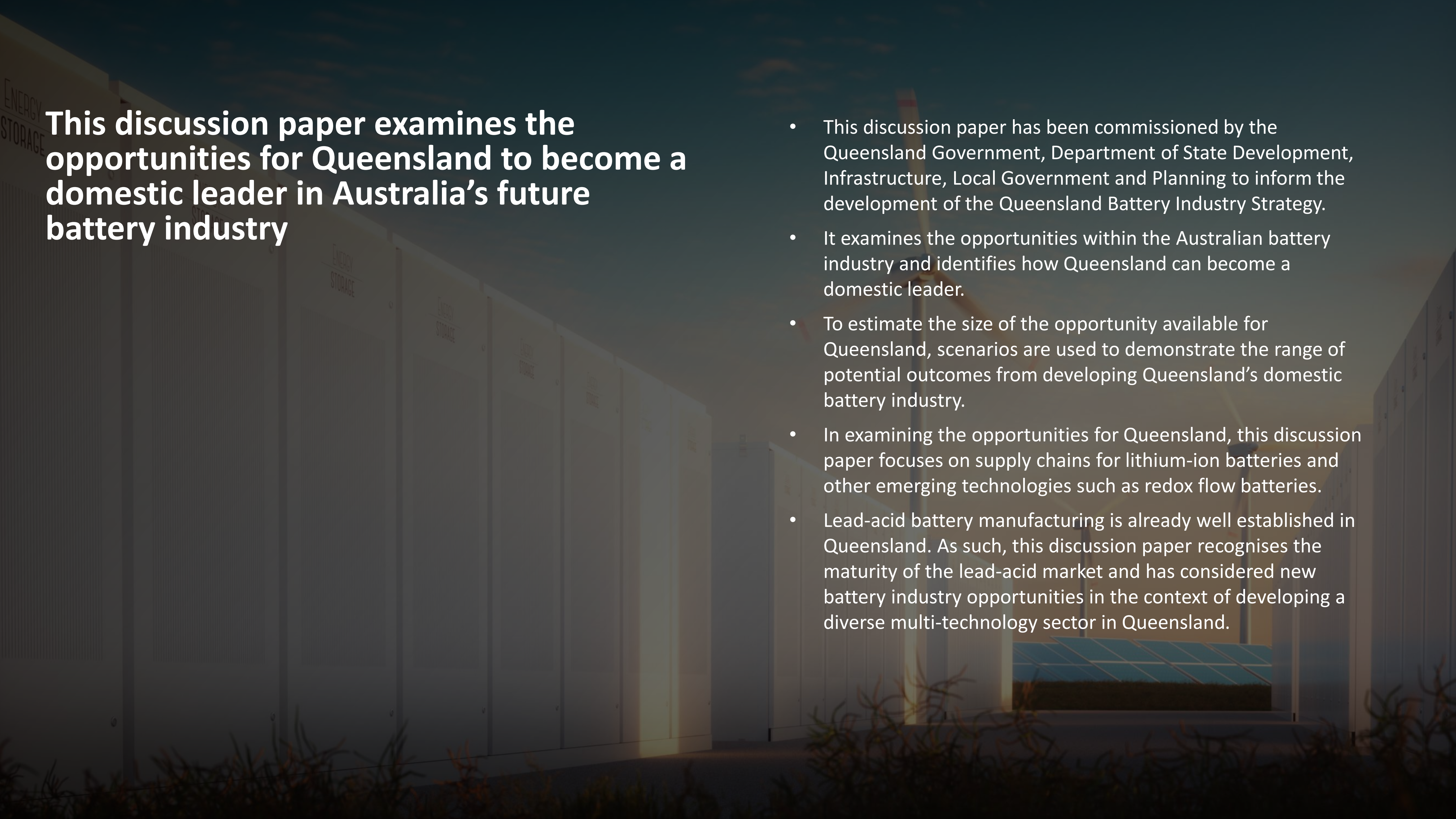
Battery industry opportunities for Queensland

Discussion paper

accenture



This discussion paper examines the opportunities for Queensland to become a domestic leader in Australia’s future battery industry

- This discussion paper has been commissioned by the Queensland Government, Department of State Development, Infrastructure, Local Government and Planning to inform the development of the Queensland Battery Industry Strategy.
- It examines the opportunities within the Australian battery industry and identifies how Queensland can become a domestic leader.
- To estimate the size of the opportunity available for Queensland, scenarios are used to demonstrate the range of potential outcomes from developing Queensland’s domestic battery industry.
- In examining the opportunities for Queensland, this discussion paper focuses on supply chains for lithium-ion batteries and other emerging technologies such as redox flow batteries.
- Lead-acid battery manufacturing is already well established in Queensland. As such, this discussion paper recognises the maturity of the lead-acid market and has considered new battery industry opportunities in the context of developing a diverse multi-technology sector in Queensland.

Executive summary

Domestic battery demand will total 90 GWh to 2030, with opportunities for a range of technologies, especially lithium-ion.

Global battery demand is expected to reach 2,045 GWh by 2030, nearly 11 times 2020 levels, and this will be driven by demand for electric vehicles.

Australian domestic demand is growing at the same rate and is forecast to provide 90 GWh of demand to 2030, including 26 GWh of Queensland demand that should be easily accessed by local producers.

While electric vehicles are the largest segment of battery demand, on-grid stationary storage is the fastest growing segment within the battery market with 37% annual growth across the decade. The domestic stationary storage market will be a key opportunity for Queensland in the medium term. As cell manufacturing capabilities build out, there is potential to target the markets in the international electric vehicle industry.

There are currently many battery technologies in the market. Lithium-ion technology is expected to retain its dominant market position but there are smaller applications where other technologies can compete.

Queensland can build a battery industry based on existing up-stream capabilities, and competitive advantages in reliability, R&D, vanadium, and other critical minerals.

The current battery value chain is large and growing with any segment able to support a significant industry. Cell manufacturing for lithium-ion batteries is the most significant global opportunity and is important for the growth of the industry overall.

Queensland already has developing capabilities across the battery value chain, particularly in mining, refining and active materials. Key capabilities have been developed through investments in vanadium, cobalt, nickel, and other minerals; refining activities including for vanadium, high purity alumina, cobalt and nickel, and graphene, and active materials investments in anodes, cathodes, and vanadium electrolyte.

Overall, Queensland is likely to have competitive advantages through its:

- Existing capabilities in mining, refining to chemicals and active materials;
- R&D capabilities through the value chain but particularly in active materials, cell manufacturing and pack assembly;
- Ability to position itself as a reliable participant in global battery value chains and low future energy costs from renewable energy;
- Strong environmental, social and governance (ESG) credentials throughout the value chain;
- Proximity to markets in Asia; and
- Strong end to end capabilities in vanadium and related battery technologies

To capture these opportunities, Queensland will need to respond quickly given the lead times to develop capabilities within the battery value chain, particularly for cell manufacturing. In the short-term, Queensland may be able to benefit from developing capabilities in pack assembly due to the shorter lead times as they develop capabilities elsewhere in the value chain.

Queensland's battery industry has the potential to contribute $1.3B in GVA and produce 9,100 jobs by 2030.[1]

To develop a battery industry in Queensland there are two broad pathways to pursue:

(1) a local and specialised industry that could contribute $0.6B in GVA

(2) a leading Australian industry that could contribute $1.3B in GVA

A localised and specialised industry would enable alternative technologies to continue to commercialise; meeting market opportunities as they arise.

A leading Australian industry would need to be underpinned by ambitious private sector investment and supply chain growth. This pathway has the potential to capture a greater market share outside of Queensland, while Queensland continues to develop a pipeline of alternative technology opportunities. To take advantage of this opportunity, Queensland would need to:

- Build a diverse customer base with a strong forward order book;
- Develop integrated research and development programs to support advanced materials manufacture, cell prototyping, pilot scale production, certification and testing; and
- Develop a skilled workforce to meet industry requirements

Notes: 1. There is potential for the value realised to be higher than stated, given the rapidly evolving demand profile for batteries globally and domestically, as well as the recent supply challenges for multiple critical minerals having significant price effects

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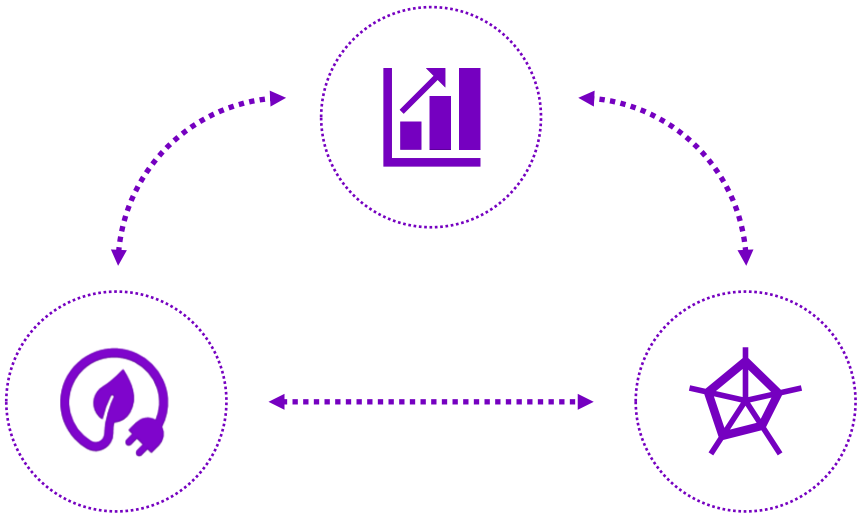
Domestic battery demand will total 90 GWh to 2030, with opportunities for a range of technologies, especially lithium-ion

There are opportunities in the battery industry for Queensland to capture given the growing market, domestic capabilities and advances in technology

1 Growing global battery market

Demand for batteries has been growing significantly over the last decade. This growth is expected to continue to 2030, driven by the demand for electric vehicles and stationary storage needs. While batteries are produced through a complex global value chain, Australia has a strong presence in mining, while China is dominant downstream.



2 Queensland’s capabilities

Queensland is in a position to leverage its existing capabilities and investments in the battery value chain to capitalise on rapidly growing opportunities.

3 Opportunities across multiple technologies

There are a number of different battery chemistries and technologies each with different strengths to meet the wide range of applications. Lithium-ion is the most dominant technology today and, while it will continue to play a critical role in the future, new technologies are being developed in response to production costs, raw material availability and emerging applications. These technologies are increasingly targeting niche opportunities in utility scale storage, defence, mining and aerospace.

Global battery demand is expected to grow over 10x this decade with annual demand reaching 2,045 GWh in 2030

Global battery demand is expected to reach 2,045 GWh by 2030, nearly 11 times 2020 levels, and this will be driven by demand for electric vehicles (EVs).

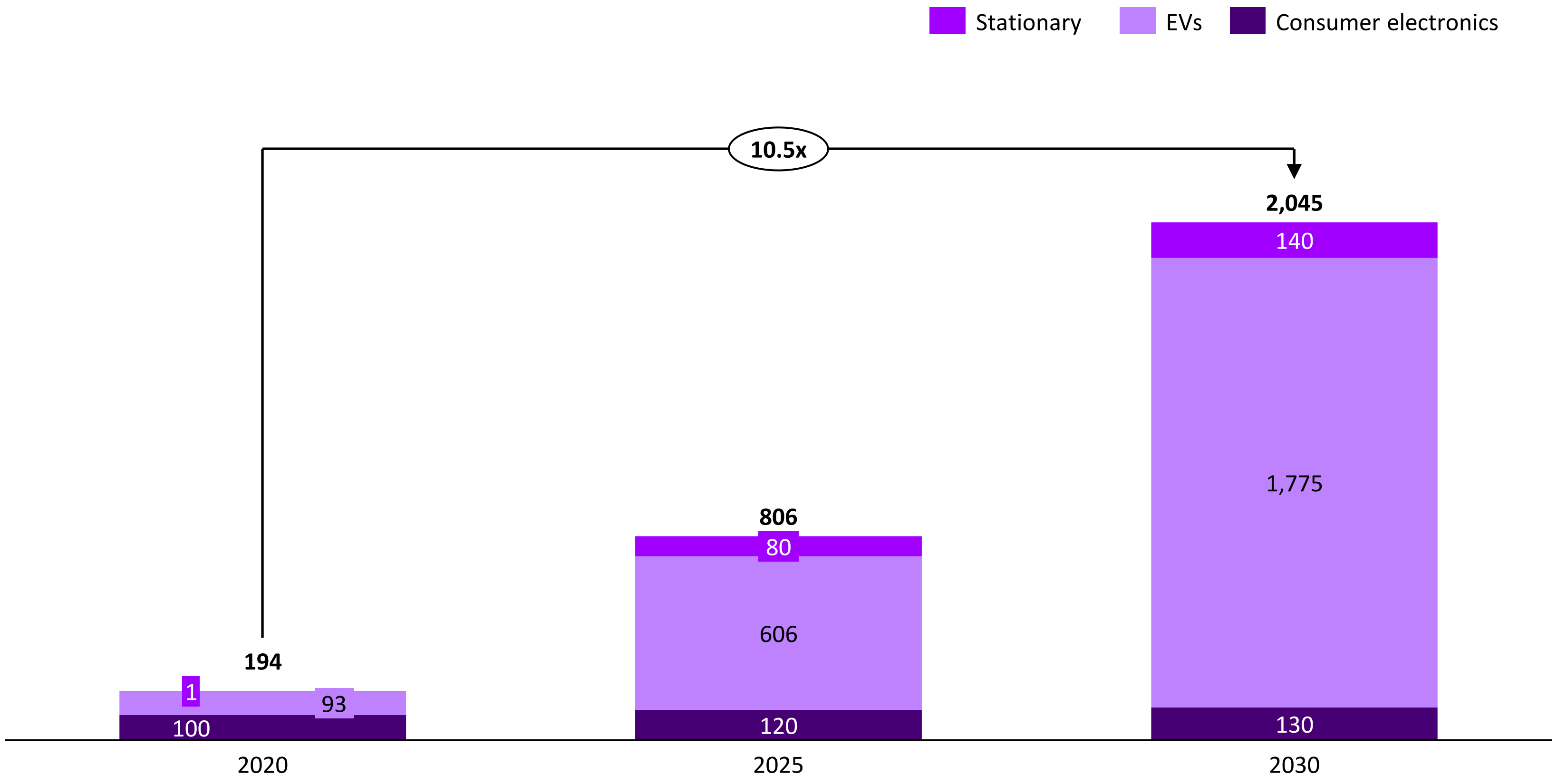
In a climate of decarbonisation, the world is transitioning to other forms of energy beyond fossil fuels. This has translated into growing demand for batteries globally, and is forecasted to increase by 10.5 times in the coming decade to 2030.

Demand for batteries in 2020 was driven by consumer electronics (52% of demand by energy storage) and electric vehicles (48%). However, this is expected to change by 2030, with electric vehicles accounting for 87% of global demand.

Stationary storage also presents a significant opportunity within the global battery industry. Battery demand for stationary storage is expected to increase by 140 times to reach 140 GWh by 2030. This accounts for 7% of global battery demand in 2030.

Exhibit 1: Project battery demand worldwide by application

GWh of annual demand, 2020-2030 (2020 = latest actual data)[1]



Notes: 1. Potential for demand to be higher than stated, given the rapidly evolving demand profile for batteries globally
Source: BNEF (2022) Electric Vehicles to Drive Massive Battery Demand: BNEF Chart.

On-grid stationary storage is the fastest growing segment within the battery market, growing annually by 37% in the decade to 2030

The global battery market is expected to increase nearly four-fold over the next decade to US$133B, and this is driven by strong growth in on-grid stationary storage (37% p.a.) and passenger electric vehicles (17% p.a.).

With strong demand expected for batteries over the coming decade, the battery market is expected to increase 267% by 2030 to be a US$133 billion industry. This will be driven by strong growth in stationary storage, particularly on-grid, as well as growing demand for passenger electric vehicles.

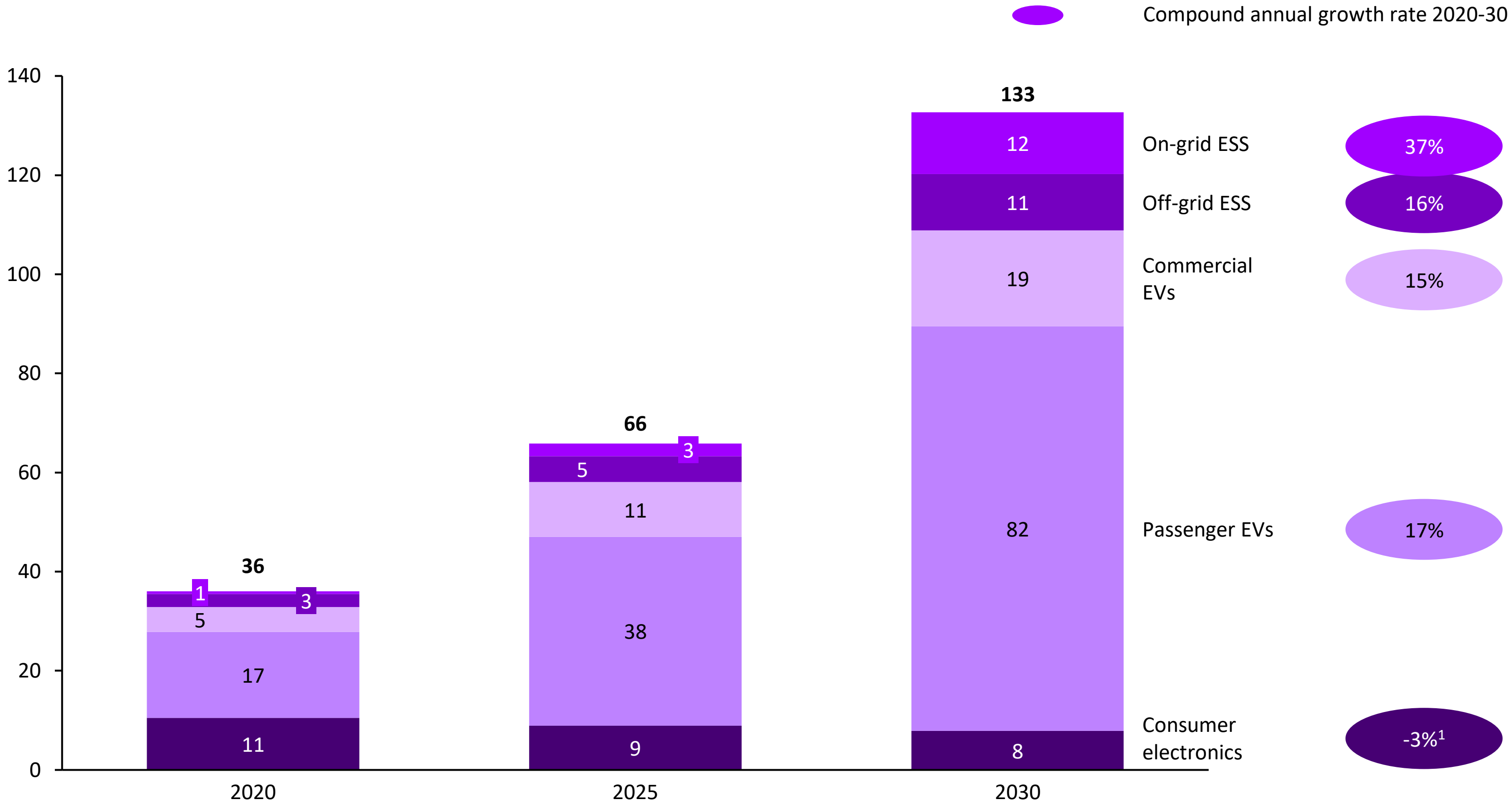
On-grid stationary storage is set to grow 22-fold (37% p.a.) to US$12 billion by 2030. This growth is underpinned by strong demand to support the energy transition.

The battery market for passenger electric vehicles will continue to play an important role in the industry. Batteries for passenger electric vehicles will grow nearly five-fold by 2030 to become a US$82 billion market.

The market for consumer electronics is expected to shrink with unit costs falling faster than the growing demand for devices.

Exhibit 2: Projected global battery market size by application

US$ billion per annum, 2020 = latest actual data[2]



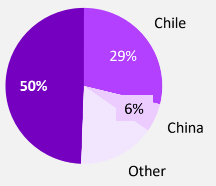
Notes: 1. Reductions in battery prices are expected to more than offset volumes growth over the next decade in consumer electronics.; 2. Potential for battery market size to be larger than stated, given the rapidly evolving demand profile for batteries globally

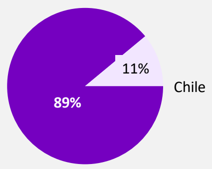
Source: FBI CRC (2021); International Renewable Energy Agency (2017) Electricity storage and renewables: Costs and markets to 2030; Accenture analysis.

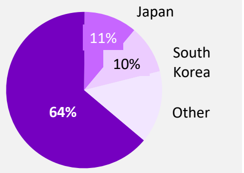
Batteries are produced through a complex global value chain, with Australia strong in mining and China dominant downstream

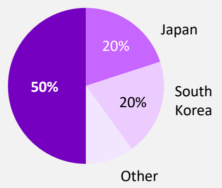
Exhibit 3: Battery value chain segments and market shares

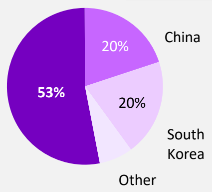
	Materials			Battery manufacturing		Integration & services	
	Mining raw materials	**Refining to chemicals**	**Active materials**	**Cell manufacturing**	**Battery pack assembly**	**Integration, service and maintenance**	**Re-use and recycling**
Description	Extraction of raw materials as ores or brines. Raw materials include lithium, graphite, nickel, manganese, cobalt, vanadium, copper and aluminium.	Refining of raw materials to highly purified chemical salts. Refined chemicals include lithium hydroxide, lithium carbonate, and nickel sulfate.	Production of precursors and finished active materials including LiNMC and LFP cathodes^1, along with graphite and silicon anodes.	Manufacturing of the battery cell including electrode chemical processing, cell assembly and cell finishing, which are critical for battery pack performance and quality.	Production of the battery pack consisting of many individual cells that are interconnected. Battery pack testing is an integrated part of battery pack manufacturing.	Integration and service of batteries for different applications, including installation and grid connection for on-grid Energy Storage Systems (ESS) and maintenance for electric vehicles (EVs).	Re-use and recycling of batteries materials through repurposing of degraded batteries, refurbishment or recycling to recover raw materials.
Opportunities for Queensland	Queensland could mine its graphite, nickel, cobalt, vanadium, aluminium, graphite and other reserves.	Queensland could use its raw material reserves and service the growing market for more diversified supplies of refined chemicals.	Queensland could use its refined chemicals to develop active materials and electrolytes.	Queensland could further develop its cell manufacturing capabilities, particularly given its emerging R&D.	Queensland could further develop its battery pack assembly capabilities, particularly given its emerging R&D.	Queensland will have opportunities to increase its integration, service and maintenance offerings as the local market for battery storage grows.	Queensland will have opportunities to increase its re-use and recycling capabilities for batteries other than lead-acid as the feedstock volume grows.
Share of segment by country (share of revenue, %)^2	**Australia**	**China**	**China**	**China**	**Japan**	**No dominant countries** Highly localised	**China**

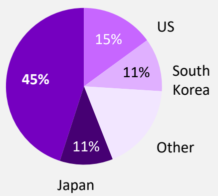












Notes: 1. Lithium nickel manganese and cobalt cathodes and lithium iron phosphate cathodes respectively; 2. Data for mining, refining, cell manufacturing and assembly are for 2017. Data for active materials is the average of country market share for anode, cathodes and electrolytes in 2019, and data for recycling uses distribution of leading recycling companies in 2019.
Source: AusTrade (2018) The Lithium-ion Battery Value Chain: New economy opportunities for Australia; Roskill (2020) Lithium-ion Batteries: Outlook to 2029, Tables 18-21 and Chapter 14; Accenture analysis.

Queensland will see 26GWh of demand from in-state markets through to 2030 plus 63GWh from the rest of Australia and 1GWh from defence opportunities

Application (not exhaustive)		Potential Queensland market to 2030[1]	Potential market from rest of Australia to 2030[1]
Grid stationary storage[2]	• State ownership of Queensland's energy utilities could offer a long-term secure base of demand for battery storage in conjunction with Queensland's development of renewable energy zones.	14 GWh	27 GWh
Behind the meter storage[3]	• Behind the meter residential storage and participation in virtual power plants is on the rise. Queensland's leading rate of solar uptake – 4.1 GW of rooftop solar from 700,000 homes – is being increasingly paired with energy storage systems.	7 GWh	18 GWh
Off-grid stationary storage[4]	• 2% of Australians live off-grid. More than 6% of Australia's electricity use occurs in these regional and remote areas.	1 GWh	5 GWh
Mining[5]	• There are currently 75 large resources projects in Queensland and over 350 operating mines in Australia. • Electrification of mining haulers represent a potential market for mobile batteries with many miners looking to decarbonise operations. However, with R&D ongoing, short-term deployments are likely to be in new mining operations. • Remote mining activities may continue deploying specialised off-grid storage.	0.7 GWh	2.6 GWh
Electric trucks and buses	• Queensland is currently home to significant bus and truck manufacturing. CSIRO projects almost 15,500 electric buses and almost 70,000 electric trucks by 2030 under a step-change scenario for Eastern Australia.	3 GWh	10 GWh
	Cumulative demand:	**26 GWh**	**63 GWh**

Two additional applications exist only at the aggregate domestic and international level		Potential Market[1]
Defence	• Specialty batteries for the military vehicle electrification represent local demand where supply chain sovereignty is of heightened value. Some manufacturing of military vehicles currently occurs in Queensland. • Queensland hosts 14 of the 64 military bases in Australia where stationary storage could either supply or backup their power grids.	Australia: 1 GWh
Electric passenger vehicles	• Demand for EV batteries is experiencing strong competition from established global players. • EVs imported by Queenslanders will contain 32 GWh of EV battery storage between now and 2030. • Without domestic manufacturing capabilities for passenger vehicles, addressing this demand is challenging.	International: 7,000 GWh Australia: 133 GWh

Notes: 1. Total cumulative demand from 2023-2030 inclusive and includes all the demand from NEM in FY30-31 from the Australian Energy Market Operator (AMO) Integrated System Plan (ISP); 2. based on AEMO Step Change scenario, for East Coast of Australia; 3. Distributed energy storage includes grid connected batteries installed to support the customer's own load as well as coordinated systems in a virtual power plant arrangement; 4. Based on 2% of Australian population, average household size of 2.6 people and average battery size of 42kWh; limited data makes this market challenging to size; 5. Based on 20% of Australian mines electrifying, with an average of 15 haulers per mine with a 2MWh battery per hauler and a battery replacement after 2.5 years as well as a 50MWh battery per mine electrifying

Source: Wood Mackenzie (2022); Renew Economy (2022); Energy Storage News (2022); SolarRun (2022); Department of Energy and Public Works (2022); AEMO WEM Electricity Statement of Opportunities (2022); AEMO Distributed Energy Resources Roadmap (2022) Renew Economy (2022); Expert interviews; Accenture analysis

Global cell manufacturing capacity is forecast to grow 14-fold with the current top six manufactures plus OEMs holding three quarters of this capacity

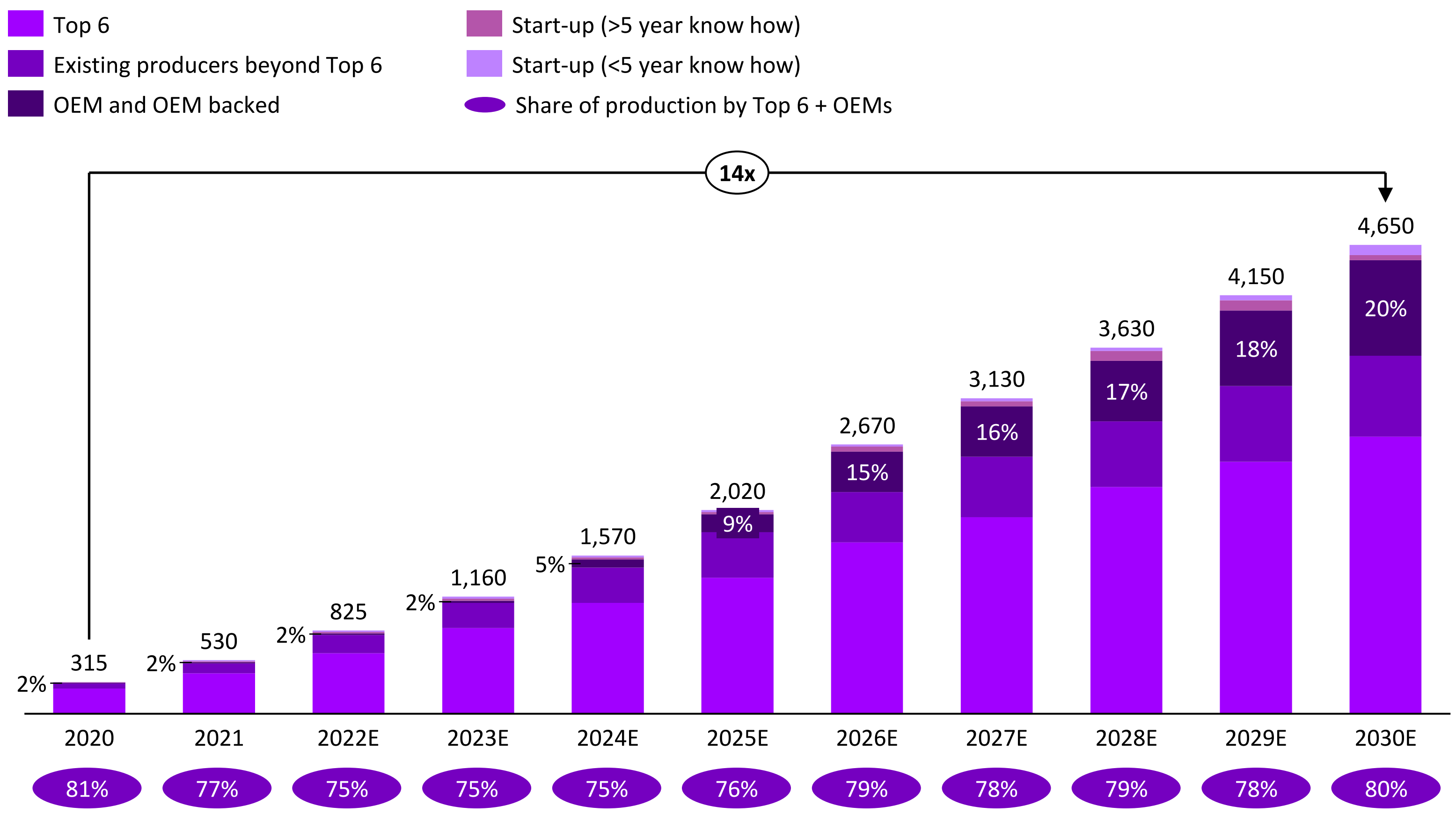
Global yield adjusted capacity for battery cells is forecast to increase 14 times to 4,650 GWh in the decade to 2030. The current top 6 global manufacturers accounted for 79% of the global cell manufacturing capacity. Over the decade it is forecast the original equipment manufacturers (OEMs), both directly and through partnerships will grow from 2% to 20%.

The cell manufacturing market will continue to be dominated by the current top 6 manufacturers and OEMs, both directly and through partnerships. The current top 6 manufacturers accounted for 79% of global production capacity in 2020. OEMs are forecast to expand their share to 20% of global cell production capacity by 2030. The top 6 manufacturers and OEMs are forecast to hold 75-81% of the total capacity across the whole decade.

New entrants on the global market face a high barrier to entry. The incumbent players and OEMs can leverage economies of scale, their technology leadership, and increasing vertical integration. This competition is also occurring in an environment with some material and skill bottlenecks which may contribute to keeping the cell manufacturing capacity consolidated beyond 2030.

Exhibit 4: Breakdown of cell manufacturing by type of manufacturer

GWh of yield adjusted capacity[1]



Notes: 1. Yield adjusted capacity captures announcements and forecast development of total capacity to produce batteries

Source: Goldman Sachs (June, 2022) Global Batteries: The Greenflation Challenge II; McKinsey (January, 2022); Capturing the battery value- chain opportunity; Accenture analysis

Strong automotive industries underpin local EV battery industries, reducing the opportunities for EV batteries for Queensland in the medium term

While global battery demand for use in electric vehicles (EVs) is expected to increase nearly 20-fold by 2030, there is currently less potential for Queensland to build a battery industry focused on EVs in the medium term.

Co-location with a large EV manufacturer and perusing strong vertical integration is a key driver to consolidate value and secure supply chains in a constrained global commodity market.

In most current instances, local EV manufacturing is underpinned by favourable domestic policy with additional support from consumer side incentives. As an example of this, the USA's Inflation Reduction Act targets support to domestic manufacturers, with some early speculation that the EU should follow suit[1].

Inflation Reduction Act – USA **Fact Box**

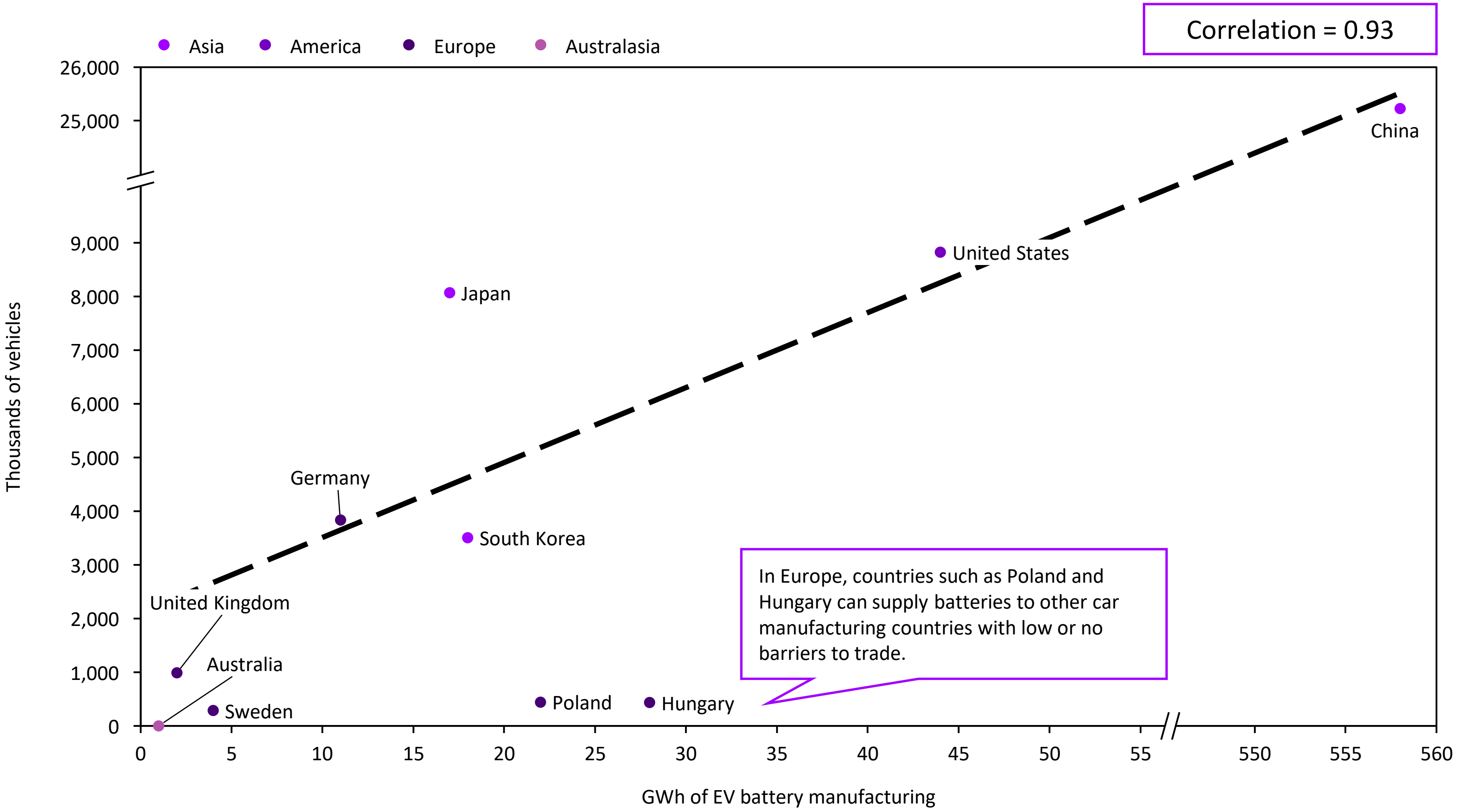
The inflation reduction act (IRA) raises significant barriers to countries outside North America participating in component manufacturing for US EVs and prioritises battery materials sourced from free trade partners, such as Australia.

The IRA creates a $7500 consumer tax incentive for the purchase of eligible EVs that meet escalating sourcing thresholds. To qualify, 100% of battery components need to be manufactured in North America (by 2028). In addition, 80% of critical minerals need to be sourced and processed from free trade partners (by 2026), which presents significant opportunities for Australia and Queensland.

The IRA also includes a $2 billion grant pool to build up domestic manufacturing facilities.

Exhibit 5: Relationship between vehicle manufacturing capacity and EV battery production by country

Y-axis: Thousands of vehicles (2022); X-axis: GWh of EV batteries manufactured (2022)



In Europe, countries such as Poland and Hungary can supply batteries to other car manufacturing countries with low or no barriers to trade.

Notes: 1).Including comments from French Finance Minister Bruno Le Maire.

Source: Bloomberg (2022); BNEF (2022) Electric Vehicles to Drive Massive Battery Demand; International Energy Agency (2022); Accenture Analysis

The energy transition calls for 63 GWh of additional stationary storage on the NEM by decade's end, a massive expansion of the current 1 GWh battery fleet

The demand for stationary storage in Australian Energy Market Operator's (AEMO) Step Change scenario called for an additional 63GWh of stationary storage through to 2030-31. This is the equivalent of building the currently commissioned utility battery fleet seven times over every year (on average). This scenario includes 21GWh of battery storage installed in Queensland.

The market for this rapidly expanding industry averages at $2.5 billion through to 2030-31. Although the demand grows more rapidly in the second half of the decade, the overall market for stationary storage grows more consistently as unit battery costs continue to fall.

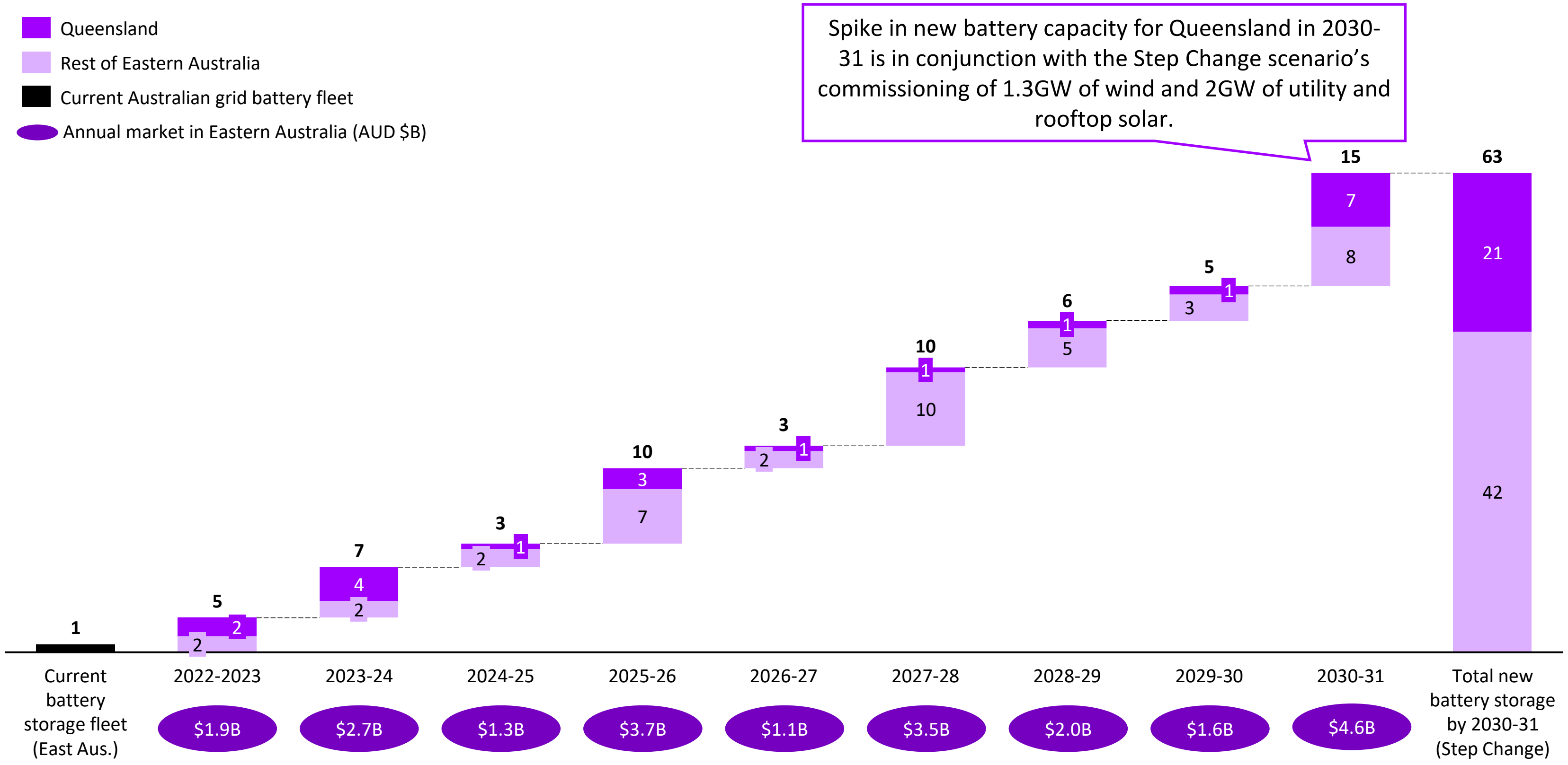
Year to year fluctuations in demand are tied to the commissioning of large renewable projects in particular states on the National Energy Market (NEM) which also influence the type of batteries commissioned in a given year.

Size of individual battery projects is set to increase with GWh scale batteries proposed by SolarQ for a 1GW/4GWh project in Gympie as well as Syncline Energy with a proposed 1.2GW/1.6GWh system in Melton, Victoria.

The role of battery systems with the grid will also continue to evolve. For example, South Australia's Hornsdale Power Reserve battery is now providing inertia services to the grid, and Stanwell's proposition of a multi-staged 1.3GW/2.6GWh project on site at its coal power station near Rockhampton, Queensland.

Exhibit 6: Australian battery demand for grid connected stationary storage

GWh of annual demand under AEMO ISP[2, 3, 4] in Queensland and the rest of Eastern Australia



Spike in new battery capacity for Queensland in 2030-31 is in conjunction with the Step Change scenario's commissioning of 1.3GW of wind and 2GW of utility and rooftop solar.

Notes: 1. Based on Step Change scenario using CSIRO forecasts (2022). 2. Based on Step Change scenario. 3. Includes medium storage, shallow storage, distributed storage and coordinated DER storage, underlying mix of these types of storage influence the size of the battery market in the given year. 4 Model begins from 2023-2024 and supplemented with data on project pipeline in AEMO Generator Information report

Source: AEMO ISP (2022); USA National Renewable Energy Laboratory (2022); AEMO Generator Information (2022); Spiire (2022); The Electricity Hub (2022); AEMO System Strength and Inertia Report (2020); Accenture analysis

Lithium-ion technology is expected to retain its dominant market position but there are applications where other technologies can compete

Technology	Description	Notable projects	Existing activity in Queensland (public, not exhaustive)
Lithium-ion	• First commercialised in 1980. • Global manufacturing scale production of batteries for use in consumer electronics and mobility applications, with chemistries such as NMC and LFP.[1] • Energy density sufficient for compact mobility applications.[2]	• Australia's nine operational grid storage batteries (totalling 760MW/1054 MWh) all utilise lithium-ion technology.	• Vena Energy Australia commissioned its 100MW/150MWh battery at Woleebee in August 2022. • Feline is producing high performance cells for niche applications, along with specialty cathodes. • VSPC are working towards pilot scale production of LFP cathodes.
Flow Batteries	• External electrolyte tanks can be scaled to match desired output with discharge duration. • Battery life typically anticipated to be 25 years with a recoverable electrolyte, which presents opportunities for recycling. • Suitable for longer duration storage.	• 2MW/8MWh battery in South Australia • 100MW/400MWh vanadium flow battery commissioned in China. • 200MW/2GWh iron flow battery purchased in the USA.	• Energy Storage Industries Asia-Pacific is constructing a pack assembly facility for iron-flow batteries from 2024 with a target production of 400MW by 2026. • Vecco Group have announced plans to build to 100MWh per annum of vanadium electrolyte production drawing from its Debella Project mine in North Queensland. • Redflow has developed zinc-bromine flow batteries for small commercial applications and have also installed a 500kW/2MWh system in California.
Lead-acid	• The first rechargeable battery, invented in 1859. • Mature technology with a 95-99% recycling rate. • Widely used as a source of stand-by or infrequent power. • Low self-discharge rate but a low power density.	• Frequently used for starting or back up power in automobiles and remote sensing. • 10MW/40MWh lead-acid battery commissioned by the Southern California Edison Company in 1988.	• Century Yuasa produces 1.2 million modern lead-acid batteries at its plant in Brisbane from new and recycled material.
Lithium sulfur	• High theoretical energy density,[3] which will likely drive usage in niche applications.[4] • Potential future applications for vehicles.	• Sion and Oxis have some commercial products available.	• Queensland headquartered Li-S is using Boron Nitride Nano-tube Technology (BNNT) with lithium sulfur batteries, which will increase energy density and extend cycle life.
Graphene aluminium-ion	• Very fast recharge time and high energy density. • Potential mobility and stationary storage applications.	• To date no large scale graphene batteries have been deployed.	• Graphene Manufacturing Group is developing end-to-end graphene battery production in Queensland in conjunction with University of Queensland (UQ).
Sodium-ion	• Similar features to lithium-ion batteries, but with improved temperature tolerance and safety features. • Suited for applications that prioritise power density,[5] with potential stationary storage applications.	• Anticipated production by Natron Energy and Clarios International of 600MW/year of sodium-ion batteries from 2023 in Michigan.	• No manufacturing capacity exists for sodium-ion battery technology. However, UQ is contributing to foundational research in this space. • Queensland University of Technology (QUT) and Sparc Technologies have formed a partnership to commercialise battery materials including for sodium-ion batteries.
Sodium-sulfur	• Suitable for longer duration storage. • First deployed in 1995 after development from NGK.	• Used for projects including grid and microgrid applications, with 700MW/4.9GWh of capacity installed globally.	• BASF and QUT are working to pilot the deployment of sodium sulfur batteries.

Given the current scale of production and expected learning rates, lithium-ion batteries are likely to have a levelised cost of storage advantage over lead-acid and vanadium flow batteries in the future. However, redox flow batteries are likely to be a cost effective option for longer duration storage, particularly given the potential to scale flow batteries by increasing the volume of electrolyte without increasing capital expenditure. Competition for raw materials could also impact production costs for lithium-ion batteries, potentially driving the development of alternate technologies that target specific applications and utilise cheaper and more readily available materials.

Notes: 1. Cathode chemistries of nickel manganese cobalt and lithium iron phosphate respectively; 2. Energy density of 100-265 Wh/kg; 3. Theoretical density of up to 2700 Wh/kg, although current cells have about 470 Wh/kg; 4. Including satellites, drones and the defence sector; 5. Including power tools and uninterruptible power supply (UPS) applications. There are also opportunities for sodium-ion batteries to be used in diesel generators and car engines.

Sources: Clean Energy Institute (2022); Yadlamalaka Energy (2022); Sacramento Municipal Utility District (2022); USA Department of Energy (2022); Vena Energy Australia (2022); Energy Storage News (2022); Graphene Manufacturing Group (2022); Century Batteries (2022); Vecco Group (2022); The Faraday Institution, (2020); The Faraday Institution, (2021); Li-S Energy (2022); The Market Herald (2022); NGK, (2022); BASF, (2020); Schmidt et al., (2019); Schmidt (2017),

02

Queensland can build a battery industry based on up-stream capabilities and competitive advantages in reliability, R&D and vanadium

Queensland has some advantages in the upstream battery value chain, but cell manufacturing capabilities are key to supporting a local industry

Queensland has some competitive advantage in the upstream battery value chain, particularly in mining and raw materials. However, cell manufacturing is critical to the battery value chain and Queensland will need to further develop these capabilities to establish a local battery industry.

The biggest opportunities for Queensland lie at the intersection of the most attractive markets and the areas where Queensland has the strongest capabilities.

The most attractive battery value chain opportunities lie in lithium-ion batteries, which is the dominant technology other than lead-acid batteries. These opportunities are particularly large for cell manufacturing, which is critical for industry development, accounting for 45% (US$136B) of global revenue in 2030.[1]

Queensland's capabilities are predominately in mining, refining and active materials. However, there are emerging capabilities in cell manufacturing and pack assembly.

Queensland is most cost competitive in the mining and refining of its available raw materials, which includes vanadium, aluminium, graphite, nickel and cobalt. If the supply chain for these materials were developed, Queensland could be cost competitive for some active materials.

Exhibit 7: Opportunity for Queensland in the battery value chain

Factors		Description	Summary of Queensland's opportunity
Attractiveness of the battery market	*Size*	The scale of the global opportunity for a part of the value chain, as measured by future revenue opportunities.	**Cell manufacturing** for lithium-ion batteries is the **most significant global opportunity** by size and impact on industry development, with other substantial opportunities in **pack assembly** and **refining to chemicals** for the lithium-ion battery value chain.
	Importance in value chain	The impact of a capability on broader industry development through providing supply chain security and reducing materials and logistics costs.	
Queensland's capabilities	*Current and planned activities*	The scale of current and planned activities for a part of the value chain, as measured by planned production, level of investment and importance of activities to the battery value chain.	Queensland's **mining** and **refining activities** are the most significant in the battery value chain by investment, followed by active materials and integration, service and maintenance.
	Differentiated products	The ability of Queensland to provide products which are differentiated either by their quality or by being nascent with unique applications.	There are **strong R&D capabilities** throughout the value chain in Queensland, particularly in **active materials**, **cell manufacturing**, and **pack assembly**.
	Workforce	The strength of labour skills within companies and research institutions for a part of the value chain.	Queensland has a skilled **mining workforce**, and **emerging labour skills** in refining, active materials, and pack assembly.
	Cost competitiveness	The cost competitiveness of the labour, materials, energy, logistics and tax inputs for part of the value chain.	Queensland has **cost advantages** for some **raw materials** and **refining to chemicals**. This may also reduce the materials and logistics costs for some **active materials**.

Notes: 1. There is potential for revenue to be higher than stated, given the rapidly evolving demand profile for batteries globally and domestically, as well as the recent supply challenges for multiple critical minerals having significant price effects

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; Lithium Energy (2022); Australian Mines (2022); Sconi, (2022); Queensland Government (2021); QEM (February, 2022); AFR (2021); Queensland Government (2022); Rio Tinto (2022), Aeon Metals (2021), Alpha HPA (2022); Lava Blue (2022); QPM (October, 2021); QPM (June, 2022); Vecco Group (2022a); Vecco Group (2022b); Graphene Manufacturing Group, (2022), AnteoTech (August 2022); Lithium Australia (July, 2022); FBI CRC (July, 2020); NBTC (2022); Magnis (2022); Century Yuasa (2022); Feline (2022); ESI Asia Pacific, (2022); Tritium Charging (2021); RedEarth (2019); Queensland Government (2018); ARENA (2022); ARENA (2021); Prohelion (2022); Queensland Government (2022); Queensland Government (2022), FBI CRC (March, 2020); Everledger (July, 2021); RJ Batteries (2022); ABRI (2020); Powercell (2022); Accenture Analysis.

Queensland has the opportunity to pursue the significant opportunities in cell manufacturing by linking up its refining capabilities with midstream activities

Exhibit 8: Battery value chain opportunities for Queensland

Scale: █ ▓ ▒ ░
Larger Smaller

	Materials			Battery manufacturing		Integration and services		
	Mining raw materials	**Refining to chemicals**	**Active materials manufacturing**	**Cell manufacturing**	**Battery pack assembly**	**Integration, service and maintenance**	**Re-use and recycling**	**Summary**
Attractiveness of the battery market	▓	▓	▒	█	▓	Highly localised	▓	
	Global demand for minerals to be used in the battery value chain, particularly for nickel, cobalt, graphite and lithium.	Opportunities to refine to chemicals due to increased demand for battery materials as the value chain expands.	Opportunities to manufacture active materials given supply shortages and the need to improve quality to boost battery performance.	Significant opportunities given the scale of revenue available for cell manufacturing, particularly in lithium-ion batteries.	Opportunities for pack assembly to grow in order to address the demand for energy storage.	Largely localised opportunities for an installation and maintenance workforce.	Important in developing a circular battery value chain and to improve the environmental impact of batteries.	Attractive opportunities across the entire battery value chain, particularly in cell manufacturing and pack assembly due to their scale of revenue and importance for value chain development.
Queensland’s capabilities	▒	▓	▒	▒	▒	▒	░	
	Capabilities in vanadium, aluminium, and potentially graphite, nickel and cobalt, but not all materials mined will be used for the battery value chain.	Capabilities in refining vanadium, High Purity Alumina (HPA), nickel, cobalt and potentially graphite, but not all refined materials will be used for the battery value chain.	Capabilities in cathodes, anodes, vanadium electrolyte and iron electrolyte.	Capabilities in lithium-ion cell innovation, along with capabilities in graphene aluminium-ion and potentially vanadium flow cells.	Capabilities in lithium-ion battery pack innovation, along with graphene aluminium-ion and iron flow batteries, and potentially vanadium flow batteries.	Capabilities in energy storage systems and EV charging.	Capabilities in lead-acid recycling, and potentially for other types of batteries. Feedstock volume growth is needed to support facilities, but in the long term recycling can provide materials for cell manufacturing.	Emerging capabilities, particularly in the mining and refining of particular raw materials, and differentiated active materials, cell and pack products.

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; Goldman Sachs, (March, 2022), Global Batteries: The Greenflation Challenge; Goldman Sachs (June, 2022), Global Batteries: The Greenflation Challenge II; Lithium Energy (2022); Australian Mines, (2020); Australian Mines, (2022); Sconi, (2022); Queensland Government (2021); QEM (February, 2022); AFR (2021); Queensland Government (2022); Rio Tinto (2022), Aeon Metals (2021), Alpha HPA (2022); Lava Blue (2022); QPM (October, 2021); QPM (June, 2022); Vecco Group (2022a); Vecco Group (2022b); Graphene Manufacturing Group, (2022), AnteoTech (August 2022); Lithium Australia (July, 2022); FBI CRC (July, 2020); NBTC (2022); Magnis (2022); Century Yuasa (2022); Feline (2022); ESI Asia Pacific, (2022); Tritium Charging (2021); RedEarth (2019); Queensland Government (2018); ARENA (2022); ARENA (2021); Prohelion (2022); Queensland Government (2022); Queensland Government (2022), FBI CRC (March, 2020); Everledger (July, 2021); RJ Batteries (2022); ABRI (2020); Powercell (2022); Accenture Analysis.

Cell manufacturing for lithium-ion batteries will have a $136B market by 2030, contributing up to 45% of battery value-chain revenue

The lithium-ion battery industry is forecast to be a US$300B industry by 2030, with cell manufacturing presenting the largest opportunity in the value chain. Cell manufacturing will account for 45% of global revenue ($US136B).

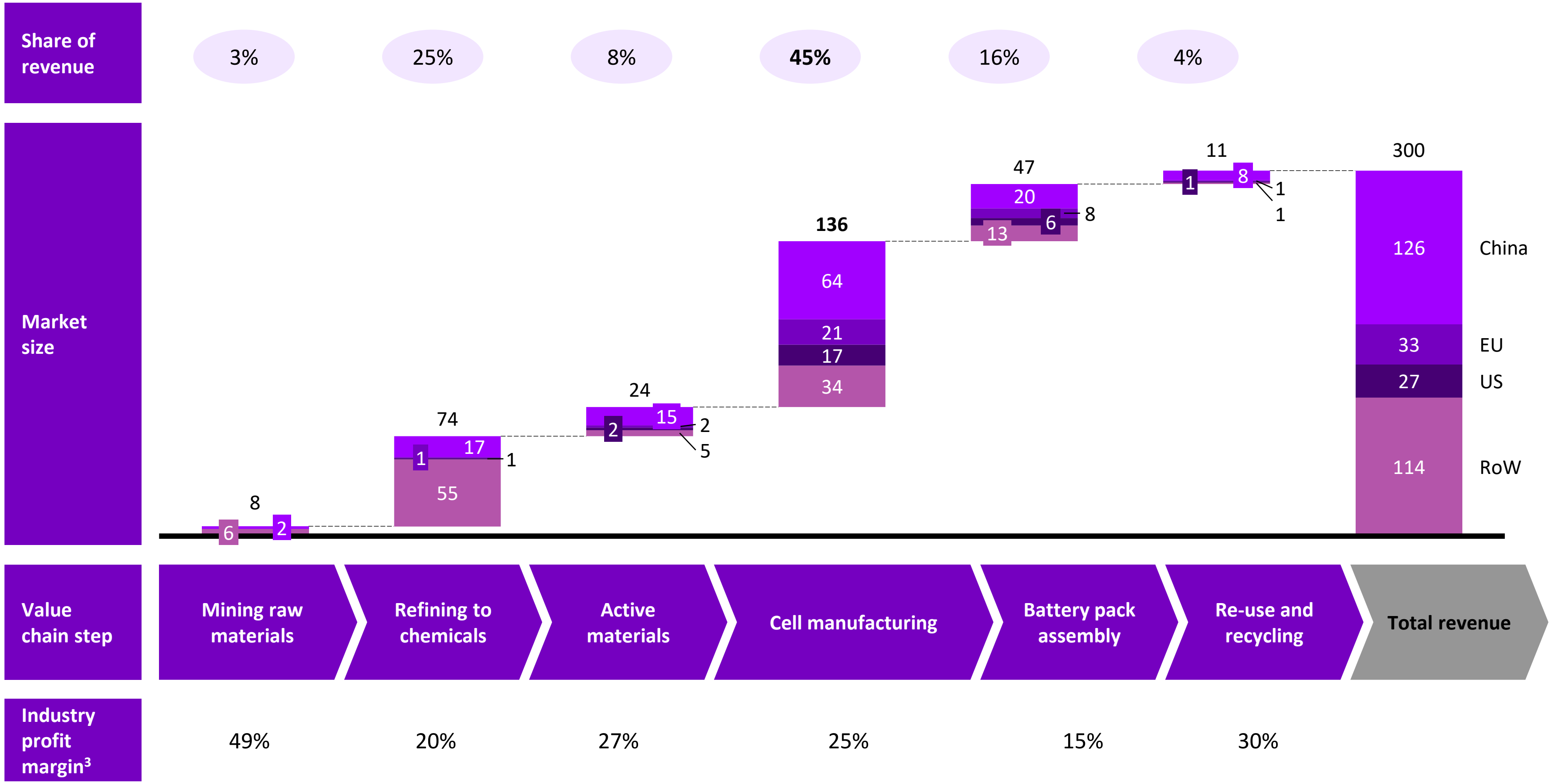
The application of lithium-ion technology within the global battery value chain is expected to grow the market to be a US$300B industry. The largest opportunity within the lithium-ion battery value chain will be cell manufacturing, accounting for 45% of global revenue and a 25% industry profit margin.

There are also other opportunities in refining chemicals (25% of global revenue) and battery pack assembly (16% of global revenue). The remaining 15% of revenue is made up by opportunities in active materials, reuse and recycling, and mining raw materials. Mining raw materials also has the largest industry profit margin, including both wages and business profits (49% industry margin).

By 2030, China is expected to remain the largest player in the global battery market, accounting for $126B of global revenue (42%), while the EU and US will make up another 20% of the global market.

Exhibit 9: Potential lithium-ion battery value chain revenue by 2030

$US billions, 2030 (base case)[1,2]



Note: 1. Totals may not sum to 100% due to rounding; 2. There is potential for revenue to be higher than stated, given the rapidly evolving demand profile for batteries globally and domestically, as well as the recent supply challenges for multiple critical minerals having significant price effects; 3. Including business profits and wages

Sources: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; Accenture (June, 2021), Future Charge- Building Australia's Battery Industries; Accenture analysis.

Queensland has growing capabilities throughout the battery value chain, particularly in refining

Exhibit 10: Queensland's capabilities across the battery value chain

Strength of capability Higher ■ ▩ ▨ □ Lower

	Materials			Battery manufacturing		Integration & services	
	Mining raw materials	**Refining to chemicals**	**Active materials & electrolytes**	**Cell manufacturing**	**Battery pack assembly**	**Integration, service and maintenance**	**Re-use and recycling**
Key areas of capability[1]	▨	▩	▨	▨	▨	▨	□
Current and planned activities	Vanadium: QEM Julia Creek, Vecco Debella, Richmond Vanadium, St Elmo mine, Critical Minerals Group Nickel and cobalt: Sconi mine, Aeon Metals Walford Creek Cobalt mine Graphite: Lithium Energy Burke project	High Purity Alumina (HPA): Lava Blue, Alpha HPA, Vecco Debella, Queensland Pacific Metals (QPM) TECH Nickel and cobalt: Sconi, QPM TECH Graphene: Graphene Manufacturing Group (GMG) Battery grade material development and qualifying: UQ, QUT	Anodes: AnteoTech Cathodes: VSPC, PBT, Feline Vanadium electrolyte: Vecco Prototyping and development of cathodes and electrolytes: UQ, QUT	Testing and prototyping: QUT's energy storage research, which encompasses the National Battery Testing Centre (NBTC) Lithium-ion battery cells: Imperium3 Gigafactory, Feline Graphene aluminium-ion battery cells: GMG Lead acid cells: Century Yuasa (CYB)	Testing: QUT's energy storage research, which encompasses the NBTC Lithium-ion batteries: Feline, RedEarth Iron flow batteries: ESI Asia Pacific Zinc-bromine flow batteries: Redflow Lead acid batteries: CYB	Testing: QUT's energy storage research, which encompasses the NBTC Electric vehicle charging: Tritium Charging, Evie Networks Electric vehicles: BusTech Energy storage systems: Redback Technologies, RedEarth, Prohelion, eleXsys Battery casing: Vaulta	Lead acid battery recycling: CYB, RJ Batteries[7], Lex Enviro Services[8], Gold Coast Resource Recovery Lithium-ion battery recycling collection: Powercell[9], MRI e-cycle, Envirostream Tracking: Everledger
Investment[2]	**$2.5-5B[3]**	**$500M- $2.5B[3]**	**$50-100M**	**>$150M[4]**	**$50-100M**	**$50-100M**	**<$50M**
Differentiated products	• Significant and shallow vanadium reserves • High grade graphite	• Ultra High Purity Alumina • Graphene using a proprietary process	• Silicon anodes • Reduced cost cathode process	• High performance lithium-ion cells • Graphene aluminium-ion cells	• High performance lithium-ion packs • Iron and zinc bromine flow packs	• Fast charging technology	• Local recycling
Workforce[5]	• Skilled mining workforce	• Current skills at GMG, and emerging skills	• Current skills at AnteoTech and VSPC	• Current skills at Feline, GMG and CYB	• Current skills at Feline, Redflow, RedEarth and CYB	• Current skills within diverse capabilities	• Current lead-acid battery recycling skills

Notes: 1. Based on the size of investment, amount of current and planned activities, and relevance of activities to the battery value chain; 2. Publicly available investment figures for activities related to emerging battery technologies within Queensland, not including investment into lead-acid capabilities or capabilities outside of Queensland. Investment figures are likely to be higher than this due to activities which don't have available investment figures; 3. Not all of the capabilities in mining and refining will be used for the battery value chain; 4. This doesn't include the $3B investment figure outlined for the Imperium3 factory in a feasibility study, as this activity is not yet planned; 5. In addition to process industry workers with transferable skills, such as chemical engineers, chemists, metallurgists, mechanical engineers, and maintenance technicians.

Source: Lithium Energy (2022); Australian Mines (2022); Sconi, (2022); Queensland Government (2021); QEM (February, 2022); AFR (2021); Queensland Government (2022); Rio Tinto (2022), Aeon Metals (2021), Australian Government, (2022); Alpha HPA (2022); Lava Blue (2022); QPM (October, 2021); QPM (June, 2022); Critical Minerals Group, (2022); Vecco Group (2022a); Vecco Group (2022b); Graphene Manufacturing Group, (2022), AnteoTech (August 2022); Pure Battery Technology, (2022); Lithium Australia (July, 2022); VSPC, (August, 2021); FBI CRC (July, 2020); NBTC (2022); Magnis (2022); Century Yuasa (2022); Feline (2022); ESI Asia Pacific, (2022); Li-S, (2022); Tritium Charging (2021); RedEarth (2019); Queensland Government (2018); ARENA (2022); ARENA (2021); Prohelion (2022); Queensland Government (2022); Queensland Government (2022), FBI CRC (March, 2020); Everledger (July, 2021); RJ Batteries (2022); ABRI (2020); Powercell (2022); Ecycle, (2022); Envirostream, (2022); Vaulta, (2021); Vaulta, (2022), eleXsys, (2022); Accenture Analysis.

Queensland's cost competitiveness in mining and refining may drive improved competitiveness in active materials, reducing costs for battery manufacturing

Queensland has cost competitiveness in mining and refining of particular raw materials, which can lower costs for active materials production, and potentially cell manufacturing and pack assembly.

The availability and grade of the critical mineral reserves in Queensland could support the cost competitiveness of active materials and electrolyte production. Utilisation of cost competitive active materials and electrolytes, coupled with industry development, would serve to reduce costs for cell manufacturing and therefore pack assembly.

Queensland is not likely to be cost competitive with China given China's scale of production and well-developed supply chains, but there is a growing global market for non-China sources of battery materials. These sources could include Queensland given the State's ESG credentials and R&D into battery materials and technology.

If Queensland can develop its local raw materials capabilities, the State is likely to be able to develop cost effective active materials[1] compared to countries other than China, including South Korea. Utilising these cost competitive active materials and electrolytes in conjunction with industry development could reduce materials and logistics cost for cell manufacturing, and therefore for pack assembly.

Queensland also has the potential to be able to provide future cheap renewable energy.[2] The State is targeting 70% renewable electricity generation by 2032, supported by the $145M QREZ initiatives. It is estimated that wholesale electricity prices in Queensland will be 15 per cent lower on average by 2040 than they would be without the Queensland Energy and Jobs Plan.

Exhibit 11: Battery value chain cost competitiveness[3]

2022

🟢 Queensland advantage
🟡 Neutral
◐ Current disadvantage improved with industry development
🔴 Queensland disadvantage

Mining raw materials | **Refining to chemicals**

🟢 Queensland has cost advantages in mining and refining due to its availability and purity of raw materials, particularly in vanadium, aluminium and graphite, along with its available nickel and cobalt.

	Active materials & electrolytes			**Cell manufacturing**			**Battery pack assembly**		
Cost factor	% of unit cost	China[4]	South Korea[4]	% of unit cost[6]	China[4]	United States[4]	% of unit cost	China[4]	United States[4]
Labour[5]	19	🔴	🔴	9	🔴	🟡	5	🔴	🟡
Energy	2	🔴	🔴	4	🔴	🔴	2	🔴	🔴
Logistics	2	🔴	🟢	7	🔴	◐	8	🔴	◐
Tax[6]	8	🔴	🔴	22	🔴	🔴	18	🔴	🔴
Materials	68	🔴	🟢	59	🔴	◐	67	🔴	◐
Overview		🔴	🟢		🔴	◐		🔴	◐

Notes: 1. Particularly for cathodes, vanadium electrolytes, and potentially iron electrolytes; 2. The greater availability of renewable energy may translate into lower costs because renewable energy is expected to have lower LCOE by 2030 compared to black coal, brown coal and gas; 3. Due to the highly localised nature of integration, service and maintenance and re-use and recycling, the cost competitiveness of Queensland globally is less relevant to developing capabilities; 4. Compared to the largest players in the EV battery value chain; 5. For the manufacturing and professional and scientific services industries; 6. Based on Federal taxes; 7. On average between countries

Source: IEA (2022), Global Supply Chains of EV batteries; ILO (2022), Average monthly earnings of employees; ABS, 2016 Census Data; Ahmed (2017), Cost and energy demand of producing nickel manganese cobalt cathode material for lithium-ion batteries; Orangi & Strømman, (2022), A Techno-Economic Model for Benchmarking the Production Cost of Lithium-Ion Battery Cells; Sakti et al., (2015), A techno-economic analysis and optimization of Li-ion batteries for light-duty passenger vehicle electrification; Argonne National Laboratory, (2019), Modeling the Performance and Cost of Lithium-Ion Batteries for Electric-Drive Vehicles; PwC (2022) Tax Summaries; Accenture (June, 2022), Future Charge- Building Australia's Battery Industries; AEMO (2022), NEM Data Dashboard; IEA (2022) Electricity Market Report July 2022; Energy Council (February, 2022) International Electricity prices: How does Australia compare?; World Bank (2018) Trade Logistics in the Global Economy; Accenture Analysis

Queensland has competitive advantages in reliability, R&D, renewable energy, ESG, and capabilities throughout the vanadium value chain

Exhibit 12: Queensland’s competitive advantages

Segments: 1 ning raw material 2 fining to chemical 3 Active materials manufacturing 4 Cell manufacturing 5 attery pack assembly 6 Integration, service and maintenance 7 Recycling

Reliability

Queensland can be a reliable global participant in the battery market that helps reduce geopolitical risk given its:

- Availability and purity of vanadium and aluminium, and potentially graphite
- Openness to trade and low sovereign risk

Queensland’s **reliability** advantage supports all parts of the value chain

Specialisation and R&D

Queensland can develop its specialisation by:

- Utilising its R&D from research institutions such as James Cook University (JCU), QUT, UQ and Griffith University, which have been supported by the early adoption of R&D support services such as the Advanced Battery Facility and the NBTC
- Growing its innovation into active materials and a diverse range of battery chemistries[1]

Queensland’s **specialisation** advantage supports refining chemicals, active materials, cell manufacturing, pack assembly and integration, service and maintenance.

Long-term renewable energy prospects

Queensland can harness its expected future availability of renewable energy[2] to:

- Reduce the carbon footprint of materials and products throughout the value chain
- Potentially help to drive down energy costs at all points in the value chain[3]

Queensland’s **potential renewable energy** advantage supports all parts of the value chain

ESG credentials

Queensland has strong ESG credentials[4] which can be used to:

- Develop products with solid ESG records, such as the products within the battery chain that are being developed with net zero or carbon neutral emissions targets[5]

Queensland’s **ESG** credentials supports all parts of the value chain

Vanadium

Queensland has 30% of the world’s supply of vanadium, which can support cost competitiveness in:

- Mining and refining vanadium, and developing vanadium electrolyte
- Vanadium flow battery manufacturing

Queensland’s **vanadium** advantage supports upstream and midstream parts of the value chain

Notes: 1. These chemistries include high performance lithium-ion batteries, lithium sulphur batteries, graphene aluminium-ion cells, zinc-bromine batteries, and iron flow packs; 2. 21.4% of electricity produced in Queensland is from renewable sources, with a target of 70% by 2032 as outlined in the Queensland Jobs and Energy Plan; 3. Renewable energy is expected to have lower LCOE by 2030 compared to black coal, brown coal and gas; 4. ESG credentials supported by Queensland’s renewable energy generation, strong human rights, skilled workforce, stable governance and free democracy; 4. Including products from Lava Blue, Critical Minerals Group, and others.

Source: ILO (2022), Average monthly earnings of employees; ABS (2022) Australian Industry, 2018-2019, Catalogue 8155; Bridge & Faigen, (2022), Towards the lithium-ion battery production network: Thinking beyond mineral supply chains; The White House (June, 2022), Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth; CSIRO (June, 2022), GenCost 2022-21; Queensland Government, (2022a), Queensland’s renewable energy target; Queensland Government, (2022b), Focus Area- ESG; Queensland Government, (2021), Queensland’s ESG credentials; Lava Blue, (2022); Critical Minerals Group, (2022); Accenture analysis

Key mineral reserves in Queensland could supply some inputs for some components of both lithium-ion and flow batteries

Queensland has reserves for key battery value chain critical minerals, including vanadium, nickel, cobalt, graphite and aluminium.

Queensland has significant vanadium reserves, but limited lithium reserves. 28% of the global reserve of vanadium is in shallow deposits in the Eromanga basin in central-northern Queensland. The 6.7Mt of vanadium expected from the deposit would represent 2,000 GWh of flow batteries. There has also been a renewed focus on lithium lepidolite and recent exploration activity both in North Queensland offers some future potential. To date no formal reserves have been reported.

Queensland also has some nickel and cobalt reserves. Nickel was historically mined at Greenvale (1972-1992), and the operations at the Sconi project are set to recommence nickel mining in the area from 2024, in addition to mining cobalt. Cobalt is a key cathode material for some lithium-ion batteries, but there are supply chain concerns given that 70% of the world's cobalt was produced by the Democratic Republic of Congo in 2022. Queensland has 1% of the global supply for cobalt due it its 57 kt of reserves. Additionally, there is an estimated 69 kt of partially processed cobalt in the Yabulu refinery tailings.

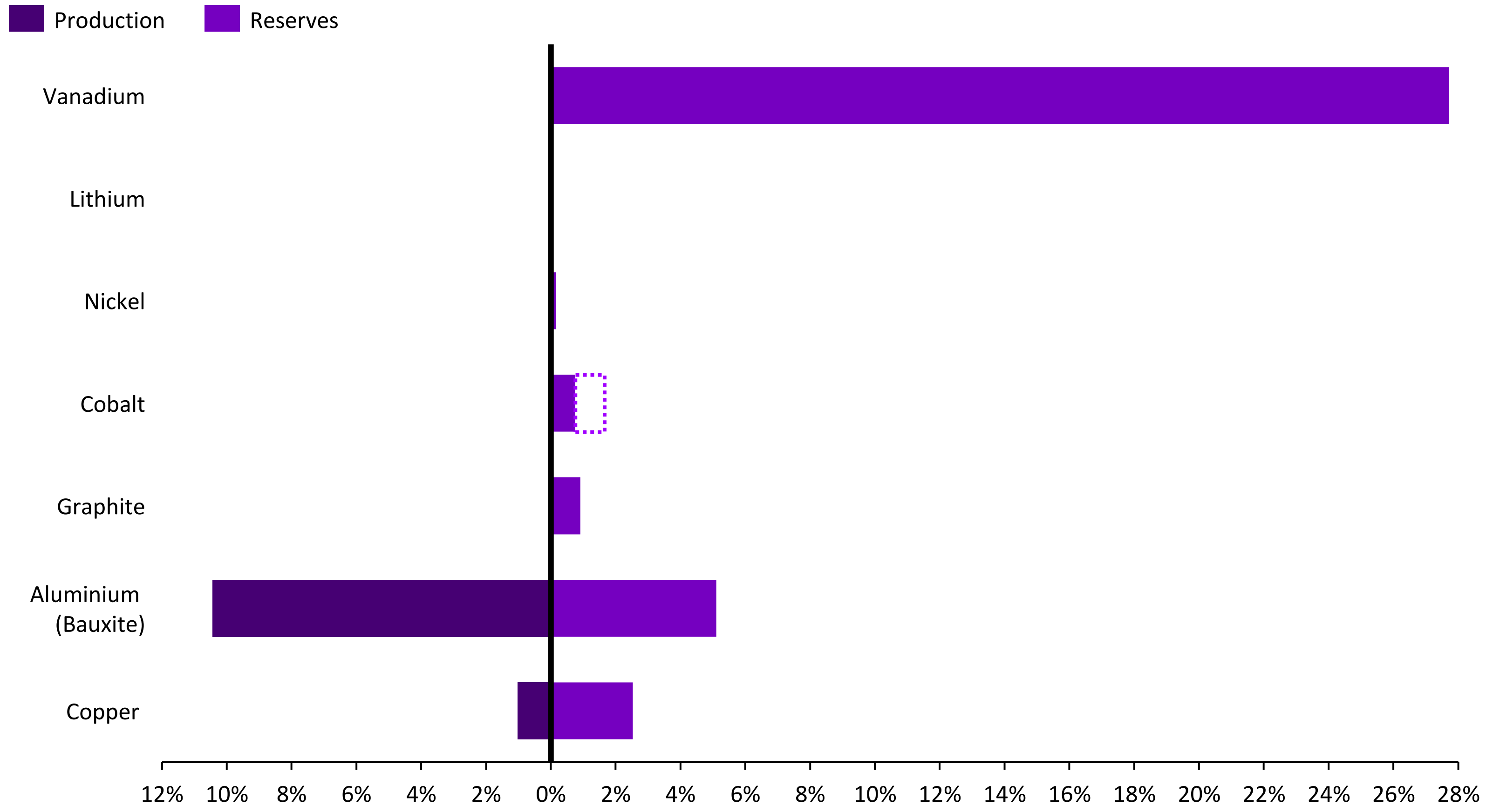
The bauxite mines on the Gulf of Carpentaria produce 10% of the world's bauxite with large reserves supporting planned mine operations until 2057 at Weipa and 2037 at Bauxite Hill.

Queensland also produces 1% of the world's copper, with deposits primarily located around Mt Isa.

However, some of Queensland's deposits are not viable or have not yet reached economic feasibility due to the remoteness and quality of the deposits.

Exhibit 13: Key mineral reserves

Queensland's share of global production volume (kt) and global reserves (kt) of key battery minerals



Source: US Geological Surveys (2022); Department of Natural Resources and Mines (2017); Accenture Analysis

Cell manufacturing is important for industry development, and as such Queensland should focus on developing its cell manufacturing capabilities

Facilitates industry development

Helps foster growth in other parts of the value chain.

The impact of cell manufacturing on the value chain is illustrated by the influence of battery gigafactories in industry dynamics. More tier 1 cell manufacturers are looking to vertically integrate through upstream partnerships with material suppliers. This reduces supply chain risk and gives product certainty to their buyers.[1]

Cell manufacturing:

- Brings together **active materials** into an integrated product, creating local demand for upstream materials.
- Reduces the risk for **pack assembly** facilities of difficulty in obtaining cells,[2] and reduces the costs of transporting heavy and hazardous cells.
- Serves as a source of demand for **recycled** materials, and provides production scrap materials for recycling.[3]

Provides supply chain sovereignty

Provides Queensland made cells and active materials for pack assembly.

The origin of the cell and active materials which go into the cell are an important factor in the **supply chain origins** of a battery pack, as is demonstrated by the local content rules for the EU and US.

Developing commercial cell manufacturing capabilities would enable packs made in Queensland to use a local cell, whilst also utilising Queensland's emerging capabilities in active materials. Enhancing the Australian made qualifications of batteries provides increased domestic sovereignty in the supply chain for Australia and supply chain diversification for overseas end-users.

Drives technology improvements

Leads innovation in cells and active materials.

The cell is a **key determinant of battery performance**, as the cell quality impacts the pack life and durability. The relative importance of improvements in battery cell technology is demonstrated by the international focus on cell manufacturing innovation. There are almost 2 times the number of patents for cells compared to the combined number of patents related to other battery developments.

Cell manufacturers also **dictate the specifications for active materials**, which are the other key primary determinant of battery performance.

Notes: 1. As illustrated by the upstream integration strategies of CATL, BYD, Northvolt and Verkor, the planned joint venture between Volkswagen's cell factories and Umicore, and downstream vertical integration with cell manufacturing for companies like BYD, Tesla and Northvolt; 2. Particularly given the expected global cell shortage from sources other than China; 3. Without production scrap, recycling will take longer to emerge due to the time delay in local batteries being ready for recycling.

Source: Bridge & Faigen, (2022), Towards the lithium-ion battery production network: Thinking beyond mineral supply chains; The White House (June, 2022), Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth; IEA (July, 2022), Global Supply Chains of EV Batteries; IPCEI, (2022), The importance of regional value creation structures in the battery industry; Batteries Europe, (2022), Strategic Research agenda for batteries; IEA, (September, 2022), Innovation in batteries and electricity storage; Accenture analysis

Queensland should move quickly to capture battery value chain opportunities, with pack assembly presenting opportunities in the short-term

Pack assembly provides a quick entry point for Queensland in the short-term, while it builds its capabilities in other areas of the value chain such as cell manufacturing.

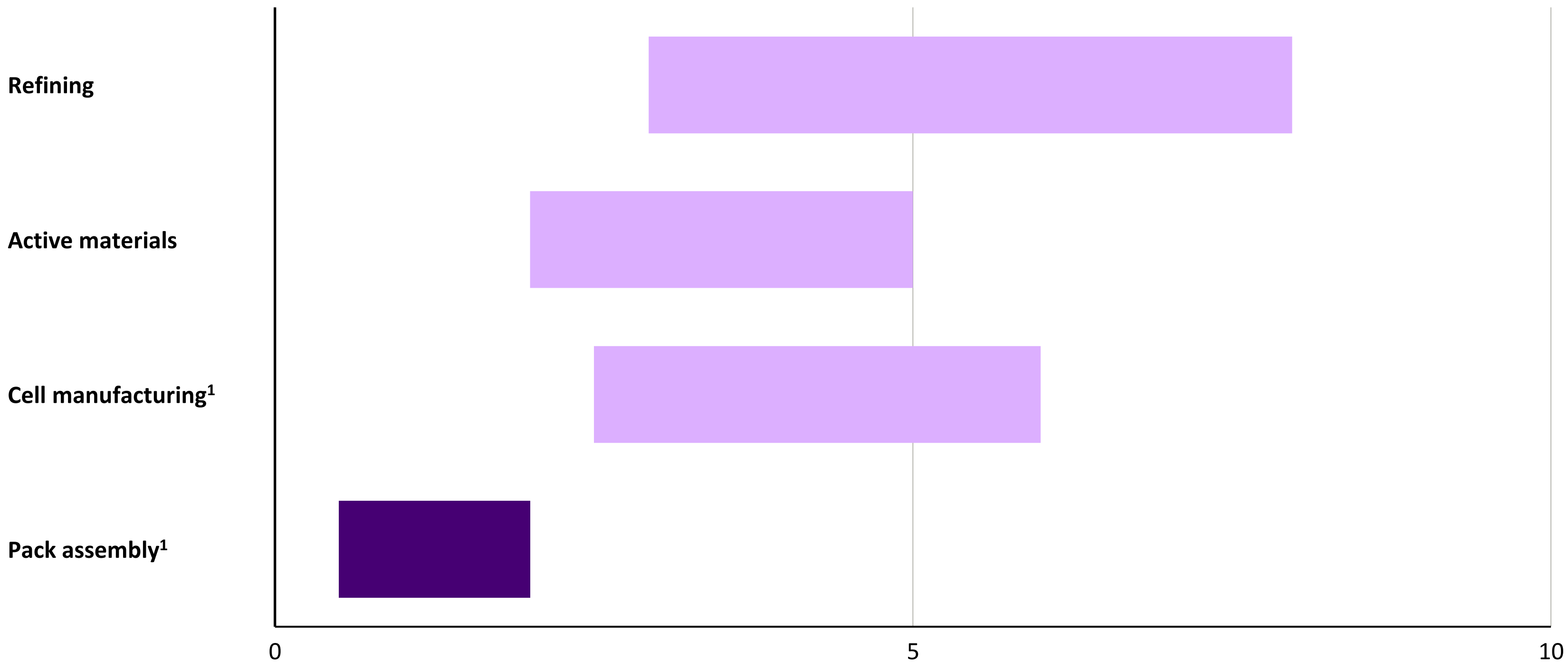
The battery value chain is growing at 20% a year, and moving quickly to capture opportunities will be important given the pace of change in the industry.

Queensland should build out its capabilities in pack assembly, as it is a relatively quick to production part of the value chain. The lead time for battery pack production is shorter than the lead times for midstream activities such as refining, active materials production, and cell manufacturing.

Given that Queensland will need batteries to support its renewable energy targets, local pack assembly capabilities will ensure that Queensland can take advantage of its own demand for batteries. Pack assembly close to the end-use location provides costs advantages, which is why pack assembly facilities are typically co-located with sources of demand.

Exhibit 14: Typical lead times to reach production in EV battery supply chain

Number of years, 2022



Notes: Based on lead times in Norway, Germany and Sweden.

Source: IEA (July, 2022), Global Supply Chains of EV Batteries; McKinsey (January, 2022), Capturing the battery value- chain opportunity; IEA, (September, 2022), Innovation in batteries and electricity storage; IPCEI, (2022), The importance of regional value creation structures in the battery industry; Norwegian Ministry of Trade, Industry and Fisheries, (June, 2022), Norway's battery strategy; The White House (June, 2022), Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth; Corvus, (2018); Siemens, (2018); Siemens (December, 2018), Annual Report AS; Morrow, (2020); BMW (2020); Freyr, (2020); Freyr, (2021); Northvolt, (2022); Morrow, (2022); BMW (2022); Accenture analysis

Queensland’s battery value chain activity is focused in the North and South East regions of the State

Queensland has mining and refining activity in the North West and North, along with refining and midstream-downstream value chain activities in the South East.

Queensland has a variety of activities which contribute to the battery value chain ecosystem:

North West Queensland has mineral deposits, including graphite deposits, vanadium deposits and lithium deposits, along with mines such as the Greenvale nickel mine and the St Elmo, Richmond, Vecco and QEM vanadium mines.

North Queensland has JCU, which engages in research on the processing of raw materials, and refining activity due to the TECH nickel refinery, along with tungsten deposits at Mount Carbine and nickel deposits west of Townsville.

Central Queensland is developing refining capabilities through AlphaHPA’s investment in Gladstone.

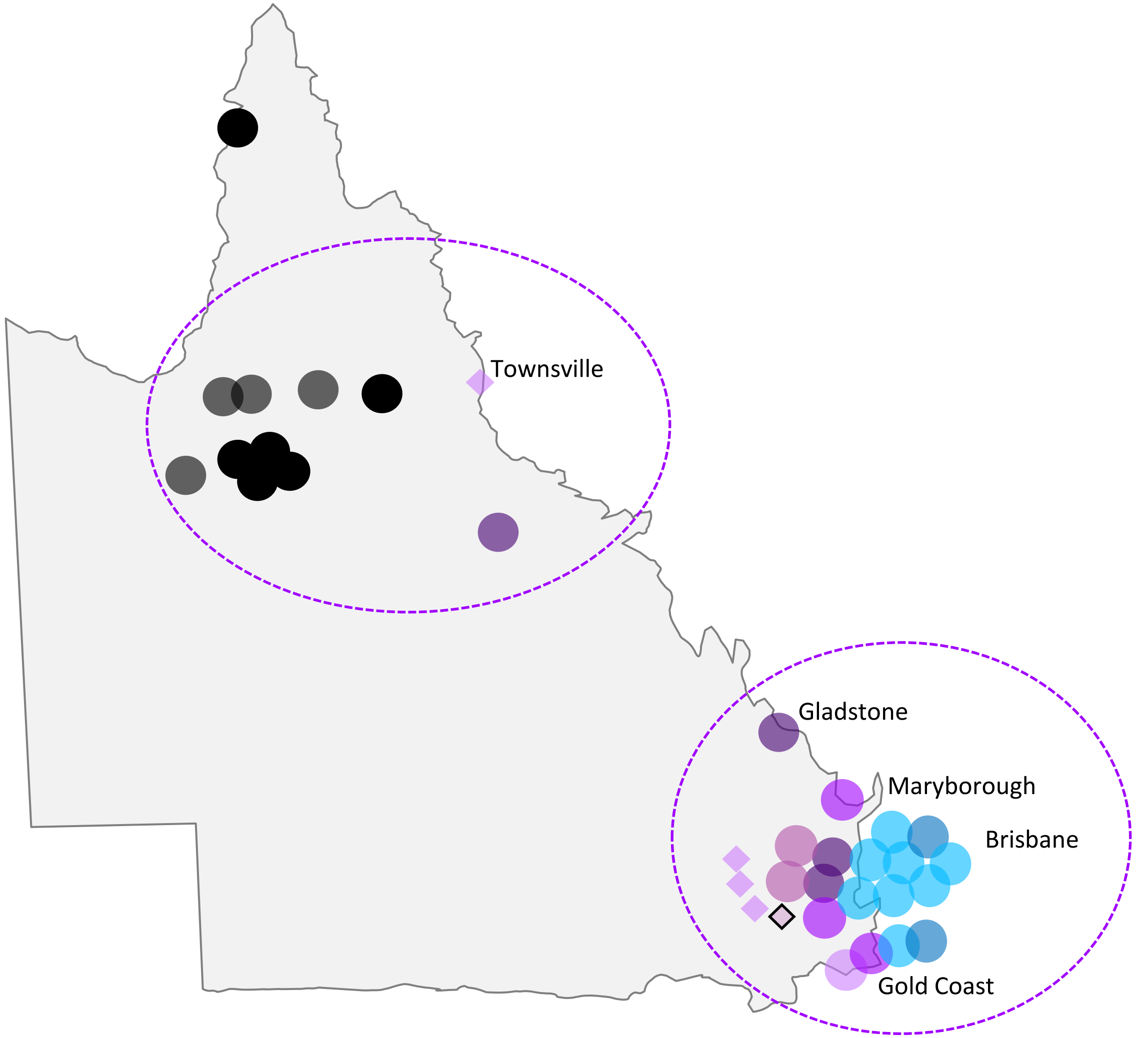
Wide Bay Burnett is developing iron flow battery assembly capability through ESI Asia Pacific’s investment in Maryborough.

South East Queensland is developing commercial scale cell manufacturing and pack assembly through Feline, and research at Griffith University, QUT, and UQ. GMG are also active in cell manufacturing and RedEarth in battery pack assembly.

South East Queensland also has integration, service and maintenance capabilities through Redback Technologies, RedEarth, Prohelion, Vaulta, eleXsys, BusTech, Tritium Charging and Evie Networks, along with research and testing at the NBTC. Everledger are active in re-use and recycling.

Key
Industry location for:
● mineral deposits
● mines
● refining
● active materials
● cell manufacturing
● pack assembly
● integration, service and maintenance
● re-use and recycling

Non-industry centre:
◆ university
◇ research hub



Source: Lithium Energy (2022); Australian Mines (2022); Sconi, (2022); Queensland Government (2022); QEM (February, 2022); AFR (2022); Queensland Government (2022); Rio Tinto (2022), Aeon Metals (2022), Alpha HPA (2022); Lava Blue (2022); QPM (October, 2022); QPM (June, 2022); Vecco Group (2022a); Vecco Group (2022b); Graphene Manufacturing Group, (2022), AnteoTech (August 2022); Lithium Australia (July, 2022); Magnis (2022); Century Yuasa (2022); Feline (2022); ESI Asia Pacific, (2022); Tritium Charging (2022); RedEarth (2019); Queensland Government (2018); Prohelion (2022); Queensland Government (2022); Queensland Government (2022), FBI CRC (March, 2022); Everledger (July, 2022); QUT (2022); Griffith University (2022), Centre for Catalysis and Clean Energy; Griffith University (2022); UQ (2022)

03

Developing Queensland’s battery industry could generate up to $1.3B of economic activity and 9,100 jobs by 2030

There are two potential paths for the future development of Queensland’s battery industry

Value potential[1,2]

Risk

Path 1

Local and specialised industry

Queensland focuses its efforts on fostering existing industry development, aiming to capture demand within Queensland while providing support for alternative technologies.

In this scenario Queensland should target 3-5 GWh of production capacity by 2030, growing production to focus on local demand for stationary and specialised mobility storage.

$590M
in gross value added, 2030

4,100
Jobs, 2030

◔

The smaller scale gives Queensland a higher chance of realising the value potential and utilizing government investment effectively.

However, the slower approach won’t position Queensland to win in other markets, and it will limit the ultimate size of the industry it can develop.

Path 2

Leading Australian industry

Significant industry investment accelerates growth to capture more market share, while continuing to support the existing industry and alternative technology opportunities.

In this scenario, Queensland should target at least 13-15 GWh of production capacity by 2030, focusing on stationary storage, and using this scale and speed to gain an early mover advantage within Australia. This pathway builds on pathway 1, while still providing support to emerging technology and local industry.

$1.3B
in gross value added, 2030

9,100
Jobs, 2030

◕

This scenario is contingent on Queensland capturing an early mover advantage within Australia and establishing a dominant market position.

Additionally, Queensland will need to become globally cost competitive in the ESS market to capture international demand.

Notes: 1. Scenarios are based on assumptions of demand capture in the Queensland, Australian and International battery markets. Path 1: QLD captures 100% of demand from QLD, but is not able to capture any demand outside of QLD. Path 2: QLD captures 100% of QLD demand, 40% from the rest of Australia, and 1% internationally. Further detail found in appendix; 2. There is potential for the value realised to be higher than stated, given the rapidly evolving demand profile for batteries globally and domestically, as well as the recent supply challenges for multiple critical minerals having significant price effects

Source: Accenture analysis

Low ◔ ◑ ◕ ● High

Scale at pace could give Queensland an early mover advantage, enabling it to capture more demand domestically, and potentially internationally

Queensland could focus on applications where it has the greatest ability to meet future demand

Queensland's local demand for stationary storage and select mobility applications, such as electric trucks and buses, have the lowest barriers for industry to capture. Much of this demand is government driven through grid storage or vehicle fleet electrification, and can be guaranteed for manufacturers with local content rules. Additionally, Queensland can leverage it's existing capabilities in specialised application to target defence, mining and off-grid stationary storage. Under the local and specialised industry path, Queensland could target meeting this local demand for stationary storage, select mobility applications, and specialised applications.

An early mover advantage gives Queensland industry a better chance of capturing demand across the rest of Australia, as it can establish brand recognition and customer loyalty as demand grows for batteries. Under the leading Australian industry path, Queensland could leverage this early mover advantage to capture demand across Australia.

Queensland's ability to compete on cost is the most significant barrier to meeting international demand, particularly in EV batteries. If Queensland can reduce production costs, and position it's battery brand as reliable, green, and as a source of diversification then capturing some global stationary storage demand may be possible. Key international markets for Queensland to target could include South East Asian countries such as Malaysia or Thailand who both have significant future grid-stationary storage demand and close geographical proximity to Australia.

Exhibit 15: Addressable market for various battery applications

Local and specialised industry, target demand

Leading Australian industry, additional target demand

Fewer barriers 🟢 🟠 🔴 Significant barriers

	Application (not exhaustive)	Addressable market	Potential size 2030[1]	Ability to meet demand
Stationary storage	Stationary storage	International	670 GWh	🔴
	Grid stationary storage[2]	Queensland	14 GWh	🟢
		Rest of Australia	27 GWh	🟠
	Residential and behind the meter stationary storage[3]	Queensland	7 GWh	🟢
		Rest of Australia	18 GWh	🟠
	Off-grid stationary storage[4]	Queensland	1 GWh	🟢
		Rest of Australia	5 GWh	🟠
Specialised storage	Defence	Australia	1 GWh	🟢
	Mining[5]	Queensland	0.7 GWh	🟢
		Rest of Australia	2.6 GWh	🟠
Mobility	Electric passenger vehicles	International	7,000 GWh	🔴
		Australia	133 GWh	🔴
	Electric trucks and buses	Queensland	3 GWh	🟢
		Rest of Australia	11 GWh	🟠

Notes: 1.Total cumulative demand from 2023-2030 inclusive; 2. Based on the AEMO Step Change scenario, for East Coast of Australia; 3. Distributed energy storage includes grid connected batteries installed to support the customer's own load as well as coordinated systems in a virtual power plant arrangement; 4. Based on 2% of Australian population, average household size of 2.6 people and average battery size of 42kWh; limited data makes this market challenging to size; 5. Based on 20% of Australian mines electrifying, with an average of 15 haulers per mine with a 2MWh battery per hauler and a battery replacement after 2.5 years as well as a 50MWh battery per mine electrifying

Sources: Wood Mackenzie (2022); Renew Economy (2022); Energy Storage News (2022); SolarRun (2020); Accenture analysis; Expert interviews

Queensland’s opportunities

There are six enablers for Queensland to develop a battery industry

Low challenge 🟢 🟠 🔴 High challenge

The enablers for industry growth are…	Impacted value-chain segment							Rating	Rationale
1. Access to customers The readiness of domestic and international customers to purchase intermediate and final battery products from Australian industries			✓	✓	✓	✓		🔴	• While there are significant sources of demand domestically, large global manufacturers and no domestic EV manufacturing industry may create challenges for some businesses in sourcing customers at significant scale
2. Access to technology and infrastructure Ease of access to the technology and infrastructure required to bring new products and services to market in the battery value-chain, such as electrolyte IP or a demonstration plant	✓	✓	✓	✓	✓			🔴	• There are high fixed costs and significant expertise required to develop a proof of concept and commercialise a product
3. A skilled workforce The availability of, and pipeline for, skilled workers, particularly in specialised technical roles such as chemical engineers, electrical engineers and industrial chemists			✓	✓	✓	✓		🔴	• There is a limited pipeline of skilled workers with battery relevant skills, and firms have difficulty finding the quality and quantity of talent
4. Access to project capital Volume of capital available and the risk appetite of capital providers for Australian industry projects	✓	✓	✓	✓	✓			🟠	• Challenges with sourcing capital is leading to some projects being delayed or cancelled
5. Regulation, policy support, and industry standards The existence and clarity of appropriate regulation, industry standards and policy support for the battery industry in Queensland		✓	✓	✓	✓	✓	✓	🟠	• There is limited existing policy, regulation and standards for industry, however there is scope to address these issues via the Queensland Battery Industry Strategy, and the Queensland Energy and Jobs Plan
6. Access to key supplies Availability of inputs required for production, and coordination of relationships with suppliers		✓	✓	✓	✓			🟠	• There will be significant lead times on developing some of Queensland’s prospective mineral resources, but key supplies can be sourced from local jurisdictions, such as WA

Source: Expert interviews; Accenture analysis

Five key initiatives will incentivise firms to locate in Queensland, supporting them to access customers, technology, people and capital

	Enabler addressed	Key initiative
01	Building a customer base	**Prioritise local content in government procurement** The electrification of the energy grid and government transport fleets will require significant battery purchasing by Queensland and other state governments, providing a large source of demand
02	Building a customer base	**Assist industry with trade promotion, and the development of a Queensland battery brand** Developing and promoting Queensland's battery brand domestically and internationally could support industry to attract new sources of demand
03	Access to technology & infrastructure	**Develop a Queensland Battery Industrialisation Centre** By developing a Battery Industrialisation Centre, Queensland could provide a hub for innovation and collaboration, link academia and industry to drive R&D, and support commercialisation activity
04	Finding skilled workers	**Develop battery specific education, upskilling and reskilling programs** Battery specific education courses across VET and university programs could support talent flows into the industry and provide reskilling opportunities for workers exiting declining industries
05	Accessing project capital	**Invest in attracting lithium-ion battery and active materials manufacturing firms** Providing Government co-investment could de-risk the up-front capital costs for larger manufacturing firms, incentivising them to locate in Queensland and accelerate the State's production capacity

Source: Expert Interviews; Accenture analysis

Capturing more domestic demand can increase the potential size of the industry, and drive downstream value in integration & services

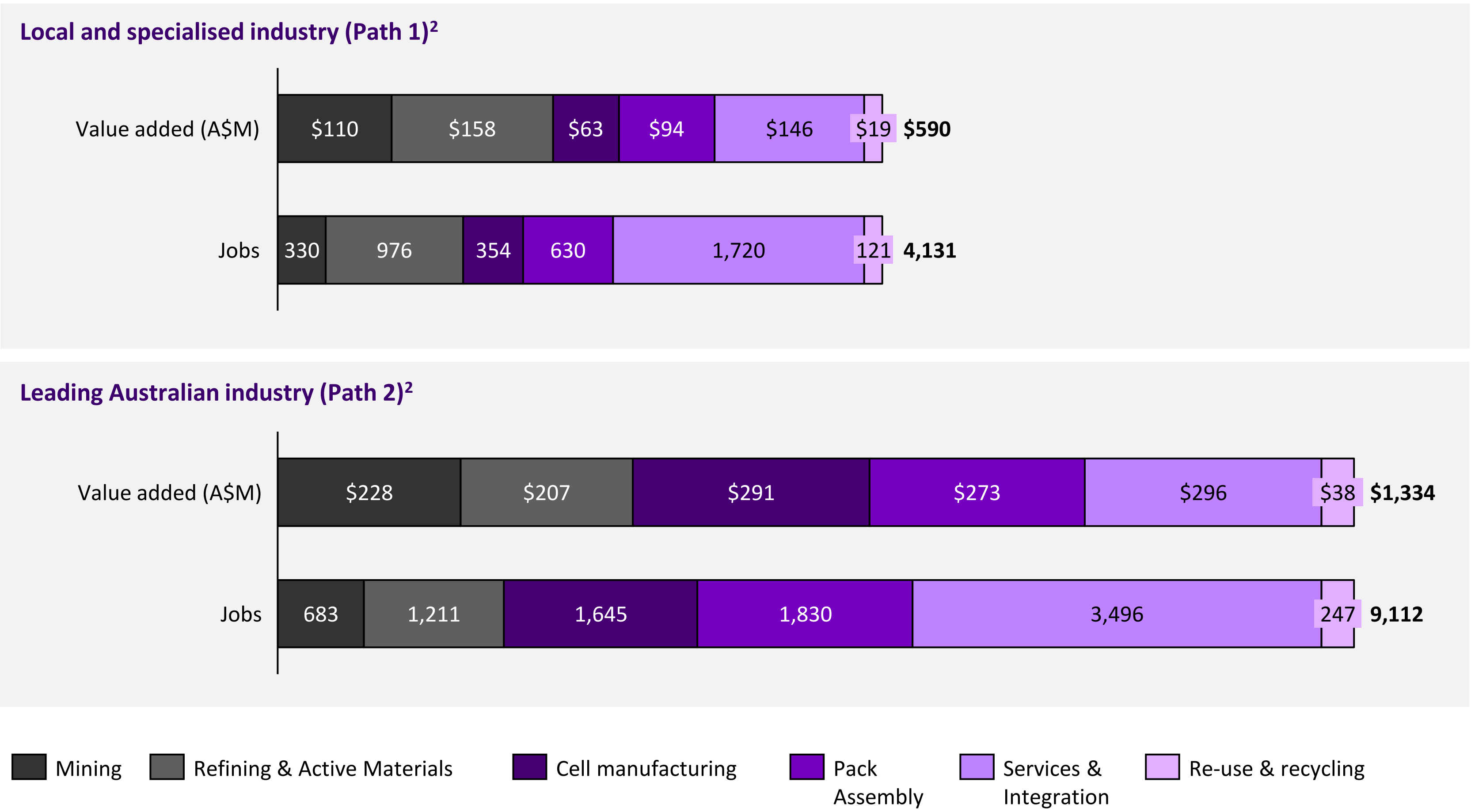
Integration and services makes the most significant contributions to value and job creation.

In both pathway 1 and 2, integration and services accounts for the majority of job creation across the value chain. This value could largely be realised through the construction, integration and maintenance of stationary storage batteries in Queensland and Australia

Pathway 2 would have relatively lower job creation in services and integration due to the export of battery products interstate and overseas.

Without a domestic automotive industry, EV battery production would require significant exports, and the majority of the value add and jobs created from this integration and services activity would not be captured domestically.

Exhibit 16: GVA and Job[1] potential by value chain segment, pathway 1 and pathway 2, 2030



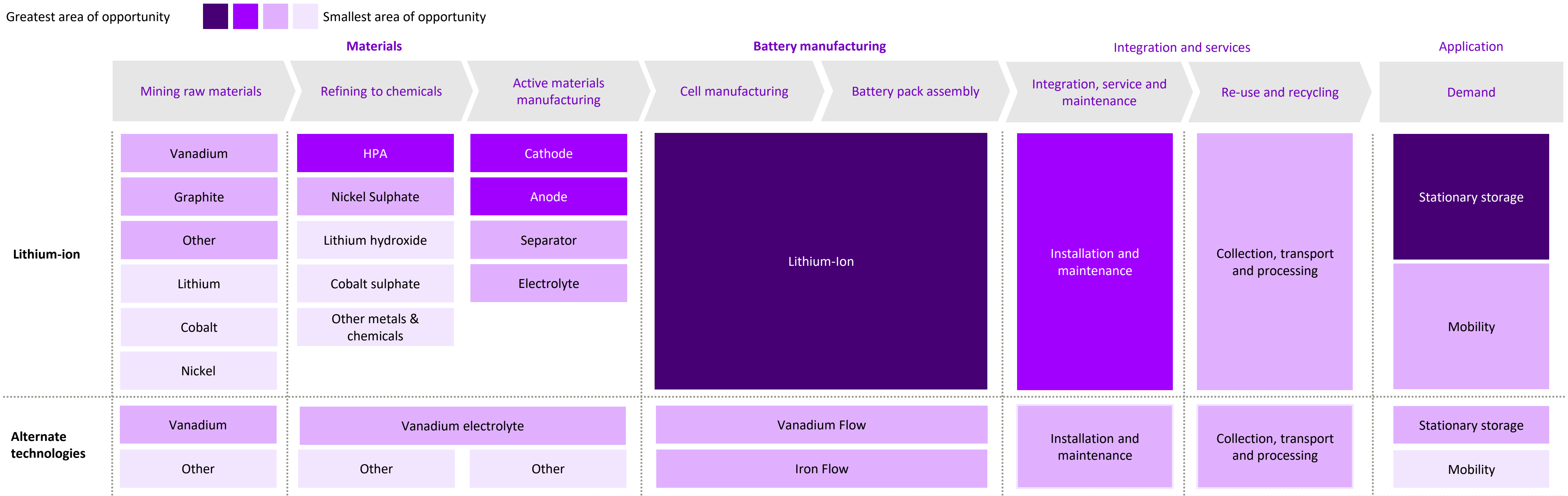
Notes: 1. Direct jobs required to operate and maintain activity. Does not include temporary construction jobs.; 2. There is potential for the value realised to be higher than stated, given the rapidly evolving demand profile for batteries globally and domestically, as well as the recent supply challenges for multiple critical minerals having significant price effects

Source: Accenture analysis

04

Appendix A1.
Value chain deep-dives

The most attractive opportunity for Queensland is lithium-ion manufacturing, with a focus on stationary storage applications



Greatest area of opportunity ■ ■ ■ □ Smallest area of opportunity

	Materials			Battery manufacturing		Integration and services		Application
	Mining raw materials	Refining to chemicals	Active materials manufacturing	Cell manufacturing	Battery pack assembly	Integration, service and maintenance	Re-use and recycling	Demand
Lithium-ion	Vanadium Graphite Other Lithium Cobalt Nickel	HPA Nickel Sulphate Lithium hydroxide Cobalt sulphate Other metals & chemicals	Cathode Anode Separator Electrolyte	Lithium-Ion		Installation and maintenance	Collection, transport and processing	Stationary storage Mobility
Alternate technologies	Vanadium Other	Vanadium electrolyte Other	Other	Vanadium Flow Iron Flow		Installation and maintenance	Collection, transport and processing	Stationary storage Mobility
Rationale	Queensland's resource strengths are in vanadium, aluminium and potentially graphite. Queensland could leverage these materials most effectively if vanadium flow battery technology is more widely adopted.	There is a strong global market for refining and active materials manufacturing. Queensland has strong existing and developing capabilities in HPA, nickel and cobalt refining, and cathode production. Queensland could also utilise its vanadium and iron resources to develop cost competitive vanadium and iron electrolytes.		Queensland's capabilities in lithium-ion battery manufacturing are currently limited, however it is the most significant opportunity to create value and further develop a battery industry. Lithium-ion is, and is expected to be, the dominant battery technology other than lead-acid going forward. Vanadium presents an opportunity for Queensland, particularly if vanadium flow batteries have more widespread adoption or cost improvements.		Growth in battery use and installation in Queensland could create demand for local installation and maintenance capabilities	Re-use and recycling will be critical to batteries in long-term, but will take time to develop into a substantial industry because the stock of batteries needs to increase	Queensland has the greatest ability to compete in Lithium-ion stationary storage unless alternate technologies are adopted. It's unlikely Queensland can compete in mobility applications

Source: Lithium Energy (2022); Australian Mines (2022); Sconi, (2022); Queensland Government (2021); QEM (February, 2022); AFR (2021); Queensland Government (2022); Rio Tinto (2022), Aeon Metals (2021), Alpha HPA (2022); Lava Blue (2022); QPM (October, 2021); QPM (June, 2022); Vecco Group (2022a); Vecco Group (2022b); Graphene Manufacturing Group, (2022), AnteoTech (August 2022); Lithium Australia (July, 2022); FBI CRC (July, 2020); NBTC (2022); Magnis (2022); Century Yuasa (2022); Feline (2022); ESI Asia Pacific, (2022); Li-S, (2022); Tritium Charging (2021); RedEarth (2019); Queensland Government (2018); ARENA (2022); ARENA (2021); Prohelion (2022); Queensland Government (2022); Queensland Government (2022), FBI CRC (March, 2020); Everledger (July, 2021); RJ Batteries (2022); ABRI (2020); Powercell (2022); Ecycle, (2022); Envirostream, (2022); Accenture analysis

Queensland has opportunities to mine the raw materials for the battery industry, but the scale varies by mineral

Scale of opportunity | Lower ◔ ◑ ◕ ● Higher

Criteria | **Summary of opportunity** | **Rating** | **Revenue and investment**

Attractiveness

- Significant global market for lithium due to its use in lithium-ion batteries, which is the predominant battery technology other than lead-acid.
- Vanadium, graphite, aluminium, nickel and cobalt are in demand for battery active materials and electrolytes.

Rating: ◔

$8B in global revenue by 2030[2]

SQM
Pilbara Minerals
JINCHUAN 金川
BHP

Capabilities in Queensland

Current and planned activities

- $2B+ of planned vanadium mining to produce 35,000 tonnes of vanadium pentoxide and 12,000 tonnes of vanadium pentoxide flake p.a.
- $1.5B of planned nickel and cobalt mining to produce 71,000Mt and 7,000Mt dry metric tonnes respectively.[1]

Queensland’s competitive advantages

- 28% of global vanadium reserves.
- Shallow vanadium deposits, which reduces mining costs.
- Aluminium reserves of sufficient grade and scale to already be commercialised.
- Graphite reserves with a pure grade of 16%.

Rating: ●

$2.5-5B in current Queensland investment[3]

Current

RioTinto

Planned

QEM
Richmond Vanadium Technology
VECCO Group
MULTICOM

Notes: 1. Produced over 6 years; 2. Global revenue in USD; 3. Current investment in AUD

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; IEA (July, 2022), Global Supply Chains of EV Batteries; Goldman Sachs (March, 2022), Electric Vehicles: What’s Next VII: Confronting Greenflation; IEA, (May, 2022), Critical minerals threaten a decades-long trend of cost declines for clean energy technologies; IEA, (May, 2021), The Role of Critical Minerals in Clean Energy Transitions; Lithium Energy (2022); Australian Mines (2022); Sconi, (2022); Queensland Government (2021); QEM (February, 2022); AFR (2021); Queensland Government (2022); Rio Tinto (2022), Aeon Metals (2021); Accenture Analysis

These opportunities can be captured through Queensland's competitive advantage in mining vanadium and aluminium

Strength | Lower ⬜ 🟪 🟪 Higher

		Vanadium	Lithium	Aluminium	Graphite	Nickel	Cobalt	
Size and attractiveness of opportunity	Global opportunity	$0.1B-$0.3B of revenue[1,2]	$3B[2]		$2B[2]	$2B[2]	$1B[2]	• The largest opportunities by revenue from the battery value chain are in nickel, lithium and graphite.
	Importance in value chain	Significant determinant of 33% of vanadium flow battery pack capital costs[3]	11% of battery pack price[4]	0.5% of battery pack price[4]	5% of battery pack price[4]	8% of battery pack price[4]	2% of battery pack price[4]	• Lithium and nickel are key contributors to battery pack prices, and are important capabilities in reducing materials and logistics costs due to the use of lithium in electrolyte, and the use of lithium and nickel in some cathodes. Vanadium is a key contributor to vanadium flow battery prices through its use in vanadium electrolyte.
Capabilities	Current and planned activities	Investment from Multicom, QEM, Vecco and Richmond vanadium	Limited investment outside of exploration from Strategic Metals Australia[5]	Investment from Rio Tinto into bauxite production	Limited investment[6]	Investment from Sconi and planned investment from Aeon Metals		• Queensland has current mining of bauxite out of the Weipa mines, planned vanadium mining out of projects from Multicom, QEM, Vecco Debella and Richmond vanadium, planned nickel and cobalt mining out of the Sconi mine, and nickel and cobalt exploration from Aeon Metals.
	Cost competitiveness	28% of world's reserves, medium grade, shallow deposit	0% of world's reserves[7]	5% of world's reserves, medium-high grade	1% of world's reserves, high grade	0.2% of world's reserves, lower grade	2% of world's reserves, including reserves in tailings	• Queensland has the greatest cost competitiveness in vanadium, aluminium and graphite due to the availability and grade of reserves, which reduces mining costs. The vanadium reserves are in shallow deposits and some cobalt reserves are in tailings, which would reduce mining costs.
	Ability to provide differentiated products							• Queensland has the highest ability to provide differentiated products for the materials with available and higher grade reserves, such as vanadium, aluminium and graphite.
	Skills of labour			Current skills in bauxite at Weipa mines				• Skilled Queensland mining workforce, and training at the Mackay Resources Centre of Excellence • Current bauxite mining workforce

Notes: 1. Higher revenue if early adoption of vanadium redox flow batteries; 2. Revenue from expected 2030 sales of materials to be used in the battery value chain, using current prices, scaled by the $8b revenue opportunity for mining raw materials for batteries in 2030; 3. The concentration of vanadium, volume of solution and the cost of vanadium determine the cost of vanadium solution, which is 33% of battery pack capital costs; 4. Expected percentage of 2025 battery pack prices; 5. Strategic Metals Australia made a pegmatite discovery near Georgetown; 6. Lithium Energy is engaging in testing of the Burke Graphite deposit; 7. Lithium pegmatites in the Georgetown region which could be explored

Sources: Goldman Sachs, (June, 2022), Batteries: The Greenflation Challenge II: Raising battery price forecasts; addressing six key investor debates (March, 2022), IEA, (May, 2021), The Role of Critical Minerals in Clean Energy Transitions; Lithium Energy (2022); Australian Mines (2022); Sconi, (2022); Queensland Government (2021); Vecco Group, (2022); QEM (February, 2022); Queensland Government (2022); Lithium Energy, (2021); Rio Tinto (2022), Aeon Metals (2021); Strategic Metals Australia, (2022); Accenture Analysis

There are opportunities for Queensland to play a key role in refining minerals that are mined locally

Scale of opportunity | Lower ◔ ◑ ◕ ● Higher

Criteria	Summary of opportunity	Rating	Revenue and investment	Key players
Attractiveness	- Large global market for lithium hydroxide and lithium carbonate, due to its importance in lithium-ion batteries. - Vanadium pentoxide, alumina, nickel sulfate, cobalt sulfate and graphite are in demand for a range of battery applications.	◕	**$74B** in global revenue by 2030[1]	Livent GEM 格林美 资源有限 循环无限 Recycling for future! Freeport Cobalt
Capabilities in Queensland	***Current and planned activities*** - Lava Blue, AlphaHPA, Vecco Debella and QPM TECH are planning on producing 21,000 tonnes of HPA per annum collectively. - QPM TECH is planning on producing 16,000 tonnes of nickel sulfate and 1,800 tonnes of cobalt sulfate. ***Competitive advantages*** - Locally mined vanadium, aluminium, nickel, cobalt and graphite would provide a cost advantage for Queensland refining.	●	**$0.5-2.5B** in current Queensland investment[2]	***Current*** RioTinto ***Planned*** QEM GMG Graphene Manufacturing Group Richmond Vanadium Technology Queensland Pacific Metals VECCO Group Lava Blue Multicom Alpha HPA

Notes: 1. Global revenue in USD; 2. Current investment in AUD

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; IEA (July, 2022), Global Supply Chains of EV Batteries; Vecco Group, (2022); Sconi, (2022); Multicom (2022); QEM (February, 2022); Vecco Group, (2022); Queensland Government, (2022); Horizon Minerals, (2022); Rio Tinto (2022); QUT, (2022); AlphaHPA, (2020); QPM, (2021); GMG, (2022); Accenture Analysis

Similar to mining, these opportunities are predominately in refining vanadium and aluminium

Strength | Higher ▨ ▨ ▨ Lower

		Vanadium	Lithium	Aluminium	Graphite	Nickel	Cobalt	
Size and attractiveness of opportunity	Global opportunity	$1-3B of revenue[1]	$25-30B[1]		$15-20B[1]	$20-25B[1]	$10-15B[1]	• The largest refining revenue opportunities for the battery value chain are in lithium, nickel and graphite.
	Importance in value chain	Significant determinant of 33% of battery pack capital costs	11% of battery pack price	0.5% of battery pack price	5% of battery pack price	9% of battery pack price	2% of battery pack price	• Lithium and nickel are key contributors to battery pack prices, and are important refining capabilities in reducing materials and logistics costs due to the use of lithium in electrolyte, and the use of lithium and nickel in some cathodes. Vanadium is a key contributor to vanadium flow battery prices through its use in vanadium electrolyte.
Capabilities	Current and planned activities	Potential refining from Multicom, QEM or Vecco	Limited investment	Investment from Lava Blue, AlphaHPA, Vecco Debella and QPM TECH[2]	Investment from GMG into graphene production[3]	Investment from Sconi and QPM TECH[4]		• Pilot common user vanadium processing infrastructure, planned HPA production from Lava Blue, AlphaHPA, Vecco Debella and QPM TECH, planned graphene production from GMG, and planned nickel and cobalt sulfate production from Sconi and QPM TECH.
	Cost competitiveness	28% of world's reserves, medium grade	0% of world's reserves[5]	5% of world's reserves, medium-high grade	1% of world's reserves, high grade	0.2% of world's reserves, lower grade	2% of world's reserves, including in tailings	• Queensland has the greatest cost competitiveness in vanadium, aluminium and graphite due to the availability and grade of reserves, which reduces mining costs.
	Ability to provide differentiated products	Significant reserves of medium grade	Limited reserves	Higher purity HPA	Graphene using a proprietary process	Production of low emissions high grade refined products using imported materials		• Queensland can produce more differentiated refined chemicals by using higher grade and more available reserves, unique processes such as GMG's graphene production, and the research into materials processing at JCU, UQ and QUT.
	Skills of labour							• Skills at JCU, UQ and QUT,[6] training at the Mackay Resources Centre of Excellence, and emerging skills from companies with planned activities.

Notes: 1. Revenue from expected 2030 sales of materials to be used in the battery value chain, scaled by the $74b revenue opportunity for mining raw materials for batteries; 2. In addition to the aluminium refining from Rio Tinto; 3. Using natural gas instead of mined graphite; 4. Nickel laterite projects employing PAL typically do mining and refining to an intermediate, or often a finished product, in the same facility; 5. Lithium pegmatites in the Georgetown region which could be explored; 6. Through research on materials processing at JCU, and battery grade materials testing and qualification at QUT and UQ.

Sources: Goldman Sachs (March, 2022), Electric Vehicles: What's Next VII: Confronting Greenflation; IEA, (May, 2022), Critical minerals threaten a decades-long trend of cost declines for clean energy technologies; IEA, (May, 2021), The Role of Critical Minerals in Clean Energy Transitions; Vecco Group, (2022); Sconi, (2022); Multicom (2022); QEM (February, 2022); Vecco Group, (2022); Queensland Government, (2022); Horizon Minerals, (2022); Rio Tinto (2022); QUT, (2022); AlphaHPA, (2020); QPM, (2021); GMG, (2022); Accenture Analysis

Queensland has the capabilities to produce cathodes, anodes, and electrolytes, which will help establish a local battery industry

Scale of opportunity | Lower ◔ ◑ ◕ ● Higher

Criteria	Summary of opportunity	Rating	Revenue and investment	Key players[3]
Attractiveness	• Global opportunities in anodes and cathodes because of the attractive market size and supply shortages. • Opportunities to produce vanadium electrolyte, particularly if there is early adoption of vanadium redox flow batteries.	◑	**$24B** in global revenue by 2030[1]	Sumitomo Corporation 杉杉股份 Shanshan BTR 贝特瑞
Capabilities in Queensland	***Current and planned activities*** • AnteoTech is developing silicon anodes, and VSPC is planning on producing 10,000 tonnes of LFP cathode powder per annum. • UQ, QUT and Griffith University have research on active materials, particularly in cathodes and anodes. ***Competitive advantages*** • Queensland has cost advantages in iron and vanadium electrolytes, as there is mining of raw materials which could be used in to reduce logistics and material costs. • Queensland could produce differentiated anodes and cathodes for high performance cells and niche applications given the strength of R&D into these active materials.	◕	**$50-100M** in current Queensland investment[2]	***Current*** Feline Advancing Technologies ***Planned*** AnteoTech Pure Battery Technologies VECCO Group VSPC

Notes: 1. In USD; 2. Current investment, in AUD; 3. Key players globally also include Tianjin B&M Science and Technology, Shenzhen Dynanonic, Ningbo Shanshan, Zhuhai Enjie New Material Technology, and Zhangjiagang Guotai-Huarong New Chemical Materials.

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; IEA (July, 2022), Global Supply Chains of EV Batteries; Source: AnteoTech (August 2022), Annual Report 2022; Lithium Australia (July, 2022), Investor Presentation; FBI CRC (July, 2020), Li-ion battery cathode manufacture in Australia; NBTC (2022), Electrochemical Testing of Li-ion Battery Materials; The Faraday Institution (January, 2020), High-energy battery technologies; Batteries Europe (November, 2021), Roadmap on Advanced Materials for Batteries; Lagadec et al., (January, 2019), Characterization and performance evaluation of lithium-ion battery separators; Orangi & Strømman, (2022), A Techno-Economic Model for Benchmarking the Production Cost of Lithium-Ion Battery Cells; QUT (2022); Griffith University (2022); UQ (2022); Pure Battery Technologies (2022a); Pure Battery Technologies (2022b); Vecco Group (2022); BNEF, (July, 2017), Lithium-ion Battery Costs and Market; Lithium Australia, (April, 2018); AFR, (April, 2021); UQ (June, 2018); Accenture Analysis

Queensland has competitive advantages in producing vanadium and iron electrolytes, and emerging R&D into cathode and anode innovation

Strength | Higher 🟪 ▨ ⬜ Lower

		Lithium-ion materials				**Flow battery materials**		
		Anode	**Cathode**	**Electrolyte**	**Separator**	**Iron electrolyte**	**Vanadium electrolyte**	
Size and attractiveness of opportunity	Global opportunity	Significant revenue opportunity	Significant revenue opportunity	Smaller revenue opportunity	Smaller revenue opportunity	Iron flow batteries make up a small proportion of the market	Vanadium flow batteries make up a small proportion of the market	• The largest revenue opportunities for battery active materials in the battery value chain are in cathodes and anodes, which the world is in short supply of.
	Importance in value chain	13% of cell material costs	57% of cell material costs	8% of cell material costs	7% of cell material costs	Key contributor to battery costs	33% of battery capital costs	• Anodes and cathodes make up a significant proportion of lithium-ion cell material costs, and vanadium electrolyte makes up a significant proportion of vanadium flow battery capital costs. As such, these capabilities help facilitate battery manufacturing by lowering materials and logistics costs.
Capabilities	Current and planned activities	Current development of silicon anodes	Investment from VSPC and Feline	Limited investment	Limited investment in separator, but investment into HPA which coats separators	Planned production	Planned production from Vecco	• AnteoTech is developing a silicon anode, PBT developed precursor cathode active materials and is manufacturing them overseas, VSPC is manufacturing LFP cathodes, Feline is manufacturing cathodes, and Vecco Group is planning on manufacturing vanadium electrolyte. UQ, QUT and Griffith University also engage in active materials R&D, particularly in anodes and cathodes.
	Cost competitiveness	Lack of graphite production	Planed vanadium, nickel and cobalt production	Lack of lithium production	Planned HPA production[1]	Cost competitive with vanadium electrolyte	Planned vanadium production	• Queensland has the greatest cost competitiveness in vanadium and some cathode types due to planned local mining and refining for necessary inputs, which reduces materials and logistics costs.
	Ability to provide differentiated products	Silicon anodes	LFP, LFMP, NMC cathodes, vanadium based cathodes[2]	Opportunities which Queensland could pursue[3]	Higher purity HPA, and other opportunities which Queensland could pursue[4]	Higher purity electrolyte	Higher purity electrolyte	• Queensland has the ability to provide silicon anodes, which are differentiated in performance from graphite anodes, develop vanadium based cathodes, improve phosphate based cathodes, alter the ratios in NMC cathodes, and improve the purity of iron or vanadium electrolyte.
	Skills of labour	Current skills through AnteoTech	Emerging skills through PBT and VSPC	No current workforce	No current workforce	Potential emerging workforce	Emerging skills at Vecco	• Queensland has skilled labour through the current and planned active materials activities, in addition to the skills at UQ, QUT, Griffith University, JCU and the NBTC.

Notes: 1. PE and PP is also needed, although these are inexpensive materials; 2. Specific cathode chemistries: lithium iron phosphate, lithium iron manganese phosphate, nickel manganese and cobalt, and vanadium based cathodes. Opportunities for Queensland include optimising phosphate chemistries such as LFP and LFMP, increasing capacity by altering the ratios in nickel based cathodes, and developing vanadium based cathodes; 3. Opportunities exist globally to develop solid or semi-solid electrolytes, stabilise electrolyte formations, or replace flammable electrolytes; 4. Opportunities exist globally to develop reduced thickness separators, or design separators for specific cell chemistries

Source: AnteoTech (August 2022), Annual Report 2022; Lithium Australia (July, 2022), Investor Presentation; FBI CRC (July, 2020), Li-ion battery cathode manufacture in Australia; NBTC (2022), Electrochemical Testing of Li-ion Battery Materials; The Faraday Institution (January, 2020), High-energy battery technologies; Batteries Europe (November, 2021), Roadmap on Advanced Materials for Batteries; Lagadec et al., (January, 2019), Characterization and performance evaluation of lithium-ion battery separators; Orangi & Strømman, (2022), A Techno-Economic Model for Benchmarking the Production Cost of Lithium-Ion Battery Cells; QUT (2022); Griffith University (2022); UQ (2022); Pure Battery Technologies (2022a); Pure Battery Technologies (2022b); Vecco Group (2022); BNEF, (July, 2017), Lithium-ion Battery Costs and Market; Accenture Analysis

Cell manufacturing presents an attractive opportunity for Queensland due to its capabilities in battery cell innovation

Scale of opportunity | Lower ◔ ◑ ◕ ● Higher

Criteria	Summary of opportunity	Rating	Revenue and investment	Key players
Attractiveness	• Lithium-ion cells have a significant global market, with $136B in expected revenue by 2030. • Flow battery cells have a smaller expected global market, but have applications for stationary storage in particular.	●	**$ 136B** in global revenue by 2030[1]	CATL LG Chem Panasonic
Capabilities in Queensland	***Current and planned activities*** • High performance lithium-ion cells are being produced by Feline, and QUT providing lithium-ion cell prototyping for active material validation and qualification and the NBTC providing cell certification for transport and use. • Graphene aluminium-ion coin cells are being manufactured at a pilot scale by the Graphene Manufacturing Group. ***Competitive advantages*** • Cost competitiveness of vanadium flow, iron flow and potentially graphene aluminium-ion cells given the planned local input materials. • Queensland's strong battery industry R&D would help enable the State to produce a differentiated product, such as graphene aluminium-ion and flow battery cells, and high performance lithium-ion cells.	◔	**$1-50M** in current Queensland investment[2]	***Current*** Feline Advancing Technologies ***Planned*** GMG Graphene Manufacturing Group Zero Emissions Developments ***Prototyping*** QUT Future Battery Industries CRC National Battery Testing Centre

Notes: 1. In USD; 2. Current investment, in AUD

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; IEA (July, 2022), Global Supply Chains of EV Batteries; ESI Asia Pacific, (2022); Queensland Government; Graphene Manufacturing Group, (September, 2022), Corporate Presentation; Graphene Manufacturing Group (December, 2021), Battery Pilot Plant; Redflow (August, 2021), FY2021 Results; Redflow (2022), Why Redflow?; Koo et al., (2019), Modeling the Performance of a Zinc/Bromine Flow Battery; Feline (2022); NBTC (2022); QUT (2022); Griffith University (2022); UQ (2022); UQ, (April, 2021); GMG, (April, 2021); UQ, Dow Centre Annual Report 2020, (2020); AMGC, (2022); Accenture Analysis

Queensland has capabilities in lithium-ion, vanadium lithium-ion and graphene aluminium-ion cells

Strength Higher ■ ▨ □ Lower

		Lithium-ion cells	Vanadium lithium-ion cells	Graphene aluminium-ion cells	Flow battery cells		
					Iron	Vanadium	
Size and attractiveness of opportunity	Global opportunity	$136B of revenue	Higher voltage and energy density has the potential to displace existing cathodes as the main lithium battery cathode	Emerging technology with characteristics including high energy density, high power density, and fast charging speed	Emerging technology with characteristics including high cycle life, and cost advantages over vanadium flow	Largest market for alternative technologies to lead-acid and lithium-ion[1]	• Lithium-ion batteries have a significant global market, but vanadium lithium-ion and graphene aluminium-ion batteries may grow in market share due to appealing performance characteristics. Flow batteries may grow in market share as they have a higher cycle life, and battery capacity can be increased by increasing the quantity of electrolyte without changing capital expenditure.
	Importance in value chain	74% of battery costs	Significant contributor to battery costs, and reduction of supply instability for materials such as cobalt	Significant contributor to battery costs	Significant contributor to battery costs	Significant contributor to battery costs	• Cell manufacturing facilitates pack assembly by reducing materials and logistics costs and creates demand for active materials production.
Capabilities	Current and planned activities	Current production of high performance cells[2]	Planned commercial scale cell manufacturing	Coin cell pilot scale production and pouch cell prototyping	No current or planned activities	No current or planned activities	• Feline is producing high performance lithium-ion and vanadium lithium-ion cells for niche applications, QUT is engaging in prototyping of lithium-ion cells (coin, cylindrical, pouch) and the GMG is prototyping graphene aluminium-ion coin and pouch cells.
	Cost competitiveness	Planned cathode production	Planned vanadium production and higher cell capacity	Current graphene production	Planned iron electrolyte production	Planned vanadium electrolyte production	• Queensland has the greatest potential cost competitiveness in manufacturing vanadium lithium-ion, graphene aluminium-ion, iron flow and vanadium flow cells, as necessary active materials components for these cells will also be produced in Queensland.[3]
	Ability to provide differentiated products	Current production of high performance cells	Planned production of uniquely advanced technology	Current production of cells that are unique on the market	Emerging technology with differentiated characteristics	Emerging technology with differentiated characteristics	• Queensland can develop highly differentiated cells and cell stacks as there are high performance lithium-ion and vanadium lithium-ion cells and unique graphene aluminium-ion cells being produced, and R&D into electrodes and cell fabrication at UQ and QUT with cell certification at the NBTC. In addition, flow battery cells are differentiated from lithium-ion cells due to characteristics such as high cycle life.
	Certification for transport and use	NBTC developing certification capability to existing Australian standards	NBTC developing certification capability to existing Australian standards	NBTC developing certification capability to existing Australian standards	NBTC developing best practice to inform standards generation	NBTC developing best practice to inform standards generation	• Certification for both cells and packs is required for battery products to be sold. Current certification covers lithium-ion and aluminium-ion cells and packs with no standards for flow batteries. NBTC is developing data sets to inform best practice and standards generation for flow battery certification.
	Skills of labour	Current skills through Feline and the NBTC	Current skills through Feline	Current skills through GMG and UQ	Emerging skills through ESI Asia Pacific	No current workforce	• Queensland has skilled labour through current and planned activities, the NBTC, and research from UQ, QUT and Griffith University.

Notes: 1. Potential for vanadium redox flow batteries to replace LFP batteries for utility-scale storage if there was early stage VRFB commercialisation, with the potential to capture almost a third of the energy storage market by 2050; 2. In addition to a completed feasibility study by Magnis Energy for a $3B cell manufacturing plant; 3. Active materials production reduces materials and logistics costs.

Source: Magnis (August, 2020), Media Release; FBI CRC (2020), State of Play- Australia’s Battery Industries; Roland Berger (2022), The Lithium-Ion Battery Market Supply Chain; LaRocca (July, 2020), Office of Industries Working Paper, Global Value Chains: Lithium in Lithium-ion Batteries for Electric Vehicles; Queensland Government Department of Energy and Public Works, (2022), Queensland’s renewable energy target; The Faraday Institution (November, 2021), The UK: A Low Carbon Location to Manufacture, Drive and Recycle Electric Vehicles; Magnis, (2022), Media Release; Magnis, (2020), iM3TSV Lithium-ion Battery Factory in Australia; Feline (2022); NBTC (2022); QUT (2022); Griffith University (2022), Centre for Catalysis and Clean Energy; Griffith University (2022); UQ (2022); Graphene Manufacturing Group, (September, 2022), Corporate Presentation; IEA, (May, 2021), The Role of Critical Minerals in Clean Energy Transitions; Accenture Analysis

The global market for lithium-ion battery packs is attractive, but Queensland has advantages in vanadium and iron flow batteries

Scale of opportunity | Lower ◔ ◑ ◕ ● Higher

Criteria	Summary of opportunity	Rating	Revenue and investment	Key players
Attractiveness	- Lithium-ion battery packs have a $47B global market. - Flow battery packs have a smaller expected global market, but have applications for stationary storage in particular.	◕	**$47B** in global revenue by 2030[1]	BYD CATL
Capabilities in Queensland	***Current and planned activities*** - Lithium-ion packs are being produced by RedEarth and Feline, who make high performance batteries for niche applications. - ESI Asia Pacific are planning to produce 400MW of energy storage per annum from a $70M iron flow pack assembly facility. - The NBTC is developing module and pack certification capability for transport and use with certification services being critical to enabling cost-effective pack manufacture. ***Competitive advantages*** - Differentiated products, and innovative emerging technologies such as iron flow and graphene aluminium-ion. - Cost competitiveness for vanadium flow and iron flow batteries due to local supplies of materials.	◑	**$50-100M** in current Queensland investment[2]	***Current*** Feline Advancing Technologies RedEarth ENERGY STORAGE ***Planned*** ENERGY STORAGE INDUSTRIES ASIA PACIFIC ***Certification*** QUT FUTURE BATTERY INDUSTRIES CRC NATIONAL BATTERY TESTING CENTRE

Notes: 1. In USD; 2. Current investment, in AUD

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; IEA (July, 2022), Global Supply Chains of EV Batteries; ESI Asia Pacific, (2022); Queensland Government;, Battery Pilot Plant; Redflow (August, 2021), FY2021 Results; Redflow (2022), Why Redflow?; Koo et al., (2019), Modeling the Performance of a Zinc/Bromine Flow Battery; Feline (2022); NBTC (2022); QUT (2022); Griffith University (2022); UQ (2022); Accenture Analysis

Queensland has capabilities in lithium-ion pack assembly, with planned assembly for other battery chemistries

Strength | Higher 🟪 ▨ ⬜ Lower

		Lithium-ion batteries	Vanadium lithium-ion batteries	Graphene aluminium-ion batteries	Flow batteries			
					Iron	Vanadium	Zinc bromine	
Size and attractiveness of opportunity	Global opportunity	$47B in revenue	Higher voltage and energy density has the potential to displace existing cathodes as the main lithium battery cathode	Emerging technology with characteristics including high energy density, power density and charging speed	Emerging technology with characteristics including high cycle life, and cost advantages over vanadium flow	Largest market for alternative technology to lead-acid and lithium-ion[1]	Emerging technology with low cost materials, and characteristics including high energy density	• Lithium-ion batteries have a significant global market, but graphene aluminium-ion batteries may grow in market share due to appealing performance characteristics. Flow batteries may grow in market share as they have a higher cycle life, and battery capacity can be increased by increasing the quantity of electrolyte without changing capital expenditure.
	Importance in value chain	Primarily mobility applications	Significant contributor to battery costs, and reduction of supply instability for materials such as cobalt	Multiple potential applications, including stationary and mobility	Primarily stationary applications	Primarily stationary applications	Primarily stationary applications	• Pack assembly provides demand for cell manufacturing, and reduces logistics costs for the integration, service and maintenance industry. The largest battery markets are in mobility applications, which lithium-ion and potentially graphene aluminium-ion are suited to, but Queensland will also need stationary applications.
Capabilities	Current and planned activities	Current production of high performance packs	Planned commercial scale manufacturing	Potential production	Planned production	No current or planned activity	Current overseas manufacturing	• Feline is producing high performance lithium-ion and vanadium lithium-ion battery packs for niche applications, ESI Asia Pacific has planned production of iron flow batteries, and Redflow produces zinc bromine batteries overseas.
	Cost competitiveness	High performance cell production	Planned vanadium production and higher cell capacity	Graphene production using natural gas, planned cell manufacturing	Electrolyte production, but no cell manufacturing	Electrolyte production, but no cell manufacturing	No cell manufacturing	• Queensland has current lithium-ion and vanadium lithium-ion cell production, planned graphene aluminium-ion cell production, and planned iron and vanadium electrolyte production, which reduces materials and logistics costs for battery packs.
	Ability to provide differentiated products	Current production of high performance packs	Planned production of uniquely advanced technology	Unique on the market	Emerging technology with differentiated characteristics	Emerging technology with differentiated characteristics	Emerging technology, and the world's smallest zinc bromine battery[2]	• Queensland can develop highly differentiated batteries such as high performance lithium-ion batteries and unique graphene aluminium-ion batteries. In addition, flow batteries are differentiated from lithium-ion batteries due to characteristics such as high cycle life.
	Certification for transport and use	NBTC developing certification capability to existing Australian standards	NBTC developing certification capability to existing Australian standards	NBTC developing certification capability to existing Australian standards	NBTC developing best practice to inform standards generation	NBTC developing best practice to inform standards generation	May have parallels with iron and vanadium flow best practice	• Certification cells and packs is required for battery products to be sold. Current certification covers lithium-ion and aluminium-ion cells and packs with no standards for flow batteries. NBTC is developing data sets to inform best practice and standards generation for flow battery certification.
	Skills of labour	Current skills through Feline	Current skills through Feline	Emerging skills through GMG and UQ	Emerging skills through ESI Asia Pacific	No current workforce	Current skills at Redflow	• Queensland has emerging labour skills in pack assembly through current and planned activities, and research institutions.

Notes: 1. Potential for vanadium redox flow batteries to replace LFP batteries for utility-scale storage if there was early stage VRFB commercialisation, with the potential to capture almost a third of the energy storage market by 2050; 2. The smallest zinc bromine battery which is commercially available.

Source: ESI Asia Pacific, (2022); Queensland Government; Graphene Manufacturing Group, (September, 2022), Corporate Presentation; Graphene Manufacturing Group (December, 2021), Battery Pilot Plant; Redflow (August, 2021), FY2021 Results; Redflow (2022), Why Redflow?; Koo et al., (2019), Modeling the Performance of a Zinc/Bromine Flow Battery; Feline (2022); NBTC (2022); QUT (2022); Griffith University (2022); UQ (2022); IEA, (May, 2021), The Role of Critical Minerals in Clean Energy Transitions; Accenture Analysis

Queensland has diverse integration, service and maintenance capabilities including in battery systems and EV charging

Scale of opportunity | Lower ◔ ◑ ◕ ● Higher

Criteria	Summary of opportunity	Rating	Investment	Key players
Attractiveness	- The integration, service and maintenance market is highly localised, as many services and products are provided directly to the end user of the battery. - Integration, service and maintenance is necessary in order to satisfy customer demand for batteries in mobility and stationary storage applications.			BYD
Capabilities in Queensland	***Current and planned activities*** - Redback Technologies offers offers home storage systems and now grid-tied PV inverters, supporting more than 150 operational jobs. - RedEarth aims to produce $70M of LFP lithium-ion battery systems over four years. - Evie Networks has received $50M in funding for its 42 fast charging EV stations. - BusTech has manufactured 3,000 electric buses, with capacity to build 500 new vehicles annually. - Tritium made $78M in revenue during 2021 for DC fast charging technology selling to customers globally. ***Competitive advantages*** - Testing facilities, including the NBTC, and Tritium's electromagnetic compatibility testing chambers - QUT's Battery Testing Microgrid and Energy Queensland's MIST battery testing facility (Cairns)	◑	**$50-100M** in current Queensland investment[3]	***Current*** redback technologies RedEarth ENERGY STORAGE BusTech Group EViE GO ELECTRIC. GO ANYWHERE PROHELION VAULTA elexsys QUT FUTURE BATTERY INDUSTRIES CRC NATIONAL BATTERY TESTING CENTRE

Notes: 1. In USD; 2. Current investment, in AUD; 3. Investment within Queensland, which doesn't include investment by Tritium into facilities or capabilities outside the State

Source: IEA (July, 2022), Global Supply Chains of EV Batteries; Tritium Charging (2021); RedEarth (2019); Queensland Government (February, 2018); ARENA (2022); ARENA (2021); Prohelion (2022); Queensland Government, (August, 2018); Accenture Analysis

Queensland has lead-acid recycling, but recycling capabilities for lithium-ion and flow batteries will also need to expand

Scale of opportunity | Lower ◔ ◑ ◕ ● Higher

Criteria	Summary of opportunity	Rating	Revenue and investment	Key players
Attractiveness	• $11B global revenue opportunity for lithium-ion battery recycling by 2030 with highly localised activities due to waste regulations. • Opportunity to recover critical minerals profitably,[1] and use these minerals to reduce the impacts of raw material supply shortages.	◔	**$11B** in global revenue by 2030[2]	umicore CALB
Capabilities in Queensland	***Current and planned activities*** • Lead acid battery recycling, including the national Battery Recycling Centres from Century Yuasa. • Everledger can track critical minerals and batteries throughout supply chains. • E-Cycle and Envirostream have lithium-ion battery collection throughout Australia, including in Queensland, for recycling. ***Competitive advantages*** • Existing recycling network for lead-acid batteries, which could be expanded to include other battery types.	◔	**$1-50M** in Queensland lithium-ion investment[3]	***Current*** Century Yuasa Gold Coast Resource Recovery RJ Batteries LEX Enviro Services PowerCell envirostream ecycle solutions Zero Emissions Developments Everledger

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Notes: 1. The profitability of recycling is dependent on the proportion and value of the component minerals; 2. In USD; 3. Current investment within Queensland for lithium-ion batteries, in AUD

Source: WEF (2019), A Vision for a Sustainable Battery Value Chain in 2030; CSIRO (February, 2021), Australian landscape for lithium-ion battery recycling and reuse in 2020; Energy Sector Management Assistance Program (ESMAP), World Bank, (2020), Re-use and Recycling: Environment Sustainability of Lithium-ion Battery Energy Storage Systems; Everledger, (July, 2021); FBI CRC (March, 2020); Everledger (July, 2021); RJ Batteries (2022); ABRI (2020); Powercell (2022); Ecycle, (2022); Envirostream, (2022); Accenture Analysis