**Queensland University of Technology response to the Queensland Battery Industry Strategy**

QUT welcomes the opportunity to contribute to the *Battery industry opportunities for Queensland discussion paper* and consultation being conducted by the Department of State Development, Infrastructure, Local Government and Planning. QUT provides this input from extensive experience in energy storage research and development (R&D) and industry engagement. The Queensland-based National Battery Testing Centre (NBTC), funded in part by the Future Battery Industries – Cooperative Research Centre (FBICRC), is co-located at the QUT Banyo Pilot Plant Precinct with the QUT Advanced Battery Facility (ABF). Together these facilities provide nation-leading services in battery and battery active material testing, qualification and translational R&D. The ABF was established six years ago through funding from the Automotive Australia CRC and combined, these facilities constitute more than $40 million of co-investment from government, university and industry.

## 1. Do you agree with the market opportunities identified in the discussion paper?

Yes, QUT agrees with the market opportunities identified in the discussion paper. However, careful consideration needs to be applied where overseas companies working across the battery value chain may be incentivised to set up shop in Queensland. These businesses need to be strategically identified, keeping front and centre the localised and specialised industry working in niche applications. The Government should be selective in what Queensland can't / won't develop capabilities in to ensure opportunities are not ruined for localised and specialised battery industries.

## 2. What do you consider to be the key challenges in securing these markets by 2030?

### 2.1. Raw mineral mining

**Elements/minerals critical to battery technologies include but are not limited to**: lithium, vanadium, iron, nickel, manganese, cobalt, aluminium, copper, zinc, graphite, phosphorous, sodium, sulphur and rare earths.

### 2.2. Refining to chemicals

**Iron and vanadium flow battery electrolytes**: Queensland is rich in vanadium and iron deposits and there exists an opportunity to value add to these raw minerals to manufacture vanadium and iron-based flow battery electrolytes for domestic and export markets.

*Potential barriers:*

- Further R&D support for pilot-scale service provision of bespoke refining equipment will be required with a focus on vertical integration with processes to value-add. The Queensland Government's Townsville critical minerals demonstration facility will provide some support across Northern Australia.
- More work is need on testing and qualification services to assist with iterative R&D to develop high-quality and/or advanced performance battery precursors. QUT's Advanced Battery Facility (ABF) as well as the Queensland Energy Storage Technology Hub (QUEST Hub) are developing standardised testing and qualification laboratories to provide this service to industry which will also support refiners/manufactures with third party performance validation to enable entry into the battery supply chain locally and internationally.

**Rare Earth Elements (REE):** Development of sustainable electrochemical processing technologies, which are much less energy-intensive than traditional processes used overseas.
*Potential barriers:*

- REE demand is being driven by the requirement of wind turbines, electric vehicles & electronics.
- China maintains its pre-eminence in rare earths, owing to state subsidisation of the companies that mine and process them.
- REE deposits require unique R&D for optimal mid-stream processing.
- The nature of the minerals in which the REE are contained varies significantly within the ore and across different ores.
- The cost of energy to conduct the mid-stream processing of REE is significant and a critical ESG requirement in light of reforms such as EU's new mandatory sustainability laws.

**Lithium:** With lithium demand being driven by the growing Li-ion battery market, realising the value of lithium from our spodumene deposits through the development of new technology, with vastly reduced energy inputs compared to conventional processing with improved overall extraction, would be of significant value to our Critical Minerals industry.
*Potential barriers:*

- The majority of Australia's lithium deposits are in the form of spodumene, where conventional extraction is in a rotary kiln & involves very high temperatures (>1000oC).
- The traditional method of extracting lithium is highly energy intensive with a large portion of lithium remaining in the ore post processing.
- There is a strong demand for lithium and lack of projects at the construction and ramp-up stage.

**Nickel laterites:** Development of sustainable processes for nickel extraction from laterite deposits that meet Environmental, Social and Governance (ESG) requirements.
*Potential barriers*

- There are minimal skills in laterite processing technology in Western countries due to environmental concerns.
- Current technologies used to process nickel laterites are not environmentally friendly resulting in expensive waste treatment and disposal of chemicals used in the extraction process.
- Many years of nickel sulphide exploitation have depleted these ore bodies and/or made them more expensive to mine.
- Companies are increasingly interested in nickel production from nickel laterites. More than half of Australia's nickel reserves are nickel laterites, however, the nickel (and cobalt) grade is low and the mineralogy is complex.

### 2.3. Cell manufacturing

**High TRL lithium-ion batteries cells with enhanced safety:** Australia needs a secure supply of high-quality lithium-ion batteries (LIBs) to meet the demand created by the need for efficient and on-demand electricity distribution utilising renewable energy generation sources to meet our clean energy targets. Cells manufactured in Australia should focus on proven, high TRL LIB cell formats with enhanced safety for large-scale grid support and domestic use. Existing domestic capability in this sector (i.e. existing cell manufactures such as Feline Pty Ltd) should be supported to grow further and increase manufacturing throughput, enabling organic growth of Australian technology and companies to better support training and the creation of local jobs.
*Potential barriers:*

- Lack of domestic accredited certification services to certify cells to Australian transport and use standards. The NBTC is currently developing this service at QUT.

**Flow battery cell stacks:** Australia needs a secure supply of battery energy storage systems (BESS) with long-duration storage capability (LIBs not ideal for long-duration applications). Flow batteries are currently one of the only high TRL long-duration BESS solutions available commercially.
To enable domestic manufacturing of vanadium and iron flow BESS, manufacturing of flow battery cell stacks must also be enabled.
*Potential barriers:*

- Further R&D support will be required with a focus on translation to industry 4.0 manufacturing of commercial products. Initiatives such as QUT's QUEST Hub will support such endeavours through provision of 'industry incubator' spaces to bridge the gap between lab and pilot-scale manufacturing and support IP and technology translation to real-world outcomes.

2.4. Battery pack/system assembly

**Iron and vanadium for large-scale BESS:** Queensland is rich in vanadium and iron deposits and there exists an opportunity to move further downstream towards manufacturing of complete flow battery systems. Apart from the flow cell stack, flow battery systems comprise of common, simple components which allows for local manufacturing of these systems.
*Potential barriers:*

- Further R&D support will be required with focus on translation to industry 4.0 manufacturing of commercial products. Initiatives such as QUT's QUEST Hub will support such endeavours through provision of 'industry incubator' spaces to bridge the gap between lab and pilot-scale manufacturing and support IP and technology translation to real-world outcomes.

**Assembly of lithium-ion battery packs and modules:** There is a large and increasing local demand for LIB BESS in supporting residential and community energy storage and distribution. Currently local manufacturers must import LIBs to manufacture LIB BESS. Once domestic LIB cell manufacturing increases in volume, there is potential to supply to local pack manufactures with mature BESS products.
*Potential barriers:*

- Lack of domestic accredited certification services to certify LIB modules and packs to Australian transport and use standards. This requires local manufactures to export systems overseas for certification which is costly and time consuming. The National Battery Testing Centre is currently developing this service at QUT to enable local manufactures to get products to market quicker.

2.5. Integration, service and maintenance

**Technology demonstration to allow grid connection and training with large-scale BESS:** To enable uptake of large-scale BESS in Australia, technology demonstration is crucial. This includes identification of and integration with appropriate (Australian compliant) power conversion systems for grid connection. Both Government and privately owned energy generation and supply companies are hesitant to procure/install new energy storage technologies (non-lithium) without having first seen domestic third-party testing and validation.
*Potential barriers:*

- Limited facilities capable of testing/demonstration of large-scale BESS. QUT is developing a Battery Testing Microgrid capable of testing up to 250 kW BESS in a grid connected environment.

- Government and privately owned energy companies need to build collaborations in testing/demonstration endeavours across a wide range of energy storage technologies. A collaborative testbed for grid connection of large-scale BESS would significantly reduce the cost of demonstration and testing and facilitate rapid uptake of systems. The testbed would minimise duplication of efforts, expedite testing campaigns and assist with standardising and best practice generation for grid connection. Through QUEST Hub, QUT will be working with multiple Government and privately owned energy corporations and BESS suppliers to develop this capability local to Brisbane. This large-scale BESS demonstration testbed will also serve as a training ground to upskill Australians to support Australia's clean energy transition.

**Standards and best practice generation:** Urgent updating and generation of best practice and Australian standards is required to enable safe and efficient implementation of BESS in Australia. Currently, standards pertaining to BESS utilisation are not keeping pace with the speed of consumer uptake in Australia, and significant work needs to be done to accelerate this, particularly in regard to the safety of LIBs and other emerging intercalation storage technologies (such as sodium-ion) as well as emerging technologies such as flow batteries and sodium sulphur liquid metal (NAS).
*Potential barriers:*

- More testing and validation facilities will be required to generate the data needed to inform standards development. The National Battery Testing Centre, operated by QUT, is currently providing this service through testing of a wide range of energy storage technologies to generate high-quality data and best practice for BESS utilisation to inform standards generation. Such endeavours should be supported and grown to meet demand.
- Lack of expertise in the field of battery energy storage on the EL-005: Secondary Batteries Standards Australia committee. QUT as a registered nominating organisation with Standards Australia is currently requesting representation on EL-005 to provide access to their experts in supporting the acceleration of improved safety standards generation in energy storage.

2.6. Recycling & reuse of batteries

- A national & state plan for battery recycling will be required as part of any broader National & Queensland Battery Strategy. Initiatives including a recycling guarantee for batteries manufactured in Australia for domestic should be considered.

**3. Are there any additional opportunities that Queensland's battery industry could target?**

Iron and Vanadium for Large-scale Battery Energy Storage Systems (BESS)

- There are opportunities that we can leverage beyond electric vehicles, particularly in large-scale storage, in the context of recycling. Large-scale flow battery technologies also use vanadium and iron-based electrolytes.

Sodium-sulphur liquid metal batteries (NAS).

- NAS batteries are a commercially proven large-scale long-duration energy storage solution that have been in operation globally for 20 years.
- Due to increased global demand in NAS systems, manufacturer BASF/NGK are currently exploring options for expanding manufacturing capacity globally.
- NAS represent a mature energy storage technology of high use to support renewable energy generation and grid stabilisation in meeting clean energy targets.
- QUT, through the National Battery Testing Centre project, has deployed Australia's first NAS battery in January 2023 to demonstrate system functionality in Australia.
- There exists the opportunity to attract manufacturing of NAS battery systems to Australia by further demonstration of larger scale deployment of these system (2-4 MW installation, 6-18 20ft containerised units).

- Demonstration of off-take and use of these systems in Australia would not only potentially attract manufacturing to Australia but would also provide confidence in the technology to energy generation and supply companies searching for large-scale long-duration storage solutions required to meet clean energy targets.
- Manufacturing of NAS systems in Australia will not disrupt or compete against local industry as there is currently no activity domestically in this space.
- Government support in attracting NAS manufacturing to Australia would create jobs, advance skills in specialist manufacturing and provide security to Australia by providing local supply of a large-scale long-duration energy storage technology needed to meet clean energy targets.
- Due to increased global demand and current limited production quantities, it is anticipated by Q4 this 2023 all NAS offtake will be committed until ~2026.
- QUT has a mature and existing collaborative relationship with BASF and NGK and is able to support in securing off-take of up to 40 units (125 kW / 1.45 MWh per 20 ft container unit) for local deployment in supporting renewable energy generation and the electricity grid.

Recycling & reuse of batteries

- A national & state plan for battery recycling will be required as part of any broader National & Queensland Battery Strategy. Initiatives including a recycling guarantee for batteries manufactured in Australia for domestic should be considered.

**4. Where in the supply chain do you consider partnerships and collaborative investment to be most critical?**

Collaboration across the entire supply chain is required to ensure the success of a local battery industry. Collaboration and investment are specifically required to support research and development to help accelerate innovation, local production of critical components and improve product performance. Partnerships between government, industry, universities and research organisations leveraging existing capabilities and investments across the entire battery value chain are critical to ensure rapid pace in delivery of required industry support services. QUT has been active in supporting research and development across the battery value chain for over 6 years, with existing facilities constituting over $40M in prior investment in establishing QUT's Advanced Battery Facility (ABF) and current Future Battery Industry CRC projects. The recent $15M in Queensland State Government investment to establish the Queensland Energy Storage and Technology Hub (QUEST Hub) to scale up QUT's capabilities and services will also provide crucial services across the value chain required to support and enable the growth of local industry.

**5. How could Queensland carve out a niche in cell manufacturing? What do you see as the biggest opportunities?**

QUT believes that the establishment of standardised testing and qualification processes for battery materials, cells and systems as well as accredited certification to Australian & international standards will enable entry into the supply chain and provide confidence that Australian product safety risks are effectively understood, mitigated and managed.

To address this, QUT has existing capabilities and investments across the battery value chain that are providing and/or developing these necessary services which include:

1. *Lava Blue Ltd – Centre for Predictive Research into Specialty Materials (Lava Blue & QUT)*

Lava Blue, in collaboration with QUT, has developed a research, development and demonstration facility at QUT's Redlands research precinct known as the Centre for Predictive Research into Specialty Materials (PRISM).

The first specialty material that Lava Blue is focused on is the production of battery and glass grades of High Purity Alumina (HPA) from a variety of aluminium sources, particularly from the aluminium rich waste streams of other mineral processing facilities. Lava Blue have demonstrated manufacture of +4N HPA for a number of mineral project developers and has two licensees in place with a total planned capacity of 6,000 tpa of production and with plans to advance a further two licensees with similar production targets.

PRISM is a unique facility in Australia, combining laboratory grade quality control and small batch scale processing capacity. Staffed by a team of QUT post-doctoral researchers, PRISM fills an essential gap in commercialisation of scaling up laboratory processes to a demonstration scale from which vital engineering data can be captured.
Lava Blue has been working closely with QUT for the past five years and has assembled a world class team of researchers in HPA manufacturing. The capabilities at PRISM will be continually enhanced to establish a data rich, machine learning driven demonstration scale mineral processing facility utilising advanced extraction and refining techniques. Ultimately, this will build a foundation in machine learning capabilities capable of modelling new processes and materials using AI techniques and deliver a research and training capacity for a new cohort seeking to enter the advanced minerals manufacturing industry addressing a critical skills need for the Nation.

2. *FBICRC National Battery Testing Centre (NBTC)*

The NBTC is the emerging national facility that Australia will require for standardised and application-based testing, validation and certification of battery energy storage systems (BESS). The facility contributes to Australian battery standards development and assists in advancing the technology readiness level (TRL) of developing battery technologies for deployment of functional BESS solutions within Australia. The NBTC actively supports and enables Australian battery industries through commercially relevant, results-driven collaborations co-located with industry partners and centred around the generation of high-quality data for practical outcomes. The current core capabilities of the NBTC include:

- A battery cell/module/pack and systems testing facility for validation and non-destructive safety testing of all types of energy storage devices such as lithium-ion batteries (LIB) and vanadium/iron redox flow batteries (RFB). Consisting of dedicated battery testing units, specialised test fixtures, environmental chambers and advanced testing protocols, this facility enables Australian manufacturers to rapidly develop safe and reduced-cost market-ready BESS products within Queensland.
- A renewable energy Battery Testing Microgrid (BTM) powered by a 100kW roof-top solar PV array. The BTM provides testing, validation and standards compliance services for a diverse range of large-scale BESS under real-world operational conditions, enabling deployment of these systems to meet Australia's rapidly growing large-scale energy storage requirements.

3. *Advanced Battery Facility (ABF)*

The ABF is a pilot-scale facility for standard format LIB cell manufacturing within Queensland. It is the only facility capable of manufacturing commercial-grade cylindrical-format LIB cells in Australia. The Facility provides battery-grade materials validation in standard, commercially representative cell formats, enabling the transition of early-stage research and development to industrial pilot-scale and large volume manufacturing. The ABF also enables performance validation and benchmarking of LIB materials and componentry and prototyping of a diverse range of LIB cell formats and configurations. The facility's current core capabilities include:

- The ability to manufacture prototype and standardised cell formats at pilot-scale. This includes test cells (coin cells, single-layer pouch cells) for fundamental property analysis, to industry-representative cell formats (multi-layered pouch cells, cylindrical cells) in humidity controlled, clean room environments.
- A battery materials and components testing laboratory. This laboratory provides testing and qualification services based on the most advanced industry aligned protocols. The laboratory enables Australian miners, refiners, mid-stream processors and LIB active material manufacturers to enter local and international battery supply chains as well as fundamental research and development in novel LIB materials.
- A training facility for LIB cell assembly, testing and manufacture. The ABF was designed to enable training in LIB cell building, qualification testing and LIB manufacturing processes. QUT is working to create dedicated training spaces and programs to up-skill scientists and engineers for work in the energy storage sector in Australia.
- A curated test results database for battery materials and components performance under standardised conditions (software modelling and machine-learning ready).

*4. The Queensland Energy Storage Technology Hub (QUEST Hub)*

Through support from the Queensland Government, Queensland universities and local industry partners, QUT will establish the Queensland Energy Storage Technology Hub (QUEST Hub) which aims to achieve growth and support of battery industries through targeted research, development, testing and practical deployment of high TRL large-scale energy storage technologies to enable the production of these systems within Queensland. This includes iron and vanadium redox flow batteries (RFBs), sodium sulphur (NAS) batteries as well as lithium-ion batteries (LIBs) incorporating advanced safety features.

Key pathways to linking these technologies and unlocking industry collaboration in generating value-added products and battery solutions within Queensland are research, development and manufacturing of:

- valued-added energy storage materials derived from Queensland's vanadium resources such as vanadium RFB electrolyte and lithium-vanadium-phosphate (LVP) LIB cathode.
- separator membranes used in RFB and LIB cells, including the addition of high-purity alumina (HPA) for increased LIB safety performance.
- advanced LIB cells and systems for niche and high-performance specialist applications such as space, defence, mining, harsh conditions etc.
- a diverse range of large-scale, long-duration BESS and associated components such as iron and vanadium RFB cell stacks and systems and NAS batteries.
- power conversion systems required for connection of large-scale BESS to electricity grids.

QUEST Hub will focus on enabling the production of these components and systems within Queensland through the growth of existing QUT capabilities, including support for the National Battery Testing Centre in the development of accredited certification services to enable market entry for Australian products. QUEST Hub will create dedicated prototyping and pilot-scale demonstration facilities for industry partners supported by skilled battery technologists and engineers. These 'industry incubator' spaces will unlock the collaboration potential between Queensland industry partners and foster the development of advanced energy storage technologies for the generation of world-leading products. QUEST Hub will support and enable Queensland-based battery component and system manufacturing, supplying a diverse range of domestic and international battery supply chains and markets.

**6. How could Queensland collectively market our commitments to developing a sustainable battery industry?**

QUT together with Queensland Universities is actively supporting Queensland Government to establish the Battery Industrialisation Centre (BIC). The BIC will bring together training organisations, universities, industry, government and research organisations nationwide to leverage and scale existing capabilities and investments across the battery value chain. The base capabilities provided through the university consortium will enable the BIC to hit the ground running and reduce the development time of the centre significantly, getting support to and growing Australian battery industries faster.

Queensland has an opportunity to lead the nation in the development of a battery manufacturing industry through government investment, co-location of industry, state-of-the-art teaching and research & battery testing services to

- Training & skills development to a job ready workforce.
- Drive translation and product development by overcoming late-stage commercialisation batteries across the battery value chain through collaboration, knowledge exchange, sharing of infrastructure.
- A battery testing service accredited to test Australian standards to meet industry needs and increase market acceptance of products and establish credibility.

Linking activities across regional locations to encourage new market supply and demand along the critical minerals and battery value chain, attract investment and reduce imports to support local industries and job creation.

*Australian Standards and testing*
A significant opportunity exists for Queensland to establish a national **Battery Testing and Standards Authority** as part of a BIC and QUEST Hub extension. QUT is currently working with relevant industry partners to identify gaps and opportunities for an Authority. This opportunity is significant because national battery standards for modern battery chemistries and formats do not exist in Australia, with only international standards currently available to best guide implementation. There also exists gaps in the international standards environment for emerging energy storage technologies which presents opportunities. Should Queensland take the national lead in standards and testing, this will automatically create advantage for manufacturers of cells, and products and offering the potential vertical integration across the battery value chain creating both domestic and global supply opportunities. It will also significantly contribute to sovereign manufacturer capability by providing assurances to companies wanting to establish in Queensland and Australia.

Queensland has a natural advantage due to the NBTC and QUEST Hub initiative. It has the added advantage of State Government ownership of electricity generating and distribution assets and strong government policy in the Queensland Energy and Jobs Plan and proposed Battery Industry Strategy. Government ownership of electricity assets mean a significant capacity exists in electrical trades and engineering. This is both an opportunity and a challenge as the State moves to its 70 per cent renewable energy target by 2032. Batteries will be a vital component for grid stability and at the same time skilled workers will need to transition into the renewable energy industry.

*Proposed Authority Governance structure*
Queensland Government could establish a Battery Testing and Standards Authority and invite other States and Territories to participate. The Authority could also offer partnerships and fee-for-service operations.

QUT again commends the Queensland Government for its foresight in developing a Queensland Battery Industry Strategy. Queensland is uniquely positioned to leverage its existing capabilities and investments in the upstream battery value chain across the State, including regional centres, to capitalise on the emerging downstream battery manufacturing industry.

**Ends**

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