FUTURE BATTERY INDUSTRIES CRC

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Accelerating Battery Industry Hub Development in Australia

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Executive Summary

With the growing need for global action on climate change, national concerns on resource security and supply chain vulnerabilities, green technologies and energy storage systems have become critical. This has increased the significance of critical minerals and batteries manufacturing, the sectors delivering renewable energy storage systems and electric vehicles. Whilst China has dominated these supply chains, nations - such as Germany, Norway, Belgium, Korea, USA and Japan - are moving into or strengthening existing battery value chain positions to increase their respective capacities. Australia is also investing in a move downstream in the battery value chain, from its current position as primarily a raw materials producer with some refining and chemical production.

The competition to attract key industry players in the batteries manufacturing industry is global, with locations in Europe, USA and Japan offering better infrastructure, more streamlined processes, more tax breaks and incentives than Australia does. If Australia wishes to move further into downstream production within this highly-competitive, fast-emerging industry, it needs a coordinated and strategic approach to accelerate hub development and streamline industrial and governance processes for greater efficiency.

Growing an advanced manufacturing battery hub in Australia implies an understanding of competitive advantages, as well as addressing barriers through innovative approaches to industry development. Australia's natural resource endowment in batteries minerals must be viewed as an intergenerational opportunity to develop future industries. However, its potential to grow such an industry must be contextualised by the large number of nations that have already invested heavily (both government and industry), and are existing original equipment manufacturer (OEM) consumer markets.

This report unpacks the value proposition for geography in different batteries manufacturing hubs globally, drawing lessons to strengthen battery hub development in Australia. It examines the three international case study sites of: 1) Leipzig-Dresden-Berlin (LDB) Triangle, Germany; 2) the Gigafactory in Nevada, USA; and, 3) Osaka, Japan. From these case studies, it is clear there is no perfect 'hub' location or model. Each evolved through and offers access to different complementary industries, small-to-medium businesses, multinationals, government services, training facilities, R&D institutes, universities, infrastructure, etc., as well as different policy or operational contexts.

Two key challenges in the creation of advanced battery manufacturing hubs emerged for Australia in this report - its distance from battery consumer markets, and the scale of policy measures and funding by governments in the UK and Europe in particular in encouraging research and battery industry hub development. Nonetheless, the advanced batteries industry is a high growth sector of many players, with future expected expansions incentivising collaborations between SMEs and large firms.

Earlier reports commissioned by the Future Battery Industries Cooperative Research Centre have also looked at the challenges for Australia in building battery industries. A recent report Future Charge: Building Australia's Battery Industries (June 2021)[167] which assessed the most prospective opportunities across the value chain identified the role of battery materials and manufacturing hubs as key to stimulating development. This report in particular noted the role of an anchor tenant model with established international firms.

This report covers different hub models used internationally. It did not examine potential hubs in Australia specifically, but similarities to the international case studies were found in Australia. Irrespective of why firms may choose to locate somewhere – the overarching driver to site choice was firm profit maximisation and ease of operation. A hub must generate a clear globally competitive strategic advantage – that is, it must have a value proposition associated with its geography and related to its hub proposition (see figure 12). Therefore, decisions to invest in a particular location to develop an industry hub must account for a locations' 'assets'. While Australia has relatively high labour and energy costs, they are comparable with major OECD peers development battery industries. Australia's key assets relate to the following five areas:

Access to utilities infrastructure

Access to mineral resources

Access to skilled and educated workforce

Access to consumers and/or suppliers

Policy, governance and government strategies for investment attraction and hub creation

Drawing on the international case studies and interviews with Australian proponents, a hub proposition for Australia emerged (see figure 12) which informed key insights for Australia. As such, the insights are highly relevant to and embedded in an understanding of the Australian context. Each is framed by what is needed to grow an Australian battery manufacturing industry and concludes with a hub development action list. This produced nine recommendations and associated short to medium term priorities for action for implementation. The recommendations were:

- Leverage current Australian assets to grow advanced battery industry, and support hub development.
- Identify and work with champions for change.
- Seek to aggregate production efficiencies through site strategic selection and design.
- Work with relevant stakeholder to optimise and streamline hub governance and regulations.
- Increase industry innovation capacity and global competitiveness.
- Advocate for and progress agendas to decarbonise production.
- Facilitate industry accreditation and the introduction of resource traceability technologies.
- Capacity build across industry.
- Implement circular economy and industrial symbiosis principles and practices.

The recommendations and key priorities for action contained in this report will be implemented differently in different hub locations, with no 'one-size-fits-all' framework for operation. As such, there is a need for further research into possible hub locations within Australia, and into how this report's lessons and priorities for action might be critically interpreted and applied.

While an Australian battery production hub needs to be positioned and well-connected globally, domestic cross-industry synergies are also key in supporting hub emergence and development. For example, an active and efficient batteries manufacturing hub is compatible with Australian Department of Defence efforts to develop in-country manufacturing capacity. Similarly, batteries are needed to store energy for the emerging hydrogen fuel industries, and can assist in the de-carbonising of the mining industry. Indeed, such cross-industry connections may well be the beginning of a virtuous circle that could support building a transition to more sustainable industries in Australia – and the development of battery manufacturing hubs is strategic in progressing this.

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1. Background

With a growing need for global action on climate change, national concerns on resource security and supply chain vulnerabilities, green technologies and energy storage have become critical. This has increased the significance of critical minerals and batteries manufacturing, the sector delivering - for example - renewable energy storage systems and electric vehicles. Whilst China has dominated these supply chains,[1,2] nations - such as Germany, Norway, Belgium, Korea, USA and Japan - are moving into new or strengthening existing battery value chain positions to increase their respective capacities in battery manufacturing.

Australia is also investigating the move downstream towards manufacturing from its position as primarily a raw materials producer with some refining and chemicals capabilities, given its wealth in critical battery minerals, R&D capacity and highly skilled labour. Figure 1 illustrates the batteries manufacturing raw materials to final products value chain, highlighting the integral role of R&D, services and the recycling sectors.

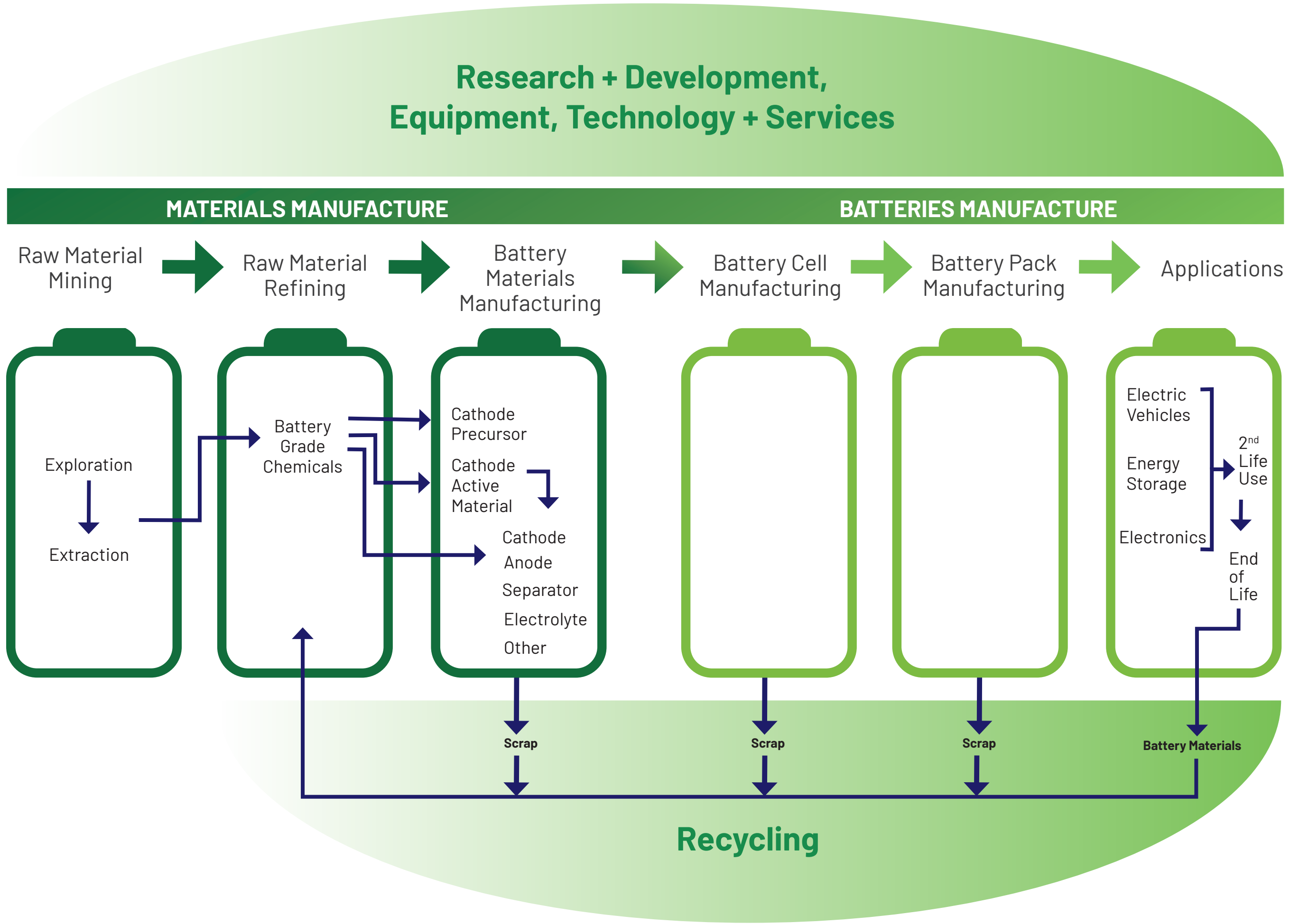


Figure 1: Components of the batteries manufacturing value chain

Despite considerable expertise in parts of the batteries value chain in Australia, there are dispersed industry understandings on what is needed to grow an efficient and productive industry hub. This includes the policies and frameworks needed to accelerate hub development and facilitation of Australia's entry into the highly competitive global industry. This report aims to fill this gap by examining successful hub examples in Japan, USA and Germany, drawing insights and lessons of relevance for Australia.

The report is structured as follows. Section 2 provides a brief literature review on hubs from conception to current understandings. This review guided the development of interview questions to unpack the international case studies and provide insights into the creation of a batteries manufacturing hub in Australia. Section 3 details the three case study sites: Osaka, Japan; the Leipzig-Dresden-Berlin triangle, Germany; and, the Tesla-Panasonic Gigafactory, Nevada, USA. Data was derived from an Internet search and from around 20 interviewees who were selected for their knowledge on the batteries manufacturing industry or hub development. Each case study is organised by first, providing an overview of industry development; second, describing two emergent themes relevant to Australia; and, third, future directions or challenges in the development of the hub. Section 4 sets out a general hub proposition, which is unpacked across nine lessons specific to industry growth in Australia. The final section gives the value proposition of geography for an advanced batteries manufacturing hub, and then recommendations.

Our findings show there is no perfect 'hub' location or model. It is clear that each case study evolved distinctly - offering access to different combinations of complementary industries, small-to-medium businesses, multinationals, government services, training facilities, R&D institutes, universities, infrastructure, etc., as well as different policy or operational contexts. As such, the lessons and key priorities for action outlined in the report will be implemented differently according to a specific hub location. Conceptual similarities between the case study sites allowed lessons for Australia to emerge regarding the importance of co-location, with no 'one-size-fits-all' framework for implementation. There is a need for further research into possible hub locations within Australia, and into how the lessons and priorities for action may apply.

Nonetheless, one thing is clear. If Australia wishes to move further into downstream production within this highly competitive fast-emerging industry, it needs a coordinated and strategic approach to accelerate hub development. Australia's hubs must have mechanisms established from the beginning to flexibly and nimbly address, adapt to and evolve with industry issues as they emerge. This is not an easy task, but there is strong motivation to try given the substantial economic multipliers of a globally competitive batteries industry. Ensuring Australia is a key player in this space means policies and mechanisms must be articulated into specific contexts. As one interviewee stated:

We're going into a new jurisdiction, this is an emerging industry. It doesn't matter who you talk to - most haven't got a clue, whether it's the biggest automotive manufacturer in the world or a local mayor of a small town. They all are learning about this industry.

2. Industry hubs as spatial networks of firms

This section reviews key aspects of relevance to the development of an Australian advanced batteries manufacturing hub, with the following three sub-sections:

1. Overviewing the complexity of spatial and non-spatial relationships leading to a successful hub;
2. Outlining a policy framework for hub development, and strategic considerations in firm location decision-making; and,
3. Providing an underlying business model and strategic framework for hub development.

Working definitions of this report

Cluster: a group of entities that may share a common relationship (e.g. a data cluster) and are attracted to a location not through strategy or design but other factors. For example, geology may lead to clustering. Clusters can refer to entities distributed across a city and/or surrounding metropolitan areas (e.g. Johannesburg in South Africa is an economic cluster rather than hub or a precinct).

Precinct: a fairly dense geographic space of shared facilities, infrastructure and collaboration, and may be focused on a particular industry or objective (i.e. research). It would seldom include a whole town, city or region. A technology park can be a precinct.

Industry hub: a dedicated economic zone with entry requirements and designed to ensure economic, social and environmental sustainability. It has good access to port, rail and airports, waste disposal, energy, water, trained and skilled communities, and a range of interdependent businesses. For example, firms involved in refining, chemicals manufacture, materials manufacture, component manufacture and the provision of integrated services around research, marketing and logistics.

2.1. What is an industry hub?

Hubs, as spatial networks of firms, are not new. In the 1890's, Alfred Marshall observed the success of certain 'industrial districts' of concentrated enterprise. Then, in the 1960's, Jane Jacobs added that success was due to knowledge spillovers between clustered firms as it enabled innovation. Silicon Valley demonstrated the importance of this with the co-location of R&D institutes, industry and movement of workers accelerating innovative activity between firms. This sparked a worldwide policy rollout from the 1970's of science parks and university towns.

Nonetheless, the purposeful co-location of industry and R&D institutes failed to generate the highly interactive and innovative districts expected. And, though Harvard Professor Michael Porter argued in the 1990's of the importance of clusters in advancing regional and economic development, we still struggle to define exactly what makes an industry hub successful. Particularly against the backdrop of the Internet which has changed how firms and workers interact across space.

The success of an industry cluster largely lies in the advantages **geographic proximity** brings to organisations in a specific location. Some argue it is the merely the **seed** for a relationship, and that sustaining and continuing relationships depends on other proximity types of:

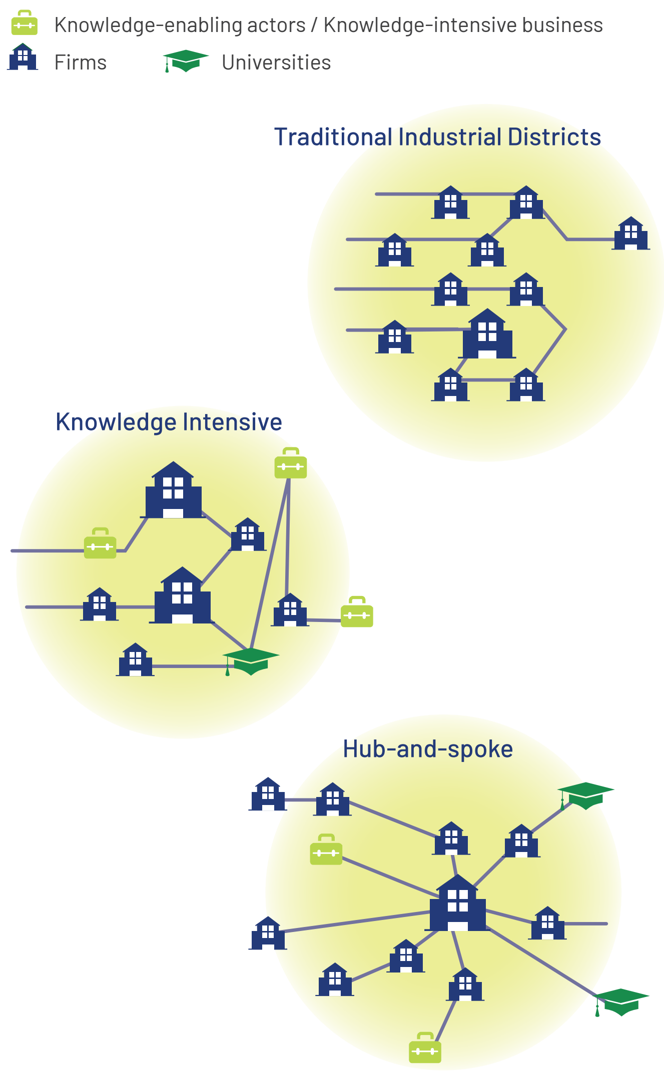
1. **Social** - with informal networking a key component of business success;
2. **Cognitive** – as it is easier for those in closely aligned knowledge fields or industry to communicate; and,
3. **Institutional** – given that firms, government and academia all speak their 'own language', and engagement across these stakeholder types takes more effort.

As such, co-location – and hub development - needs to be combined with opportunities for social interaction, methods to encourage cross-institutional dealings, and knowledge or technology transfer mechanisms to promote exchange. This must be within a hub, and to the outside.

There are, of course, different types of hubs depending on proponents. Figure 2 provides some examples.

Traditional (Marshallian) industrial districts may be a cluster of small shoe manufacturers in an Italian village. This is different from a branch economy where a cluster of small offices is connected to multinational headquarters found elsewhere - Perth, Western Australia has often been described as such[3]. A **hub-and-spoke model** has a dominant firm or anchor tenant. And, a **knowledge-intensive cluster** contains a range of firm sizes, universities, knowledge-enabling actors (KEAs, e.g., specialist R&D institutes) and knowledge-intensive business services (KIBS, e.g. centres for specialist training and skills, business development support). They are most appropriate for highly competitive environments, where cutting-edge R&D-led innovation is needed.

Figure 2: Various industrial hub typologies
Adapted from: Markusen (1996)[4]



2.2. Policy settings for hub development

Successful hub development recognises the complexity of interactions within it and with other regions. What works in one site cannot be transplanted and guaranteed to work elsewhere. A site's unique economic, social and environmental factors must be considered within a supportive governance framework, including a range of industrial, technology and regional policies. Figure 3 illustrates how these elements converge for sustainable cluster development.

Notably, figure 3 views the economy as nested within society and, in turn, the environment. This is a critical departure from the standard three 'interlocking' circles of sustainability approach[5], where the economy intersects only partially with the society and environment. In the nested approach, the economy is dependent and embedded. The fourth pillar of sustainability is governance - and included in figure 3 as a component of each sector and influenced by the interlocking technology, regional and industrial policy circles. These are critical understandings for successful hub development.

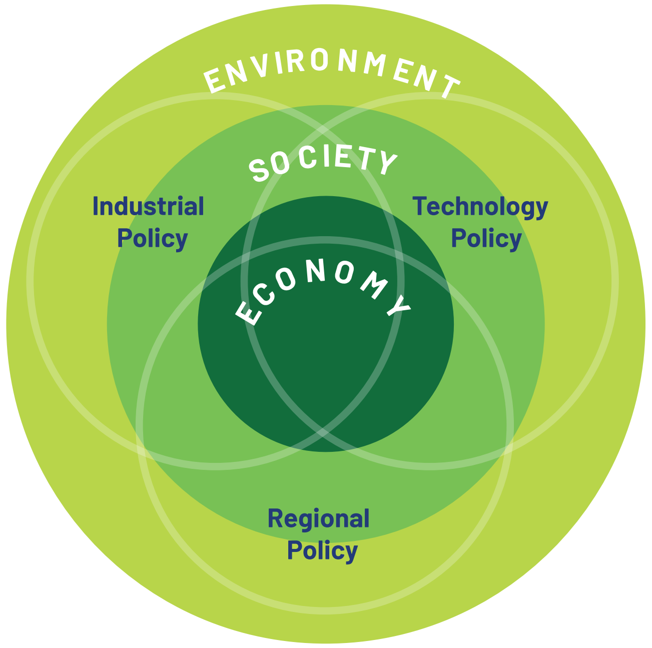


Figure 3: Sustainable hub development framework
Adapted from: Giddings et al. (2002)[5] and Paytas et al. (2004)[6]

Table 1 provides examples of firm economic, societal, environmental and governance considerations in site selection, with repetition across the quadrants providing insight into the multiplicity and complexity of hub dynamics.

Table 1: Examples of site economic, societal, environmental and governance considerations

Economic considerations	Societal considerations
Such as: • Other firms in hub. • Available technology, government incentives. • Locational competitive advantages, like: existing infrastructure, access to mineral resources, access to downstream markets, logistics (transport of waste, access to skills and consumers). • Renewable energy mix and exchange potentials (heat, steam, cooling water). • Economies of scale and scope. • Educated staff (regional staff mobility). • By-products or re-usable wastes. • Pooling and purchasing of raw materials. • Better management around warehousing and storage and supporting logistics. • Proximity of deep water port, international airport and adequate rail infrastructure. • IP access and freedom to operate (e.g. licence arrangements).	Such as: • Skilled population. • Knowledge base. • Working conditions. • Local community support. • Buffers to major population centre(s). • Licence to operate (ethical and green practices). • Social infrastructure, such as entertainment, good primary & secondary schools, sport facilities, tertiary education institutions, hospitals. • Natural habitat and outdoor facilities. • Functional infrastructure, such as reliable water, energy and transport (roads, airport) infrastructure. • Temperate climate.

Environmental considerations (both humans on the environment, and environment on humans)	Governance considerations
Such as: • Industry impact. • Licence to operate (ethical and green practices). • Reuse/recycling opportunities for by-products and co-products. • Renewable energy mix. • Water scarcity. Green practices of other firms in the value chain (impacts claims on green production processes). • Resource depletion. • Waste and pollution. Deforestation. Climate change. • Logistics. • Likelihood of natural disasters (either natural or human-caused due to mining activities), such as earthquakes, tsunamis, droughts/floods, temperature extremes, humidity, soil stability. • Proximity to geopolitically "challenging" neighbours. • Elevation above sea level, existing pollution and smog, severe thunderstorms and lightning strikes, tornadoes, cyclones (e.g. Pilbara), agricultural activities.	Such as: • Various national, state, local policies and the mix of these. • Governance and coordination at the site. • Supporting business services and organisations. • Hub philosophy underpinning business operations. • Institutional settings. • Tax strategies. • Political lobbying power by being part of the hub. Renewable energy mix. • Logistics. • Branding and marketing associated with site. • Permitting (red and green tape) and timelines. • Community pressures ("not-in-my-back-yard" - NIMBY). • Labour policy. • Capacity of State Government to service policy requirements (e.g. lack of adequately trained staff may lead to backlogs).

2.3. Circular economy and industrial symbioses

The circular economy is a philosophical way of thinking, which tries to minimise waste in an industrial system by purposefully designing it to be regenerative and restorative. The principles and strategic framing are set out in figure 4, as well as the business models it draws on to increase industrial sustainability.

One of these is industrial symbiosis, which is a cooperative network of organisations working together to enhance processes and reduce waste.

Such a system is aligned with an economic, societal and environmental nested approach to hub development. That is, an individual firm's strategic visioning and business design works collaboratively with others in the hub to reduce environmental and societal impact. The system is responsive to the need for corporate social responsibility as the license to operate, which is increasingly not just about the actions of an individual firm - but all the firms in the value chain.

Figure 4: Principles and framework of the circular economy business model of a hub

Adapted from: Baldassarre et al. (2019, p.448)[7]

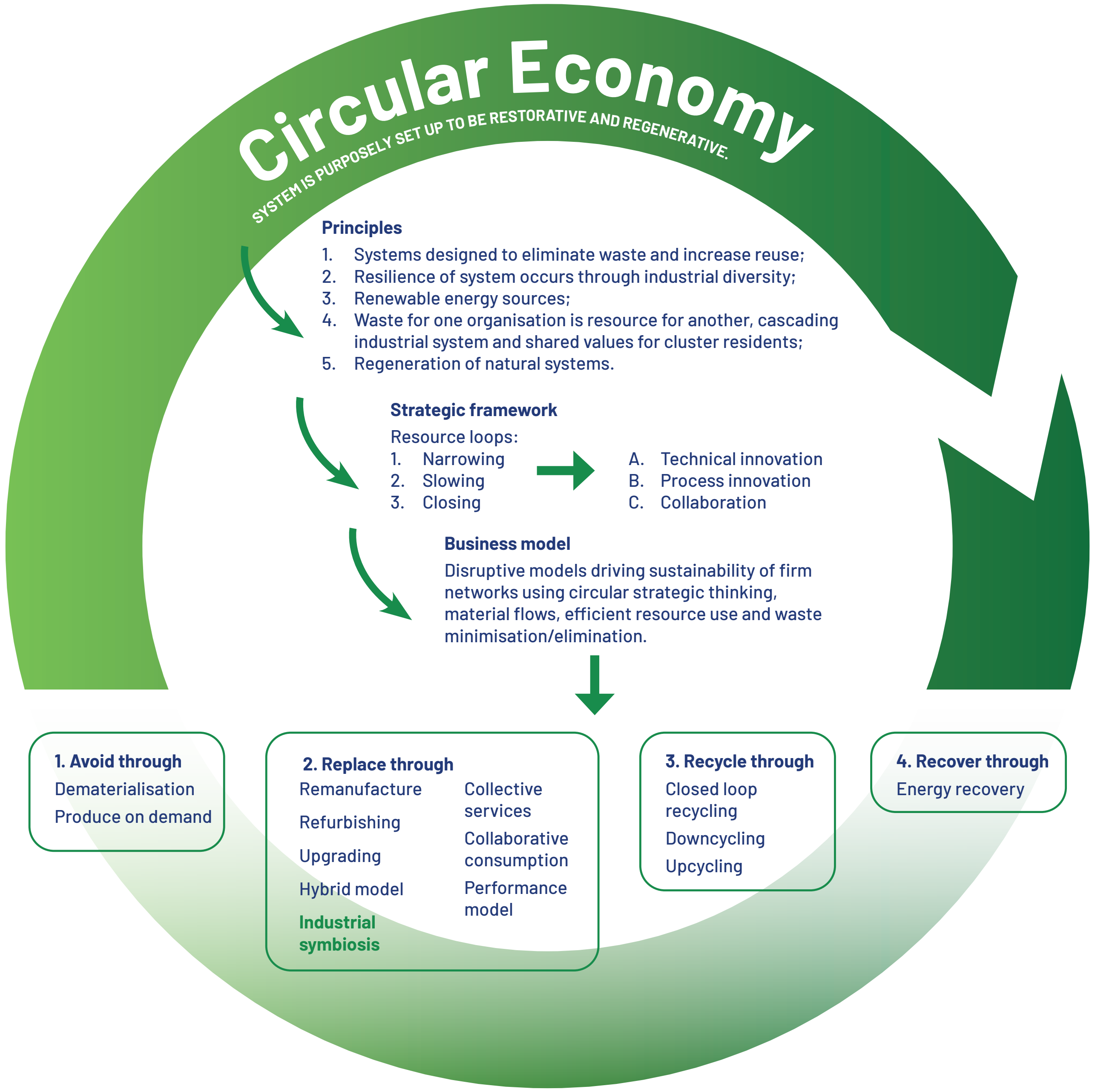
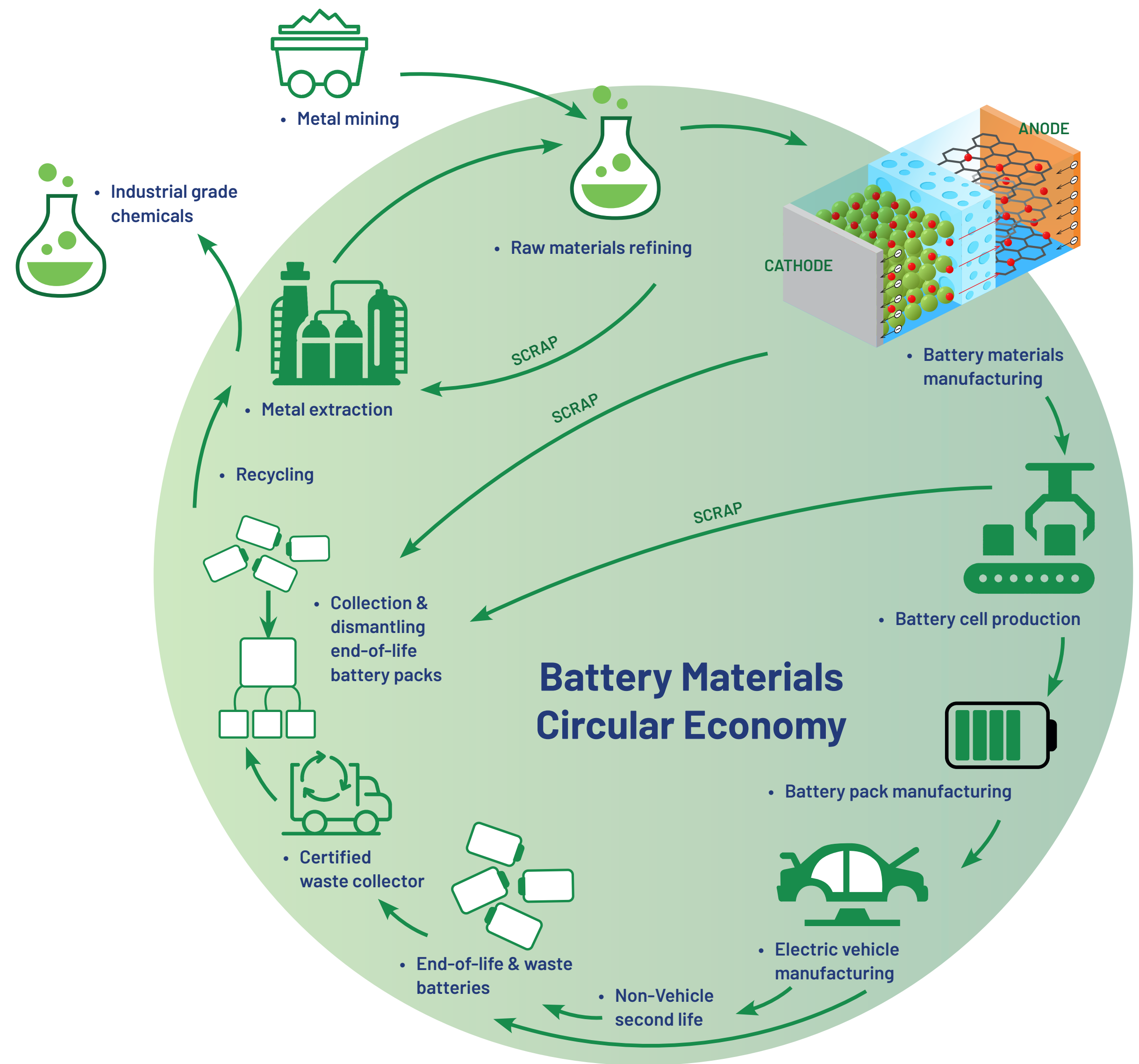


Figure 5 demonstrates how a circular economy may function in a battery manufacturing value chain (see figure 1) from resource extraction to final product, alongside second life or recycling parallel value chains. Such a system provides opportunities for government and hub management to support the creation of new waste-to-resource connections between firms. There will be various product sales, technology licensing, joint venture opportunities and fee-for-service possibilities emerging through innovations in business processes and products to enable new links in the value chain (see section 4.5, figure 14).

Figure 5: Battery value chain circular economy example

Adapted from: Finland battery value chain industry signed letter of agreement[8], and Neometals recycling model[9]



3. Case study sites

This section provides the findings of research into three battery manufacturing hubs found in Germany, Japan and USA. Although all demonstrate hybrid bottom-up and top-down development styles through initiatives at different stages, each has a dominant style shaped by its own national capitalist and governance system.

For example, Germany and Japan are both highly coordinated economies, with strong top-down/policy-driven initiatives encouraging cluster development. Policy interventions vary, but include 'soft' strategies (like networking support) and hard strategies (like direct R&D support and financing)[10]. In contrast, USA has tended to adopt a more spontaneous/bottom-up firm-driven hub development style, often benefiting from large anchor tenant or gatekeeper firms who collaborate with research institutions[11–13]. Tax or land incentives from the government often attract firms, particularly in initial development stages.

As such, each hub case study given in this report is unique, having emerged through different processes and policies and being at various stages of maturity. This section documents the findings of desktop research and interviews in three parts. The first provides the hub background story, including critical social, economic, policy and infrastructure elements leading to hub formation. The second showcases two lessons of relevance to Australia, before a third part provides future directions and challenges for the site.

3.1. Germany: the Leipzig-Dresden-Berlin triangle

The creation of a clean green innovative chemical industry in the Leipzig-Dresden-Berlin (LDB) triangle has created community and sense of place by strategically leveraging existing industry strengths and learnt experiences (e.g. its innovative solar panel industry being lost to China). It is a product of limited planning, being the merger of three locations that began 150 years ago. It sits across the two East German States of Brandenburg-Berlin and Saxony-Anhalt States, claiming the battery operations of five automotive firms across its 3 cities (see figure 6).

Despite significant investments since unification in 1990, the LDB triangle has continued to lag in infrastructure and economic development with lower income, population and higher unemployment than West Germany where most of the automotive industry is found[14]. To the east, it competes with the cheaper manufacturing area of Poland with lower land rent and labour costs yet relatively skilled labour. The LDB triangle hosts firms involved in the manufacture of battery cells, packs and systems production, servicing global car manufacturers and an emerging European electric vehicle (EV) market. It has grown a niche industry leveraging:

1. Existing industrial German strengths in car manufacturing and chemical production;
2. Access to global consumers (car manufacturers); and,
3. Lower operating costs.

Indeed, Germany is at the heart of Europe's automotive industry, with established reputable brands and a large pool of highly skilled professionals and technicians for manufacturing. The national government is supportive in developing this through a variety of subsidies in this and related industries (see appendix 1). The three largest automotive companies of BMW, Volkswagen and Daimler (Mercedes Benz) established in the LDB from the 1990s, and are globally and nationally integrated with other car manufacturing and chemical firms in other regions across Europe and the world.

Figure 6: Map of Leipzig-Dresden-Berlin triangle

The LDB triangle will assist in reducing national dependence on Asian or American battery producers. Key future developments expected between 2021 and 2023 are:

- Tesla to produce battery systems, powertrains and EVs.
- BMW to produce battery modules and continue EV assembly. BMW procures different battery cell types from partners, assembling cells into an aluminium case with connectors, controls and cooling units to produce high-voltage batteries for various EV model specifications[15].
- Farasis to build battery cells exclusively for Daimler battery plants.
- Accumotive produces drivetrain and batteries systems for electric and electrified vehicles since 2012.
- BASF produces Cathode Active Materials (CAM) to improve battery performance.
- ChemiePark (Bitterfeld-Wolfen).
- Primobius Li-ion battery recycling plant.

Lessons for Australia

- Leverage existing industries – the Verbund system.
- Government policy and subsidies support shift to EV adoption and manufacturing.
- Investment in research and development.
- Multi-level governance structures.
- Recycling / industrial ecosystem building.

The Verbund system

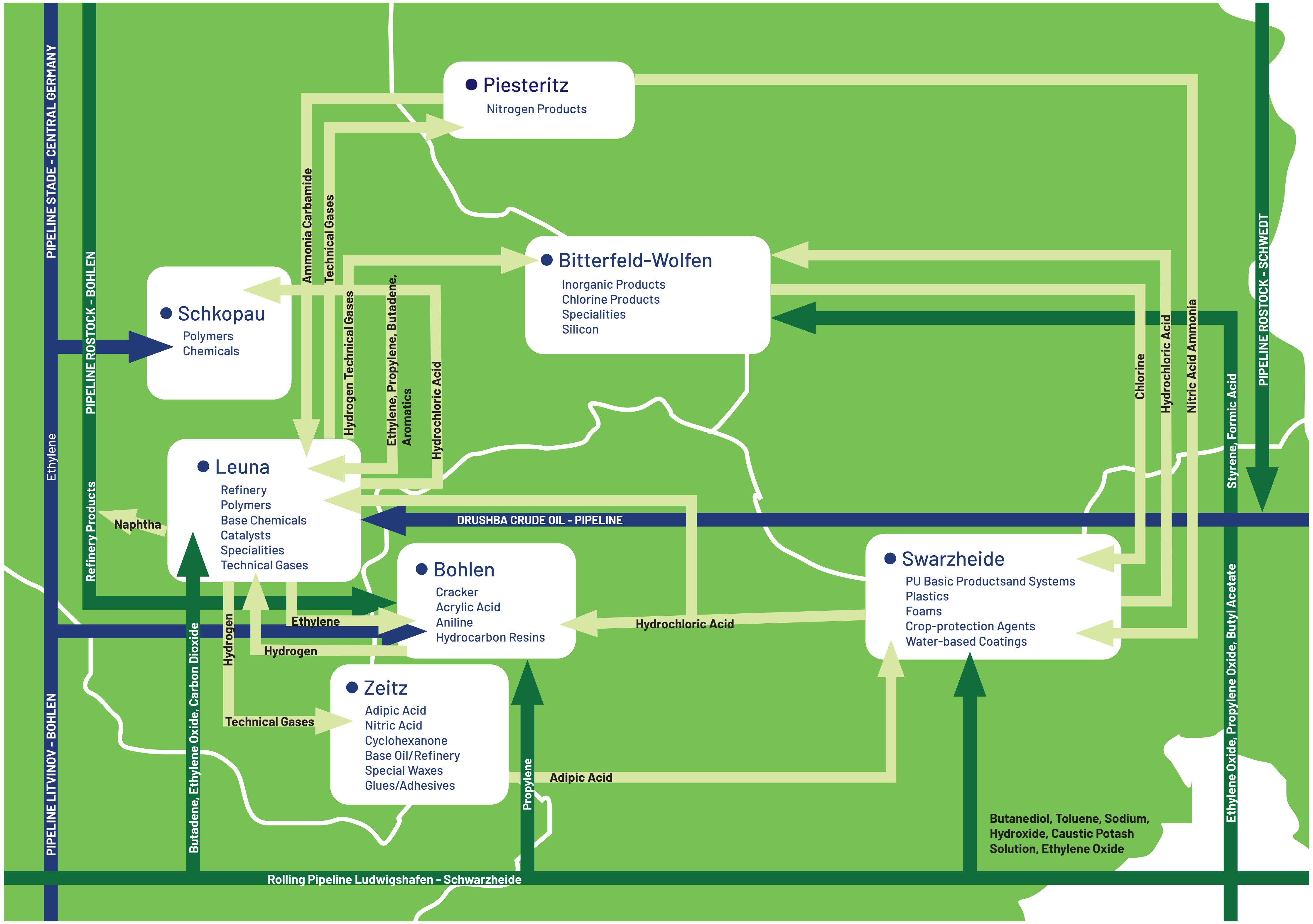
"The Verbund system creates efficient value chains that extend from basic chemicals all the way to consumer products. In this system, chemical processes make use of energy more efficiently, achieve higher product yields and conserve resources" — BASF[16]

Verbund is a German word meaning a group of composite items working together as a whole, being intimately connected at multiple levels. It has been adopted by BASF as a core philosophy driving their business strategy across production, digital, market and technology. But, it is also used by other hubs in Germany as a strategy for global competitiveness, those in the LDB triangle are shown in figure 7. Verbund therefore is a strategic integrated system coordinating production and R&D across value chains and/or within a single business. Its goal is to create value for the firms involved - both in terms of profits and return on assets.

For multinational conglomerates, Verbund recognises that business units within a firm may operate separately for tax reasons, and in some cases include outside firms. Collaboration across the units occurs for a common goal of growing a site's competitive capacity. For example, over 300 plants work as a Verbund in BASF Schwarzheide with decisions to bring in outside expertise based on a compelling economic argument. BASF Schwarzheide runs a Verbund simulator to model different scenarios to optimise business streams, acknowledging some operations must keep running for strategic reasons.

Figure 7: Verbund interactions between industry hubs in Saxony-Anhalt

Adapted from: https://www.invest-in-saxony-anhalt.com/chemical-parks-feedstock



Full integration of business units across a large site

Verbund is easier to coordinate if entities have mutual headquarter ties, or if there is a power imbalance between a multinational and smaller local entities. Nonetheless, even though BASF operates largely independent of other businesses in a hub, it recognises hub relationships are critical for future business success.

The hub experience is different **for small to medium enterprises (SMEs)**, with ChemiePark Bitterfeld-Wolfen using the same principle through the key idea that:

Competitors can also be collaborators.

Unlike large multinational corporations, SMEs are more reliant on the success of firm collaborations within a hub in creating verbund efficiencies. The role of a hub development manager is to identify strategic alliances and business investments to advance hub common goals, emulating the coordinated integration of a multinational's different business units. This may be through business matching or company executive networking events. For example, ChemiePark holds an informal networking event at the managing director level to allow new collaborations or business connections to emerge. Verbund allows a hub of SMEs to take advantage of:

1. Economies of size and scope of large organisations;
2. The nimbleness and flexibility of small firms.

The key aim is to gain control over the supply chain, be more competitive on price and offer quality. **If the businesses in a hub grow together as a stronger value chain and larger mass of firms, then it is more difficult for outside regions to move in on these sections of the value chain**. Establishing trust between otherwise competing firms is crucial for a Verbund, intermediary agencies can provide assistance and coordination in this. Verbund employs two key principles:

1. **Lean production and business systems** where waste and energy is minimised across all aspects of production, technology, business systems, logistics, etc. This requires processes and practices to be implemented which reduce inefficiencies and/or costs. For example, reducing or diverting waste into resources elsewhere, or gaining process efficiencies through better intra- and inter-organisational coordination.

2. **Green and sustainable production and business systems** seeking better use of energy, resources and more efficient strategies. Minimising or redeploying waste into resources increases business sustainability to meet future targets to reduce carbon footprints.

Verbund is achieved through:

1. R&D investment into new business streams for waste or process innovations; and
1. A multi-level governance approach to business development across departments, businesses and even between hubs.

Examples of waste-to-resource Verbund capacity building:

- BMW accepts used battery packs to recycle 96% of its EV batteries globally in collaboration with Duesenfeld – a German recycling specialist[154].
- Volkswagen aims to recycle 90% of EV batteries in the Salzgitter plant[155].
- Daimler aims for batteries with in-built recycling capacity[156].
- BASF, Eramet and SUEZ received 4.7 Million Euros from EIT RawMaterials (see https://eitrawmaterials.eu/) and others to develop 'Recycling Li-ion batteries for electric vehicles' (Relieve), a closed loop EV battery recycling initiative[157].

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Profit maximisation, cost minimisation and license to operate

Irrespective of the market bargaining position of a firm, profit maximisation is a key to continued viable operation. If labour costs are high and not a competitive advantage, then profit maximisation must leverage the efficiencies of other 'assets'. This includes the production and process efficiencies gained through a hub's geography, being linked to three key locational factors:

1. Access to customer base (markets of demand);
2. Access to resources (markets of resource supply, labour pools to provide skills as needed); and,
3. Logistics (allowing people movement, access to products, energy (source and cost), and waste removal).

Firms will locate within a hub after weighing up trade-offs - where no site is perfect. Hub 'assets' provide a competitive advantage for business, and marketing point for the hub. Interviewees reported a shift in what were seen as 'assets' - from a previous purely economic focus (e.g. access to cheap labour) to one that is more on sustainability. For example, energy considerations took in cost as well as mix given the need to lower the carbon footprint across the entire supply chain. Other 'assets' for LDB triangle selection were its educated (but under-utilised) labour force, and its business development political support at the national and regional level.

Why the Leipzig-Dresden-Berlin triangle?

- Tesla didn't choose cheaper manufacturing locations of Poland or Czech Republic, but Germany's automaking tradition and deep pool of engineer expertise[158].
- Strong research capability. E.g. Fraunhofer Research Institute researching improved battery cell production and recycling[159].

As such, LDB triangle development depended on profit maximisation, cost minimisation and license to operate in the context of the higher short-run production costs associated with **sustainability and ethics** (these costs will be cheaper in the long term as overheads are reduced and risk of license to operate being revoked are lower). This is relevant to both SMEs and large multinationals.

Cost minimisation along the value chain is driven by the final products sold to the customers who give companies their license to operate. It is achieved through process and production efficiencies and innovations in the context of sustainability and ethical operations.

Further, and related, hub development and on-going management must incorporate the various efficiency needs of different firm size. For example, large corporations have more bargaining power and can demand lower prices than SMEs - unless SMEs collaborate in a way that mimics a large firm. Whereas, competitiveness for SMEs comes from being nimble and having a focus on service and quality.

Whilst highly regulated markets require additional environmental protection and ethical considerations to be put into place for operations, these additional steps also provide a company with their license to operate. Interviewees noted the license to operate was increasingly important in ensuring future business viability, being strongly connected to ESG credentials (see appendix 2). For large companies, like BASF, it is key in their global business strategy and future emission reduction targets[18].

Therefore, effective and integrated governance and regulatory systems are important in decreasing firm operational costs. This will be achieved via:

1. Investment in R&D for process and production efficiencies; and,
2. Multi-level governance structures and coordination.

This occurs through various coordination and funding structures for the LDB Triangle at the national (both State and National) and European Union levels. For example:

- The Investment and Marketing Corporation (IMG) is the economic development arm of the Federal State of Saxony-Anhalt, and 'one-stop-shop' partners with firms in business development from ideation to value chain integration. Priority sectors are battery chemistries, production and development. It offers no-fee services.
- The German Federal Ministry for Economic Affairs and Energy has committed one billion Euro through the Energy and Climate Fund until 2022 to establish Germany as a global leader in battery cell production under the European Battery Alliance (EBA)[19].
- The EBA, launched late 2017, aims to ensure all Europeans benefit from safer traffic, cleaner vehicles and more sustainable technological solutions by creating a European competitive and sustainable battery cell manufacturing value chain[20].

Effective regional coordination of funding and governance is also a hub 'asset' attracting firms. For example, in fast-track permitting processes to construct a plant and start chemical production. In ChemiePark Bitterfeld-Wolfen, permitting is organised under strict German requirements where established relationships with regulatory bodies enable approvals in only months compared to other locations where it might take years.

Future directions and challenges

A key challenge of the LDB Triangle is overcoming perceptions that industry will move to nations offering cheaper labour - as was the case with their innovative solar panel industry. This experience emphasised the importance of integrated value chains for interviewees, who acknowledged that the more complex 'integration' arrangements (e.g. via formal contracts or informal agreements) of a hub were only attractive to firms if future benefits and payouts compensated risks. The hub has a role in ensuring this.

An effective, flexible and responsive hub development model, like the open collaborative model of German automotive industry, was seen as preferable to the closed shop one of the chemical industry.

There were several points made regarding future directions and regional capacity building:

1. A need to address global supply chain vulnerabilities, particularly around raw material dependencies. Gaining control over parts of the batteries manufacturing supply chain is seen as strategic in ensuring other nations do not later take over production. This includes:
   - Greater collaboration across the supply chain, with Australian firms viewed favourably. For example, Neometals (in Promobius JV with SMS Group) and Talga Group are planning facilities in German hubs, and BASF has interests in Australia. Vulcan Energy (a company intending to extract lithium from brine) has a Head Office in Perth, and plans operations in the Upper Rhine.
   - Recognition of Germany's mature chemical industry, but limited batteries manufacturing - unlike Japan, South Korea and China. There is intense competition from Asian manufacturers with high battery expertise and operations across Asia and Europe. For example, through the lower production costs of the LG Chem Poland EV battery plant[21].
2. Germany has a political push for the greening and securing of regional economies and for supply chains to be 80% domestic. Europe aims for zero-carbon by 2050 decreasing greenhouse gas emissions according to the Paris Agreement and European Green Deal[22]. Industry examples towards this are:
   - Daimler in Kamenz was designed for CO2 neutral heat and power with a 2-megawatt photovoltaic system powering production with geothermal energy[23].
   - BASF Schwarzheide is increasing the eco-energy efficiency of its gas and steam turbine power plant for heat and power generation[24].
   - Tesla will plant three times more native trees to counter deforestation after site construction[25], minimise water use and use solar power.
3. Germany will focus on workers training for the technologically competitive industry.

Chemical material hub circular economy to reduce industrial CO_2 emissions

Fraunhofer Institutes, Chemiepark Bitterfeld-Wolfen, Nobian and the power plant of envia THERM will conduct the CarbonCycleMeOH feasibility study to examine methanol production in Chemiepark Bitterfeld-Wolfen.

Funded by the German Federal Ministry of Education and Research (BMBF), it aims for circular flows where wastes of one process become the inputs of another. It will reduce waste by converting CO_2 emissions to green methanol. Methanol is used in the production of goods such as: construction materials, paints or renewable fuels. CO_2 is by-product of various thermal, chemical and biological processes.

—LinkedIn, Chemiepark Bitterfeld-Wolfen

3.2. USA: Tesla-Panasonic Nevada Gigafactory

The Tahoe Reno Industrial Centre (TRIC) is located in a remote area just east of Reno, a 3-hour drive from San Francisco and the Silicon Valley. Investment began in 1994 when the State of Nevada funded infrastructure connecting it to the adjacent Interstate 80 and Union Pacific Railroad, and to power and water. TRIC struggled to attract business until 1998, when two private investors purchased it to develop a large-scale industrial centre in public-private partnership with the State and County.

The County identified the sites' competitive advantages compared to other locations – specifically its relative isolation from urban populations (the county had under 3,500 persons, and Reno under 300,000 in 1998) and space for large footprint facilities. It was rezoned as heavy industry to allow the expedition of permitting/planning processes for any industry.

Though Walmart moved distribution facilities to TRIC in 2005, TRIC's growth was accelerated by Tesla locating its Gigafactory 1 there in 2014. Reno-Tahoe International Airport began to fly non-stop flights globally from that year also.

TRIC now has around 93 companies, 25 being large corporate anchor tenants including Panasonic, Google, Switch Citadel, FedEx and James Hardie[26,27].

TRIC itself is not a 'hub' – but it has enabled the Gigafactory to accelerate electric vehicle production and expansion into battery value chains.

Panasonic co-invested in Gigafactory 1 to begin battery cell production in 2017. Panasonic has been making Tesla batteries since 2006, with a US subsidiary established solely for this purpose making lithium-ion batteries for Tesla cars[28], PowerPacks (commercial use) and PowerWalls (residential use). Co-location has streamlined operations with economies of scale reducing costs.

Lower costs have opened markets as Tesla batteries become more affordable, speeding up global transitions to more sustainable energy alternatives. The 'gigafactory' model of co-locating companies under one roof for economies of scale is a new 'hub' model led by companies primarily in the USA and Europe[29]. Figure 8 shows the competitive battery manufacturing landscape of current and future mega- and giga-factory corporate projects in the USA.

Panasonic brings experience in large-scale cell manufacturing to Gigafactory 1, and Tesla brings creative thinking and end product design. The partnership has attracted the German company Heitkamp & Thumann Group, who produces the outer metal cell cases for Tesla PowerWalls at the Gigafactory[30,31,32]. Battery cells and packs for Tesla electric vehicles are assembled at its car manufacturing facilities in Fremont, California, and Tilburg, Netherlands[33].

After the 2015 Gigafactory announcement, Tesla received US$800 million in orders – leading Elon Musk to reveal further expansion plans[34]. By 2018, Gigafactory 1 had created over 7,000 local jobs (original projections were 6,500) and invested more than US$5 billion in infrastructure and equipment[35]. It is currently over 4.9 million square feet[36], and the only non-Asian location manufacturing lithium-ion batteries for electric vehicles[37]. Tesla continues to explore how to lower battery production costs, by:

- Funding research at Nevada University in battery production enhancement and recycling[38].
- Signing agreements with a Canadian mining company to provide lithium to Gigafactory 1 from Nevada lithium deposits[39,40].

In addition, TRIC batteries industry capacity continues to grow with the American Battery Technology Company establishing one of the few global lithium-ion battery recycling facilities. The facility will produce raw materials such as lithium, manganese, cobalt and nickel, through closed-loop processes with no air emissions, material or liquid waste[41].

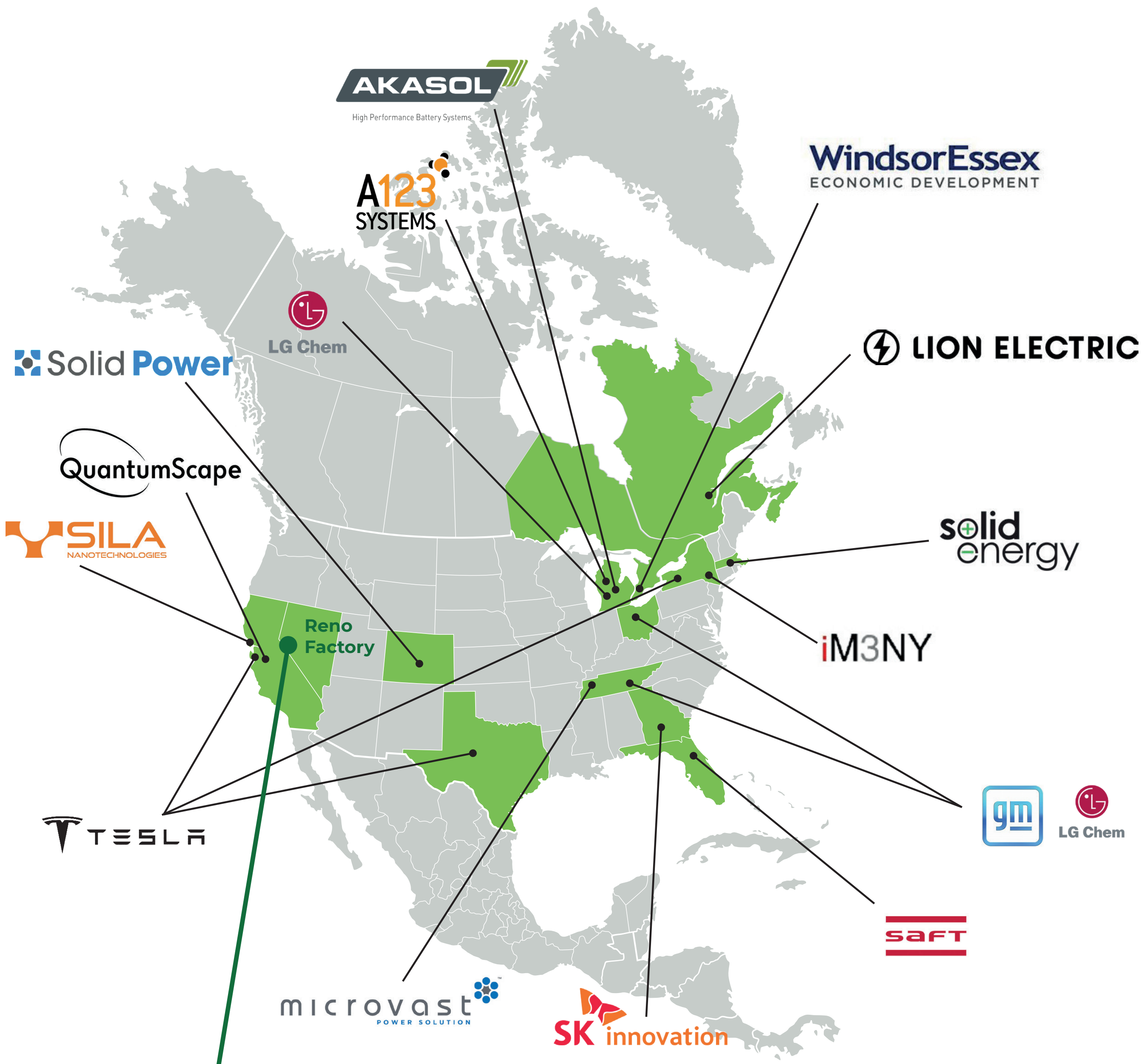


Figure 8: Tesla-Panasonic Nevada Gigafactory and other major US battery manufacturing producers, current and future mega- and giga- factory corporate projects

Adapted from: Gisbert and Careaga (2021)[29]

The hub is situated within the Tahoe Reno Industrial Centre (TRIC). TRIC is a 107.000 acres park with 30,000 acres of developable industrial complex in the desert, about 15 miles east from Reno. It has 12 miles of dedicated frontage of the Interstate 80 connecting San Francisco and Chicago, and serviced by the Union Pacific Intercontinental Railway and the Burlington Northern Santa Fe Railway. It is a 15-minute drive from the Reno Tahoe International Airport.

Lessons for Australia

- Relevance of an anchor tenant in accelerating hub growth in remote areas.
- Role of government in facilitating permitting processes and providing tax incentives.
- Competitive advantage in fully integrated hub facilities.
- Public-private partnerships in hub development.
- Capacity building and moving into upstream markets.
- Level of service from government(s) facilitates business establishment, e.g. turn-around time in permitting as well as general response.

Attracting anchor tenants to accelerate remote hub growth

Gigafactory 1 opened opportunities in a remote area where there was little manufacturing before 2014, especially compared to neighbouring California[26]. There were three key mechanisms accelerating this.

First, a public-private partnership where TRIC developers assumes some risk under agreements with the County (who was close to bankruptcy in the 1990s). These agreements meant the County:

- Paid back (interest-free) developer capital infrastructure investment costs once TRIC showed profits, including roads, flood control, fire stations, and other public infrastructure.
- Facilitated all local, state and federal government dealings for the developers, with a 24-hour support service to ensure no construction delays[26].

Second, the County's fast permitting and planning approvals. This accelerated Gigafactory 1 decision-making and construction processes, and later that of other battery-related firms (e.g. American Battery Technology Company and Heitkamp & Thumann).

Tesla executives had flown in for what was supposed to be a 15-minute session... after already touring the nation in a well-publicized search for a massive factory site with five potential sites in different states competing for the Gigafactory[42]. They were asked why they hadn't yet signed a contract. Tesla cited scheduling risks – delays that cost companies money, and asked "how long... would it take to receive a grading permit?". The County's community development director then pushed a permit across the table and told them simply to fill it out.[26]

The advantages for companies were the following:

- Heavy industry zoning status preapproval of almost any industry use without special discretionary permits.
- An expedited permitting process allowing operation within 48 hours, with building permits taking only one to two weeks[26,43].
- Access to lithium minerals in nearby Nevada clays and soils[44].
- Access to transport and utilities infrastructure partly funded by government[27].
- Land lease agreements prohibited any new County fees or regulations above what applied in 2000, freezing many fees and charges[26].

Third, various State and Federal government tax incentives and subsidies[45,46,47] directly or indirectly contributed to Tesla's success building Gigafactory 1. For example, government investment via industry (i.e. other car companies) or consumer incentives. But, as Musk argued – the size and scope of subsidies to Big Oil companies is much more[48]. The following summarises key support received by Tesla[49]:

- Around US$1.25 billion in State of Nevada tax incentives over 20 years for Gigafactory construction, including no tax for first 10 years.
- Department of Energy Advanced Technology Vehicle Manufacturing Program loaned Tesla US$45 million in 2013; it was re-paid in advance with interest.
- Federal income tax credits for buyers of electric vehicles (EVs), estimated at US$284 million by 2015. Similarly, State of California rebates of EVs, totalling US$38 million by 2015.

- Income through a government program where high emissions vehicle manufacturers buy credits from low emissions vehicle manufacturers (i.e. Tesla); amount by 2015 was US$517.2 million.
- State of California rebates to companies supporting distributed energy resources. Tesla received US$126 million by 2015. This support to the company assisted in its expansion in other states.

High-tech one-stop-shop manufacturing, open-source and the competitive edge

Gigafactory 1 aspires to be a vertically integrated one-stop-shop manufacturing facility from chemical production to full assembly of battery packs. Panasonic also engages in research to improve chemistries for Tesla[50,51]. Tesla is moving into other parts of the batteries value chain, planning to source raw materials from the State of Nevada and recycling within the Gigafactory[52]. Elon Musk describes Gigafactory 1 as:

> *The machine that built the machine.*

There are four factors driving competitiveness of the Gigafactory. First, its sheer size provides economies of scale and scope in the same facility at a level never before seen. Second, cutting-edge technologies replace labour – including artificial intelligence, robotics, digital twinning (with robots negotiating the factory via virtual maps), autonomous vehicles, internal GPS systems and floor magnets/navigational beacons (to guide robots and automated guided vehicles). There are also possibilities for additive manufacturing (i.e. 3-D printing). Third, its heating and cooling systems are highly efficient, are 100% renewable and allow cost saving. Fourth, building design efficiencies (alignment for maximum sun for solar energy and GPS satellite tracking) and product design (i.e. less parts to streamline production)[53–57].

Yet, the Tesla and Panasonic relationship is strained by cultural differences[58] and Tesla's moves to internalise battery production. 2019 reports cited that Tesla had a secret battery research lab to reduce dependency on Panasonic[59,60], and has diversified to Chinese battery suppliers – whose low-cost batteries charge slower and have shorter lifespans[61,62]. In 2020, Panasonic pulled out of solar cells and modules production in the Tesla Buffalo Gigafactory (New York)[63].

Panasonic is also looking at building battery manufacturing facilities in China[64] and Europe[65]. However, Chinese Government regulations stipulating foreign companies must work with local companies may mean intellectual property (IP) leaks or other regulatory difficulties. For example, Samsung and LG Chem were excluded by the Chinese government as licensed suppliers after establishing factories there[51]. These tensions point to the high competitiveness and need for secrecy as key multinationals, and nations, seek to dominate the emerging market.

IP and innovation are key in creating and maintaining firm and national competitiveness. Tesla both holds patents (and trade secrets) and promotes open innovation, stating:

> *If we clear a path to the creation of compelling electric vehicles, but then lay intellectual property landmines behind us to inhibit others, we are acting in a manner contrary to that goal. Tesla will not initiate patent lawsuits against anyone who, in good faith, wants to use our technology. (Elon Musk)[66]*

In the fine print, Tesla can use developments on their technologies by competitors, and competitors cannot simply copy products. This allows Tesla to retain original IP rights[67,68]. Whilst the move is bold, it is based on two long-discussed factors. First, patents do not protect against copying – particularly given the high cost of patenting in different regions, and patenting in one country or region does not protect from firms in other nations copying. Musk has argued patenting stifles innovation and competition, and lines lawyer pockets. Arguably, it is better to build on current innovations, gaining competitive advantage through other means (e.g. first-mover advantage). Second, Musk's mission to reduce global carbon dependence also recognises that Tesla cannot fulfil global battery demand and that more manufacturers are needed[68–71].

Future directions and challenges

Remoteness challenges the Gigafactory, but is also an advantage given fast-track permitting and planning approval processes. The sheer size and operational needs of the gigafactory have also presented challenges. Some are solved, others not yet. For example:

- Water scarcity has been a concern since initial planning, but eventually sourced and piped from a treatment plant in neighbouring Washoe County – stored in a 1.5 million US gallon (5.7 million litre) water tank[72,73].
- Alignment with carbon-zero commitments, the Gigafactory did not connect to TRIC natural gas lines. It runs on 100% renewable energy, with 200,000 rooftop solar panels making it the largest in the world. It is estimated to need power equivalent of 80,000 homes per day[74,75].
- Access to and housing for an appropriately trained workforce. There are reports of: a housing shortage with workers sleeping in the carpark; a lack of occupational health and safety leading to a large number of emergency calls (e.g. amputations due to mechnical disasters or respiratory or other issues from chemical spills); low levels of training (a few minutes) for repetitive work; and, a culture of intense long work weeks[36,76]. Tesla's workplace safety violation fines have either been reduced or cancelled[77].
- The highly competitive global batteries manufacturing industry means Tesla is continually internalising more of the value chain, such as lithium mining[78]. The State of Nevada has opened up opportunities for lithium mining in the State[79], including from a mine near the Gigafactory[44,80]. Tesla is also interested in Australian minerals and to build a cathode factory. Australia is looking to reduce value chain emissions by domestically refining its minerals, and there is speculation of Tesla's interest in Gigafactories in Australia[81–83].
- The rising demand and lack of supply across the batteries manufacturing value chain meant production needs were initially underestimated in 2015. It expanded in 2018, and has expansion plans for Panasonic battery cell manufacturing, raw materials and manufacturing[84]. The US Federal government established a Federal Consortium for Advanced Batteries (FCAB) in 2020 to accelerate battery industry development via domestic R&D, manufacturing capacity building and battery commercialisation[85].
- Tesla works with third parties for battery recycling, but is planning to recycle at Gigafactory 1[52]. The large amount of factory waste may be partly driving the urgency for an internal recycling solution.

3.3. Japan: Osaka Prefecture and the Kansai Region

Kansai is historically a key region of Japan, containing the ancient capitals of Kyoto and Nara as well as Osaka – an ancient trading hub, and developed agricultural and commercial centre. The Kansai Region consists of seven prefectures – Osaka, Kyoto, Hyogo, Nara, Mie, Shiga and Wakayama. Osaka, Kyoto and Hyogo house the bulk of Kansai's industry and people - making it the largest industrial area outside of Kanto (i.e. the Greater Tokyo Area with the Tokyo metropolis, Yokohama, Kawasaki, Chiba, etc.). Kansai's strong manufacturing contributes to a regional economy ranked 17th globally[86] and equal to the Gross Domestic Product of Hong Kong and Singapore[87].

By 2010, Kansai was already a hub for electric vehicle (EV) battery production, with multiple manufacturing plants of Panasonic (battery production since 1933), Hitachi Maxell (battery production since 1960s) and GS Yuasa[87] (as shown in figure 9). There are other firms manufacturing battery components and materials (mainly chemicals), as well as devices using batteries[88]. In 2016, Kansai had the largest battery-related production in Japan, with 46% of lithium-ion battery and 58% of solar battery module production[89].

The Kansai cluster has three key locations: the Osaka Bay area, Osaka city centre and Kyoto (see figure 9). It is critical to the global market - Japan is one of the world's largest battery cell producers with built-up expertise around battery production. About half of the Japanese industry operates there - firms (SMEs and major corporations), R&D institutes, universities, government bodies, national battery testing and analytical facilities, certification authorities, and space for trade shows. For firms, Osaka is cheaper than Tokyo, with industrial land priced at 41.3%, residential land 43.3% and residential rent 67.7% lower. And, average worker salaries around 15% lower[89].

Figure 9: Electric vehicle battery production of Kansai; insert shows batteries manufacture cluster components in Osaka Bay Area and city centre.

PCs, mobile equipment etc.
Automobiles
Household fuel cells

Panasonic

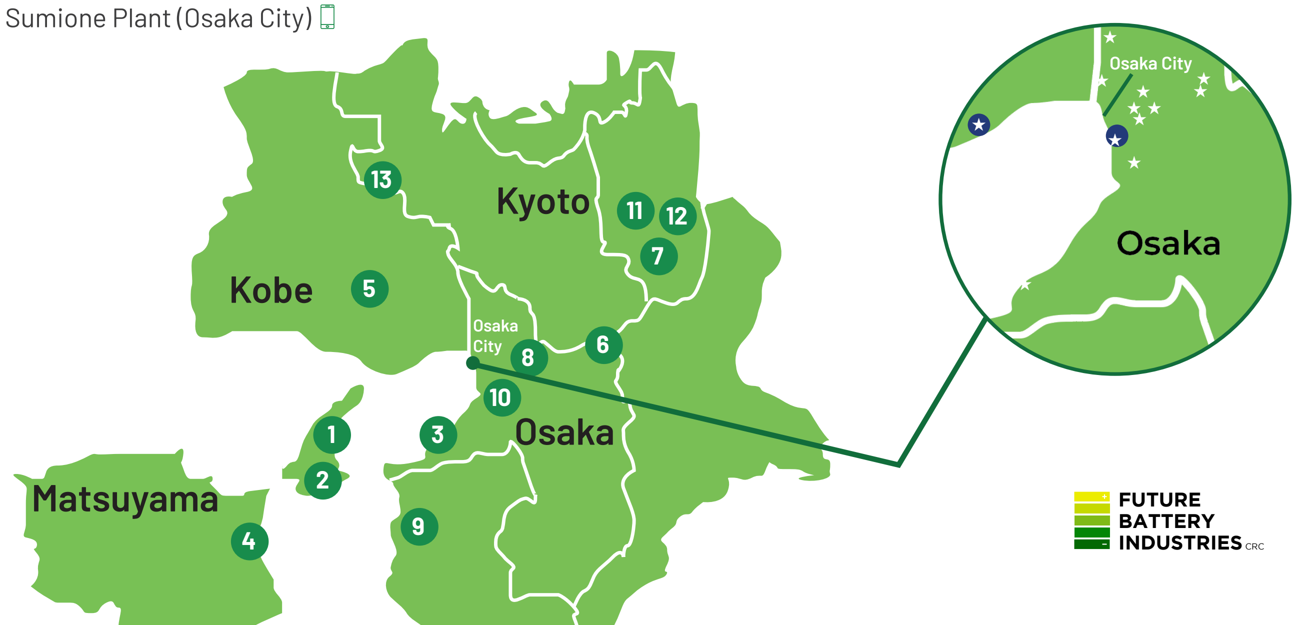
1. Sumoto Plant (Sumoto City)
2. Minami-Awaji Plant (Minami-Awaji City)
3. Kaizuka Plant (Kaizuka City)
4. Tokushima Plant (Matsushige Town)
5. Kasai Plant (Kasai City)*
7. Kusatsu Plant (Kusatsu City)
8. Moriguchi Plant (Moriguchi City)
9. Wakayama Plant (Kinokawa City)
10. Sumione Plant (Osaka City)

maxell

6. Kyoto Plant (Oyamazaki Town)

GS YUASA

11. Lithium Energy Japan: Kusatsu Plant (Kusatsu City)
12. Lithium Energy Japan: A new plant (Ritto City)
13. Blue Energy Co., Ltd: Fukuchiyama Plant (Fukuchiyama City)



Kansai is the second biggest and most productive region of Japan, only after Kanto region, where Tokyo is located. This area has multiple industries, such as electronics, pharmaceutical, machinery, chemical, food, construction, and commerce which are intertwined with the residential areas. There is proximity to ports, including the Osaka and the Kobe Ports, two international airports, namely the Osaka International Airport and the Kansai International Airport, and a wide- spread and efficient train system for passengers.

The electronics industry of Osaka and car manufacturing elsewhere in Japan are the key customers for cluster participants, with joint ventures between electronics and car manufacturers supporting battery development (a recent EV project between Panasonic and Toyota[90]). There is also proximity to key Asian EV markets, especially China and Korea.

Japan battery recycling: a streamlined and efficient process nationwide

Nippon (Japan) Recycle Center (NRC) is a leading battery recycle company in Osaka, across nickel-cadmium, nickel-metal-hydride, lithium-ion as well as industrial alkaline batteries. Operating since 1976, it doubled operations in 2019. It recycles batteries from manufacturers and end users in Japan and other Asian countries.

It also has a contract with the not-for-profit Japan Portable Rechargeable Battery Recycle centre (JBCR) who collects used batteries nationwide and sends them to NRC for processing[160,161].

In total, it recycles around 75% of all portable rechargeable batteries in Japan. This represents a high volume of end-of-life batteries and battery scrap processed each year. NRC has developed highly efficient processes, with environmental safeguards to ensure by-products and wastes are discharged harmlessly. The resultant high yields of extracted metals are sold as raw materials.

Lessons for Australia

- Leveraging connections of existing industries (battery and car manufacturing).
- Coordination between and within industry, government and academic sectors to build capacity in specific industry.
- A range of policy and subsidies to attract business investment, support R&D, and develop SMEs capacity and collaborations with large firms.
- Importance of quality - supported through national testing facilities and development of standards.

Government strategic planning and regional development

Kansai has emerged as an economic powerhouse through both history and Japanese Government strategic visioning after World War II. Japan's industrial focus moved from light to heavy industries (through Pacific Industrial Belt strategies of 1950-70), and then from the 1970s to high-tech knowledge and services (through national programs such as the Technopolis Program, Knowledge Cluster Plan and New Growth Strategy)[91].

In Kansai, two key entities influence National policy implementation by the Kansai local and prefectural governments. First, METI-Kansai (National Ministry of Economy, Trade and Industry – Kansai division) who aims to develop existing industrial strengths and policies. Second, the Kansai Economic Federation (Kankeiren) comprising of eight prefectural governors and four city mayors who lobby to develop Kansai's contribution to the Japanese economy[92].

However, Kansai is a loose collection of prefectures competing for industrial growth, and how prefectures and cities support their industries is ad hoc and open to interpretation. In 2010, the Union of Kansai Governments (Koikorengo)[93] was formed to balance the National government's centralised planning. The Union consists of Kansai companies who lobby the national government on matters to support Kansai business development. But, the National government continues to shape strategic directions via policies and programs targeting specific technology development through legislation and industry standards[94].

The National government has supported battery development since the 1970s for electronics, electric vehicles and grid applications advocating collaborations between the utilities sector, electronics and automotive firms, battery manufacturers, R&D centres and universities[94,96]. Japan was the first to develop the lithium-ion battery for the electronics industry - largely in Osaka - with commercial production starting in 1991[95]. The National Institute of Agency of Industrial Science and Technology (AIST) has been critical, its mission being to create bridges between '**technological seeds**' and '**societal needs**' with its' first large scale lithium-ion battery research program starting in 1992. The New Energy and Industrial Technology Development Organization (NEDO, administered by METI) has also been key, funding technological innovations to solve energy and environmental issues[97].

Given strengths in the advanced manufacturing, chemicals, medicine/pharmaceutical and energy-related sectors, the Osaka Prefecture Government established a Battery Strategic Promotion Centre in 2012. It aims to develop a battery manufacturing cluster[98] by matching '**technological needs and seeds**' (quote from Osaka Prefecture Government presentation) as well as by supporting SMEs, strategic projects, programs and subsidies.

Through support and governance (e.g. funding and support from NEDO), Osaka Prefecture has built substantial batteries manufacturing industry mass, including testing and analytical bodies, certification authorities, universities and research institutes, and in both major companies and SMEs. Figure 10 shows how these components network across the Prefecture. How government builds capacity is outlined in the next section (see figure 11).

The Osaka Prefecture Government strengthens regional industry via various business attraction strategies. For example, setting up subsidies to attract foreign or domestic investment, and establishing special economic zones for battery-related industries[99] (e.g. electric cars, sunlight or wind power technologies, advanced lithium batteries, advanced energy-saving devices, or products promoting smart communities[87]).

Firms who establish in these zones are offered special tax concessions and incentives, such as:

- No taxes for the first 5 years, and then 50% of taxes for 5 years thereafter.
- Special tax concessions for firms moving from elsewhere in Osaka Prefecture.
- Land and planning tax concessions for firms meeting certain conditions[87].

Figure 10: Industry network supporting battery manufacturing

Adapted from: Osaka Prefectural Government presentation, 2021

Strategic approach to supporting R&D and industry capacity building

Interesting examples of industry development support are:

- The largest testing and evaluation facility for batteries in the world - National Laboratory for Advanced Energy Storage Technologies (NLAB) - opened in 2016, as part of the National Institute of Technology and Evaluation (NITE) in the Osaka Bay Area[162].
- The Osaka Science & Technology Centre supports industry-academia-government partnerships strengthening technological development in Kansai[163]. For example, through membership fee-based study groups or sub-committees for general networking and information exchange on specific topics[164], such as:
  - Smart Grid Study /Smart Community Study Group (est. 2013) examining next generation energy consumption.
  - Advanced Battery Technology Study Group (est.1992) exploring issues related to rechargeable batteries, e.g. power storage devices and safety/life evaluation.

Industry capacity building by regional authorities

Battery production is extremely difficult due to deep experience and expertise needed in producing chemical reactions. This is concentrated in five core battery manufacturers in Japan, largely in Kansai. Korean and Chinese companies, respectively Samsung and CATL, have expanded operations to include lithium battery manufacturing by learning from the Japanese and hiring Japanese workers.

Production experience is very important in battery manufacture. (Interviewee from Osaka)

Continual development in knowledge through technological advancement and network sharing is crucial in retaining global competitiveness in the batteries manufacturing industry. Short-term market advantages may be achieved through intellectual property rights and/or trade secrets, but corporate knowledge or industry skills are tradeable between firms or expire as new knowledge or technologies become available.

Market advantages can also be achieved through local workforce capacity building. This may be by strengthening local organisational networks (across industry, academia and government), regional governance and government support mechanisms, coordination between firms and testing/analytical bodies and certification authorities, and community enhancement strategies. The Osaka Prefectural government works across these areas.

Approximately 65% of all industry production in Osaka City is by SMEs[87], and Osaka Prefecture has over 15,800 manufacturing firms across many industries – more than any other prefecture in Japan (from Osaka Prefecture Government presentation). The Osaka Prefecture government is active in supporting battery manufacturing.

Highly developed research capability across Kansai

15 universities and two research centres engage in battery-related discussions and research[165]:

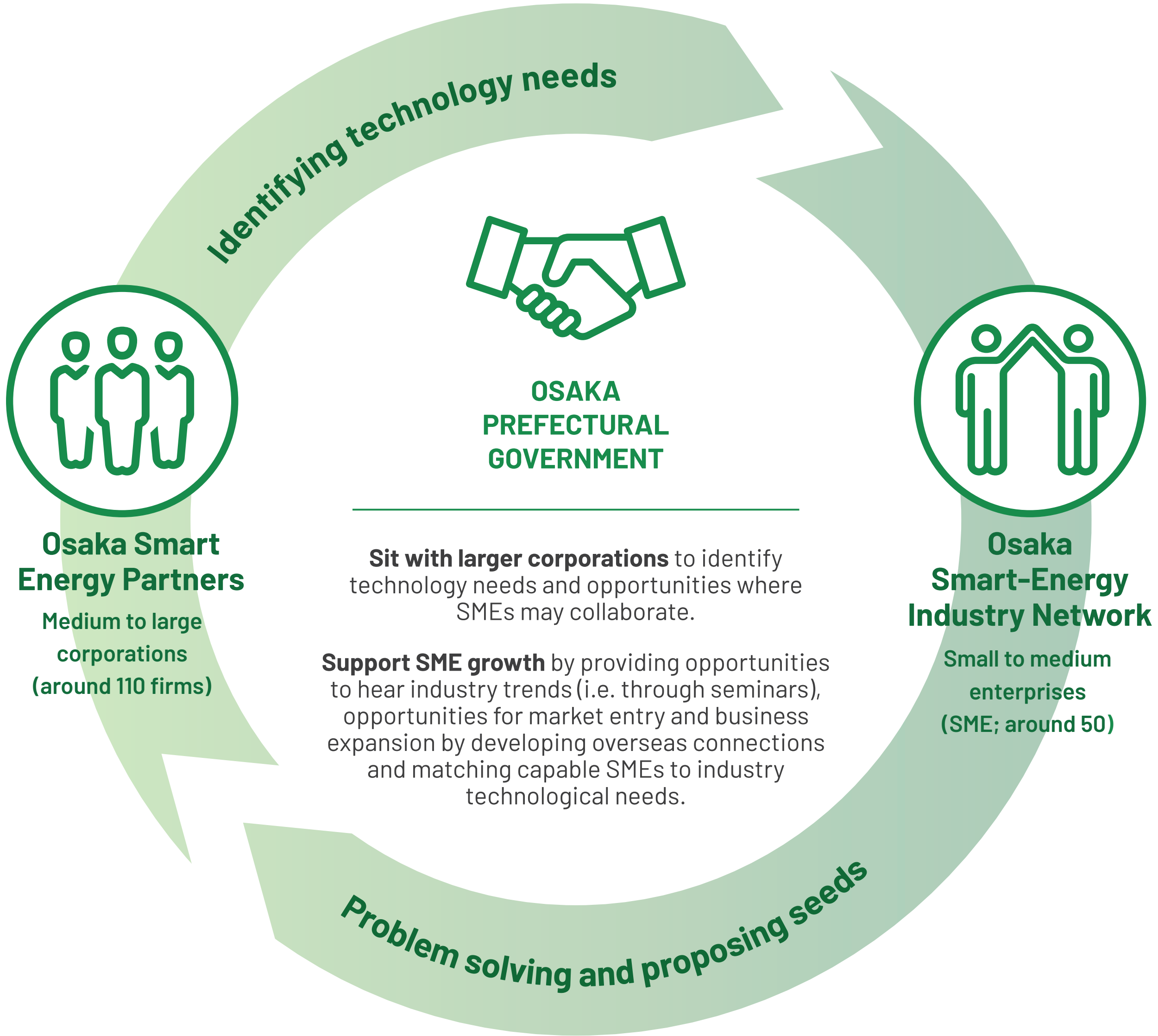
- Iwate University
- Doshisha University
- Osaka City University
- Nara College of Technology
- Kanagawa University
- Mie University
- Kansai University
- Yamagata University
- Kyushu University
- Yamanashi University
- Kyoto University
- Waseda University
- Keio University
- National Institute of Advanced Industrial Science and Technology
- Kobe University
- High Brightness Photon Science Research Center
- Energy Research Institute

Its Battery Strategic Promotion Centre, staffed with industry experts, helps SMEs collaborate with large battery-related corporations, coordinates firms, universities, R&D institutes, and other government departments, and subsidises R&D[99]. This is through primarily three activities:

1. SME support in business expansion and overseas development, for example, by:
   - Holding business forums with domestic and international participants.
   - Facilitating overseas collaborations, e.g. it has a Memorandum of Understanding with the North Rhine-Westphalia State in Germany and supports trade missions there.
   - Working with the National Government to business match, e.g. Japan External Trade Organisation (JETRO).
2. Encourage and support industry demonstration projects in the community by:
   - Providing SMEs with subsidies for R&D, trial production or demonstration projects. Such as the commercialisation of: 1) 11-seat EV bus; and, 2) ultra-thin and lightweight lithium-ion battery.
   - Working with Osaka City Government, Osaka Chamber of Commerce and Industry to demonstrate proof of concept, assist with commercialisation and coordinate regulatory processes.
   - Facilitating the establishment of a national government testing body - NLAB (National Laboratory for Advanced Energy Storage Technologies) - in Osaka.
   - Collaborating with NLAB in Osaka and National certification authorities to develop industry.
3. Encourage and facilitate open (or semi-open) innovation between Osaka Smart Energy Partners and Osaka SMArt-ENErgy Industry network, as shown in figure 11.

Figure 11: Open or semi-open innovation model of Osaka Prefectural Government

Adapted from: Osaka Prefectural Government presentation, 2021



Future directions and challenges

There are several challenges for the Osaka cluster. One, rising global competition in the battery industry. The unsteady global joint partnerships between Tesla and Panasonic as Tesla moves into battery manufacturing signals market uncertainty. There is need for new overseas industry connections to ensure cluster competitiveness.

Two, a focus on addressing societal needs through technological advancements. This is particularly in relation to the persistent challenges of Japan's aging population and declining workforce and what these mean to industry and regional sustainability[100].

Three, a lack of mineral resources leaves Japanese industry dependent on resource nations, such as Australia and China. This can be alleviated by developing greater efficiencies in battery recycling and reuse. Other nations also see recycling as a way to overcome resource dependencies, such as China with Australian iron ore[101]. Raw batteries materials recycling also aligns with Japan's initiatives to green industries and enhance specialised recycling expertise.

Further, there is strong National government support around carbon zero production, for example:

- Support for non-CO_2 emitting electric vehicles (EV) by METI through subsidies for R&D and domestic manufacturing of high-performance next-generation batteries. The aim is to stay abreast of Chinese manufacturers[102].
- Doubling subsidies for EVs (private and company-owned) in the 2020 supplementary national budget[103].

Also, in 2019, Tesla installed an emergency railway battery for the Osaka Kintetsu train line to move trains for up to 30 minutes during grid failures. It is the largest battery storage system in Asia to date[104], and points to the commitment of Japanese firms in working towards carbon-neutral operations and Tesla's recognition of Japan as a key future market.

The interviewees raised several points regarding future directions and regional capacity building:

- Importance of promoting and increasing international collaborations with Japanese business to support regional development and bolster industry. For example, Memorandums of Understanding at the prefecture level with other international governments or agencies in the battery manufacturing value chain.
- Challenges in sourcing minerals, being reliant on trade and recycling, leading to diversifying where minerals are bought from. This is opening opportunities for Australian firms to receive Japanese government funding (see Japan Oil, Gas and Metals National Corporation (JOGMEG) Carbon Neutral Initiative and Action Plan in appendix 1).
- Japan is a mountainous country, and any available land is highly urbanised making industry expansion difficult.
- Energy in Japan is expensive and not easily accessible; the National government proactively addresses this.
- Japan's aging population and little migration means planning for workforce futures is difficult, with robots and/or the streamlining of processes used to decrease the need for workers.

4. Lessons for Australia

Whilst Australia is a major global supplier of almost all minerals used in battery production, there has been limited development of downstream battery manufacturing. Currently, the battery manufacturing supply chain is dominated by China[2], with its own reserves of battery minerals, strengths in manufacturing and its proactive seizing of market opportunities. Recent supply chain shocks and trade wars have caused global insecurities and vulnerabilities regarding this dominance. For example, the 2020 USA trade war with China[105] saw EV batteries leveraged in trade negotiations causing market disruptions and price rises. As a result, many nations have increased their domestic investments, including the USA[106] and Norway[107], to develop downstream battery manufacturing capabilities.

Australia is well-placed to develop a battery manufacturing industry hub. It holds much of the worlds' raw battery minerals, and has a stable political environment to ensure secure supply for other nations. But, there are **two key challenges for Australia.**

First, its **distance to battery consumer markets** (e.g. car or renewable energy storage manufacturers[108]) in USA, Europe and Asia. This increases logistic difficulties and costs in the transport of materials, products and waste – all critical factors taken into account in firm location decision-making. This challenge can be overcome if designated hubs secure 'anchor' tenants who can generate consumer mass or gravity. Another way is 'hubbing' firms already in Australia, for example, those in resources and refining.

Second, **the scale of policy measures and funding by other governments, in the UK and Europe in particular, in encouraging research and battery industry hub development illustrates the global competition to attract investment.** There are arguments for the protection and support of infant industries, such as the advanced batteries industry, who face fierce competition from overseas and provide a means to better monetise Australia's mineral wealth (currently sent overseas with little-to-no value add). Indeed, the withdrawal of government support saw the car industry move overseas. However, there are also examples of Australian industries emerging as globally competitive despite limited initial government support. These include:

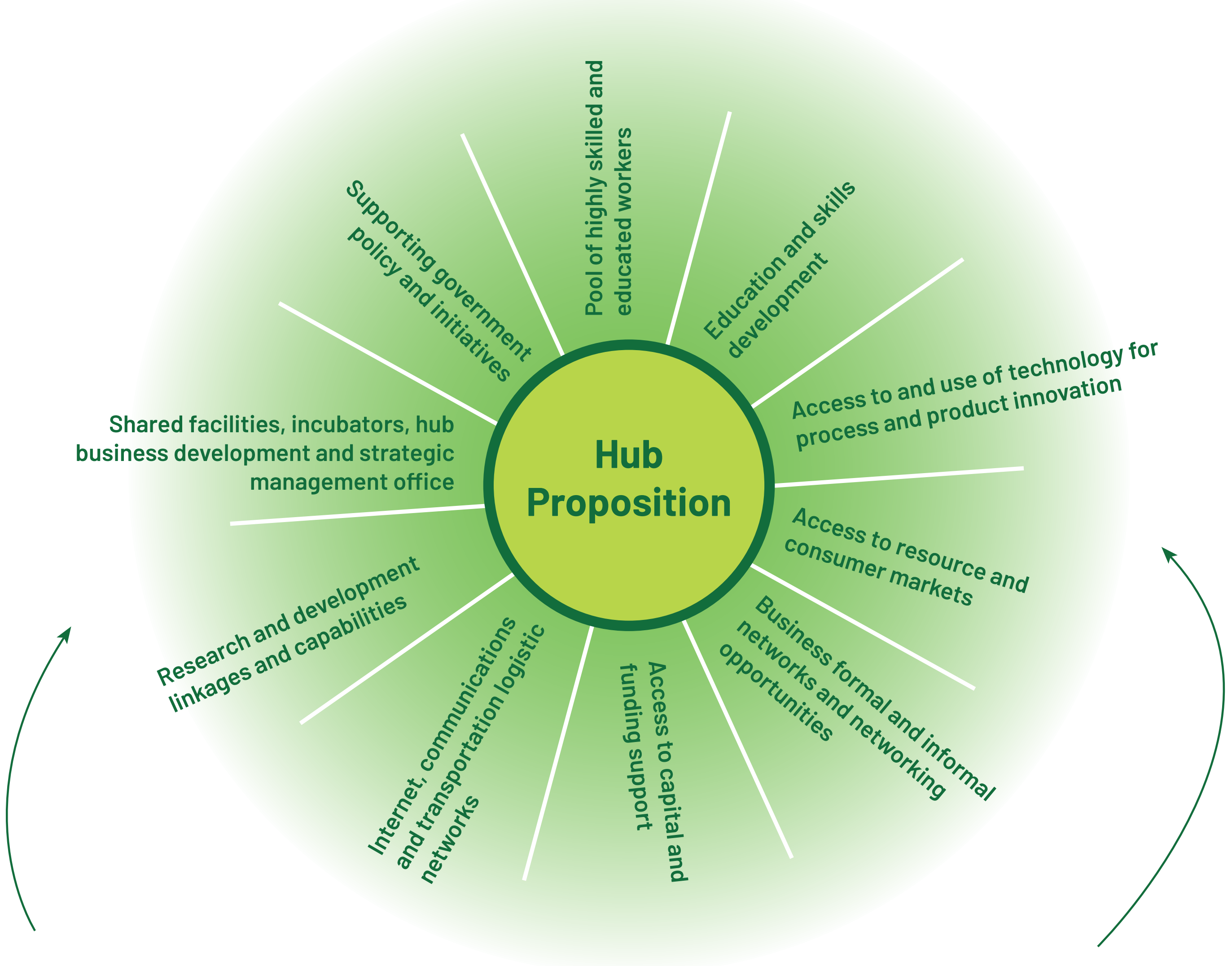
1. The ship-building hub in Henderson, WA, centred on Austal[109]. Austal emerged from an expertise in building lightweight fast crayfish boats, and several attempts in the 1990s to win the America's Cup. It is now a leading global shipbuilder whose competitive advantage is not in cheap labour, but in the skills, knowledge, innovative culture and passion found in Western Australia.
2. The agricultural industry lost much of its government protection and support from the 1980s, yet continues to rank as a top Australian export despite relatively high labour costs and increasingly harsh growing conditions under climate change. The industry is one of the most globally innovative, competing in price-based commodity markets through productivity gains due to innovation and knowledge, and in alternative markets based on quality, ethical operations and environmental protection.

The key lessons from the international case studies was they did not offer the cheapest labour, nor provide a perfect hub location in all aspects, but that industry and government collaborated to identify and leverage competitive advantages to strengthen regional development. Similarly, an advanced manufacturing battery hub in Australia must be based on competitive advantages, drawing on innovative approaches to industry development. Australia's natural endowment in the minerals needed for advanced battery manufacture must be viewed as an intergenerational opportunity to develop future industries. But its potential to grow such an industry must be contextualised by the nations that have already invested heavily (both government and industry), and have existing original equipment manufacturer (OEM) consumer markets.

Nonetheless, future expected expansions of the emerging advanced batteries industry is an incentive for collaboration between SMEs and large firms. But, there is **a need for a burning industry platform to motivate stakeholders** to establish an advanced battery manufacturing hub. This section outlines a hub proposition for Australia based on the case study insights and interviews with Australian-based organisations. This hub proposition is summarised in figure 12.

The remainder of the section gives key insights for Australia based on the hub proposition. Each insight is highly relevant to and embedded in an understanding of the Australian context, and what is needed to grow an Australian battery manufacturing industry. Each concludes with a **hub development action list**, which needs to be adapted to an individual hubs' unique context.

Figure 12: Hub proposition for Australia based on international case study site findings



Region

- Global champions of change in industry and government
- Quality of Life
- Branding/Marketing
- Emerging industry leveraging well- established assets

Cluster development

- Cross organisational capacity building
- Governance structure and financing
- Special considerations for waste to resource
- Efficiencies of scale and scope for SMEs

4.1. Emerging industry leveraging well-established assets

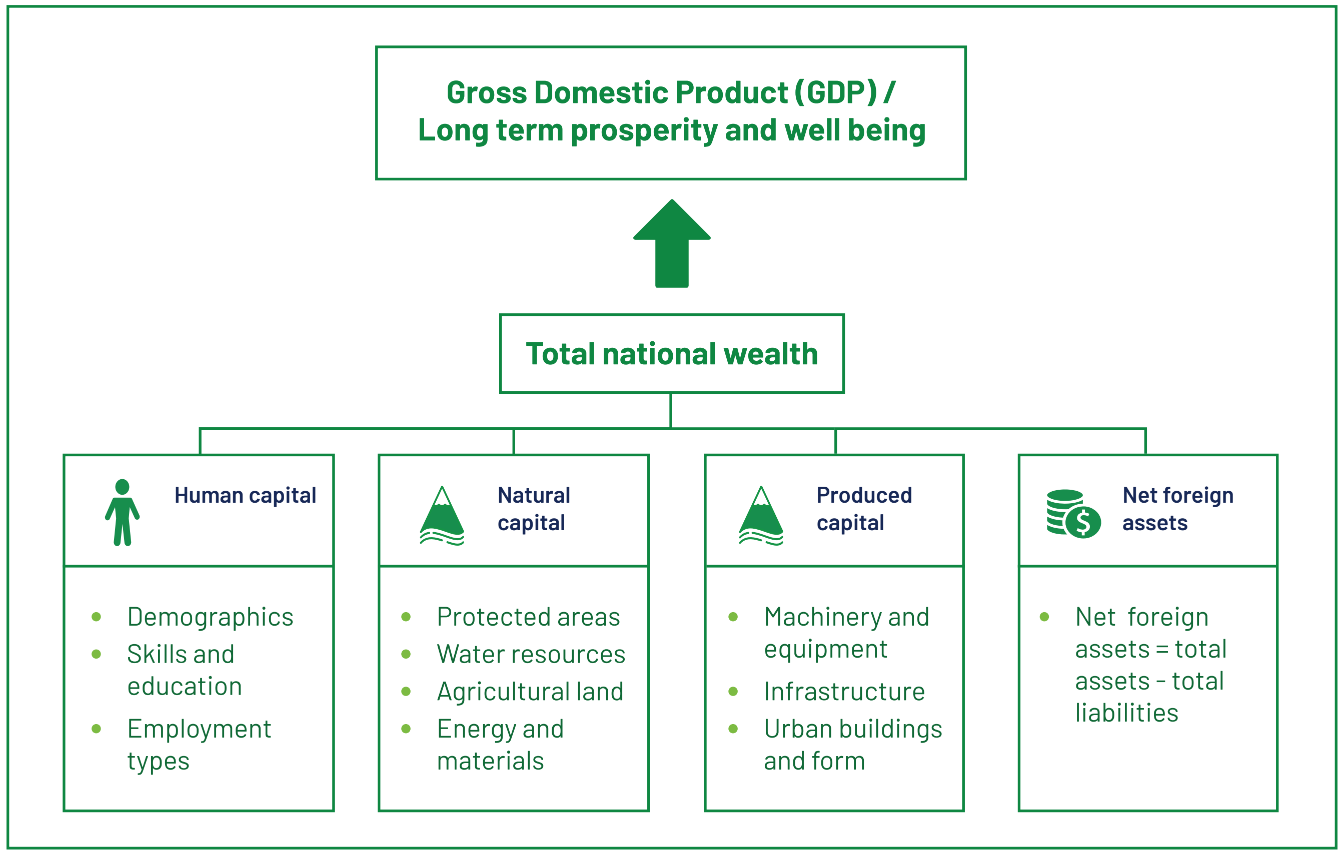
Australian 'luck' has always hinged off an abundance of natural assets, and there has been minimal need to value-add these assets or monetise the 'Australian' brand in the resources industry. But, if a metal has a higher value, then concentrating and refining it in Australia captures more of this value. Currently, too little of the battery metals and minerals value-chain value is retained, and shipping concentrate means overall gross domestic product (GDP) contributions remain fairly insignificant (compared with iron ore, coal, gold, etc.). As such, there is a need to produce at least battery chemicals, with a later aim of moving into precursor and active materials.

The emergence of the batteries industry is a critical inflection point in Australia's resource extraction history from which to move downstream in an industry with a predicted explosive trajectory. This presents an inter-generational opportunity to establish new industry capabilities and export markets for a future beyond the actual resources extracted today.

There are risks, and Australia tends to be risk-averse, but there are also opportunities in parts of the battery supply chain where Australia has competitive advantages. For example, combining knowledge and technology to create new opportunities in refining and mineral purities, or developing global standardisations and methods to improve product traceability. Australia's highly entrepreneurial and innovative Mining, Equipment, Technology and Services (METS) sector supporting the resources and related industries are also an asset.

But, successful market entry means investing in decarbonising futures and battery technology R&D to build capacity at 'easy wins' points of the battery chain. It requires thinking beyond current national income, or gross domestic product (GDP), to realise the assets Australia's national wealth is based on. These national 'assets' are illustrated in the elements of figure 13, being the development base from which to position Australia in the global battery manufacturing market.

Figure 13: The wealth of nations beyond GDP
Adapted from: World Bank (2018)[110]



First, there are advantages to entering an emerging industry in a state of rapid technological change. The batteries industry is fast-moving and competitive, with nations around the world posturing to secure resource supplies as well as positions in the value chain. Indeed, USA, Germany, Finland, Norway and Belgium have all accelerated entry into various parts of the chain, especially battery materials, cell and pack manufacturing. It is crucial that Australia does not become the preferred supplier of raw materials to battery manufacturing hubs worldwide, but develops capacity downstream.

Second, the rise in global interest across the battery chain (from resources to end product) is partly driven by geopolitics and global tensions. This is due to the: 1) dominance of China across most of the chain; and, 2) trade wars at different parts of the chain – e.g. graphite prices rises after Chinese withdrawal of supply (2017), US tariff hikes on Chinese batteries to protect US domestic market (2020), China's restrictions on rare earth exports (2010) and tensions surrounding Japan's supply of battery materials to South Korea (2018). Australia's stable political economy can position it as a preferred location and partner for nations looking to secure resources and manufactured battery components.

Third, Australia has a strong and extensive base in mining and mineral knowledge, skills, entrepreneurship and networks across the resources and METS sectors. There is an active culture of sharing and employee rotation between resources companies, e.g. through poaching and short-term contract work. This has developed embedded regional capacities and specialisations, facilitating further industry collaborations, trust and knowledge circulation. Moving downstream will capitalise on these strengths, building on existing and developing new technical competencies in the resource and related sectors. Further, there are well-established capital raising avenues, such as the Australian Securities Exchange (ASX), particularly in mining and related sectors. But, there is a need to educate investors on advanced manufacturing where there is less investor knowledge and confidence, and advanced manufacturing firms on what matters to fund managers.

Fourth, Australia has other globally competitive industries offering cross-industry collaborations. Whilst car and battery manufacturers (e.g. Tesla's PowerWall for houses) are far away, there are opportunities at home. For example, to align with the Australian defence industry who sees on-shore manufacturing in critical sectors as paramount to national security[111]. Or, with the globally-recognised shipbuilding hub at Henderson, WA, or the emerging hydrogen industry as both a customer of battery products and an energy source for carbon zero manufacturing futures. Or, with the Australian mining industry as it decarbonises mineral extraction and processing, e.g. using EVs at the mines.

Lastly, Australia is remote but well-connected nationally and globally via good roads, rail, (air) ports and communications infrastructure. However, exporting raw materials elsewhere for processing using this infrastructure represents lost revenues for Australia and added carbon costs in production. As consumer preferences shift to support the United Nations Sustainability Goals and ESG (see appendix 2), decreasing carbon footprints means localising and regionalising supply chains. Australia has a role to play in this.

Leveraging assets - hub development action list

- Investigate venture capital raising potential for batteries industries on the Australian Stock Exchange and other funding raising apparatus, such as private equity funds.
- Identify key skills and training relevant to the batteries industry, investigate gaps in Australia's workforce, and create internships and jobs to enhance cross-industry development and skill sharing.
- Establish mechanisms to facilitate cross-industry discussions or collaborations, like mining, defence, shipbuilding and the hydrogen industry.
- Examine how application of technologies (i.e. blockchain) and creation of global standardisations can be used to monetise the Australian brand as a superior resource. In particular, investigate how Australian battery materials can align to the certification requirements of the WEF "Battery Passport".
- Map sources and sinks (supply and demand) of materials, energy, water, skills in regions where co-location makes sense.
- Perform an overall hub SWOT analysis and scenario analysis to map various economic and political futures and evaluate their impacts at the mega-trend level.
- Investigate ways to strengthen demand from local battery module and pack, and battery management systems, through policies around local content in the deployment of stationary battery systems in communities, defence, mining and grid applications.
- Transition to renewable energy provision for existing industry hubs.

4.2. Champions for change in industry and government

A key barrier to the growth of hubs in battery manufacturing is the absence of champions for change in industry and government. The speed at which other nations are accelerating industry development is already creating advantages at various points of the global value chain. If Australia is not proactive in securing its position and does not have the strong leadership to generate the needed changes, it will lose important opportunities to value add to national assets.

Australia already has a strong resource sector and related industries. This includes a large number of entrepreneurs looking to capitalise on and develop new business opportunities, and who understand current and future industry needs. Interviewees noted that the batteries industry is an emerging and unknown landscape across the globe, and that:

> *Australia must produce clean energy minerals with the lowest carbon footprint and most sustainable way possible. (Australian mining/refining company interviewee)*

Industry leaders need to encourage the shift towards more sustainable production, and work with technical colleges and universities to ensure a flexible and adequately skilled workforce. This includes collaborating with government to enhance job opportunities for disadvantaged groups, e.g. trainee programs for women and indigenous workers. Industry leaders also have a role to play in educating capital markets on the risk around advanced manufacturing to increase the availability of capital. Whilst the mining sector has established markets and investor confidence, sectors further downstream do not. Opening up this potential will be critical, particularly for smaller firms.

Government leaders are the central figures in the decision-making, writing and enacting of policies, shaping industry and the research environment. A lack of cohesion across government may be detrimental to industry competitiveness and futures, e.g. through greater strategic engagement by Federal and State governments, and faster more transparent decision-making. Interviewees felt government needed to move from 'cheering from the sidelines' to being an active collaborator - as other governments around the world have done.

There are three levels of government to consider. Critical areas for Federal level leadership are around:

1. Support for trade, e.g. through free trade agreements.
2. National targets for greenhouse gas emissions to meet or exceed international commitments.
3. Business attraction mechanisms, e.g. special economic zones, tax or R&D breaks, etc.
4. Increase use of local content, e.g. encourage employment and skilling of local workers or through government purchasing arrangements, policy and other initiatives.
5. National funding schemes to support business, cross-industry collaborations and R&D. Whilst rare earths attract special funding (e.g. Lynas will build a facility in the USA for processing through Australian Department of Defence funds[112]), Australia provides less support than other nations in the batteries manufacturing space. This is an issue especially for junior miners where seed funding supports difficult start-up periods or downstream production moves outside of core business.

A key area of State leadership is transitioning from raw materials extraction industries to value-add services and products. This means:

1. Future-proofing the resources industry, e.g. by encouraging industry adoption of renewable energy sources and facilitating cross-industry projects.
2. Efficiency in regulatory and permitting processes, e.g. lowering costs to establish operations (including around provision of major infrastructure such as roads and power), and proactive or pre-emptive planning approvals.
3. Strategies to attract business, e.g. tax breaks, subsidies, favourable land purchase or leasing arrangements (e.g. peppercorn).
4. Strategic planning and support around hub development.
5. Partnering with business in speculative projects to advance industry development and opportunities.

Local government leadership revolves around:

1. Support for a batteries industry hub development. Local government provides the surrounding quality of life and environment, and therefore plays a role in attracting skilled and educated workers and providing conditions to foster productive and innovative workforces.
2. Assist regulatory and permitting processes, including lowering costs to establish operations. Indeed, one interviewee cited locating to Kalgoorlie-Boulder because of the incentives and assistance provided by the local government.
3. Partner with industry by funding pilot or demonstration industry projects (e.g. Osaka case study) or purchasing batteries in advance for community installation to pre-fund projects. Such joint initiatives can promote the greening of local communities and provide national examples of excellence.
4. Collaborate with industry and academia to increase regional sustainability through targeted projects and investments. For example, the City of Rockingham has been active in shifting from a base of dirty heavy industry to more sustainable futures, e.g. supporting Australia's second waste-to-energy plant[113].

The final area of leadership is the hub itself, being in the form of a coordinating or managing entity to support and develop hub activities and assist new members with regulatory and other processes. This entity is not a 'real estate' agent, but enhances firm activities in the hub in collaboration with R&D institutes, government and industry. This may be in conducting business gap analysis, e.g. in how waste are used, calculating carbon footprints or ratings for ESG (see appendix 2). And, then, suggesting strategies to address gaps and encourage local content.

Indeed, any hub proposed will compete for businesses who will evaluate the pros and cons of different hub locations globally. If Australia wants to attract and retain the best business, then it needs strong leadership supporting industry and governing processes.

Champions for change - hub development action list

- Identify possible batteries manufacturing industry issues across government-industry-academia, establish networking groups to exchange information around these and lead national discussions.
- Examine the regulations, permitting processes and costs for establishing different types of hubs which may be relevant in different locations. Work with government to streamline and simplify processes.
- Identify mechanisms to promote community demonstration or pilot projects to assist in business development and community education of the industry.
- Encourage firm literacy in international accreditation standards, incorporate into data collection and information management systems.
- Assist firms in understanding what data is relevant to collect and serve multiple means.
- Foster and develop mechanisms for SMEs to access opportunities to work with large enterprises and advocate for larger overall Commonwealth support towards manufacturing in hub environments.
- Advocate for policies to curb emissions consistent with achieving net zero by 2050 and leverage trade agreements.
- Advocate for the creation of special economic zones or other incentives to attract industries in the batteries industry value chain.
- Investigate and advocate for appropriate models of open innovation.
- Investigate avenues for investor education in advanced manufacturing to increase firm access to capital, and how to educate advanced manufacturing firm in what matters for investors and investment.
- Work with government to encourage use of local content (both workforce and purchasing).

4.3. Efficiencies of agglomeration, density, scale, scope and logistics

The benefits of hubs are well known and summarised for all firm types in figure 14, which shows hub economies of competitive advantages. In large organisations, these benefits accrue not only when they are part of a hub, but internally within the organisation with more functions in-house. SMEs are more likely to collaborate with or outsource to other companies because they do not have the internal capacity.

Hub Economies of	Production	Distribution	Consumption
Agglomeration	Linkages between manufacturing, resource, industrial and service sectors	Clustering of activities reduces transport and logistics costs	Lower input costs with clustering of retail activities
Scale	Larger facilities (offices, plants, warehouses) reduces unit costs	Larger transport and logistics nodes reduces unit costs	More concentrated consumer demand (larger retail facilities or corporate clients) reduces unit costs
Scope	More product streams reduces unit costs	Bundling of product streams in transport and logistics movements reduces unit costs	More product streams attracts more customers
Density	Greater access to skilled and educated labour where there is urban density	Greater urban density reduces transport and logistic costs	Greater urban density increases access to range of goods and services
Transport	Access to suppliers and customers reduces unit costs	Less transport and logistic links reduce unit costs	Access to suppliers and customers reduces unit costs

Figure 14: Economies of competitive advantage provided by a hub

Adapted from: Rodrigue (2020)[114]

A hub can facilitate and establish support mechanisms to enhance economies of competitive advantage by working with government, industry and academia. This provides process efficiencies, which enhances competitiveness enabling firms to move downstream more quickly in competitive global markets, even if government funding support is lower than other regions like the European Union and Japan (see appendix 1).

It is critical then to understanding economies of competitive advantage in a specific hub location, and how these can be enhanced. For example, SMEs tend to be more integrated, open to collaborations and reliant on a hub than multinationals who are more likely to be hub anchor tenants attracting SMEs, workers, etc. A hub needs to provide for both. The efficiencies found in **economies of agglomeration** mean when firms can be bulked together if they are in synergistic parts of the value chain, e.g. mining, refining, and precursor production. A hub allows clustered SMEs to gain the efficiencies of a large firm, making them more globally price-competitive, e.g. firm transaction costs are reduced when there are shared transport services or materials, facilities (e.g. waste disposal) or if they co-create new markets (e.g. via waste-to-resource discoveries).

Similarly, **economies of transport** facilitate access to workers located in adjacent urban areas, avoiding the fly-in / fly-out workforces (FIFO) of the mining sector. FIFO may be efficient in delivering workers to remote mine sites, but suffer high personal costs in the long term. This is not conducive to an effective and fully motivated workforce. Efficiencies in **economies of density** are found in urban areas where required skills, labour pools and other businesses are accessible when needed. The similar needs across the mining sector mean firms already share knowledge and skills through competitive staff sourcing and contractual working arrangements. This has led to capacity building of the Australian workforce in the mining and related (such as METS) sectors, which is transferrable to sections of the batteries manufacturing value chain (e.g. refining).

Indeed, a diversity of businesses provide for a more stimulating work environment and career mobility, and proximity to tertiary learning and research institutions provides opportunities for continued and advanced education. As such, the concentration of industry and workers can lead to more extensive training opportunities, and allow for both career horizontal expansion and vertical growth. Learnings from one sector of the industry can be transferred, combined in new and novel ways, adopted and benefit other sectors easily.

Aggregated production efficiencies - hub development action list

- Identify locations where there are already natural industry clusters related to battery manufacturing forming as well as related value chain components that should be located there (i.e. based on circular economy flows).
- Conduct audit of potential hub sites to understand performance across various measures (i.e. related to economies of scale and circular economy flows) critical for battery hub development.
- Examine how an industrial eco-system can be created to increase hub efficiencies by identifying, qualifying, quantifying and mapping material/energy sources and sinks, material (raw materials, water, products, by-products, wastes, emissions, effluents, consumables) and energy (heat, electricity) flows.
- Investigate hub coordinator model most appropriate for a specific site, given that the three case studies demonstrated different coordination mechanisms (i.e. organised by government, private business development firm, anchor tenant, etc.).

4.4. Hub governance and support

Australia is a politically stable nation with relatively high industrial standards, very strong governance and institutions that can ensure a consistent supply of battery materials and manufactured products and transparency in supply chains. Securing energy futures through reliable value chains is a priority for nations worldwide, Australia is well-placed to be a global trade partner in this.

Government funding support is critical to establish Australia in the global battery manufacturing value chain. Without it or protectionist policies, industry development requires efficient and appropriate governance structures across various types of policy (i.e. local, State and Federal), industry alliances and industry task forces, regulatory and compliance laws, and hub mechanisms promoting member growth (strategic plans, administration, ESG rating as outlined in appendix 2), etc. In this context, a hub must be evolutionary, and responsive to issues not yet known.

Whilst governance across systems is complex, several aspects emerged from the interviews. First, all government (local, State, and Federal) and industry need alignment to ensure regulatory efficiency and systems integration. Second, the use of renewable energy and move towards zero - (or low) carbon business certifications is critical - creating a quasi-protectionism that can sheild the emerging batteries industry from nations competing under cheaper labour or less stringent environmental regulations. The Europeans have achieved this through a legislative framework and tariff systems to discourage non-compliant business. Buying low-carbon produced goods is attractive for final goods producers who cannot afford to have 'dirty' practices in their supply chains.

Australia exports raw product as it is cheaper than dealing with refining, waste removal and permitting/approvals processes. Currently, most industries accept unethical and unsustainable practices in exchange for lower costs. But, the batteries industry is driven by environmentally-concerned end-users, who will not switch to most expensive EVs from conventional combustion engine cars unless EVs have a clean, green and ethical stamp.

Clean, green and ethical is the competitive advantage for the batteries industry – not price. Australian minerals are currently not always refined in a clean, green or ethical way, which decreases the value of our minerals in the battery market. This represents a missed opportunity to further monetise Australia's natural assets. (Australian mining company interviewee)

For example, current spodumene exports are low value - containing only 5-6% of the lithium utilised in battery materials. Once Australian spodumene is refined and purified, say for example in China, it is no longer Australian - but stamped as Chinese. The 95% waste or by-product from the refining process represents additional value loss, as it can be used as road base or as a replacement for fly ash in cement, saving money in other industries.

An Australian batteries industry would allow more value to be extracted from Australian resources as:

1. Value-adding to Australian raw resources allows more value to be captured by Australian industries and government as opposed to internationally;
2. Value adding to the portion of the resource that is currently sold at little-to-no value (i.e. waste from the raw materials refining process) by turning the by-products from refining or other processes into alternative uses;
3. Value adding as the Australian 'brand' is stamped on Australian products, given that the high quality and standards associated with this brand enable products to be sold at a higher price in global markets.
4. Capturing more of the value chain in Australia decreases the logistics, transport (of product and waste) and carbon costs incurred when raw materials are shipped elsewhere for refinement and processing.

A battery hub in Australia will better monetise Australia's brand, competitive advantages and natural assets. But, it requires a efficient regulatory and policy framework to enable value chain capture and foreign investment – and there are many other nations more competitive in providing this than Australia. Appendix 1 provides international examples of policies and programs stimulating growth across the battery value chain.

Australia is just one location for firms operating along the battery value chain, with other nations offering more competitive start-up grants and assistance to facilitate foreign investment in the batteries industry in their nations.

Restructuring governance framework - hub development action list

- Investigate how Australia's current policy and regulatory framework can better facilitate domestic and foreign firms locating battery operations in Australia.
- Through policy and incentives, encourage collaboration with international partners with access to overseas funds that can be leveraged to grow the global batteries industry.
- Create an entity within specific hubs to assist with: collaborations across industry, academia and government; access to funds; identifying new waste-to-resource opportunities; and permitting and permission processes.
- Investigate the investment attraction potential of hubs with decarbonised power sources, and the value of government guarantees to clean energy provision to the hub.
- Investigate methods to streamline current processes (government or other) involved in establishing business operations.
- Advocate for a legislative framework to force industry compliance to high environmental standards through tariffs to move Australian industry towards zero carbon footprint.
- Encourage firm literacy in international accreditation standards, with understandings incorporated into data collection and information management systems.
- Assist firms in understanding what data is relevant to collect, in a way that serves multiple means.
- Investigate how technology can be used to improve traceability and accountability in the batteries materials and products supply chain.
- Examine the global attractiveness of potential batteries industry hubs as instruments to improve national branding around green and ethical production, identify operational gaps to be addressed to develop global recognition.

4.5. Process innovations for a lean industry, product innovations for new ventures

A key aspect of hub development is understanding a hub's role in facilitating and supporting innovation. The difficulties in, but need for, working across government, industry and academia in building globally competitive regions are well known. In product development, issues emerge around intellectual property (IP) ownership and how the knowledge is distributed publically with industry, academia and government all having different needs and expectations. Adding hub objectives on top of this complicates collaborations further.

If a collaborative R&D project requires relinquishing corporate trade secrets, businesses may be less inclined to get involved than R&D projects focusing on regional capacity building or solving common problems. For example, around access to renewable energy sources, how to reduce, reuse waste, decrease carbon footprints, improve permitting processes, decrease transportation costs and/or other industry synergies. A hub can also facilitate open innovation R&D – as in the Osaka and Gigafactory case studies.

There are two general innovation types: process innovations - to lower overall business costs; or, product innovations – to create new business opportunities. A hub can provide opportunities for industry to address scale-up risks of promising technologies at a consortium level, allowing shared learnings and reducing risks. Innovations can be applied according to individual firm operations or materials, but produced at lower individual firm cost. The FBI CRC and various other CRC's utilise this model.

Businesses are more globally competitive and have greater opportunities through both collaboration and co-location where synergies and solutions to core industry problems can be exploited. When this involves new product, process or business development, spin-off companies may emerge with royalties assigned to project collaborators or other arrangements, such as new joint ventures, product sales or fees for service arrangements (see figure 15).

These innovative opportunities should be incorporated into a hub's development model and value proposition. Innovation can also be a platform to increase local content in production, adding to regional development and capacity by raising demand for local products and jobs.

It's coming up with innovative solutions to solve existing problems, then you are tacking on new earning opportunities – like how to increase the purity of Australian minerals to sell directly into consumer markets who want to take advantage of what the Australian brand represents to increase their own competitiveness. Currently, purifying minerals is a highly energy-intensive process that may be environmentally harmful. Australia has an opportunity to be part of the global solution. (Combined from 2 separate Australian mining/refining company interviewees)

Innovation and problem solving also requires understanding and facilitating business engagement with Industry 4.0. Where Industry 3.0 is the application of internet and social media technologies, Industry 4.0 connects the physical and digital worlds through big data, sensor technology and analytics, artificial intelligence and machine learning, integrated systems, robotics, etc. Australia is already a leader in this space, with remote service delivery arrangements (i.e. telehealth), sensor technologies and robotics (i.e. remote control vehicles for mining and agriculture), blockchain technologies (i.e. traceability of diamonds, gems and batteries[116]) and digital twinning (i.e. virtual replication of physical mine sites to run simulations for maintenance, training or occupational health and safety).

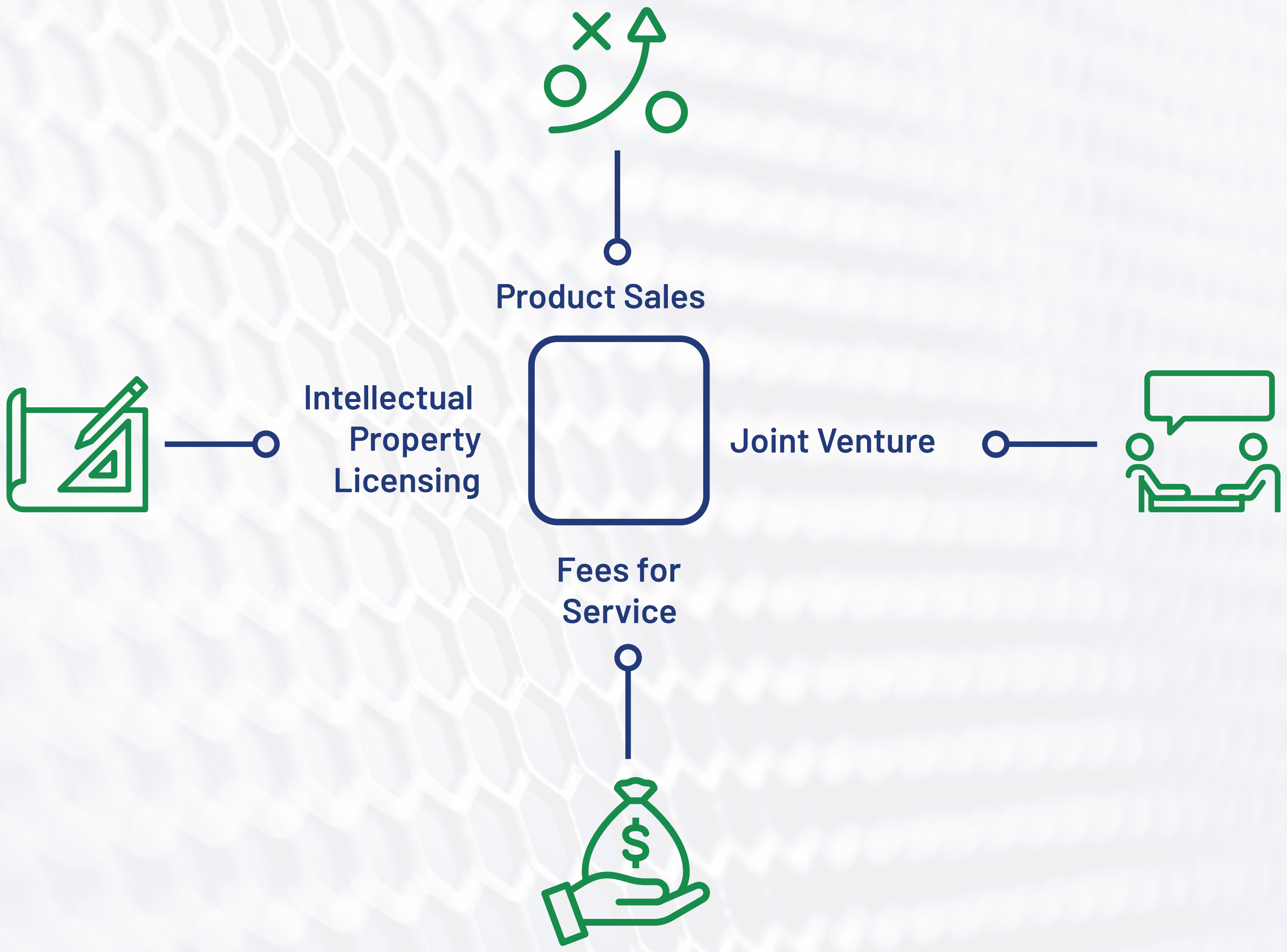


Figure 15: Opportunities emerging from new product or process innovations (see section 2.3)

"We are kings and queens of doing things remotely. We can monitor, manage and control things in the physical world through a digital remote setting. Australia is a big country, and we've got stuff everywhere and are used to playing in this space". (Australian engineering company interviewee)

Figure 16 outlines how Industry 4.0 applies to manufacturing. A hub can coordinate and assist business transitions to ensure production and logistic efficiency as well as identify areas for R&D, e.g. related to carbon zero manufacturing, international standards, product traceability and/or improved governance. For example, assisting in data certification for hub members as localisation of offset initiatives (like carbon capture and renewable energy generation) become more important in product life cycle analysis. This will certify and provide hub members with a competitive edge[117]. The hub itself will not be certified, but co-location and ESG education, networking and shared lessons in the hub will assist firms to achieve better ESG outcomes. A related example is greater R&D into the traceability of Australian resources to leverage and monetise the Australian brand, e.g. through blockchain technology[118].

There has already been work done in Australia on what Industry 4.0 means for domestic manufacturing[119], but not specifically for the batteries industry. Though companies, such as Covalent Lithium and Tianqi Lithium, report moving into automation of large scale production as a means to compete against the labour-intensive small batch processing of overseas manufacturers. The greater capital costs involved in this will need to be recouped through better yields and/or long-run savings.

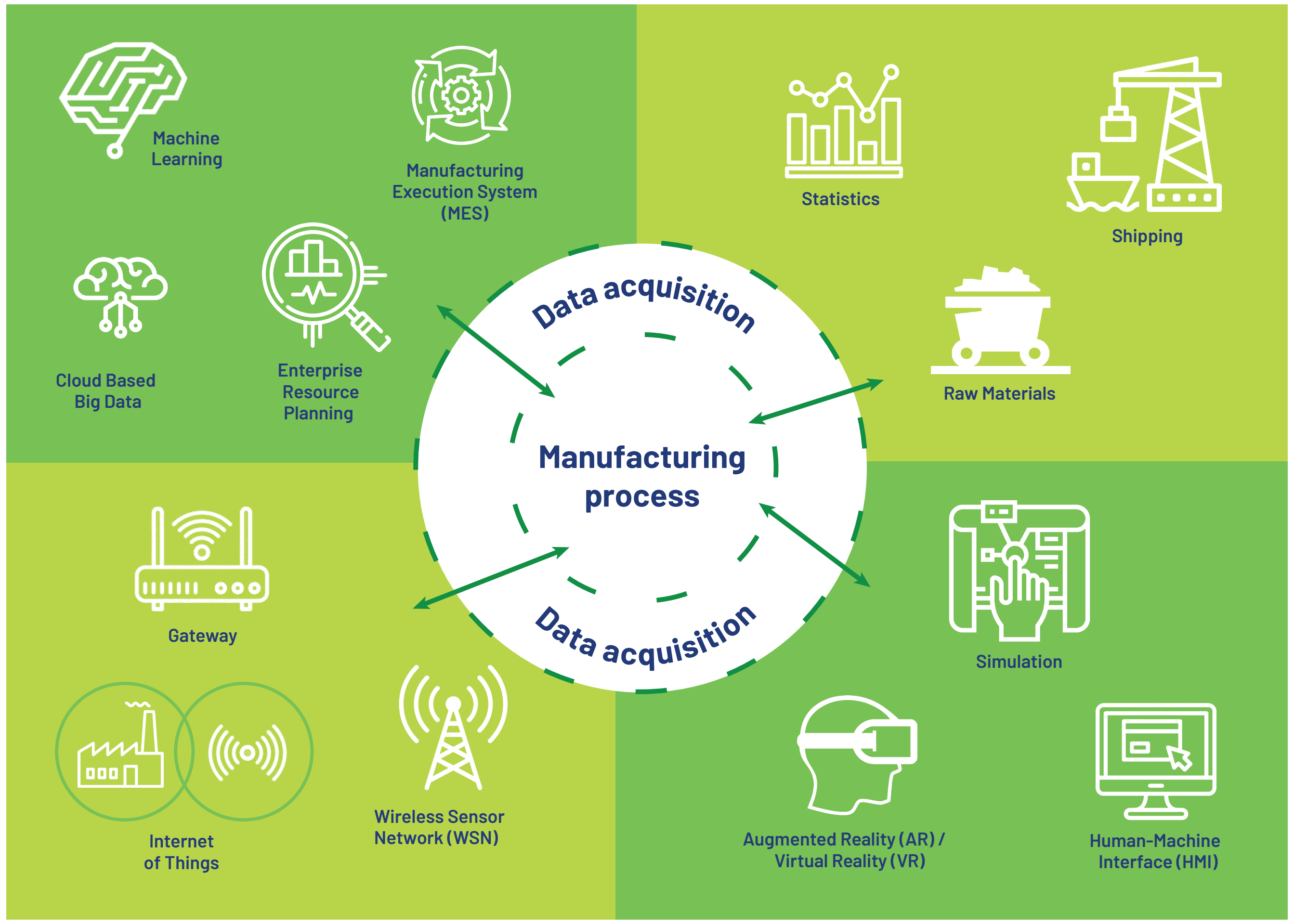


Figure 16: Industry 4.0 manufacturing

Industry innovation and competitiveness - hub development action list

- Investigate what is needed to upgrade the Australian batteries industry to Industry 4.0, including appropriate models of (semi) open innovation.
- Understand the benefits and challenges of Industry 4.0 to ensure ethical and responsible systems are implemented.
- Conduct a needs analysis to identify gaps or areas of further R&D to benefit hub members by increasing business efficiencies, industry competitiveness and create new business opportunities, such as delivering cheap renewable energy to remote locations.
- Create industry-academia-government networking and information exchange groups around issues facing battery manufacturing in Australia.
- Work with government to provide opportunities for community demonstration or pilot projects to pressure test ideas and attract funding for large scale commercialisation.

4.6. Green, carbon-neutral, sustainable industry value chains

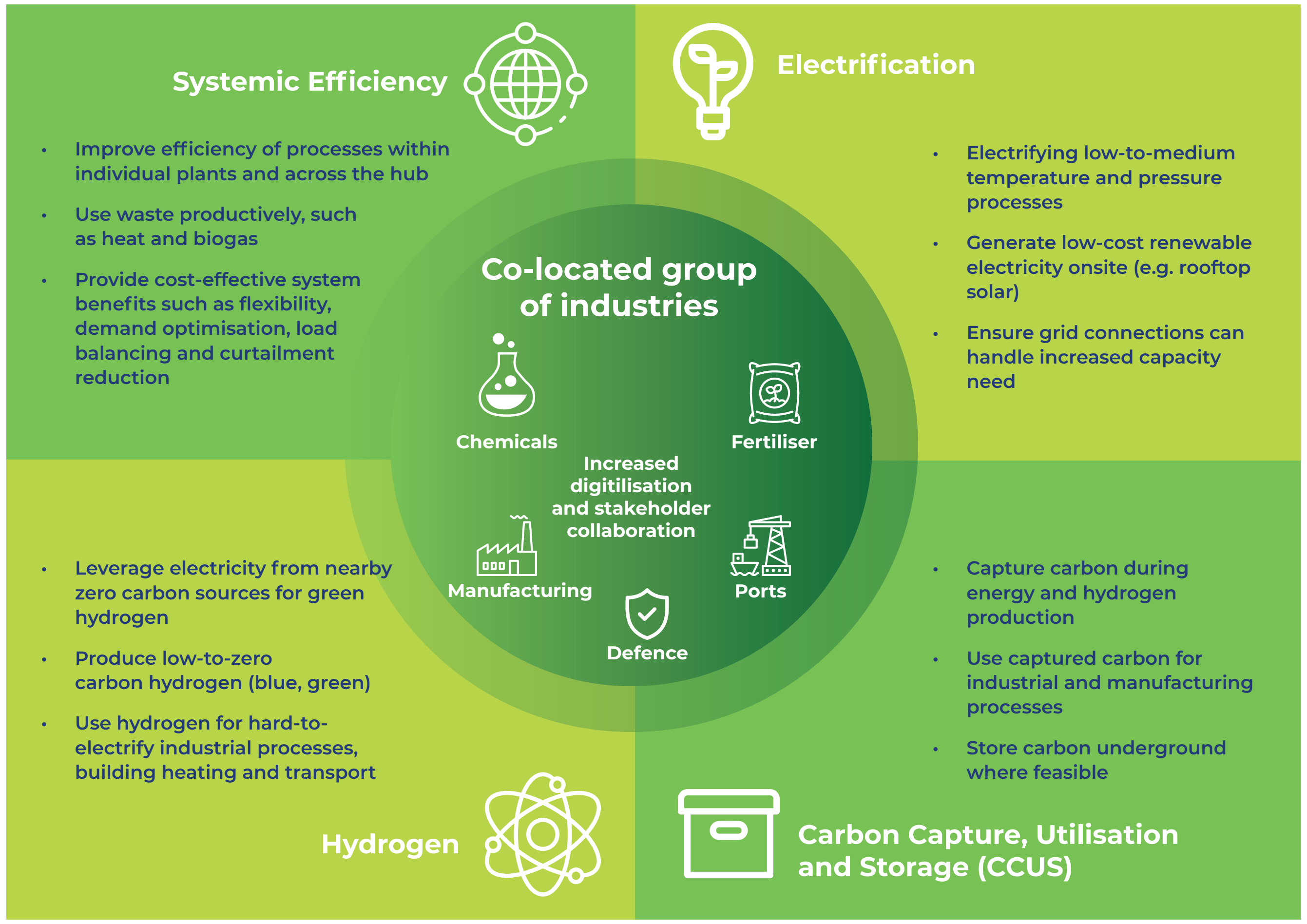
Previously, global competitiveness centred on minimising costs by locating manufacturing in nations with cheap labour and minimal regulations, allowing certain nations to dominate global supply chains. The 1980s exit of businesses to these nations meant the collapse of domestic industries in others, e.g. the car industry from cities such as Flint, USA, and Geelong, Australia. But, concerns regarding climate change, labour, environmental degradation, etc., have shifted consumer demand and preferences towards more sustainable, ethical and environmentally-sensitive products and processes[120,121]. COVID-19 accelerated this as links between human activity, disease emergence and the environment became more apparent and as global supply chains were disrupted[121,122].

There is now rising concern across value chains - where materials are sourced and the processes used – and a greater focus on decarbonising industry and compliance around labour and the environment[120]. This means a shift to more local and regional supply chains, with industry hubs playing a role in this transition. Co-located firms can share certain processes (e.g. waste disposal, or symbiotic waste to resource relationships) to raise overall efficiency and minimise cost, allowing a region or nation to market itself to global battery manufacturers or users, like Panasonic, BMW or VW. Such companies will increasingly move towards green manufacturing, as 'ugly' processes in the supply chain challenge firm claims of corporate social responsibility and threaten future licenses to operate.

Compared to isolated firms, hubs can facilitate the establishment of sustainable industries by cutting out process steps, rework and non-value added transport. For example:

1. The manufacture of lithium carbonate creates low-value sodium sulphate as a by-product. Integrated processes may improve reagent recovery, re-use and recycle, allowing conversion to fertilisers. The presence of fertiliser producers and distributors in a hub, such as Kwinana, would allow integration into an existing fertiliser storage, logistics and marketing network.
2. Co-location of recycling plants with primary mineral and chemical refineries creates efficiencies, particularly when firms have same battery chemical end products.

In the near future, products entering the EU will require labelling of their embodied carbon footprint. Australia's abundance of natural resources and green energy sources, strict regulatory environment and skilled labour makes it a key player in achieving carbon-neutral global battery manufacturing value chains if its industries decarbonise. Australia needs to set equal or higher targets than what is being set elsewhere, and transition to renewable or green (such as hydrogen) energies. Indeed, Mineral Commodities reported that buying



energy for 2 to 3 cents a kilowatt-hour in Norway was a critical factor in locating there. Figure 17 illustrates some of the elements needed for Australia to achieve cheaper and greener industry energy futures.

Figure 17: Possible industry energy futures
Adapted from: Panerali and Jamison, 2020[120]

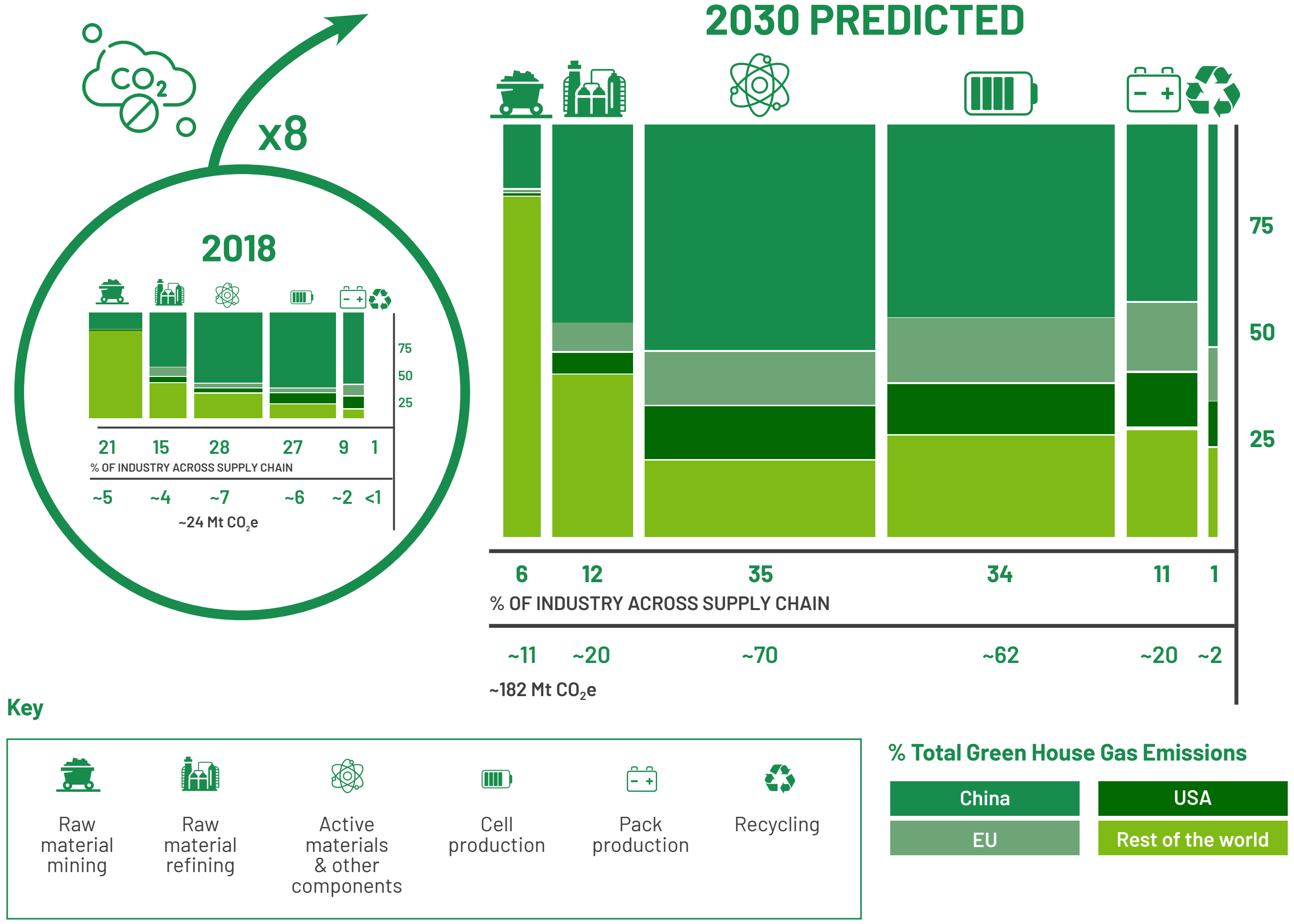
Further, transporting unprocessed material for purification off-shore (e.g. spodumene from Australia to China which is over 90% waste), then to final battery manufacturing nations (e.g. China to Europe), is a highly carbon-intense process. Also, there is a future value loss if extraction technology improve enabling previously landfilled waste to yield further minerals.

If the carbon footprint of building an electric car is higher than building an internal combustion engine motor car – that is a problem. (Australian mining/refining company interviewee)

Processing Australian raw materials into pure battery-grade minerals in foreign jurisdictions with low regulatory requirements means materials become unethical, unsustainable and have a high carbon footprint irrespective of efforts to improve Australian processes. Figure 18 gives the battery value chain carbon footprint for raw material mining, refining, active material production, cell production and pack production. Australian mining and refining are already decarbonising – particularly in the critical minerals space. For example, Western Australian nickel producers, e.g. BHP, mainly use nickel sulphide processes (except for Murrin Murrin and Ravensthorpe)[123] which produces one third or less of the carbon dioxide of laterite processes. And, Covalent Lithium is examining 'greening' lithium using

Kwinana eco-industrial synergies (see appendix 3), refining innovations and renewable energy. Australian companies have the capacity to pledge commitments to net zero carbon by 2050, and global trust in Australia to deliver provides competitive advantages against less-trusted nations.

Figure 18: Greenhouse gas footprint across the battery value chain, 2018 (actual) and 2030 (predicted), in metric tons of carbon dioxide equivalent (MTCO2e)
Adapted from: World Economic Forum (2019)[166]



There is already significant investments in renewable energies in Europe and Japan to decrease production costs and facilitate low carbon mining (e.g. Norway), and battery materials manufacturing. And, Australian companies also are investing, e.g. BHP bought a stake in Merredin Solar Farm. However, Australian renewable energy infrastructures (e.g. wind turbines) are largely sourced from overseas. There is a missed capacity building opportunity to create a knowledge base connecting Australian designers and manufacturers, given overseas firms often maintain infrastructure with their own workers, conduct their own R&D and retain IP and manufacturing knowledge.

Decarbonising production – hub development action list

- Facilitate infrastructure investments to decarbonise production.
- Employ hub case managers to identify firm waste and reduction strategies, local resource use and waste-to-resource opportunities.
- Explore how international industry standards and zero-carbon credentials can be used to market hub firms, as well as provide access to market funds.

4.7. National branding, standards and accreditation

Australian goods and services are generally regarded globally as high-quality and produced under environmental, governance and labour protection. This has created a global brand, with the 'Australia stamp' marketable at a premium price. This national brand is largely related to how Australia is perceived internationally, the components of which are shown in figure 19.

'Australia' is a brand. It can be monetised when there are global industry standards it can market itself against. (Australian mining/refining company interviewee)

In the raw materials, energy and related sectors, Australia is perceived as a geopolitically stable market to buy from. But, these resources are currently untraceable, being sold directly from the mine site to markets where Australian raw materials can be blended. This may not matter in mineral markets where product origin is known (i.e. iron ore is largely from Western Australia). But, battery materials, such as lithium carbonate and lithium hydroxide, are generic products that can be sourced from many other nations. This is problematic for industries needing high-quality high-purity product where traceability matters to prove zero-carbon, ethical, socially responsible and green credentials.

'We can certainly be building on the story, and differentiate Australia and sell Australia. Now, when lithium goes to China, it's Chinese lithium. It's not Australian'. (Australian mining/refining company interviewee)

Australia is in a unique position to market and monetise its brand to those moving to green and ethical production. Policies which place downward pressure on emissions and encourage development of low emissions technology and industrial capacity will be important in this regard. The Australian batteries materials and manufacturing industry can potentially lead Australian industries as a 'pin-up' industry (as stated in recent Australian Prime Minister press release[125]) in the move towards zero- to low carbon operations.

The future of a batteries industry depends on establishing international industry standards, and that these are adopted as a framework for assigning firm accreditation. Such standards should align with ESG principles of appendix 2. Figure 20 demonstrates how international standards are used to calibrate and document production measures and standards for greater traceability[126]. As such, using international standards in conjunction with technologies, such as blockchain, will enable Australian raw materials and products to better leverage the 'Australia' brand.

Accreditation and traceability - hub development action list

- Investigate how technology can improve traceability and accountability in the batteries materials and products industry.
- Examine the global attractiveness of potential batteries industry hubs as instruments to improve national branding around green and ethical production, identify operational gaps to be addressed to develop global recognition.
- Provide information and evidence to guide the development of Australian standards and provide a factual basis for alignment to international certification requirements.
- Encourage firm literacy in international accreditation standards, incorporated into data collection and information management systems.
- Assist firms in understanding what data is relevant to collect in a way that serves multiple means.

Figure 19: Components of a nation's brand

Adapted from: Andreja (2018)[124]

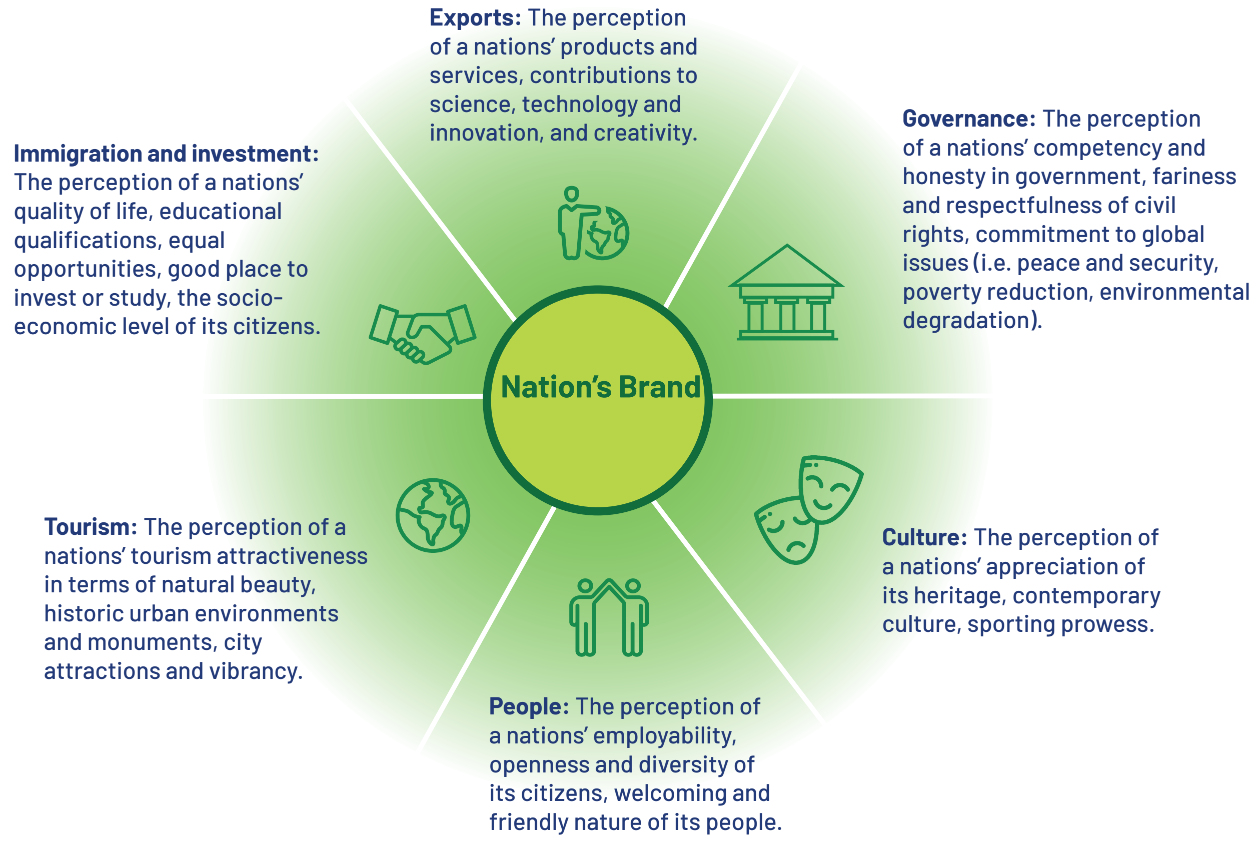


Figure 20: Calibration to international standards to increase traceability and assign product value

4.8. Cross-organisational capacity building and solving common problems

A key role of a hub is to facilitate regional and firm capacity building by solving common problems and identifying niche global markets. As such, a coordinating body is needed to translate different thinking, objectives and required outputs (across government, academia, industry) to the benefit of all hub members. The staff of the body should be highly specialised regional development strategists and risk-takers, rather than have the real estate function of previous industrial precinct managers. Further, as in the Osaka case, the coordinating role can be assumed by specific government departments, particularly if there is no centrally located battery manufacturing industry (e.g. testing centres, R&D facilities, government, firms, etc.) within a city or region. Who pays for 'hub' coordinator services depends on the model used - which may vary between hubs depending on local conditions and hub dynamics. In Japan, it was the local government, and in Germany it was a private firm.

The extremely large number of SMEs operating across the Australian mining and manufacturing sectors (junior miners and METS) engage independently in a range of manufacturing projects and activities, with limited R&D resources. A coordinating body can pull ideas together for cross-institutional R&D projects, allowing cross-learning, co-development and industry capacity building.

> *'Competitors can be collaborators' approach to park management.*
> *(Interviewee from international hub)*

Figure 21 demonstrates the cross-boundary nature of a hub coordinating body, whose mission is to grow hub member collaborations, production efficiencies, business opportunities, global recognition and credentials. As informed by the Osaka case, there are special provisions for SME support and/or engagement. Industry capacity of the hub and in the region will be enhanced through R&D, as new products and services emerge through firm joint ventures or collaborations. Technology transfer organisations (TTO) working between research institutions and hub members may assist in developing, for example, a hub's waste-to-recovery capacity.

Also, from figure 21, the hubs' role can be to increase local knowledge content by facilitating connections with firms in other hubs or overseas. This may be through formal or informal networking events - such in the German case. There are opportunities to link with Australian companies who have learnings from overseas and want to grow Australian industry capacity. Increasing local knowledge availability may lead to novel product or process innovations as knowledge is combined and absorbed differently by firms.

Capacity building - hub development action list

- Set out a framework of operation and terms of reference for a hub coordinating body to allow a range of formal and informal cross-institutional interactions, with particular attention to SME involvement.
- Identify intermediary bodies to work with the hub for special purposes, such as Technology Transfer Organisations.
- Quantify and map sources and sinks (suppliers and users) and material (raw materials, water, products, by-products, waste materials and intermediates) and energy flows (heat and electricity).
- Examine the niche markets of various potential battery manufacturing hubs across Australia, and how they coordinate and connect nationally.
- Set up industry-academia-government networking and information exchange groups around specific issues related to battery manufacturing development.

Regional coordinating and regulatory bodies

- Faciliate regulatory processes to enable streamlining between government and quasi-government departments on behalf of hub member organisations (i.e. in permitting and establishing operations in the park).
- Work with other organisations (such as universities and government) to create intermediatory bodies for specific purposes (i.e. technology transfer organisations to assist the transfer of R&D to commercial use by hub participants).
- Coordinate relevant education and skills development with training providers and universities to ensure needs of hub members are met by the local workforce.
- Identify and facilitate capital and funding access (ie through government programs and incentives, equity markets (i.e. outside of traditional resources) or venture capital opportunities) for members.
- Organise certification of the hub based on low carbon emissions and waste of hub members (i.e. create a marketable and recognisable brand overseas).

Partnerships between individual organisations

- Coordinate hub member partnerships for hub benefit and greater efficiency (e.g. waste to resource use).
- Work in collaboration with member firms for solutions to common issues (i.e. coordinating role with government and academia to research and advocate for international industry standards and certification system).
- Assist members to identify appropriate incubator or business support programs (i.e. as new member joint ventures create new business opportunities).
- Coordinate member collaborations to develop ownstream capabilities.

Informal Networks

- Build relationships between firms in the hub.
- Facilitate information exchange between hub members and outside organisations.
- Identify common interests and issues.
- Build international networks to facilitate knowledge exchange and business opportunities.

Figure 21: Role of hub coordinating body across informal and formal boundaries

4.9. Special considerations for waste-to-resources

Interviewees expressed the importance of carbon zero, green and ethical credentials driving eco-industrial and circular flow considerations through a closed-loop waste-to-resource system across all aspects of 'waste', e.g. carbon emissions, energy use, sewerage, etc. Figure 22 demonstrates the hierarchy of waste applicable at all levels of industry, including within a hub. Transporting low-valued 'waste' long distances to be used as a by-product elsewhere is often not viable, the co-location of firms supporting a hub's circular economy can minimise such transport. Kwinana is an example of such eco-industrial synergies (see appendix 3).

It's an ongoing business optimisation imperative. The journey at the Kwinana refinery has been fascinating because we don't have any solid waste leaving. Even our tailings residue is sold ... and our water is all evaporated. There is obviously an enhanced economic benefit selling those products. (Australian mining/refining company interviewee)

There are two steps in establishing eco-industrial synergies. Firstly, waste stream opportunity identification to better realise intrinsic values, particularly as companies move into new areas of the batteries industry value chain. This includes reducing logistics and transport as carbon emissions increase the further waste or products travel.

Secondly, the R&D to recover, reuse, recycle identified streams – where the most efficient is if firm waste is used or recycled within the hub, or if there are shared waste facilities. R&D institutes and universities can facilitate the identification of new production streams and TTOs can assist in commercialisation, industry-level scale-up and firm adoption.

A closed-loop minimal-waste system must be coordinated by a dedicated individual or team, such as an eco-industrial hub association with representatives from hub firms and other stakeholders. Activities include mapping hub energy and materials flows to create a dashboard or database of efficiencies.

Battery hubs are not just as a group of industries coming together to create batteries, but are an ecosystem of supporting firms. (Government employee specialising in the circular economy)

Government policy and incentives can also encourage emission reductions and waste targets. For example, lower environmental fees for firms with minimal waste through licensing or approval mechanisms. Such firms will benefit the entire region, if high regional sustainability or ESG ratings are marketable (see appendix 2). A hub can facilitate firm over-the-fence acquisition to reduce production costs and carbon emissions, and assist in capturing new markets as waste can be converted into by-products for other industries. For example, the new Covalent refinery in Kwinana will examine repurposing tailings into road base (instead of limestone) and/or fly ash for the cement industry. This will reduce the demand for other more expensive materials in the construction sector and the amount of waste that Covalent produces.

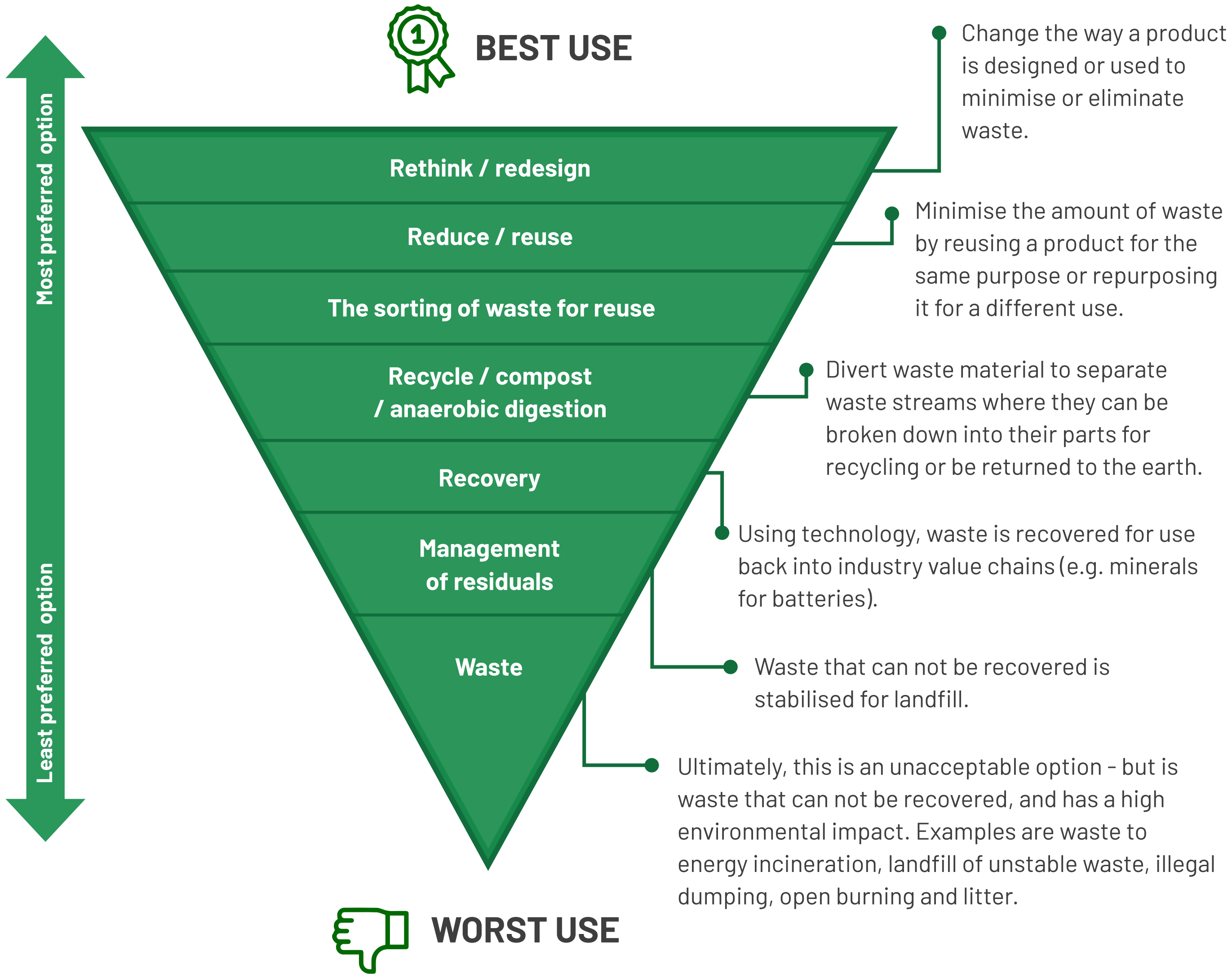


Figure 22: Waste hierarchy

Adapted from: Zero Waste Europe127

Circular economy - hub development action list

- Define the role of hub coordinating body to deliver circular flows in a specific location.
- Identify technology transfer organisations to work with R&D institutes and hub residents to commercialise and up-scale research outputs to industry applications.
- Detect waste (or underutilised by-products) sources and identify what can be done, with minimal processing, to convert into by-products with larger market uptake.
- Work with waste, water and environmental authorities and regulatory bodies to facilitate policies around waste to by-product conversions.
- Investigate how the 'BASF verbund simulator' (modelling business stream scenarios) may assist hubs in Australia in optimising functionality.

5. Value proposition of geography in batteries manufacturing

This report highlights the importance of geography in the batteries manufacturing industry. Since the 1970s, industry hub development has had limited success due to flawed assumptions that collaboration occurs with firm co-location. Indeed, **there is no 'one-size-fits-all' model for hub development which fits every different industry or location**. This report aimed to specifically understand the development of a batteries manufacturing industry in Australia by examining:

> *What is the value proposition of geography in different batteries manufacturing hubs globally, and what lessons are applicable for Australia?*

COVID has pushed us further into digital work. We have become used to (and like) video conferencing rather than going into the office, and employers have realised workers can be happier and more productive at home[128,129]. Therefore, **the value proposition of a specific geographic location for firm co-location needs to be stronger than ever**. Indeed, locations globally are competing for key industries, such as critical minerals and batteries manufacturing, with locations in Europe, USA and Japan offering substantially more funds, better infrastructure, more streamlined processes, closer to large consumer/end user markets, more tax breaks and incentives than Australia.

Australia needs to get smarter with how it organises and supports the industry. As an interviewee stated:

> *Similar to your question about Kwinana and Kalgoorlie - how about Kwinana and Europe? Certainly Europe gives you the incentives to build there. Why not there? (Australia mining/refining company interviewee)*

The competition for key industry players is global, and for Australia to be in the race – it needs to grasp the advantages entering an emerging industry in a state of rapid technological change. Mechanisms must be put in place to accelerate hub development and streamline the efficiencies of industrial and governance processes. This means understanding the competitive advantages of different hub locations around Australia, and how the lessons and priority actions for hub development should be critically interpreted and applied. The key lessons from international case study sites were:

- Leveraging well-established assets for emerging industry.
- The need for industry and government champions for change.
- Understanding efficiencies of agglomeration, density, scale, scope and logistics in specific hub locations.
- Examining models of hub governance and support.
- Importance of process innovations for a lean industry and product innovations for new ventures.
- Move towards green, carbon-neutral and sustainable industry value chains.
- Better leveraging of national brand, including adoption of standards and accreditation.
- Importance of cross-organisational capacity building and solving common problems.
- Attention to special hub considerations in the shift of waste to resources.

This report did not examine potential hubs in Australia specifically, but the advantages of different locations did emerge - with similarities to the international case studies noted. For example, interviewee comments on Kalgoorlie-Boulder and Gladstone aligned with those of Nevada, USA – local governments provided location incentives. Kwinana Industrial Area (KIA) appeared similar to the LDB triangle, with issues of urban encroachment and firm symbiotic relations. And, Queensland drew similarity with Kansai, with a more proactive government in terms of policy, funding and community demonstration projects to grow battery industries.

The overarching driver for firm site choice appeared to be profit maximisation and ease of operation. Several interviewees noted choosing their current location after in-depth financial and other (such as political environment, transportation costs, access to production inputs) comparisons between sites (sometimes around the world). A hub must generate a clear globally competitive strategic advantage – that is, **a value proposition associated with its geography and related to its hub proposition** (see figure 12) taking into account 'assets'. In Australia, these assets will not be access to cheap labour or the savings gained from operating in a jurisdiction with lenient work and/or environmental regulations. But, instead, be related to the following.

First, **access to utilities infrastructure**. This is the transport and logistics networks through quality road, rail and port infrastructure connecting the hub to other locations. And, infrastructure supplying cheap clean energy, water and/or shared specialised waste facilities. Such utilities infrastructure may mean exploring synergies with other emerging industries, such as hydrogen. This would allow cross-linkages with the Future Fuels Cooperative Research Centre[130] or other industry hubs such as the Henderson Marine Research Complex which links with the Department of Defence.

Second, **access to mineral resources**, for example, in remote Western Australia or Queensland. Indeed, whilst some interviewees reported KIA was suitable for production, others cited Kalgoorlie as it allowed them to be closer to resources and waste disposal sites. Indeed, the limited land and the urban location of KIA meant more stringent criteria around firm waste and reuse.

Third, **access a skilled and educated workforce** which is greater in 'lifestyle' locations with more amenities and infrastructure. This includes access to good schools or other education (for vocational or tertiary training), which are also in remote locations. One interviewee noted that the contractual agreement to locate in Kalgoorlie-Boulder included a commitment to train and use local workers, and that a strong METS industry already supported mining and related industries there.

Fourth, **access to consumers and/or suppliers** using raw materials, battery chemicals, components and by-products. Firm co-location decreases transport and logistics costs, shortens value chains and encourages companies to move along the supply chain. There are four aspects to this:

1. Most advanced battery manufacturing and final end users are in Asia (China, Korea, and Japan), USA and Europe. Firms supplying products to these markets need connecting (air)port infrastructure.
2. Firm consumers of intermediate batteries manufacturing value chain products. For example, in KIA, the mining firm, Tianqi Lithium, is planning to produce lithium hydroxide which could attract downstream battery manufacturing firms. And, Wesfarmers supply ammonia to BHP for refining.
3. Firms whose by-products are used by firms in the battery manufacturing industry may move into the industry themselves (e.g. Wesfarmers is moving into battery production through interests in Covalent Lithium).
4. Firms from a completely different industry may be attracted to a hub because of the by-products of batteries manufacturing firms (e.g. BHP who supply ammonium sulphate to Wesfarmers). This facilitates hub circular economy flows and industrial symbiosis.

Fifth, **policy, governance and government strategies for investment attraction and hub creation**, including via capital, land (e.g. peppercorn arrangements), fast-track permitting, tax breaks or special economic zones. This will shape industrial futures, and may spark hub development (e.g. the Nevada Gigafactory case). This may relate to distance from residential areas and community acceptance of an industry (i.e. interviewees comments showed residents of Kwinana and the LDB triangle were more open to chemical industries due to histories - both also had policies and regulations making permitting easier). Indeed, 'undesirable' industry can be politicised and licenses to operate revoked (i.e. the case of Lynas in Malaysia[131,132], and Adani coal mines in Australia[133]).

Overall, interviewees struggled to find firm disadvantages to locating in a battery industries hub[133]. The only point raised was around the lack of land supply in certain areas, creating difficulties especially for SMEs who were less able to cut favourable deals than multinationals (e.g. in costs of water and energy supply). For example, KIA land shortage meant the State government did not need to provide firm location incentives and governments in charge of infrastructure (roads, water, energy) could make unreasonable financing demands. One company noted pushing back on demands to improve roads they would not use. Special provisions to support SMEs will accelerate industry growth as it will encourage local competition and regional capacity building - as shown in the Osaka case.

While an Australian battery production hub needs to be positioned and well-connected globally, domestic cross-industry synergies are key in supporting hub emergence and development. For example, an active and efficient batteries manufacturing hub is compatible with Australian Department of Defence efforts to develop in-country manufacturing capacity[111]. Similarly, batteries are needed to store energy for the emerging hydrogen fuel industries[134,135], and can assist in the de-carbonizing[136,137] of the mining industry. Indeed, such cross-industry connections may well be the beginning of a virtuous circle that could support building a transition to more sustainable industries in Australia – and the development of battery manufacturing hubs is strategic in progressing this.

5.1. Recommendations

The hub proposition in this report builds on insights from the overseas case study sites, informing key lessons for Australia. This produced the following **nine recommendations** and associated short to medium term priorities for action.

1. **Leverage current Australian assets to grow advanced battery industry, and support hub development**

   - Identify key skills and training relevant to the batteries industry, investigate gaps in Australia's workforce, and create internships and jobs to enhance cross-industry development and skill sharing.
   - Investigate venture capital raising potential for batteries industries on the Australian Stock Exchange and other funding raising apparatus, such as private equity funds.
   - Establish mechanisms to facilitate cross-industry discussions or collaborations, like mining, defence, shipbuilding and the hydrogen industry.
   - Examine how application of technologies (i.e. blockchain) and accreditation to global standards can be used to monetise the Australian brand as a superior resource. In particular, investigate how Australian battery materials can align to the certification requirments of the WEF "Battery Passport".
   - Map sources and sinks (supply and demand) of materials, energy, water, skills in regions where co-location makes sense.
   - Perform an overall hub SWOT analysis and scenario analysis to map various economic and political futures and evaluate their impacts at the mega-trend level.
   - Investigate ways to strengthen demand from local battery module and pack, and battery management systems, through policies around local content in the deployment of stationary battery systems in communities, defence, mining and grid applications.
   - Transition to renewable energy provision for existing industry hubs.

2. **Identify and work with champions for change**

   - Identify possible batteries manufacturing industry issues across government-industry-academia, establish networking groups to exchange information around these and lead national discussions.
   - Examine the regulations, permitting processes and costs for establishing different types of hubs which may be relevant in different locations. Work with government to streamline and simplify processes.
   - Identify mechanisms to promote community demonstration or pilot projects to assist in business development and community education of the industry.
   - Foster and develop mechanisms for SMEs to access opportunities to work with large enterprises and advocate for larger overall Commonwealth support towards manufacturing in hub environments.
   - Advocate for policies to curb emissions consistent with achieving net zero by 2050 and leverage trade agreements.
   - Advocate for the creation of special economic zones or other incentives to attract industries in the batteries industry value chain.
   - Investigate and advocate for appropriate models of open innovation.
   - Investigate avenues for investor education in advanced manufacturing to increase firm access to capital, and in how to educate advanced manufacturing firm in what matters for investors and investment.
   - Use local content policies to develop Australian battery industries skills and capabilities.

3. **Seek to aggregate production efficiencies through site strategic selection and design**
   - Identify locations where natural industry clusters related to battery manufacturing are already forming as well as related value chain components that should be located there (i.e. based on circular economy flows).
   - Conduct audit of these sites to understand performance across various measures (i.e. related to economies of scale and circular economy flows) critical for battery hub development.
   - Examine how an industrial eco-system can be created to increase hub efficiencies by identifying, qualifying, quantifying and mapping material/energy sources and sinks, material (raw materials, water, products, by-products, wastes, emissions, effluents, consumables) and energy (heat, electricity) flows.
   - Investigate hub coordinator model most appropriate for a specific site, given that the three case studies demonstrated different coordination mechanisms (i.e. organised by government, private business development firm, anchor tenant, etc.).

4. **Work with relevant stakeholders to optimise and streamline hub governance and regulations**
   - Investigate how Australia's current policy and regulatory framework facilitate domestic and foreign firms locating battery operations in Australia.
   - Through policy and incentives, encourage collaboration with international partners with access to overseas funds that can be leveraged to grow the global batteries industry.
   - Create an entity within specific hubs to assist with: collaborations across industry, academia and government; access to funds; identifying new waste-to-resource opportunities; and, permitting and permission processes.
   - Investigate the investment attraction potential of hubs with decarbonised power sources, and the value of government guarantees of clean energy provision to the hub.
   - Investigate methods to streamline current processes (government or other) involved in establishing business operations.
   - Lobby for a legislative framework to force industry compliance to high environmental standards through tariffs to move Australian industry towards zero carbon footprint.

5. **Increase industry innovation capacity and global competitiveness**
   - Investigate what is needed to upgrade the Australian batteries industry to Industry 4.0, including appropriate models of (semi-)open innovation.
   - Understand the benefits and challenges of Industry 4.0 to ensure ethical and responsible systems are implemented.
   - Conduct a needs analysis to identify gaps or areas of further R&D benefiting hub members by increasing business efficiencies, industry competitiveness and create new business opportunities, such as delivering cheap renewable energy to remote locations.
   - Create industry-academia-government networking and information exchange groups around issues facing battery manufacturing in Australia.
   - Work with government to provide opportunities for community demonstration or pilot projects to pressure test ideas and attract funding for large scale commercialisation.

6. **Advocate for and progress agendas to decarbonise production**
   - Facilitate infrastructure investments to decarbonise production.
   - Employ hub case managers to identify firm waste and reduction strategies, local resource use and waste-to-resource opportunities.
   - Explore how international industry standards and zero-carbon credentials can be used to market hub firms, as well as provide access to market funds.

7. **Facilitate industry accreditation and the introduction of resource traceability technologies**
   - Invest in R&D to generate international standards for batteries raw materials and products, advocate globally for the introduction of these standards.
   - Investigate how technology can improve traceability and accountability in the batteries materials and products industry.
   - Examine the global attractiveness of potential batteries industry hubs as instruments to improve national branding around green and ethical production, identify operational gaps to be addressed to develop global recognition.
   - Provide information and evidence to guide the development of Australian standards and provide a factual basis for alignment to international certification requirements.
   - Encourage firm literacy in international accreditation standards, incorporate into data collection and information management systems.
   - Assist firms in understanding what data is relevant to collect in a way that serves multiple means.

8. **Capacity build across industry**
   - Set out a framework of operation and terms of reference for a hub coordinating body to allow a range of formal and informal cross-institutional interactions, with particular attention to SME involvement.
   - Identify intermediary bodies to work with the hub for special purposes, such as Technology Transfer Organisations.
   - Examine the niche markets of various potential battery manufacturing hubs across Australia, and how they coordinate and connect nationally.
   - Set up industry-academia-government networking and information exchange groups around specific issues related to batteries manufacturing development.
   - Quantify and map sources and sinks (suppliers and users) and material (raw materials, water, products, by-products, waste materials and intermediates) and energy flows (heat and electricity).

9. **Implement circular economy and industrial symbiosis principles and practices**
   - Define the role of the coordinating body responsible for delivering hub circular economy flows in specific locational contexts.
   - Identify technology transfer organisations to work with R&D institutes and hub residents to commercialise and up-scale research outputs to industry useful technologies.
   - Detect current waste (or underutilised by-products) sources and identify what can be done, with minimal processing, to convert this into by-products with larger market uptake.
   - Work with Waste Authorities and Department of Water and Environmental Regulation (or their equivalent) to facilitate policies around waste to by-product conversions.
   - Investigate and consider how the 'BASF verbund simulator' (modelling scenarios to optimise business streams) may assist hubs in Australia towards optimal functionality.

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- Lynas Corporation
- Mineral Commodities
- Multicom Resources - Nathan Cammerman, Executive Director
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Appendix 1: Hub support accelerator policies and mechanisms

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
Strategies and action plans		
Strategic Action Plan on Batteries (2018) European Union	Outlines key actions for development of circular economy batteries industry.	Five strategic areas: 1. Secure sustainable supply of raw materials. 2. Support European projects across battery value chain, including cell manufacture. 3. Strengthen EU research and innovation support across full value chain. 4. Develop and strengthen highly skilled workforce across value chain. 5. Setting out requirements for safe and sustainable production.
EU New Green Deal (2019) European Union	Sets agenda for sustainable growth; outlines investment and finance mechanisms for cleaner, circular economy, restore biodiversity and reduce pollution.	Targets decarbonisation of energy sector, cleaner transport, and improvement to environmental standards as policy and investment priorities areas.
Circular Economy Action Plan (2020) European Union	Outlines key priorities for generating circular product value chains in critical industries.	Priorities to circular batteries industry production: 1. Define rules on recycled content. 2. Outline strategies to phase out non-rechargeable batteries. 3. Establish sustainability and transparency requirements for battery production.
Green Growth Strategy 2050 (2021) Japan	Industrial policy defining priority actions and funding for carbon-neutrality by 2050. Five key policy mechanisms: 1. 2 trillion yen in grant funding over 10 years. 2. 1.7 trillion yen in tax incentives over 10 years to stimulate investment. 3. Formulate guidelines to transition finance to attract global ESG investment. 4. Regulatory reform for key industries, e.g. hydrogen and mobility/batteries. 5. International collaboration on innovation and joint projects towards decarbonization.	Includes mobility and batteries as one of the 14 key growth sectors.

FUTURE BATTERY INDUSTRIES CRC

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
Regulation		
The Battery Directive (2006) European Union	Regulates use of certain materials (e.g mercury) in battery manufacturing; sets standards for battery waste management.	• Prohibits marketingbatteries with hazardous materials in the European market. • Sets standards for labelling and removability of batteries . • Requires member states to separate and recycle batteries. • Fixes battery collection and recycling targets. • Improves environmental performance of all operators involved in the lifecycle of batteries
Proposal of a regulation on batteries and waste batteries (2020) European Union	Updates the Batteries Directive (above) and defines parameters to minimise environmental impact of batteries.	• Establishes mandatory requirements for all batteries in Europe, including specific levels of recyclable material. • Defines requirements for battery producers on end of life collection, treatment and recycling. • Sets digital passport to track battery life.
Motor Vehicle Tax Act (2016) Germany	Incentivates acquisition of electric vehicles with tax regime based on size of the engine capacity and CO_2 emissions.	Boosts consumption of electric vehicles and batteries.
Funding		
EU Innovation Fund European Union	• €10 billion funding programme to demonstrate innovative low-carbon technologies. • Supports up to 60% of large-scale project capital and operational costs and small-scale project capital costs (<€7.5 million). • Managed by Executive Agency for Innovation and Networks for European Commission.	Development of energy storage technologies.
Horizon Europe European Union	€95.5 billion funding program (2021-2027) for research and innovation towards UN Sustainable Development Goals.	Funds Battery 2030+ research program.

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
Important Project of Common European Interest (IPCEIs) European Union	• Public funding from State aid for cutting-edge large-scale projects contributing to growth, jobs and competitiveness of EU industry and economy. • Co-funds innovation and research projects[138] up to 100% of funding gap. Projects may include collaborations between multiple partners, organisations from different States, sectors and different sizes. • Covers costs of first product deployment - from pilot line to mass production.	€3.2 billion from seven Member States to co-fund research and innovation projects anywhere in battery value chain (2019-2031)[139].
Joint Taskforce for Improving Regional Economic Structures (GRW) Germany	• Coordination framework for regional economic support in economically lagging regions, financed by Federal and State-level authorities to reduce regional disparities[140]. • Issued by the Federal Ministry for Economic Affairs and Energy. • Funds allocated based on incentive maps[141]. • State authorities oversee implementation of funding in the respective region. • Funding directed towards cash grants and loans for firms investing in the region, infrastructure investment linked to industry and non-investment business activities, cooperation networks and cluster management.	Creates economic incentives to future technology firms to settle in Saxony-Anhalt and Brandenburg regions supporting transition from coal mining[142]
Battery Recycling Prize Contests United States	• Competition supported by U.S. Department of Energy and the National Renewable Energy Laboratory. • Participants go through a 3-phase program to develop, prototype and validate a battery recycling pilot for a cash prize.	Completed two phases - awarding USD$3.5 million in prizes and pre-selecting 7 potential battery recycling projects to continue the pilot phase.
Technology Investment Agreements United States	Funds from Department of Defense to establish domestic processing of light rare earth elements (LREEs).	An American subsidiary of Lynas Co. awarded $30.5 million for LREE separation capacity in Texas

FUTURE BATTERY INDUSTRIES CRC

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
Basic Energy Science (BES) Funding United States	Funds for research to secure domestic supply chain of critical elements and materials.	US$30 million in research grants and awards to understanding fundamental properties of rare earth and platinum group elements and basic chemistry, materials sciences, and geosciences of substitutes.
Japan Oil, Gas and Metals National Corporation (JOGMEG)' Carbon Neutral Initiative and Action Plan Japan	Financial and technical support to secure stable, affordable carbon-neutral energy and mineral resources for Japanese industries.	• Fund exploration and development of carbon neutral-relevant minerals, incl. lithium and rare earths. • Support financial and technical decarbonization of mines and smelters.
Collaborative Platforms		
European Raw Materials Alliance (ERMA) European Union	Platform to: • Develop consultation processes to identify raw material challenges in industrial ecosystems and target solutions. • Channels investment to priority raw material projects; identifying financial strategies and sources in/out of Europe; connects potential investors.	• Coordinates stakeholder consultation platform – Cluster on Materials for Energy Storage and Conversion. • Includes over 160 stakeholders from industry, academia, government, financial institutions. • Consultation to improve competitiveness of European raw and advanced material producers and recyclers for more sustainable and resilient batteries industry value chain, and other aims[143].
European Battery Alliance (EBA) European Union	Battery stakeholder cooperation platform where: • Public policy recommendations for European Commission. • Battery-related regulatory insights shared by EBA members. • Battery projects monitored, and battery market intelligence shared to EBA members. • Facilitates networking opportunities with academic and over 600 industry partners across battery value chain. • Access to InnoEnergy funding, InnoEnergy Venture capital community, and EBA financial partners (e.g. European Investment Bank).	• Development of an active batteries industry ecosystem. • Participates in the Battery Value Chain IPCEI. • Workshops define battery-related policy recommendations to European Commission, including: priority actions for battery value chain development and input to European Strategic Action Plan for Batteries. • Workshops address technical value chain aspects such as standardisation and alignment of business and financial needs.

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
EIT RawMaterials European Union	Collaborative platform enhancing metal and mineral raw materials sector innovation, via: • Knowledge sharing across European raw materials sector. • Networking activities. • Development and commercialisation of innovative technologies. • Support of business creation, incl. advice and mentoring to start-ups, and scale-ups. • Training via short courses, Master and PhD selected programs.	• Developed innovation ecosystem along raw materials value chain. • Coordinates European Raw Materials Alliance (ERMA).
Batteries Europe European Union	• Forum financed by European Commission for all relevant innovation and research organisations supporting European battery value chain development. • Coordinates efforts and mobilises resources to implement research in battery field. • Coordinate initiatives, e.g. European Battery Alliance, EIT RawMaterials, European Automotive Research Partners Association and others.	Coordinates 6 battery-related working groups and 4 task forces to identify new challenges and issues facing batteries industry. Working Groups: • New and emerging battery technologies • Raw materials and recycling • Advanced materials • Cell design and manufacturing • Application and integration: mobile • Application and integration: stationary Task forces: • Digitalisation • Education and skills • Safety • Sustainability
Battery Ecosystem Accelerator of Norway (BEACON) Norway	Network of industry, research, and public sector stakeholders, that: • Provide input for further battery strategies through thematic groups. • Contribute to policy documents for technological development. • Develops partnerships and cooperation among the partners. • Connects Norwegian partners to European battery organisations.	Develops thematic groups, and formulates battery strategy in three areas: 1. Advanced materials and cell design. 2. Module design, battery systems and system integration. 3. Charging and electricity infrastructure.

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
Battery Norway Norway	National industrial collaboration platform, that: • Provides a voice to industry in policy forums. • Contributes to sharing key information and opportunities among batteries industry members.	Contributes to: • Development of national battery strategy. • Building industrial infrastructure and competence. • Creating synergies with other Nordic battery ecosystems. • Connecting Norwegian companies to international initiatives. • Guiding firms in fast track permitting processes. • Promotion of Norway as a battery nation.
U.S. Advanced Battery Consortium United States	Group from United States Council for Automotive Research (USCAR) with interests in battery development, that: • Provide funds for battery research and innovation projects. • Conducts battery benchmarking activities. • Identifies challenges and barriers to industry. • Coordinates with Vehicle Technologies Office (VTO).	• Awarded R&D funds to firms and universities to develop battery technology, incl. USD$4.1 million to Farasis Energy for low-cost battery program[144] and USD$2 million to Worcester Polytechnic Institute for battery recycling technology development[145]. • Helped development of test procedure manuals.
Vehicle Technologies Office (VTO) United States	Office under U.S. Department of Energy, that: • Collaborates with national laboratories and industry partners to improve batteries and develop charging infrastructure. • Supports development of test procedures through Advanced Vehicle Testing Activity (AVTA) simulation software. • Coordinates with other Federal agencies, like U.S. Department of Transport.	Creates and funds programs to: • Research new battery chemistry and cell technologies (Developed the Batteries, Charging and Electric Vehicles program). • Bring together researchers, battery developers and automakers to design tools to lower costs and optimise batteries (Computer-Aided Engineering for Electric-Vehicle Batteries (CAEBAT)). • Financially support research, testing and benchmarking through USCAR, including models to calculate potential battery costs.

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
Calls for public comments on Strategic and Critical Materials value chains United States	The Department of Defense expressed interest and opened communication channel for comments and policy recommendations on domestic strategic and critical materials value chains.	Welcomes comments in 7 strategic areas: 1. Diversification of raw critical material supply and production along the value chain. 2. Availability of domestic skilled personnel and manufacturing capabilities. 3. Promotion of environmental, health and safety, labour and fair trade in global critical material markets. 4. Spectrum of risk to supply disruptions, development and maintenance of sustainable critical material chains. 5. Methods to reduce exposure to price volatility. 6. Research development priorities to support production. 7. Recommendations of key regulation for more resilient supply chains.
Advanced Battery Research Group Japan	Research group coordinated by Research Institute of Electrochemical Energy at Department of Energy and Environment researching performance improvements for rechargeable batteries.	Research on: • Analysis of fuel cell reactions. • Interface control. • Material development.
Entrepreneurial development and innovation support		
European Institute of Innovation & Technology (EIT) European Union	Drives innovations in Europe by supporting entrepreneurs, innovators and students to turn ideas into real projects, through: • Training for entrepreneurs, through short courses and EIT-labelled Master and PhD programs in select European universities. • Support for development of business and financial strategies for innovative products and services, start-ups and scale-ups	Supports EIT InnoEnergy and EIT RawMaterials innovation communities.

Mechanism	Mechanisms to deliver assistance	Support for batteries industry
EIT InnoEnergy European Union	Community of innovation accelerating energy transitions, through: • Access to new attractive technologies across sustainable energy value chain, ranging from pilots to commercialised technologies. • Support for start-ups, scale-ups and innovators in sustainable energy sector to de-risk business and speed up market entry. • Training through short courses and 8 Master programs at selected European Universities.	• Has supported development and commercialisation of more than 480 sustainable energy innovations, including industry partnerships between start-ups and large firms. • Has developed active sustainable energy ecosystem comprised of alumni, industry stakeholders, investors and government. • Coordinates European Battery Alliance, and industry alliances for green hydrogen and solar photovoltaics.
Battery 2030+ European Union	Large-scale research initiative funded by European Commission. • Coordinates 7 battery research projects and 23 research partners across Europe. • Coordinates and monitors Battery 2030+ research roadmap. • Identifies research gaps to achieve Battery 2030+ roadmap. • Contributes to curricula in battery technologies. • Communication and engagement for scientific dialogue. • Data standards and guidelines.	Creating toolbox to improve battery development and design, including: • Accelerated discovery of battery interfaces and materials. • Integration of smart functionalities in sensing and self-healing. • Improvement of recycling and manufacturing.
Innovation Norway Norway	Innovation Norway is government agency supporting companies to enhance their innovation and competitive advantage, through: • Advisory and mentoring services for start-ups and internationalising Norwegian firms. • Grants and loans for innovation, commercialisation, and international ventures. • Training in entrepreneurship and international market development. • Cluster and network development.	Innovation Norway provides grants for innovation and development of new environmental technology. This includes a recent grant of USD$4.6 million to firm FREYR to support development of new battery cell production facility[146].

Appendix 2: The big ESG shift

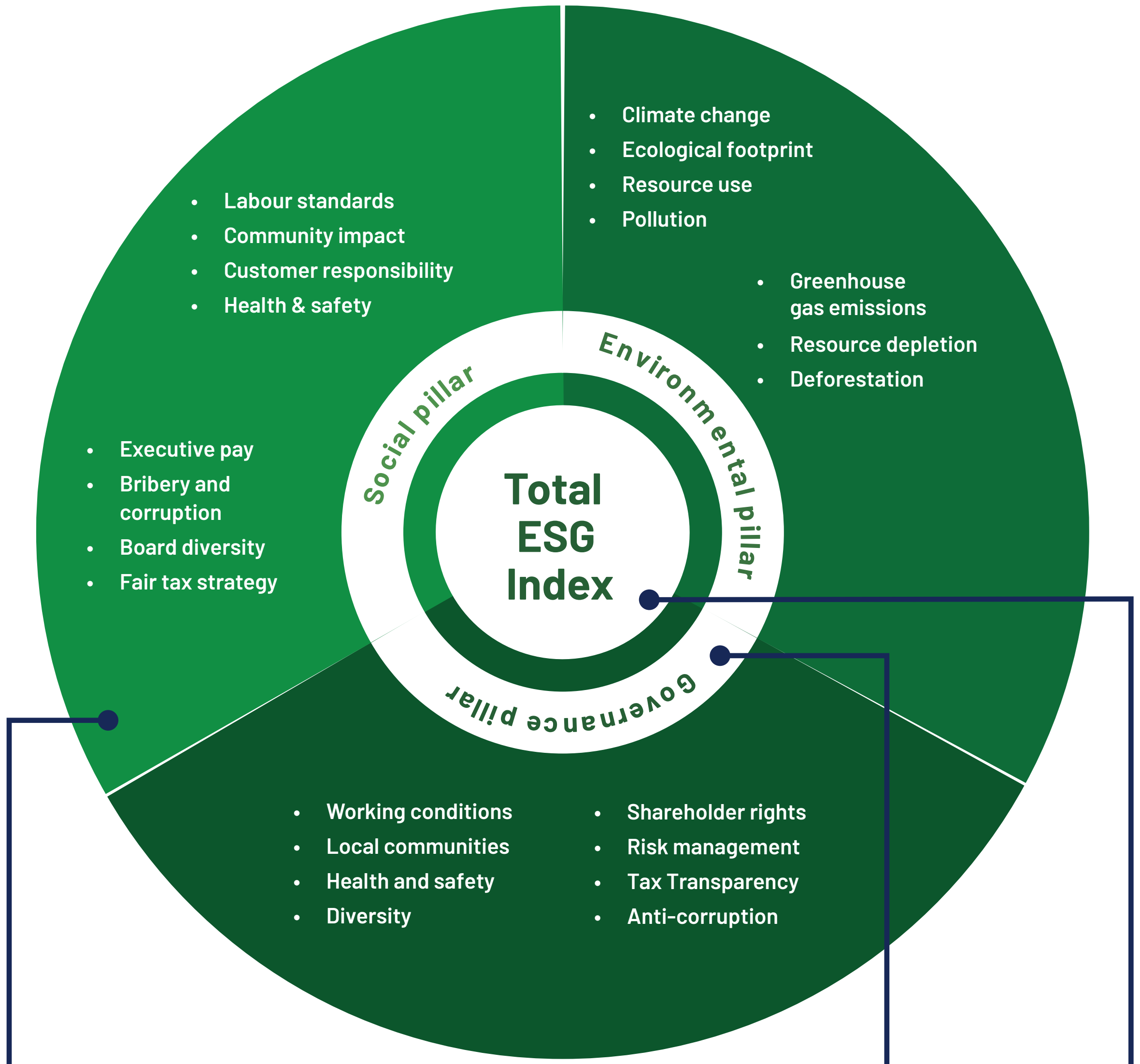
In the 2020s, corporate and investment strategies will not be just about profit, but about the broad implementation of sustainable practices in corporate and investment strategies based on environmental, social and governance (ESG) factors. The foundations of this were laid from 2010[147], when firms implemented new governance strategies to restore trust in capital markets after the Global Financial Crisis. Social and environmental concerns which continued to rise through a series of corporate disasters, such as the Gulf of Mexico oil spill[148], triggering changes in business practices.

Since 2015, these shifts have intensified. For example, greater private participation in negotiations of the Paris Agreement, a record number of asset managers and owners pledging to uphold United Nation (UN) principles for Responsible Investment[147], and UN Sustainable Development Goals incorporated into firm values and business strategies[149,150].

Disruptive events such as the bush fires in Australia, #Metoo / #Blacklivesmatter movements and COVID-19 pandemic have highlighted the need for more sustainable ESG corporate practices[151]. And, firms implementing such practices do not incur additional costs. Instead, often outperform peers in attracting customers and investors[152]. Figure 23 demonstrates how the more than 1000 indices across the three ESG pillars can be used to provide an ESG overall rating for organisations, projects, etc.

The following ESG corporate trends are expected[147,151,153]:

1. Commitments to net-zero carbon operations, reinforced by climate risk assessments in investments and reporting mechanisms.
2. Commitments to protecting biodiversity and natural habitats, with clear reporting mechanisms.
3. Rise in consumer awareness and questioning of corporate practices across ESG measures.
4. Investor interest in social issues and risk assessments based on ESG measures.
5. Proactive ESG asset management, implementing ESG standards and risk assessments.
6. New smart mechanisms for ESG data generation, demands for more data disclosure and standardisation of ESG reporting.
7. Mental wellbeing programs and discussions around more positive working environments.
8. Diversity, and racial and gender equality across all corporate spheres.
9. Transparency in incentives and executive awards based on measured performance.
10. Geopolitical tensions and populist rhetoric affecting business deals, especially in critical industries like energy, putting public pressure on implementation of ESG practices.



Individual scores across more than a 1,000 possible measures across the three pillars. A score for issues in each ESG pillar e.g. Climate Change, which is calculated using criteria e.g. emissions per year.

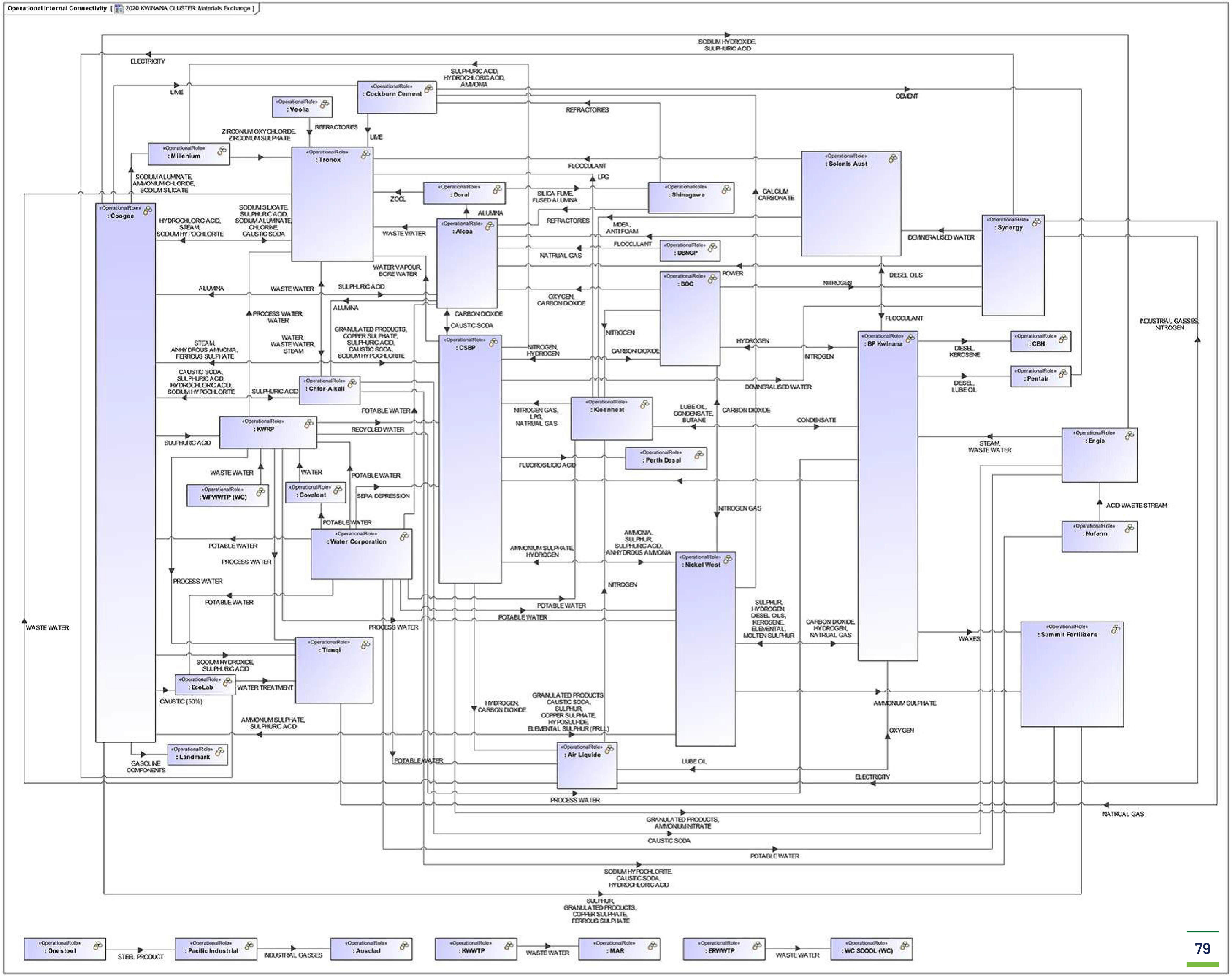
Total index for each pillar is calculated by summing up each of the index score. This provides comparison across the three pillars.

Overall ESG score is calculated by summing up each of the pillar scores. This gives a total ESG performance.

Figure 23: ESG rating method

Appendix 3: Kwinana Industry Synergies, 2021

Permission to use granted by: Kwinana Industries Council. Original available from: Kwinana Industries Council (2021) Synergies. Found at: https://kic.org.au/industry/synergies/#what



Glossary of terms frequently used in the industry

Advanced Manufacturing Growth Centre (AMGC): Industry Growth Centre that provides funding and supports collaborations between manufacturers, research organisations and export hubs to enhance the innovation, productivity and competitiveness of the Australian manufacturing industry.

Anode and Cathode: Constitute the positive and negative side of the battery, respectively. When charging a battery, positively charged ions move from the cathode to the anode. When the battery discharges, ions move back from the anode to the cathode. The cathode composition defines the capacity and power of the battery.

Anode Active Materials: Typically, graphite in micro-particle powder form, coated on a thin copper foil to shape rolled sheets. It allows lithium-ions to move back to the cathode while battery is charging.

ARC Centres of Excellence: Australian Government funding program supporting prestigious research groups developing cutting-edge, high-quality research in national priority areas.

Battery cell: Result from the assembly of cathode, anode, separator and electrolyte, within a battery can.

Battery pack or module: Set of interconnected battery cells, controlled by a management system that regulates temperature, voltage and charging.

Cathode Active Materials (CAM): Combination of lithium and metal compounds in micro-particle powder form. These are coated on a thin aluminium foil to make rolled sheets. It defines the features of the cathode.

Cathode Precursors: Constitute, together with lithium compounds, the base for the production of CAM. Precursors are comprised by synthesized metal sulphates, such as nickel, cobalt and manganese.

Circular Economy: Philosophical way of thinking that tries to minimise waste in an industrial system by purposefully designing it to be regenerative and restorative.

Cluster: a group of entities that may share a common relationship (e.g. a data cluster) and attracted to a location not through strategy or design but other factors. For example, geology may lead to clustering. Clusters can refer to entities distributed across a city and/or surrounding metropolitan areas (e.g. Johannesburg in South Africa is an economic cluster rather than hub or a precinct).

Co-location: Describes when two or more things (organisations, functions, etc) are in a single location.

Collaborative Research Centres Projects (CRCPs): Australian Government grant program funding short-term research collaborations between industry and research organisations.

Cooperative Research Centres (CRC): Australian Government program co-funding short to long-term research collaborations between industry and research organisations to solve industry-identified problems.

Electrolyte: Liquid solution that allows ions to move between the anode and the cathode, across the separator.

Industrial Ecosystem: Community of interconnected industrial organisations that work closely together to develop and manufacture products.

Industry Growth Centres: Created through the Australian Government's Industry Growth Centres Initiative. These are six government-funded non-for-profit organisations supporting industry growth and job creation by increasing collaboration and commercialisation, improving market access and workforce skills, and identifying opportunities for regulatory reform. Each centre works in a strategic priority area: Advanced Manufacturing, Cyber Security, Food and Agribusiness, Medical Technology and Pharmaceuticals, Mining Equipment, Technology and Services (METS), Oil, Gas and Energy Resources.

Industry hub: It is a dedicated economic zone – with minimum requirements, and designed so as, to ensure economic, social and environmental sustainability. It has good access to port, rail and airports, waste disposal, energy, water, trained and skilled communities, and a range of interdependent businesses. For example, firms involved in refining, chemicals manufacture, materials manufacture, component manufacture and the provision of integrated services around research, marketing and logistics.

Industrial Transformation Training Centres: Australian Government scheme supporting training and research collaborations between university-based and non-university researchers to help the transformation of priority industry areas.

METS: Sector that includes firms specialised in Mining Equipment, Technology and Services.

METS Ignited: Industry Growth Centre that funds and supports collaborations between suppliers to the mining industry, research organisations and capital providers to improve the productivity and global competitiveness of the Australian METS sector.

Minerals Research Institute of Western Australia (MRIWA): Statutory body established by the Western Australian Government stimulating high-impact applied minerals research through funding, industry engagement, dissemination of research findings and ministerial advice.

Modern Manufacturing Initiative (MMI): Australian Government grants program supporting projects that integrate Australian businesses into domestic and international value chains.

National Energy Resources Australia (NERA): Industry growth centre providing funding and supporting collaborative programs to improve the global competitiveness, sustainability, innovation and diversity of the Australian energy resources sector.

Precinct: a fairly dense geographic space of shared facilities, infrastructure and collaboration, and may be focused on a particular industry or objective (i.e. research). It would seldom include a whole town, city or region. A Technology Park can be a precinct.

Raw material refining: Process of developing battery grade chemicals. This includes lithium hydroxide or carbonate from lithium spodumene or brine respectively to be later used in Cathode Active Materials (CAM).

Separator: Permeable membrane between the battery's anode and cathode.

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