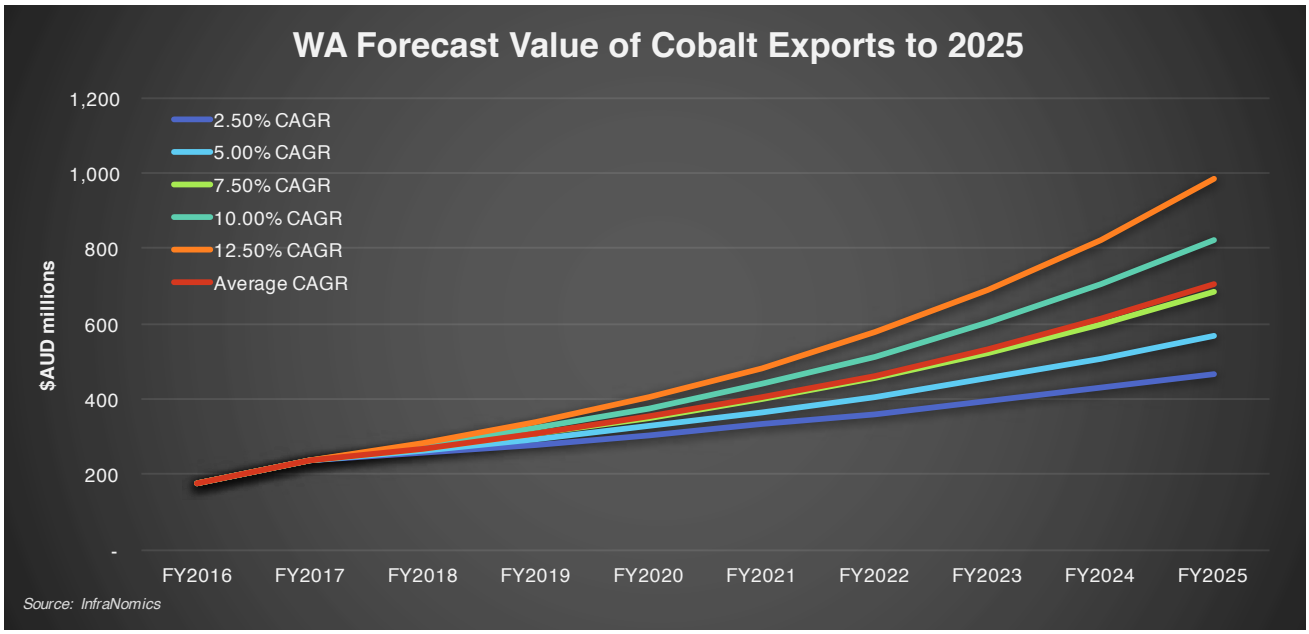
Source: InfraNomics

76 Gindalbie Metals Ltd (2017), Cobalt, https://www.gindalbie.com.au/strategies-and-commodities/cobalt/. (Accessed: 01 May 2018)

77 Lazenby, H (2017), "Zinc price on the up as supply tightens; cobalt forecast revised upwards as demand intensifies", 26 September 2017, ***Mining Weekly***, http://www.miningweekly.com/article/zinc-price-on-the-up-as-supply-tightens-cobalt-forecast-revised-upwards-as-demand-intensifies-2017-09-26. (Accessed: 01 May 2018)

Expanding on the methodology as set out above, a forecast of the value of cobalt exports has been derived. Figure 37 outlines the forecast trend of export value ($Am):

37 ***Figure 37:*** *WA Forecast Value of Cobalt Exports to 2025*



The forecast in Table 14 applies a CAGR range on export value per tonne in addition to the increases in WA export volume. Table 15 sets out a number of key outputs from the analysis.

Table 14: ***WA Key forecast export value changes for Cobalt Exports***

	FY2017	FY2020	FY2025
Export value ($Am)	$237.5m	$305.4m – $403.8m	$467.4m - $984.3m
Export increase ($Am) – previous period	n/a	$67.9m – $166.3m	$162.0m – $580.5m
Export increase ($Am) – previous period	n/a	29% - 70%	53% - 144%

Source: InfraNomics

11.3 Nickel

Nickel is used in more NCA-type (Lithium, Nickel, Cobalt, Aluminium Oxide) batteries than any other metal. NCA-type batteries form the core of Tesla's electric powertrain but have applications more broadly in medical devices and industry. There are currently only eight (8) nickel mines in operation in WA, with 25 others currently under care-and-maintenance.

Figure 38 and Table 15 illustrate both the total quantity and value of nickel exports in WA.

38 ***Figure 38:*** *WA Quarterly nickel exports (Sept '13 – Jun '17)*

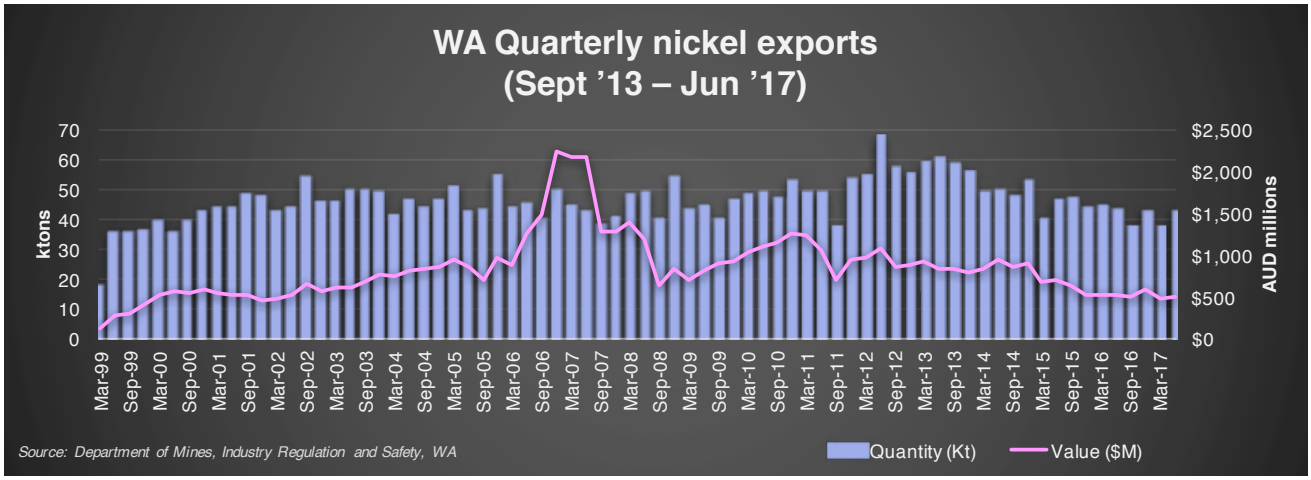


Table 15: ***WA Quarterly nickel export growth (Mar'15 – Jun '17)***

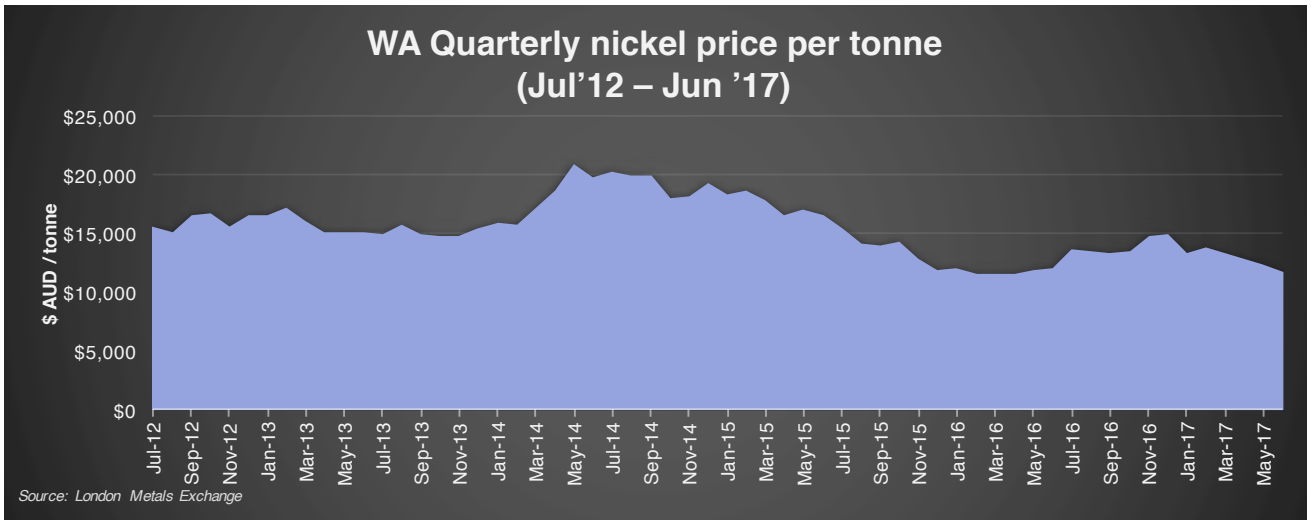
Quarter	Quantity (kt)	Quantity growth (kt)	Quantity growth (%)	Value ($Am)	Value growth ($Am)	Value growth (%)
Mar-15	39.12			675.54		
Jun-15	45.72	6.59	6.66%	714.86	39.32	81.97%
Sep-15	46.32	0.61	0.61%	638.46	-76.40	-159.30%
Dec-15	42.81	-3.51	-3.55%	528.36	-110.10	-229.56%
Mar-16	43.99	1.18	1.19%	518.42	-9.93	-20.71%
Jun-16	42.63	-1.36	-1.37%	517.49	-0.93	-1.94%
Sep-16	36.74	-5.89	-5.95%	493.70	-23.79	-49.61%
Dec-16	42.13	5.38	5.44%	593.52	99.81	208.12%
Mar-17	36.59	-5.54	-5.60%	484.44	-109.08	-227.44%
Jun-17	41.97	5.38	5.44%	509.41	24.97	52.06%

Source: Department of Mines, Industry Regulation and Safety, WA

The above chart and table highlight the stagnant export volume, and decreasing in overall sales value of nickel in WA, particularly in the last few years. In the financial year 2016-17, some 157.4kt were exported at a value of A$2,109m.

Figure 39 illustrates the nickel price movement, in AUD, between July 2012 and June 2017.

Figure 39: *WA Quarterly nickel price per tonne (Jul'12 – Jun '17)*



The nickel industry has struggled through a period of low prices, principally due to large global inventories and weak demand. General price decreases and stagnation have been seen since peaks in 2014. Price per tonne in FY 2016/17 was A$13,460 per tonne, peaking at A$15,015 in December 2016 from a low of A$11,813 per tonne in June 2017 (27.1% decrease).

Table 16 highlights the current WA export market for nickel in FY2016-17:

Table 16: ***WA Nickel exports (FY2016-17)***

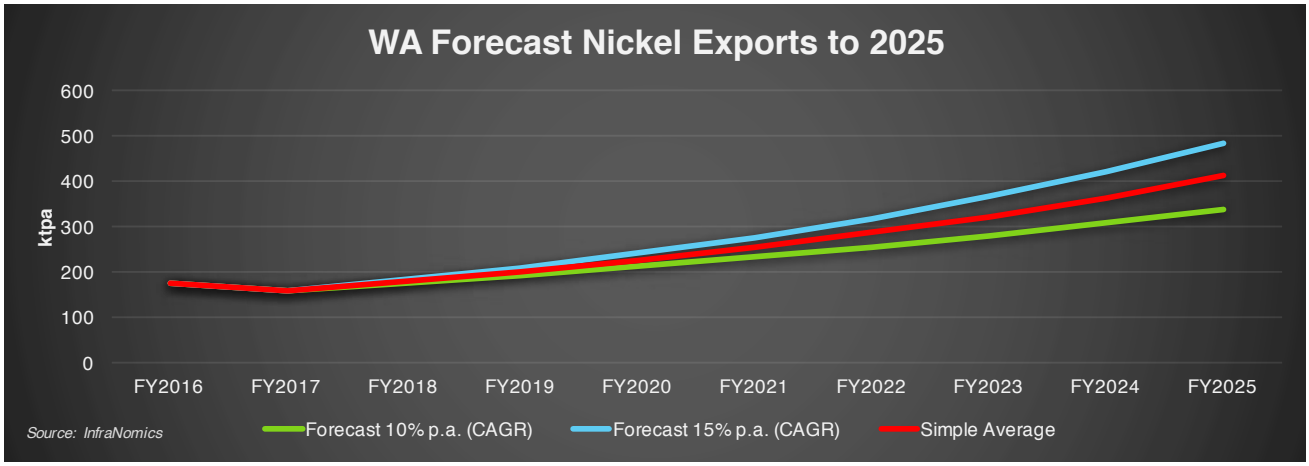
Nation	Rank	$A Export Value	% Of Total
Malaysia	1	$443,822,737	22.0%
Taiwan, Province of China	2	$430,945,960	21.3%
China	3	$376,329,414	18.6%
Korea, Republic Of	4	$257,533,243	12.8%
Japan	5	$227,028,007	11.2%
Singapore	6	$123,555,994	6.1%
India	7	$64,157,701	3.2%
Spain	8	$40,513,435	2.0%
Netherlands	9	$30,852,625	1.5%
United States	10	$9,166,538	0.5%
Other		$14,729,371	0.7%
Total		$2,018,635,024	100.0%

Source: Department of Mines, Industry Regulation and Safety, WA

Demand for Nickel over the coming decade will be driven by both the steel industry, and also storage battery sector. In 2017, nickel used for storage batteries and EVs represented only 3% on total demand, as compared to two-thirds of supply going towards stainless steel. However, as the popularity of electric vehicles continues to grow, the sector is expected to account for an increased amount of nickel demand.[78]

Lithium-ion batteries that power EVs require nickel with that need for nickel increasing going forward. UBS Group recently stated that by 2025 batteries will account for 500,000 to 600,000 tonnes of demand per year; current annual nickel demand stands at 2.1 million tonnes. Scotiabank suggests that global demand for nickel could increase (in aggregate) by between 10%-15% to 2025 from the EV sector along.[79]

40 ***Figure 40:*** *WA Forecast Volume of Nickel Exports*



The forecast export of nickel shown in Figure 40 utilises MIRS data as a basis. All other assumptions, such as WA's share of global nickel exports, potential for new and unplanned mining operations, have been left unchanged. Table 17 sets out a number of key volume increase outputs from the analysis.

Table 17: ***WA Key forecast volume changes for Nickel Exports***

	FY2017	FY2020	FY2025
Export volume (ktpa)	157.4	209.5 - 239.4	337.5 - 481.6
Export volume increase (ktpa) – previous period	n/a	52.1 - 82.0	127.9 - 272.04
Export volume increase (%) – previous period	n/a	33% - 52%	61% - 114%

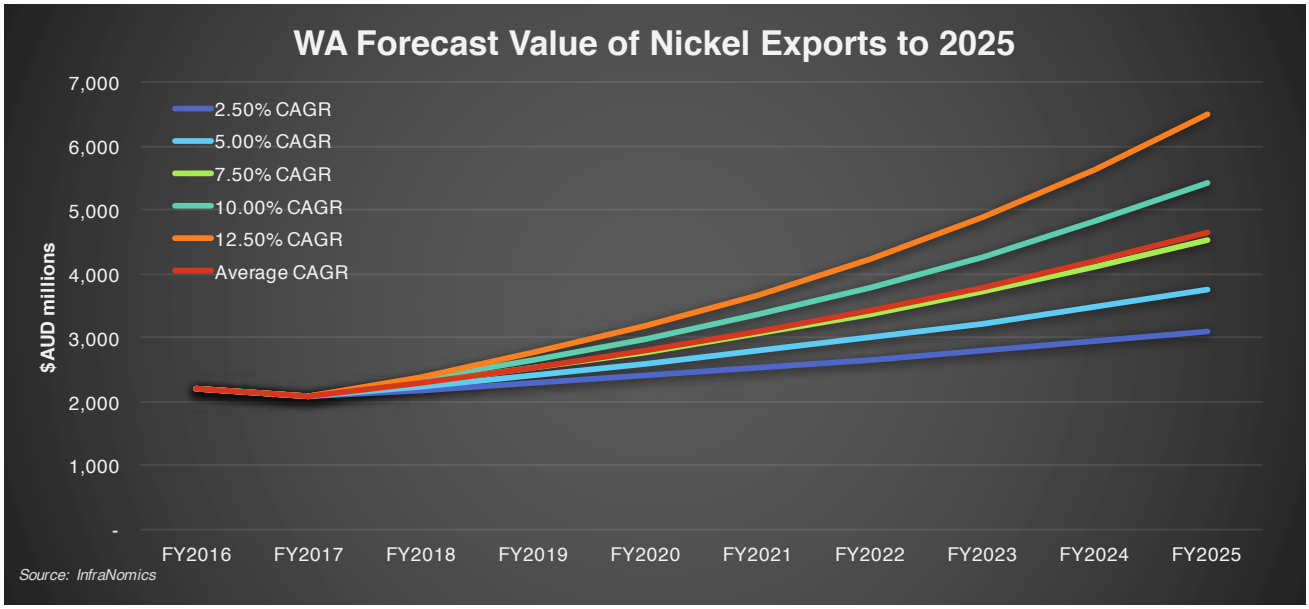
Source: InfraNomics

78 Shaw, M (2017), Nickel Outlook 2018: Price Gains and Growing Battery Boom, 7 December 2017, Investing News, https://investingnews.com/daily/resource-investing/base-metals-investing/nickel-investing/nickel-outlook-price-gains/. (Accessed: 01 May 2018)

79 Shaw, M (2017), Nickel Outlook 2018: Price Gains and Growing Battery Boom, 7 December 2017, Investing News, https://investingnews.com/daily/resource-investing/base-metals-investing/nickel-investing/nickel-outlook-price-gains/. (Accessed: 01 May 2018)

Expanding on the methodology as set out above, a forecast of the value of nickel exports has been derived. Figure 41 outlines the forecast trend of export value ($Am).

41 ***Figure 41:*** *WA Forecast Value of Nickel Exports*



The forecast in Figure 41 applies a CAGR range on export value per tonne in addition to the increases in WA export volume. Table 18 sets out a number of key outputs from the analysis:

Table 18: ***WA Key forecast export value changes for Nickel Exports***

	FY2017	FY2020	FY2025
Export value ($Am)	$2,081.1	$3,195.6 - $4,225.2	$6,595.8 - $13,889.9
Export increase ($Am) – previous period	n/a	$1,114.6 - $2,144.1	$3,400.2 - $9,664.7
Export increase ($Am) – previous period	n/a	54% - 103%	106% - 229%

Source: InfraNomics

11.4 Manganese

Typically used as part of the steel production process, manganese is being seen as a critical element in the clean energy revolution. The latest technology to use manganese is the "lithiated manganese dioxide" (LMD) battery. A typical LMD battery comprises 61% manganese and only 4% lithium. LMDs have numerous benefits, including providing higher power output, thermal stability, and improved safety compared to regular lithium-ion batteries.[80]

80 Palisade Research (2017), Manganese – the third electric vehicle metal no one is talking about, 24 March 2017, Mining.com, http://www.mining.com/web/manganese-the-third-electric-vehicle-metal-no-one-is-talking-about-it-heres-how-to-take-advantage/. (Accessed: 01 May 2018)

Metallurgical manganese has been mined in WA for more than 50 years. WA is estimated to have the fourth highest known reserves of manganese ore, after South Africa, the Ukraine and Brazil.[81] Currently there is one producing manganese project, Consolidated Minerals Ltd's Woodie Woodie mine, which has recently been reactivated. Woodie Woodie is targeting exports of 1.5 million tonnes of manganese at a price of A$4.03 per kg or approximately A$6 billion.

11.5 Vanadium

Like manganese, vanadium is primarily used in steel production, with the specific purpose of increasing steel strength. However, vanadium is being used increasingly in the provision of energy storage. Vanadium flow batteries are growing in demand as a cost-effective power storage solution. Unlike lithium-ion batteries where storage capacity decays over time, vanadium batteries flow off a 100% storage capacity for a life span of 25 years. Additionally, vanadium batteries require recharging far less frequently, in some cases charge retention can last up to a year.[82]

Vanadium flow batteries use a liquid electrolyte rather than the more familiar solid "cell" construction and this makes them easier to scale up or down as only the size of the plastic tank requires changing. Vanadium redox flow batteries can last up to 20 years or more and retain their capacity even when fully discharged and charged. These can be scaled-up for large scale commercial grid operations.

Other advantages of vanadium batteries including:

- Longer lifespan compared to lithium batteries;
- A lack of overheating and other thermal issues;
- Ease of manufacture;
- Greater efficiency over time and during variations of temperature; and,
- The ability to source more vanadium from environmental hazards such as mine tailings, depleted oil wells and oil storage depots.

With a few minor exceptions in the NT and Queensland, vanadium deposits are concentrated in WA. According to the U.S. Geological Survey's National Minerals Information Centre, Australian deposits of vanadium represent approximately 11% of the world's economic vanadium resources. This makes it the fourth largest in the world after China, Russia and South Africa.[83]

Currently approximately 92% of vanadium is used in the steel industry.[84] However, the battery storage market for Vanadium Redox Flow Batteries (VRFB) is growing and demand exceeded supply by approximately 10% or 9,000MT in 2017.[85] Forecasts indicate that VRFB could claim approximately 10% of the battery market per year that is estimated to be 11GMh of installed capacity or 1.1GWh for VRFB.[86]

81 United States Geological Survey 2018, Mineral Commodities Summaries 2018, 31 January 2018, https://minerals.usgs.gov/minerals/pubs/mcs/2018/mcs2018.pdf. (Accessed: 01 May 2018)
82 Australian Vanadium Ltd (2018), Vanadium Batteries, 2018, http://www.australianvanadium.com.au/vanadium-batteries/. (Accessed: 01 May 2018)
83 Geoscience Australia (2017), Vanadium, 01 November 2017, http://www.ga.gov.au/scientific-topics/minerals/mineral-resources/vanadium. (Accessed: 01 May 2018)
84 Australian Vanadium Ltd (2018), Vanadium Batteries, 2018, http://www.australianvanadium.com.au/vanadium-batteries/. (Accessed: 01 May 2018)
85 Australian Vanadium Ltd (2018), Vanadium Batteries, 2018, http://www.australianvanadium.com.au/vanadium-batteries/. (Accessed: 01 May 2018)
86 Australian Vanadium Ltd (2018), Vanadium in Energy Storage, March 2018, http://www.australianvanadium.com.au/wp-content/uploads/2018/03/AVL-presentation-March-2018-Paydirt-Battery-Minerals.pdf. (Accessed: 01 May 2018)

APPENDIX C - CURRENT AND PLANNED ENERGY METALS INVESTMENT

12 Appendix C – Current and Planned Energy Metals Investment

12.1 Current

Tianqi Lithium Hydroxide Processing Plant

China's Tianqi Lithium Australia Pty Ltd (Tianqi) is currently developing a two (2) stage lithium hydroxide processing plant (battery grade) in the KIA. Construction of the $400m first stage began in October 2016, with completion due in late 2018.

Due to increasing demand for lithium hydroxide for down-stream processing, particularly in China, Tianqi initiated a second stage to the plant in late 2017, increasing the investment in the processing plant to approximately $700m. This will see the plants' production double to 48k tonnes per annum, and an increase the permanent workforce to 170.[87]

42

Figure 42: *Tianqi battery grade lithium hydroxide processing plant, Kwinana*

Source: Tianqi Lithium Australia Pty Ltd

Galaxy Resources - Mt Cattlin

Galaxy Resources wholly owns the Mt Cattlin spodumene project, located two (2) kilometres north of the town of Ravensthorpe. Previously Galaxy was mining pegmatite ore at Mt Cattlin which was processed on site to produce a spodumene concentrate and a tantalum by-product. At full capacity, ore can be processed at a rate of one million tonnes per annum (tpa) with lithium oxide concentrate production of 137,000 tpa and 56,000 pounds (lbs) per annum of contained tantalum. The first shipments of lithium concentrate began in early 2017 bound for China for further downstream processing.[88]

87 Smith, S (2017), Tianqi backs WA with $300m Kwinana lithium expansion, 27 October 2017, The West Australian, *https://thewest.com.au/business/mining/tianqi-backs-wa-with-300m-kwinana-lithium-expansion-ng-b88641905z*. (Accessed: 01 May 2018)

88 Galaxy Lithium (2018), Mt Cattlin, *http://www.galaxylithium.com/projects/mt-cattlin*. (Accessed: 01 May 2018)

Mineral Resources – Mt Marion

The Mt Marion lithium project is located approximately 40km south west of Kalgoorlie and is jointly owned by Mineral Resources (43.1%), Neometals (13.8%) and one of China's largest lithium producer, Jiangxi Ganfeng Lithium (43.1%). Annual production of an initial 280,000 tonnes per annum of spodumene concentrate was achieved in 2017.[89]

Talison Lithium – Greenbushes lithium mine expansion

Talison Lithium's Greenbushes lithium mine, a JV between US based chemical company Albemarle and Tianqi Lithium Australia, is currently undergoing a $320m expansion. This will see the mines capacity double, ensuring it remains the world's largest hard rock lithium mine. It is proposed to expand the processing capacity of the existing Chemical Grade lithium production from 1.92m tonnes per annum to 4.32m tonnes per annum. With the construction of a new processing plant a notional increase in production of Chemical Grade spodumene concentrate from 0.64m tonnes per annum to 1.2m tonnes per annum is expected.

The expansion will require a contract workforce, which at the peak of the construction period is expected to be up to 200 employees. Some of the contract workforce will be accommodated locally, with the remainder commuting from Bunbury. It is envisaged that an additional 40 full-time employees will be required when the plant is operating at full capacity.[90]

Albemarle – Kemerton

Albermarle is in the final stages of the approval of its new lithium refinery in the Kemerton Strategic Industrial Area. The Albemarle Kemerton Plant will produce up to 100,000tpa of lithium hydroxide monohydrate (Lithium Hydroxide Product) from five 20,000tpa process trains. It is estimated 500 jobs will be created and up to $1 billion of capital will invested into the new refinery. Pending approvals, Albemarle aims to begin construction sometime in 2018 for an expected first production in 2020.[91]

Nickel West – Kwinana Refinery

In August 2017, BHP's Nickel West announced the construction of the worlds' largest nickel sulphate plant within the KIA. With Phase 1 funding approval and final approvals pending, the plant is scheduled for first production in April 2019.

Initially 100,000 tonnes per annum of nickel sulphate hexahydrate will be produced through dissolving nickel powder in sulphuric acid from Nickel West's Kalgoorlie Smelter. The process will be fully automated prior to the product being bagged for sale. The plant has been designed for a low-cost expansion to 200,000 tonnes per annum as demand dictates.[92]

89 Mineral Resources (2018), Mt Marion Lithium Project, http://www.mineralresources.com.au/mrl-mining/lithium.html. (Accessed: 01 May 2018)

90 Talison Lithium Australia Pty Ltd Greenbushes Mine Site CG Plant #2 Report, January 2017

91 McKinnon, S (2017), Albemarle follows lead with plans for WA lithium plant, 15 November 2017, *The West Australian,* https://thewest.com.au/business/mining/albemarle-follows-lead-with-plans-for-wa-lithium-plant-ng-b88660102z. (Accessed: 01 May 2018)

92 Haegel, E (2017), Nickel West – Energising Our Future, Presented at Diggers and Dealers conference, 09 August 2017, https://www.bhp.com/-/media/documents/media/reports-and-presentations/2017/170809_energisingourfuture.pdf. (Accessed: 01 May 2018)

43

Figure 43: *Nickel West – Nickel Sulphate Project, Kwinana*

Source: BHP

Northern Minerals – Heavy Rare Earth (HRE) Pilot Project

Northern Minerals Limited commenced development of the Browns Range HRE Pilot Plant Project in northern Western Australia in 2017. Through the development of the Project, Northern Minerals aims to be the first significant world producer of dysprosium outside of China.

The Project is 100% owned by Northern Minerals and has several deposits and prospects containing high value dysprosium and other HREs, hosted in xenotime mineralisation. Dysprosium is an essential ingredient in the production of DyNdFeB (dysprosium neodymium ironboron) magnets used in clean energy and high technology solutions. The three-year RandD pilot plant project will commence first production of heavy rare earth carbonate in the first half of 2018.[93]

Western Australia Lithium (WAL) refinery – Kwinana

Kidman Resources Limited (Kidman) 50:50 joint venture with Sociedad Quimica y Minera de Chile (SQM) called WAL, entered in May 2018 into an exclusive option with Western Australian Land Authority (Landcorp) to lease a site in Kwinana for refinery with an initial annual nameplate capacity of approximately 44,000 tonnes of lithium hydroxide or 37,000 tonnes of lithium carbonate. Commissioning of the refinery is planned to occur in 2021.[94]

12.2 Planned Activity – publicly available information

After positive results of a pre-feasibility study on its Bald Hill lithium-tantalum mine, Tawana Resources will spend $42m on developing the mine to produce 155,000 tonnes per annum of lithium concentrate.

Montezuma Mining is currently assessing the Butcherbird-Yanneri Ridge manganese project for battery-grade manganese dioxide. The Joint Ore Reserves Committee (JORC) have indicated that a scoping studying is being conducted, with the CSIRO to design the manganese-dioxide production process.[95]

93 Northern Minerals (2018), "Northern Minerals well placed to capitalise from growing US demand for rare earths", 01 March 2018, http://northernminerals.com.au/wp-content/uploads/2018/03/1803-01-NTU-US-rare-earths-demand.pdf. (Accessed: 01 May 2018)

94 Kidman Resources (2018), ASX Annoucement: Refinery Site Location, 04 May 2018, https://wcsecure.weblink.com.au/pdf/KDR/01978746.pdf. (Accessed: 30 May 2018)

95 Beardsmore, T (2018), "Western Australia: Battery Metal Powerhouse", *Geological Society of Western Australia,* 23 February 2018, http://www.dmp.wa.gov.au/Documents/Geological-Survey/09-Western%20Australia%20a%20battery%20metal%20powerhouse-Trevor%20Beardsmore.pdf. (Accessed: 01 May 2018)

Perth-based vanadium miner Atlantic, now owned by Droxford International, is expected to complete a feasibility study into a restart of the former Windimurra vanadium project near Mt Magnet by mid-2018. With the backing of an Indonesian billionaire and the support of nine-year high vanadium prices, Atlantic executive director Tony Veitch said the company estimated it would cost about $150 million to bring the fully approved project back into production. "The reality is, there's a global vanadium shortfall of about 4,000-5,000tpa and Windimurra's nameplate capacity of 4,500tpa fits very nicely into that," Mr Veitch said.[96]

Additionally, Neometals is also considering a lithium hydroxide processing plant for its Mt Marion operation. Options for the plant are being explored, and locations include Kalgoorlie and Kwinana. A front-end engineering study (FEED) is currently underway with a final investment decision due before the end of 2018.[97]

Note: Additional specific project and company information summarised in this report, including charts and graphs, are not disclosed where covered by confidentiality agreements.

96 McKinnon, S (2018), "Vanadium price boom offers hope of Windimurra revival", 03 April 2018, *The West Australian*, https://thewest.com.au/business/mining/vanadium-price-boom-offers-hope-of-windimurra-revival-ng-b88792684z. (Accessed: 01 May 2018)

97 Battern, K (2018), "WA poised for downstream battery boom", 10 January 2018, MiningNews.net http://www.miningnews.net/insight/feature-stories/wa-poised-for-downstream-battery-boom/. (Accessed: 01 May 2018)

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