



DISCUSSION PAPER

**POTENTIAL FOR ESTABLISHMENT OF A LI-ION BATTERY
MANUFACTURING INDUSTRY**

**PREPARED BY THE SW WA BRANCH BATTERY INDUSTRY
INVESTIGATION SUB-COMMITTEE**

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DISCLAIMER

This document has been prepared by a sub-committee of members of the WA branch of the AusIMM. The intent of this document is to provide a basis for discussion within the AusIMM regarding the potential for the establishment of a Lithium-ion manufacturing industry in WA.

The members of this sub-committee are listed in Appendix A. None of the members of this sub-committee have specific expertise or knowledge of the battery industry. However, all have extensive experience of the WA exploration, mining, plant operations and engineering sectors and have contributed to project development studies and implementation plans for various mineral projects.

The sub-committee participants have provided their time and input to this document on a pro-bono basis. There has been no financial payment to any person.

Several relevant Government and Industry association documents have been reviewed. However, input to the attached Strengths-Weaknesses-Opportunity-Threats (SWOT) is also informed by other referenced documents and by the general experience and industry knowledge of the participants.

The preliminary nature of this analysis is emphasised. The sub-committee has made recommendations regarding actions needed to advance the development of a battery industry in WA based on information available in the public domain, and their personal knowledge and experience. The participants will not be held accountable for any loss or expense that may be incurred by any person, the AusIMM, commercial organisation or government agency who may act on these recommendations.

It is proposed that the recommendations made in this document be used as a guide to further discussion within the AusIMM and with relevant government agencies to promote the development of a Li-ion Battery manufacturing industry in Western Australia.

11 August 2020

Revision Table

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Table of Contents

1	INTRODUCTION.....	5
2	THE WAY FORWARD	6
3	POTENTIAL VALUE OF LI-ION BATTERY INDUSTRY.....	8
3.1	Strategy Documents Reviewed.....	8
3.2	Value Chain.....	8
3.2.1	Demand Growth	8
3.2.2	Realised Value	9
3.2.3	Australian Capital and Operating Costs.....	9
3.2.4	Scale of Production	10
3.2.5	Greenhouse Gas Reduction Obligations and Renewable Energy.....	10
3.2.6	Timing Criticality	10
4	SWOT ANALYSIS.....	11
4.1	Objectives.....	11
4.2	Summary of SWOT	11
4.2.1	Strengths	11
4.2.2	Weaknesses.....	11
5	STRENGTHS-WEAKNESS-OPPORTUNITIES-THREAT (SWOT) ANALYSIS.....	12
6	STRENGTHS	12
6.1	Battery Metals	12
6.2	Demand.....	13
6.3	Equator Principles and Ethical Sourcing of Commodities.....	14
6.4	Strategic Geo-Political Considerations.....	14
6.5	Technology.....	14
6.6	Sovereign Risk	15
6.7	Society.....	15
6.8	Geographical Location	15
7	WEAKNESS	16
7.1	Technology.....	16
7.2	Logistics to End-User Markets	16
7.3	Government Policies	17
7.4	Labour and Industrial Relations	17
7.5	Production inputs.....	17
7.6	Antipathy for High-Tech Projects	18
7.7	Lithium from Brine	18
7.8	Alternate Battery Technologies	18
8	OPPORTUNITIES.....	19
8.1	Strategic Considerations	19
8.2	Broadening of Employment Opportunities	19
8.3	Recycle of Battery Metals	19
8.4	Ancillary Industries	19
9	THREATS.....	20
9.1	Alternate Locations for Battery manufacture.....	20
9.2	Government Policy.....	20
9.3	Alternate Technologies.....	20

9.4	Reduction of Free-Trade	21
9.5	Investment in R&D	21

Appendices

Appendix A:	Li-ion Battery Sub-Committee Members.....	20
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1 INTRODUCTION

The battery energy storage industry is expanding rapidly world-wide. Battery energy storage applications can be split into two broad categories:

- High energy-density applications: (E.g. electric vehicles, powered hand tools, mobile phones, laptop computers).
- Lower energy-density applications for which space requirements and energy densities are less constraining. (E.g. fixed location electrical power storage for off-grid and small-grid power networks – particularly where combined with solar and wind energy generation).

Li-ion batteries are the prime battery type used for the high energy density and/or compact storage applications.

Western Australia is a significant producer of the mineral concentrates used in the manufacture of ALL battery types. More specifically in the production of mineral concentrates required for the manufacture of Lithium-ion batteries (Ni, Co, Li, V, Mn).

Recently Tianqi¹ has commissioned a new refinery located in Kwinana to upgrade lithium flotation concentrate to Lithium hydroxide. Albemarle² is planning a similar facility at Kemerton (near Bunbury). BHP Nickel West is currently converting the Kwinana Nickel Refinery at Kwinana to produce high-value nickel and cobalt sulphate pre-cursors for Li-ion battery production.

In February 2020 the South West WA Branch of the AusIMM hosted a lithium processing workshop lead by Dr Nicholas Welham. An outcome of this workshop was a proposal for the AusIMM to advocate to both state and federal governments to support the development of a Li-ion battery industry in WA.

This work outlines considerations for the establishment of a Li-ion battery industry in WA. Government strategies and industry information were reviewed and used to assess the potential value. A SWOT analysis was completed from information published by mineral and metal producers and other sources. From this work, and within the context of Covid-19 and climate change, a way forward has been proposed.

The document aims to promote further discussion at a more tactical level; posing the question: 'What are the enablers of the decision for battery manufacture in Western Australia?'. These questions were investigated via the use of the SWOT technique.

¹ Tianqi Lithium Australia - <https://www.tianqilithium.com.au/site/About-Us/tianqi-lithium-global>

² Albemarle Corporation

2 THE WAY FORWARD

The on-going Covid-19 contagion has highlighted the need for Australia to develop local manufacturing capability and new employment options for the large number of employees shed from the entertainment, tourism and hospitality sectors.

The devastating bushfires early in 2020 demonstrated the impact of global warming on the Australian landscape. The ferocity of the fires highlighted the need for Australia to transition to renewable energy for power generation to help arrest the predicted increase of global temperature. Li-ion batteries will be integral to all future renewable energy options.

Australia produces nine of the 10 minerals that are needed for the manufacturing of Li-ion batteries³ yet realises only 0.53% of the value of a Li-ion battery⁴.

BHP Nickel West is currently modifying the Kwinana nickel refinery to produce nickel and cobalt sulphate; pre-cursor chemicals for Li-ion battery cathode manufacture. Tianqi⁵ and Albemarle⁶ have advanced projects for the upgrade of spodumene concentrate to lithium hydroxide for battery manufacture.

Western Australia has the engineering, technological, research and skilled labour to become a major manufacturer of both battery pre-cursor chemicals and manufactured batteries. Western Australia also has significant port, shipping, and internal transport infrastructure capability to export battery products into South-East Asia.

The manufacture of Li-ion batteries in Australia would have strategic defence and industrial supply-chain benefits, supporting the transition of Australia to a renewable energy future for both transport and electrical power storage applications.

Based on this SWOT analysis, coordinated and long-term vision is required by both Federal and State governments to encourage investment in strategic high-tech industries. Measures that will be required include:

- **Development of infrastructure** for roads, rail, water, power, and identification of suitable land for the development of a large-scale local pre-cursor chemical and battery manufacturing industry,
- **Identification and encouragement** of both local and foreign-based companies with the capital strength and long-term vision needed to develop high-tech/high risk industries,
- **Review of Taxation and investment rules** that might otherwise act as an impediment for private capital investment in specific new and high-tech projects and industries,
- **Direct investment of capital** via government/private consortiums to share the risks associated with the development of new high-tech industries as is being provided by other developed nations,
- **Adequate funding** of Universities, CRCs, and private research organisations needed to support the scientific and technical needs of an emerging battery industry,
- **Support for training** of labour for a large-scale pre-cursor chemical and battery manufacturing industry,
- **Management of foreign policy** to advance Australia's national interest and promote **cooperation and investment by foreign corporations** with the intellectual knowledge that will assist development of a battery manufacturing industry in a timely manner

³ BHP Nickel West central to WA's battery manufacturing industry; Australian Mining Magazine, 22 July 2020

⁴ Op.cit, - footnote 17

⁵ Op.cit, footnote 1

⁶ Op.cit; footnote 2

- **Clarification of National Energy Policy** to support private investment in renewable projects to address global warming and promote downstream industries that will utilise Li-ion battery products.

The authors conclude that there is a window of opportunity to realise the vision for Australia (WA) to become a world class battery producer. However, a coordinated effort is needed by both state and federal governments and private industry to develop the strategies and plans to deliver this vision.

3 POTENTIAL VALUE OF LI-ION BATTERY INDUSTRY

3.1 Strategy Documents Reviewed

Both the WA State and the Australian Federal Governments have recognised the potential for value-adding down-stream processing of mineral concentrate products to produce battery pre-cursor chemicals, and potential manufacture of finished Li-ion battery products. Publications reviewed include:

- Future Battery Industry Strategy – Western Australia⁷
- Australia’s Critical Mineral Strategy – 2019⁸

While outlining the case for down-stream processing of battery-metal concentrates in Australia, the above documents are high-level strategy documents. The documents do not outline the detailed policies, plans, tax and financing incentives, together with the required government support for infrastructure, planning and possibly direct investment by government that will be needed to develop a down-stream Li-ion battery industry in WA.

While focusing on the positive benefits, these documents underestimate the challenges and support that would be required at federal and state levels to establish an integrated Li-ion battery manufacturing industry in Western Australia.

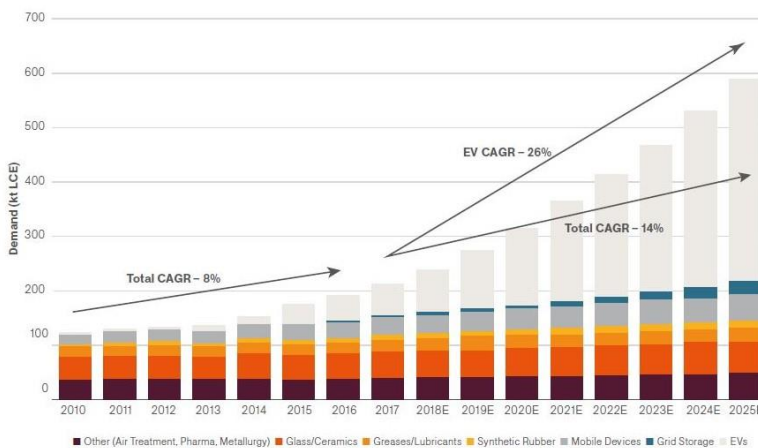
3.2 Value Chain

A recent publication by the Federal Australian Trade and Investment Commission⁹ highlights the potential benefits to Australia by value-adding to battery-metal concentrates. Significant highlights from this document are listed below.

3.2.1 Demand Growth

Demand growth, particularly for electric vehicles and renewable energy storage is increasing at an exponential rate¹⁰.

Figure 2: Forecast global annual lithium demand



7 Future Battery Industry Strategy – Western Australia, WA Department of Jobs, Tourism, Science and Innovation, Jan 2019

8 Australia’s Critical Minerals Strategy 2019, Australian Government – Department of Industry, Innovation and Science and Australian Trade and Investment Commission, 2019

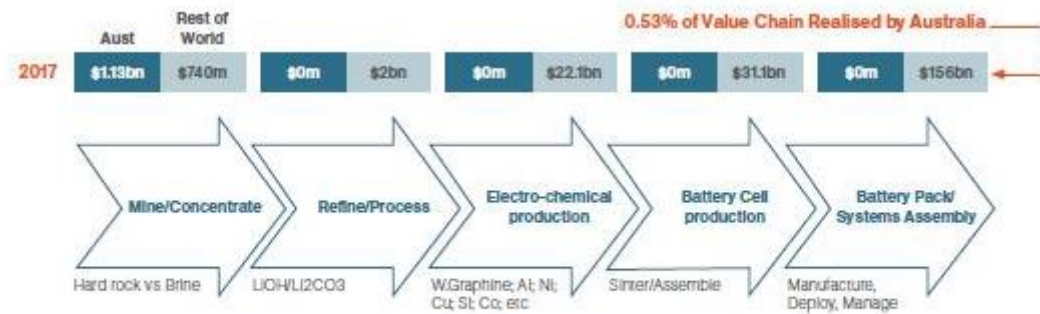
9 The Lithium-ion Battery Value Chain, Federal Australian Trade and Investment Commission, 2018

10 Refer footnote 4 - Figure 2, Comparative forecast global annual battery production (GWh) to 2023

The above market growth prediction is supported by a recent document reporting that S&P Global Market Intelligence predict that lithium demand will increase by 91% from 2019 to 2024 reaching 536,000 tonnes of lithium carbonate equivalent¹¹. The rapid growth in demand is anticipated to be driven initially by the rapid transition to electric vehicles in Europe. The demand for other battery-metals would also increase proportionally.

3.2.2 Realised Value

The selling of mineral concentrates only realises 0.53% of the value of a Li-ion battery¹².



Source: Future Smart Strategies (2018)

3.2.3 Australian Capital and Operating Costs

The direct comparison of capital and operating costs for different nations is difficult due to the relative exchange rates, differences in life-style expectations and government systems. However, as illustrated in the table below the estimated Capital and Operating costs for production of Li-ion batteries in Australia are generally comparable with alternate locations.

Australian institutions to regulate workplace standards and employee relations provide predictability for financial planning. A high level of automation that would be incorporated in a modern battery plant would also ensure high productivity and negate possible higher unit labour cost.

Figure 35: Cost variables for countries manufacturing lithium-ion battery cells

	Factory Construction cost USD/m ²	Skilled Technical labor USD/hr	Industrial electricity US c/kWh
China	333	5	14
Chile	554	9	8.05
South Korea	950	22	25
Poland	420	6	10.46
USA	656	85	10.0
Australia	578	60	9.71

Sources: Turner and Townsend; OECD; National Renewable Energy Laboratory; CEIC; Korean Times. It should be noted that the above table does not take account of effective productivity.

¹¹ All aboard the Lithium Train: Australian Financial Review Aug 9, 2020

¹² Refer footnote 4- Figure 31, Lithium Value Chain 2017-2025

3.2.4 Scale of Production

As highlighted in the above table a possible relatively higher cost of Australian labour could negatively impact on the viability of local battery industry. To offset this production would need to incorporate a high level of automation and the scale of production targeted at a large-scale domestic and export market. The near proximity to South-East Asia markets favours Western Australia for siting of a Li-ion battery manufacturing industry.

3.2.5 Greenhouse Gas Reduction Obligations and Renewable Energy

Federal policies and targets for the reduction of green-house gas and transition to renewable energy remains to be clarified. However, battery energy storage will form part of near-term strategies to achieve these objectives and to assist stabilisation to the state and national power-grids¹³.

Local manufacture of Li-ion batteries should reduce the capital and operating costs and lower the risks associated with external supply-chains for batteries, thus aiding the transition to renewable energy sources.

3.2.6 Timing Criticality

As highlighted in a 2017 industry report ¹⁴

'There is a limited window with many other countries already aggressively moving to capitalise on these opportunities. Government, industry and industry associations must collaborate to capture this opportunity.'

¹³ Technology Investment Roadmap Discussion Paper, A framework to accelerate low emissions technologies, Federal Department of Industry, Science, Energy and Technology, May 2020; Figure: Key Technology Challenges and Opportunities - Page 9

¹⁴ A Lithium Industry in Australia –Prof Ray Willis et al, Future Smart Strategies, 2018 for AMEC

4 SWOT ANALYSIS

4.1 Objectives

A sub-committee of the South West Branch of the AusIMM was tasked with preparing a briefing paper to assist AusIMM to advocate to the Federal and State governments to support development of an integrated battery metals industry in Western Australia. The benefits to the state and nation have been discussed at various conferences of Industry professionals¹⁵ and documented in industry and government sponsored reports^{16,17}

The participants to this SWOT are listed in Appendix A. This analysis is not comprehensive and none of the contributors have specific expertise or knowledge of the battery industry or technologies. However, all have extensive experience of the WA exploration, mining, plant operations and engineering and have contributed to project development studies and strategy development.

While many of the key strengths and weaknesses impacting development of are discussed in the referenced review document, the SWOT also referenced other published information and is informed by the knowledge and experience of the study participants.

4.2 Summary of SWOT

4.2.1 Strengths

Key factors favouring development of a Li-ion battery industry in WA include:

- WA is a major producer of battery-metal inputs including mineral concentrates,
- Refineries for production of battery pre-cursor chemicals are already operating or being established in WA for Li, Ni and Co,
- Australia is a low sovereign risk jurisdiction for foreign and domestic investors,
- The WA community is supportive of responsible mining and processing industries,
- Skilled labour is available,
- Perth is a world-centre for mining and industrial engineering,
- Both Fremantle and Bunbury ports are suitable for shipment of products to Asia,
- Facilitates a reduction in freight costs within the supply chain, as higher value material is exported rather than bulk materials,
- WA has world-class tertiary education and research capability.

4.2.2 Weaknesses

Key weaknesses to be overcome include:

- Battery technology is tightly controlled by predominantly North Asian based companies,
- Limited (current) local market for battery products,
- Remoteness of WA from major consumers of Li-ion batteries,
- Long time frame for environmental, heritage, social impact studies and approvals,
- Relatively higher labour costs compared with North Asian manufacturers,
- Relatively high water and power costs,
- Other jurisdictions may offer more attractive taxation and development incentives.

15 Distinguished Panel discussion - ALTA Hydrometallurgical Conference – Perth 2017

16 AMEC – Australian Battery Minerals – Investment Opportunities

17 A Lithium Industry in Australia – Future Smart Strategies 2017 - AMEC

5 STRENGTHS-WEAKNESS-OPPORTUNITIES-THREAT (SWOT) ANALYSIS

The following subsections review the Strengths, Weaknesses, Opportunities and Threats impacting the potential development of a Li-ion battery manufacturing industry in WA.

As previously discussed, the participants to this SWOT have limited specific knowledge of the Battery-metal industry but all have extensive experience of the WA exploration, mining, plant operations and engineering and have contributed to project development studies and strategy development.

The objective of the SWOT is to assist in formulation of the actions needed to progress the development of a Li-ion battery industry in WA.

6 STRENGTHS

6.1 Battery Metals

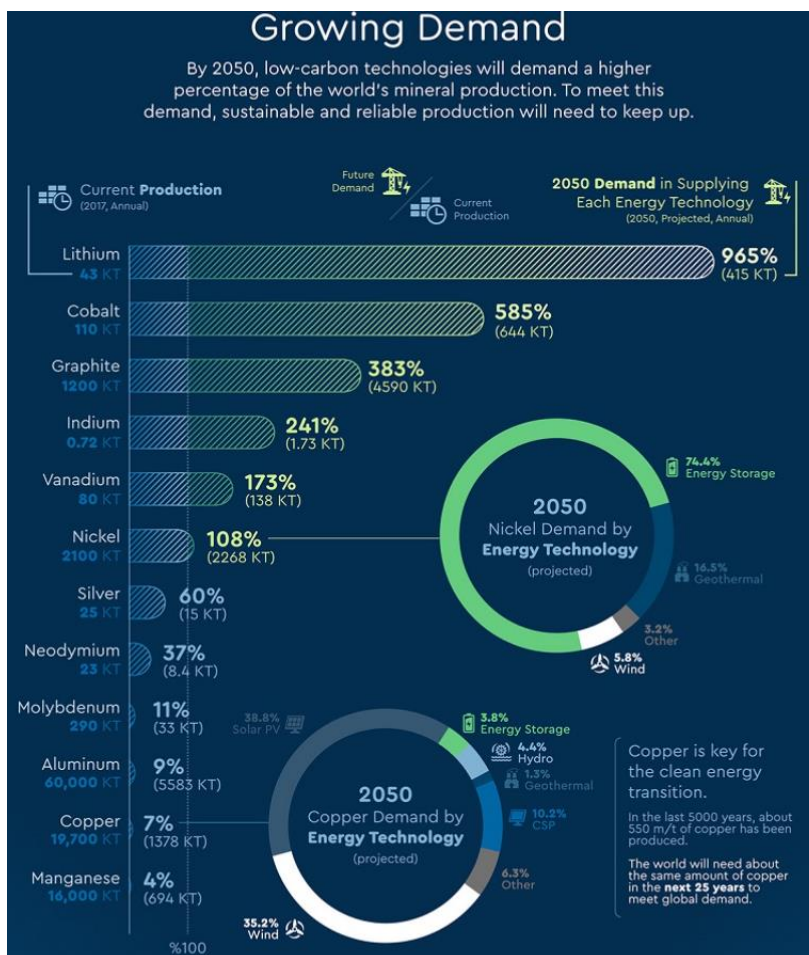
WA is a major producer of the prime metals required for manufacture of Lithium-ion batteries:

- **Nickel:** Both from sulphide and laterite sources
 - Sulphide Sources (Flotation + smelting + hydromet flowsheet)
 - Nickel West - Kambalda, Leinster, Mt Keith
 - Independence Group – Nova
 - Western Areas – Forrestania and Odysseus development
 - Poseidon – Black Swan, Silver Swan, Golden Swan (Suspended/potential)
 - Panoramic Resources – Savanna/Savanna North (Suspended)
 - St George – Mt Alexander (prospect)
 - Chalice – Julimar (prospect)
 - Laterite – Sources (Hydromet process routes)
 - Glencore - Murrin-Murrin
 - FQM – Ravensthorpe
 - Bulong, Cawse (suspended)
 - Ardea – Goongarrie Nickel Project (PFS complete)
 - Refining
 - BHP Nickel West – Kalgoorlie Nickel Smelter
 - BHP Nickel West – Kwinana Sherritt Gordon Nickel Refinery
 - **Cobalt:** Associated with both sulphide and lateritic nickel.
 - Nickel-West are modifying the Kwinana refinery to produce Cobalt Sulphate – a pre-cursor for Li-ion battery cathodes
 - Murrin-Murrin produce a cobalt metal briquette product
 - Ravensthorpe produces a mixed Nickel/cobalt hydroxide product
 - The proposed Ardea – Goongarrie flowsheet allows for production of a cobalt sulphate product
 - Cobalt metal was produced via an electro-win process at Bulong
 - **Lithium**
 - Australia has 8 ASX listed companies with Lithium deposits and is the world's top producer.
 - Australia was the world's largest producer—21.3kt contained Li, for 47% of world production—followed by Chile (14.1kt contained Li, 31%), Argentina (5.5 kt, contained Li, 12%) and China (3 kt, contained Li, 7%).
 - Flotation Concentrate
-

- Talisman - Greenbushes 1.3Mt/a – 2.4Mt/a Spodumene concentrate
- Mineral Resources - Mt Marion 206, 000 t/a Spodumene concentrate
- Mineral Resources – Wodgina - 750,000 t/a Spodumene concentrate
- Pilbara Minerals – Pilgangoora – 330, 000t/a spodumene concentrate
- Altura - Pilbara Minerals - Pilgangoora Mine 220, 000t/a spodumene concentrate
- Lithium Hydroxide
 - Tianqi – Kwinana 24 000 t/a Lithium hydroxide, expanding to 48,000t/a LiCO₃
 - Albemarle – Bunbury 100,000 t/a LiOH (proposed/pending)
 - Covalent Resources (SQM/Westfarmers) – Kwinana 45,000t/a LiOH (proposed/pending)

6.2 Demand

The report Minerals for Climate Action¹⁸ concluded the demand for graphite, lithium and cobalt could surge by approximately 500% by 2050



This report highlighted the supply risk with +60% of cobalt currently supplied from the Democratic Republic of Congo with China producing 70% of world graphite supply which is used as part of the battery anode for all current Li-ion battery variants.

¹⁸ World Bank, <https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action>

6.3 Equator Principles and Ethical Sourcing of Commodities

The Equator Principles (EPs) is a risk management framework, adopted by global financial institutions, for determining, assessing and managing environmental and social risk in project assessment. The EPs outline the minimum standard of diligence with respect to assessment of the impacts of proposed developments on local communities and the cultural and environmental impacts of proposed projects to support responsible risk decision-making.

- Feasibility studies for significant new mining, O&G and industrial projects in Australia conform to the EP provisions to ensure access to international finance,
- Major consumers of Li-ion batteries are anxious to have 'Ethically Sourced' supply chains for metals and components,
- Cobalt is of significance. Currently the DRC is the major world supplier of this element; China is the major investor in DRC production
- Australian industry is actively involved in the development of new technology and process facilities for the recovery of precursor metal chemicals from spent Li-ion batteries¹⁹ and possible use of process waste products as agricultural trace-element additives²⁰.

6.4 Strategic Geo-Political Considerations

Military and political focus by Western aligned nations for onshore production of strategic materials and/or sourcing from Western aligned nations²¹:

- China is the major producer of battery precursors - especially Lithium,
- China is the major investor in DRC cobalt supply,
- China is the major processor of both light and heavy rare-earth metals.

6.5 Technology

WA is well placed to support development of the sophisticated processing and manufacturing infrastructure needed to support a battery-metal industry

- WA is a world-hub for mining and oil and gas (O&G) engineering with both international and local engineering companies capable of managing design and construction of complex chemical processing facilities,
- Major international equipment suppliers to both the mining and O&G industries have offices in WA,
- Major international instrumentation and control system engineering companies are represented locally,
- Communications infrastructure of world standard,
- Universities and CRCs with focus on Agriculture, Mining and O&G focus capable of supporting research for battery metals,
- Future Battery Industries CRC already established in WA,
- Educated blue-colour and professional labour available together with positive interest by state and regional governments for the establishment of new employment options,

¹⁹ Lithium Australia quarterly activities report – June 2020 with special focus on Envirostream subsidiary for recovery of metals from spent batteries

²⁰ Refer footnote 32

²¹ Lynas gets US Heavy Metals Gig – Mining News – 23 April 2020

- It was recently announced that the BHP Nickel West will partner with the CSIRO via the Future Batteries Industry Cooperative Centre to research the manufacture of Li-ion cathode pre-cursor products²². This partnership provides a basis for expansion of the cathode precursor industry in WA.

6.6 Sovereign Risk

- Australia is a politically stable jurisdiction for investment by foreign-based companies,
- Australian business and government institutions generally exhibit low levels of corruption and have established independent agencies for auditing and prosecuting corruption where evidence is established,
- Australia has constitutionally based separation of governance and independence of legal institutions,
- WA has a past record of adhering to agreements relating to royalties, taxation and oversight,
- Positive attitudes to investment by foreign companies in Australian-based resource and manufacturing facilities,
- Australia is willing to engage with foreign corporations to develop Australia's Critical Mineral industries²³.

6.7 Society

- WA population generally supportive of industrial, mining and O&G development,
- Federal and State Governments have agencies and procedures to engage with the Australian community to achieve consensus, support, respect for impacted groups and care for the environment,
- Government support for the establishment of new industries and advanced technologies,
- WA has strong institutions to regulate and oversee compliance with OH&S, community and environmental obligations,
- WA has a stable industrial framework for the management of labour and working conditions (awards and negotiated site-agreements) with legal institutions to oversee and mediate when necessary,
- WA provides support for up-skilling of the workforce via technical training organisations, and cash and taxation incentives for employment and training,
- There is a growing community interest in transitioning to renewable-energy sources for electrical power and transport – the major future applications for battery metals.

6.8 Geographical Location

- WA is well positioned geographically to supply battery precursors and finished product into SE Asia,
- WA has well established port and handling infrastructure for the export of high-value battery-metal products,

²² Op.cit, footnote 3

²³ <https://corrs.com.au/insights/australias-critical-minerals-sector-is-open-for-foreign-investment-but-early-and-constructive-engagement-with-firb-is-essential>

- Land suitable for industrial use is readily available near major infrastructure and ports,
- WA is a safe, pleasant and generally accepting location for foreign owner executives and technologists to live and visit,
- An industry group - Lithium Valley WA has already been established to promote development of a lithium product industrial park in the Kwinana region^{24,25,26}.

7 WEAKNESS

7.1 Technology

Battery technology is tightly controlled by established producers:

Rank*	Company	2017 Installed Manufacturing Capacity**	Country	Revenue***	Market Cap****
1	LG Chem	17 GWh	Korea	\$23.1 Billion	\$23.9 Billion
2	BYD	16 GWh	China	\$15.5 Billion	\$15.4 Billion
3	Panasonic	8.5 GWh	Japan	\$71.8 Billion	\$31.8 Billion
4	AESC	8.4 GWh	Japan	NA	NA
5	CATL	7.5 GWh	China	\$3.0 Billion	\$23.3 Billion
6	Guoxuan High-Tech	6 GWh	China	\$718 Million	\$2.3 Billion
7	Samsung SDI	6 GWh	Korea	\$5.7 Billion	\$14.0 Million
8	Lishen	3 GWh	China	NA	NA
9	CBAK	2.5 GWh	China	\$58.4 Million	\$19.2 Million
10	CALB	2.4 GWh	China	NA	NA
11	LEJ	2.3 GWh	Japan	NA	NA
12	Wanxiang	2.1 GWh	China	\$1.7 Billion	\$2.6 Billion

Establishment of a local battery industry would likely be strengthened through a strategic alliance with one of the existing major manufacturers based in China, Korea, Japan and USA.

7.2 Logistics to End-User Markets

- The major electric and hybrid vehicle manufacturers are based in Japan, China, US, Thailand, EU,
- The major fixed electrical energy storage manufacturers are based in EU, China, Japan, USA.

²⁴ <https://www.lithiumvalleywa.com.au/>

²⁵ The authors of this discussion paper have no personal knowledge of the proponents or objectives of the Lithium Valley organisation.

²⁶ The proposed Kwinana site for the Lithium Valley lithium industry park requires careful risk review due to the geographic proximity to the CSBP ammonium nitrate production facility.

7.3 Government Policies

- Clarity by Federal and State governments with respect to renewable energy and greenhouse-gas reduction targets is required to reduce risk for investment in Australian clean energy projects,
- Australian taxation regulation competitiveness with alternate nations seeking foreign investment:
 - Taxation concessions and/or consideration of a ‘Honeymoon period’ with respect to taxation obligations may be required to encourage the development of targeted new high-tech capital-intensive industries by private investors that will drive future employment growth,
- Environmental and public reviews associated with development of new industries may result in delays relative to alternate jurisdictions,
- Recent political polarisation of US aligned nations and Australia’s major North-Asian trading partners may discourage technical cooperation and investment by potential technology suppliers if foreign policy is not carefully managed by the Federal government and with a clear focus on Australia’s long-term interests.

7.4 Labour and Industrial Relations

- Unit labour cost in Australia may be higher than some alternate locations
 - Competitive advantage may be gained by maximising productivity via instrumentation, control and automation technology,
- Lack of understanding by foreign investors of the Australian industrial relations environment
 - Government and industry advisors could assist with mitigation of this concern.

7.5 Production inputs

- WA power-costs are relatively high compared with some alternative jurisdictions,
- Water availability in WA is limited and cost may be higher than alternative locations,
- Limited local manufacture of chemical inputs including water treatment chemicals, acid, caustic, other organic chemicals,
 - Government policies and incentives could assist the development of local manufacture of industrial chemical inputs,
- Long supply-chains for chemical inputs and potential for disruption due to politics, conflict, contagion, shipping costs to WA,
- Limited local potential to utilise and recycle by-products and waste products,
- Disposal costs for intractable waste may be high relative to some alternate jurisdictions
 - Other nations are increasingly conscious of the need for environmental protection²⁷.
 - The high level of regulation and enforcement of waste management practices for Australian industry would be viewed positively by institutional investors committed to the Equator Principles for ethical investment (refer section 6.3).

²⁷ The cost for disposal of intractable waste is likely to be similar between developed countries and is being increasingly addressed in China: <https://e360.yale.edu/features/china-wrestles-with-the-toxic-aftermath-of-rare-earth-mining>

New projects seeking finance by international lenders must also conform to the Equator Principles for management of social and environmental impacts.

7.6 Antipathy for High-Tech Projects

- Preference by the Australian investment community for 'Shovel & Ship' projects with minimal onshore processing and capital requirement,
- Past hydro-metallurgical and pyrometallurgical projects (Bulong, Cawse, Murrin-Murrin²⁸, Ravensthorpe, Hot-briquetted Iron) being considered complex and non-performing,
- Reticence by Australian entrepreneurs and major mining and O&G companies to commit to long-term high-tech projects,
- Limited existing high-tech manufacturing and chemical based industries in WA,
- Culture of dependence on private enterprise to fund the development of long-term high-tech industries with limited government financial and policy support,
- Willingness by some nations to allocate significant public funds for large-scale capital-intensive processing facilities as part of a long-term nation-building vision²⁹.

7.7 Lithium from Brine

- Significant industry in Chile, Argentina, China, Tibet, US,
- Perceived superior economics relative to hardrock spodumene projects common in Australia,
 - Moderate capital cost, but long lead-time for evaporation and carbonate precipitation,
 - Only applicable where climate suitable for evaporative concentration,
 - By-products include salt and gypsum for chemical and industrial uses,
 - Significant footprint and possible environmental impacts,
- Major commercial sources already identified,
- Potential production may be approaching peak output,
- Production rate is inflexible,
 - Production from hardrock sources can be readily increased or scaled-back to match market demand.

7.8 Alternate Battery Technologies

- Active research is on-going to develop alternate battery technologies for both transport and static battery applications with a focus on reducing or eliminating cobalt,
 - In the short/medium term Li-ion technology is likely to continue to be the dominant technology for high energy-density applications including electric vehicles and grid-power stabilisation,

²⁸ As commissioned the Murrin-Murrin and Ravensthorpe projects were uneconomic at prevailing metal prices. Both experienced engineering deficiencies that extended the ramp-up period to Design output. Revenue was insufficient to service the debt financing obligations. Both projects have been sustainable following sale to new owners at heavily discounted capital cost and with available cash-flow to fund the changes needed to achieve the process intent. While the Bulong and Cawse projects achieved design, the project scale and capital and operating costs were unsustainable at prevailing metal prices.

²⁹ Finland recently allocated €450m to the state-owned battery firm Finnish Minerals Group to boost plans to increase minerals processing capacity and strengthen the country's Li-ion battery chain: Mining Magazine 5 June 2020

- Research to develop a high energy-density cobalt-free Li-ion battery has now reached commercial viability³⁰,
 - Cobalt is an ancillary metal in all Australian sulphide and lateritic nickel deposits contributing a significant although volatile revenue contribution.

8 OPPORTUNITIES

8.1 Strategic Considerations

- Interest by Western nations to secure supply of strategic metals and components from reliable and allied nations.
- Increased government and community awareness of the importance of an independent supply chain for nation critical materials,
- Increased government and community awareness of the importance of a strong and diverse manufacturing sector to deliver above independence may facilitate project approvals and taxation arrangements.

8.2 Broadening of Employment Opportunities

- WA has a large industrial/mining blue-collar workforce that could be re-skilled for manufacturing activities.
- WA has a need to expand employment opportunities for youth particularly in regional locations.
- Post the Covid-19 contagion Australia must develop new employment options due to a reduction in employment opportunities in the entertainment, restaurant, travel and tourist sectors.

8.3 Recycle of Battery Metals

- Li-ion batteries ex vehicles have a second-life application for fixed power storage,
 - Reprocessing industries established and expanding to recover pre-cursor metals from spent batteries,
 - Lithium Australia – Envirostream/MMD recycle plant operating in Melbourne,
 - Neometals have secured a site for lithium battery recycling at Kalgoorlie,
 - Recycle technology is becoming increasingly important as world stockpiles of spent Li-ion batteries increase.
- In the future, recycling of spent Li-ion batteries will become a significant source for the precursor chemicals for the manufacture of new Li-ion batteries.

8.4 Ancillary Industries

A WA based Li-ion battery manufacturing industry would:

- Attract related industries and technology to the state,

³⁰ Chinese automotive battery company SVOLT (a Great Wall Motors spin-off) has officially launched two new lithium-ion battery cells, one of them the cobalt-free NMx: The Power of Three - Issue 34, June 2020, sponsored by Lithium Australia NL

- Stimulate expansion of the renewable energy industries and broadening of power options for both on-grid, small-grid and off-grid power applications,
- Provide price stability for related industries utilising Li-ion batteries as supply would not be subject to exchange-rate variations,
- Encourage development of an electric vehicles industry – possibly utilising redundant plant in Victoria and SA, following the cessation of the local ICE³¹ vehicle manufacturing industry,
- Provide a source of trace elements for fertiliser to boost agricultural production³²
- Provide stimulus/support for the WA defence-support industries,
- Provide investment industry with options aligned to the Equator Principles.

9 THREATS

9.1 Alternate Locations for Battery manufacture

- Rapid expansion of the Ni/Co smelting and refining industries in Indonesia³³ and elsewhere in SE and North Asia (India) which are geographically closer to both technology suppliers and end-users,
- Shipping distance of WA from major markets in Europe, North Asia and America for vehicle and fixed energy storage.

9.2 Government Policy

- Potential lack of coordinated support by Federal, State and Local government agencies to encourage and facilitate the development of a WA based integrated Li-ion battery industry,
- Potential lack of Long-term vision by both government and industry leaders needed to develop new high-tech industries.

9.3 Alternate Technologies

- Development of safe alternate fuel options (hydrogen) for transport applications resulting in a lower than anticipated adoption of the electric vehicle industry,
 - Hydrogen is primarily sourced from hydrocarbons so still high carbon footprint.
- Adoption of alternate vehicle ownership trends aided by increasing IT connectivity:
 - Autonomous vehicle sharing,
 - Car-pooling,
 - Uber.
- Increased focus on urban public transport,
- Increased bicycle use in urban areas,
- Alternate near-term battery technologies³⁴
 - Li-Sulphur – higher energy density – lower cost – currently short lifespan,
 - Graphene – potential quantum leap but significant research needed,

³¹ ICE – Internal combustion engine

³² Lithium Australia – ASX Announcement 22 May 2020: Envirostream trial use of recycled battery product to boost crop fertiliser

³³ <https://www.kitco.com/news/2019-07-08/Indonesia-apos-s-new-nickel-smelters-to-add-3-9-mln-T-capacity-in-2019.html>

³⁴ <https://dgit.com/10-alternatives-lithium-ion-batteries-51067/>

- Redox-Flow battery – research and engineering needed - target market initially fixed energy storage,
- Aluminium-graphite - Long term development potential.

9.4 Reduction of Free-Trade

- International political tensions resulting in reduced international cooperation and sharing of science and technology,
- Re-emergence of protectionist and populist policies to support domestic manufacturing industries,
- Entrepreneurial Risk Aversion,
- Continued focus by investors on short-term results and aversion of technological risk,
- Perpetuation of the 'Shovel and Ship' attitude by both investors and major Australian corporations with financial capability to invest in longer-term industries.

9.5 Investment in R&D

- Tax incentives for R&D generally and in targeted industries has been scaled-back over the past decade,
- Under-funding for scientific research (CSIRO, CRCs and Universities) for the development of new technologies
 - Under-funding of Australian universities for Science and Engineering degrees as evidenced by the closure of metallurgy faculties and/or merging of metallurgy and chemical.

Appendix A: Li-ion Battery Sub-Committee Members

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