FUTURE BATTERY INDUSTRIES CRC

FBICRC PROJECT SUMMARIES

Status summary of current research projects and proposals

April 2020

Introduction

The FBICRC's research project pipeline was developed during 2019 based on an initial Expressions of Interest round for research partners to tackle industry defined challenges. More than 50 EoIs were received and evaluated by the Research Program Committee and the Board's Research Implementation Advisory Committee.

Proposals were evaluated according to:

- Alignment to Programs, Themes and Commonwealth Outputs
- Impact on growing Australian battery industries
- Industry cash and in-kind support
- Technological readiness
- Extent and breadth of cooperation amongst research institutions, industry and state government

This process resulted in 15 proposals selected from this round for further development. One additional proposal has since been identified and a targeted approach to seeking additional proposals is envisaged over the life of the CRC.

As at March 2020, the FBICRC Board as at March 2020 has approved investment subject to conditions in the first phase of four projects and in one full project proposal. The Board has also established a Commercialisation Committee which will work with the Research Implementation Advisory Committee on making further recommendations to the Board for investment in projects.

The projects listed in this summary do not include three scene setting projects commissioned by the CRC in 2019 with support from prepayments from some participants. These projects are close to finalization which will be launched in the final quarter FY 2019/20:

- Governance of global battery value chains (Perth US Asia Study Centre/UWA)
- Feasibility of WA cathode precursor and cathode active material industry (QUT/Hatch)
- State of Play of Australian battery industries (CSIRO)

Research Project Pipeline

Process Legacy

Maximising Community Value from Mining in an Environmentally Safe Manner

To determine the opportunity for industry participants to maximise economically viable co-products and minimise repository use for mining and processing operations, all within a regulatory acceptable framework.

Discovery and highlighting synergy within existing and future industrial complexes will allow by-product utilisation and the development of new co-products could revitalise third party industries such as construction and infrastructure within a sustainable context, delivering greater benefit across the complete battery industries value chain. In parallel, Process Legacy will develop and implement new risk-based tools to better inform mine site operation and closure planning.

While development and use of co-products will enhance end-user social licence to operate, the by-product location and character may provide economic and other competitive advantages. Many of their own resource requirements may be sourced locally through by-product exchange. Even internal infrastructure could utilise combinations of local materials. Ultimately this project seeks to reduce disposal cost, develop new and varied income streams and industrial jobs, reduce the waste of natural resources whilst creating new products, reduce material placed in impoundments and inform government policy.

One of FBICRC's key outputs for the FBICRC Research Program 2 is the Process Legacy project which will transform process routes to convert wastes to useful co-products. These new soil amelioration materials, supplementary cementitious materials, construction sand and geopolymers can all be scaled up massively for the domestic market and potentially creating niche products that can be marketed globally.

This project will perform rigorous assessment of mining and process streams currently co-disposed as waste, for suitability as by-products based upon performance standards and LEAF leach protocols and is split into 6 key sub-projects to achieve this end:

- Precursor for geopolymer & toxic metal encapsulation
- Cementitious materials & road base
- Soil amelioration
- Metalliferous drainage & risk assessment
- LEAF assessment
- Recapturing regional synergy

The subprojects are tied together by the overarching main project to ensure communication and continuous feedback across the subprojects.

COLLABORATION AND IMPACT

Process Legacy is led and managed by Curtin University in collaboration with subproject leaders from ChemCentre and UWA. Nine industry participants have indicated interest in this project and will provide samples, technical expertise and consultation.

This project will support 5 Doctor of Philosophy candidates, as well as 5 Honours students across the university partners.

Process Legacy will deliver on the FBICRC's aim to develop and demonstrate the technologies, methods and policy settings to enable Australia to convert its extensive new-energy mineral resources into economically valuable products; to utilise our natural resources to deliver much greater benefit. Close collaboration with industry on utilisation of mine tailings and process residue will reduce material placed in impoundments, create new products and inform government policy. The benefits of an industrial approach for this project are numerous. While development and use of co-products will enhance end-user 'Social licence to operate', the by-product location and character may provide economic and other competitive advantages. Many of their own resource requirements may be sourced locally through by-product exchange. Even internal infrastructure could utilise combinations of local materials. Ultimately this project seeks to reduce disposal cost, develop new and varied income streams, reduce the waste of natural resources and provide new industrial jobs.

This project also addresses the FBICRC's theme: Environmental and waste management strategies from extraction of materials to the end of life of batteries. The activities will deliver new and innovative waste management strategies that will result in reduced, waste and new co-products that will lower CO2 emissions, create jobs and lead to industry sustainability. The newly developed and validated risk-based and decision-support tools this project will create will also enable industry to rapidly inform environmental impact assessments, waste management and mine planning, closure and approval. New methodologies and new scientific knowledge on lithium mining and processing will inform government policy and regulatory guidelines.

OBJECTIVES AND OUTCOMES

The intended objectives and outcomes from this project include but are not limited to:

- Reduced company (and potentially government) exposure to maintenance of impoundment sites.
- Reduction in resources being wasted through co-disposal with hazardous materials.
- Develop and validate risk-based tools and decision support tools to enable industry to rapidly inform environmental impact assessment, waste management and mine planning, closure and approval.
- Address knowledge gaps in the identification and management options of long-term potential risks to the environment and the community related to mining (e.g. lithium) and processing.
- New methodologies and new scientific knowledge on mining and processing that will inform government policy and regulatory guidelines.
- Potential reduction in hazardous materials through quality specifications and use (e.g. lime).
- Immobilisation of toxic waste via encapsulation in geopolymer.

Additional foreseen benefits of this project include:

- Facilitation of the mining and processing industry's license to mine in a sustainable manner (economically, socially and environmentally) and create mine planning efficiencies with industry and government.
- Identify and promote opportunities for supply chain synergy within the greater Kwinana Industrial Area.
- Assess local industries particularly within the greater Kwinana Industrial Area for synergy and by-product use.
- New products with reduced embodied energy; lower CO2 footprint.
- Development of new jobs associated with commodity production.
- Extended life of virgin mined commodities for future generations to exploit at their discretion.
- Significant development of technical ability that could provide competitive advantage to companies, researchers, institutions, and skilled individuals while providing increased taxable revenues.

PROJECT LEADERSHIP

As a materials physicist, Professor Arie van Riessen specialises in materials microstructural analysis and has researched alumina-zirconia ceramics, minerals and geopolymers. He has collaborated with Emirates

Global Alumina (EGA) to research use of their potential by-products to manufacture geopolymers that can result in low carbon footprint and enhance resistance to fire and acids.

Professor van Riessen trained as a physicist and directed his research to materials science and microstructural analysis. A significant part of Arie's career has focussed on the establishment and management of the Electron Microscopy Facility and the X-ray Laboratory at Curtin (now the Microanalysis and Microstructure Facility within the John de Laeter Centre).

Arie has worked with CSIRO, the Parker Centre, Rio Tinto Centre for Materials & Sensors in Mining and many more groups. Much of the work involved materials characterisation at the microstructural level using electron microscopy, laboratory x-ray diffraction and synchrotron radiation. His research includes investigation of leaching behaviour of nickel laterite ores and developing a model for understanding the cause of "wet and sticky" ore.

Arie has been an active researcher in the field of Geopolymers and was Leader of the Geopolymer Research program concurrently with the position of Director of the Centre for Materials Research at Curtin. The geopolymer research resulted in collaboration with the Mongolian Academy of Science, Bologna University and the Korean Institute for Geoscience and Mineral Resources.

Previously Arie held the positions of Dean of Research and Development for the Division of Engineering, Science and Computing and Head of the Department of Applied Physics.

STATUS

The Process Legacy project was approved to commence Stage 1 - planning by the FBICRC Board in December 2019. This project is currently in the final stages of contracting to undertake Stage 1, which includes the full-scale budget and project planning for five years and will initiate the Main Project and Sub-projects 4 and 5. This stage of the project will fast track industry interviews and sample collection followed by initial characterisation for Metalliferous Drainage and Risk assessment and LEAF assessment for residue samples, tailings and mine samples. Outcomes of this stage will determine the full scope and opportunity of the full 5-year project.

Indicative Full Budget – to be finalised during Stage 1

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$5,776,778	$2,950,000	$8,726,778
Target Allocation	$2,888,389*	$11,553,556**	-
Current Allocation	$0	$2,950,000	-
Allocation Required	$2,888,389	$8,603,556	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding, if the cash required changes this will change.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and fluctuates with cash.

Establishment of the National Battery Testing Centre

World class capability for the development of Australian battery industries

To support Australia's developing battery energy storage industry it is essential to have resources to test batteries both upstream from the battery cell, providing feedback on resource development, and downstream, to test module and pack performance, and the development of safety standards.

Unique in Australia, the National Battery Testing Centre (NBTC) will test battery systems to international standards for reliable and safe operation when deployed in main grids, micro-grids, and other large-scale applications such as electric vehicles, Defence applications, and mining. In addition to testing battery performance such a cycle life, energy density, capacity, state of charge under load etc., the proposed facility will incorporate a range of equipment to evaluate battery systems safety and develop appropriate standards for deployment in the consumer and commercial markets.

This project will establish world class testing facilities for Australian manufacturers of batteries and battery components, including materials and suppliers to provide final validation of their products in real-world scenarios for Australian conditions. The facility will provide safety testing services for a range of different battery types and sizes, as well as the development of safety standards for cells, batteries and battery energy storage systems deployed in the supply grid. Standards for vanadium redox flow battery systems will be developed which do not currently have Australian Standards for use and deployment.

Building on the only research quality lithium-ion battery production facility in Australia, the NBTC will feature 'plug and play' capability for different batteries and battery systems and will include both DC/DC and DC/AC microgrids. The AC grid will be mains connected to enable real time residential battery testing, with the DC/DC microgrid able to supply to an external consumer electricity grid for performance and reliability testing. Dedicated laboratories will be established onsite to test offline battery standards and safety systems to allow benchmark testing of a range of battery types and sizes prior to integration into the microgrid.

The 4-year project timeline will establish equipment and associated infrastructure as well as establish testing regimes and standards for a range of battery chemistries and sizes as well as the development of testing and safety standards for vanadium redox flow batteries intended for domestic and grid deployed energy storage.

The project links together four sub-projects:

- Upgrade testing equipment and facilities at QUT's Redlands site to establish a national facility capable of testing a range of battery sizes and types up to 250kW/1000kWh.
- Develop fully flexible AC and DC hybrid microgrids for battery testing and performance data collection.
- Establish the capability to simultaneously test multiple batteries that are connected to the same microgrid.
- Establish equipment and facilities to perform safety testing of batteries and cells to international safety standards for transport and use and development of new standards for vanadium redox flow batteries.

COLLABORATION AND IMPACT

Led and managed by the Queensland University of Technology, with researchers from University of Melbourne, University of Western Australia, Deakin University and CSIRO, with support from 8 industry participants to date. This project also supports 3 Doctor of Philosophy and 2 Master of Philosophy scholarships across Queensland University of Technology and the University of Western Australia.

The NBTC will bring together several FBICRC projects under development, providing iterative feedback for cathode and anode precursors, electrolytes, cell manufacture and performance, and the development of safety and standards testing that does not yet exist in Australia. There is significant risk to the development of battery industries in Australia is such a facility is not created to service this sector.

Additionally, the FBICRC has a strong training requirement that straddle the trades and professional spheres. The Redlands site has adjacent lands owned by Redlands City Council with keen interest in developing educational and learning facilities that complement the nearby Alexander Hills TAFE.

OBJECTIVES AND OUTCOMES

The intended objectives and outcomes from this project include but are not limited to:

Safety and standards:

- Performance testing of battery systems to Australian and International standards.
- Testing the round-trip efficiency of the combined performance of integrated battery with DC/DC.
- Standard operating procedures for battery testing and data to support the development of Australian Standards.
- Establish a battery safety testing laboratory for certification of imported and domestically produced batteries.
- Optimised design for integration of a range of components required to test battery performance and safety standards.

Product development

- Specialised testing facilities aligned to niche deployment areas where Australia may be competitive.
- Develop and test battery management systems (BMS's) and integrated battery-converter smart algorithms with standardized communication protocols.
- Development of meaningful BESS test cycles which are suitably representative of actual systems, such as electric vehicle (EV) operation. It will also be used to develop test regimes for residential grid connection, commercial/industrial grid connection, transmission level grid connection (with or without associated PV or wind) and large scale off-grid storage.

Data

- Evaluating battery storage systems charged from different renewable technologies such as CPV and Si PV that have different frequencies rates of supplied power.
- Convertors on a DC micro-grid in a real-world testing facility.
- practical operating data from both DC/DC grid and DC/AC grids.
- optimised models, algorithms and software for battery systems control and communications.
- data relating to the efficiency of multiple and different battery systems operating on a single electricity distribution grid.

PROJECT LEADERSHIP

Peter Talbot is a Professorial Fellow at QUT, a Director of ScienceWorks Consultants and co-founder of the Very Small Particle Company Ltd. (VSPC), a nano-materials manufacturing company based in Brisbane. Peter has a PhD in materials science from The University of Queensland. After obtaining his PhD, Peter became Program Manager for ACD, Uniquest Pty Ltd., at The University of Queensland, managing a team of over 20 scientists and engineers that developed a range of advanced chemical processes and materials. The team was responsible for completing research projects for the Energy Research and Development Council, commercial projects with Australian companies such as MMCables and Minesite Remediation

Services Pty Ltd and international projects with Enya Systems in Japan, BCC cables in Wales and Nordic Superconductors in Denmark. Peter and his colleagues at VSPC developed and patented a generic process for producing complex nanoscale metal oxides. This process proved to be a platform technology for manufacture of nano-scale metal oxides which are used in a range of modern-day technologies including fuel cells, batteries, electronics, catalysts, cosmetics and pigments. Peter has an international reputation in materials science particularly in the field of nanomaterials manufacture and High Temperature Superconductors. He also holds numerous patents in the field of solid-state chemistry, automated chemical manufacture and nanomaterials. Over the past five years, Professor Talbot's research has advanced beyond controlling not only the particle size of nano-scale materials but also to controlling morphological properties of materials, such as porosity and crystal architecture. These developments have resulted in the control of physical properties for new industrial catalysts as well as electronic and battery materials for international companies such as BASF, Engelhard, Valence Technologies, Sud Chemie, Toyo Ink, Phostech Lithium, Lishen Battery Co. and RioTinto Alcan. Professor Talbot is now extending this work to high performance materials such as light and strong borides, carbides and nitrides that also demonstrate unique electrical, magnetic and optical properties and is currently Project Leader of a project to develop advanced battery materials for electric vehicles.

STATUS

The project was approved by the FBICRC Board in March 2020 and is currently in the contracting phase for the 4-year project term. The project will be managed through a series of stage gates with clear deliverables and milestones over the life of the project.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$4,947,363	$3,015,000	$7,962,363
Target Allocation	$2,473,681*	$9,894,726**	-
Current Allocation	$0	$3,015,000	-
Allocation Required	$2,473,681	$6,879,726	-

Note
* Target allocation for cash is 1:1 matching with FBICRC funding.
** Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required fluctuates with cash.

Innovative Nickel and Cobalt Extraction Technologies

Economical alternative leach technologies for extraction of nickel and cobalt from waste streams

This project will investigate applying technology to unlock upwards of $20 billion dollars' worth of nickel and cobalt to the battery industry through demonstrating economical extraction from resources previously classified as waste or marginal for the production of battery precursor chemicals . Nickel and Cobalt are both major components for lithium ion battery cathodes for the EV market and demand for these metals is anticipated to rise as the electric vehicle market matures.

This project will focus on the identification and assessment of alternative leach and processing technologies that averts the need for smelting and converting (and mineral concentrating in some cases). In addition, the novel processes will not have the same problems as acid leach systems, and may include alkaline glycine leaching, ammonia or other processes. It is anticipated that the multiple alternative leaching options will have commercial potential, and the application will vary depending upon the source material to be processed and site-specific constraints. Existing technology for nickel and cobalt production results in the loss of both metals at multiple stages in the process. For example, flotation can be difficult due to the presence of gangue minerals such as talc which cause excessive foaming and recovery losses. Smelter constraints on minimum nickel grade and maximum magnesium and iron contents in concentrates, may lead to significant recovery losses in concentrators. Cobalt losses to slag during smelting and converting can be up to 40%. Other low grade, partially oxidised and complex ores may be stockpiled or placed on waste dumps due to poor flotation response.

For stockpiled or waste materials, much of the high costs in the value chain have already been incurred – such as mining, haulage and comminution. Additional capital and operating costs would be required for heap construction or tank leaching, with reagent costs associated with reagents to top up losses that occur through liquor losses in solid liquid separation to facilitate reagent recycle and pH modification. These new technologies will also have advantages for safety and environmental impact by reducing waste streams with processes that require little energy and use no toxic chemicals by recovering some of the metal lost in conventional processing and accessing additional ores that are currently not treatable using traditional production processes.

A market need to recover nickel and cobalt from float tails, low grade ores, slags, and to a lesser extent from flotation concentrates has been identified. Current knowledge indicates that a novel alkaline leach system has the potential to address this need to recover nickel and cobalt from these sources.

This 4-year project will progress through a linear scale-up as a pathway to commercialisation of alternative leach technologies developed during the project:

- Lab-scale leaching and characterisation of sponsor samples
- Column/tank leaching and reagent loss mechanisms
- Purification and recovery and heap leach modelling
- Piloting and flowsheet development

COLLABORATION AND IMPACT

Led and managed by Curtin University in collaboration with Murdoch University, University of Western Australia and University of Melbourne, this project is currently supported by 6 industry participants. The project also supports 2 Doctor of Philosophy and 2 Master of Philosophy scholarships, with both PhD's and one MPhil being joint degrees across the institutions.

The immediate market for the technology developed in this project is expected to be Western Australian nickel producers. It has been estimated that there is in excess of 240Mt of tailings in Western Australia at 0.5% Ni and initial work has shown that 60% of this can be recovered through leaching, placing Australia as an exporter of value-added products rather than raw materials. In addition, this technology will also be evaluated on ores and concentrates. Ideally this technology is best suited for lower grade, highly disseminated nickel-cobalt sulfide ores. Once demonstrated, these technologies could be applied to large nickel operations internationally, such as in Canada and Russia with few barriers to the adoption due to the relatively low capital requirements. Commercialisation pathways will be dependent upon the process streams and the research outcomes from this project and will be continually monitored over the life of the project.

OBJECTIVES AND OUTCOMES

The primary objective of this project is to recover some of the metal lost in conventional processing and access additional ores that are currently not economically treatable with traditional processes, including a secondary objective of developing methods for treating flotation concentrates to produce a more valuable nickel sulfate product for the battery industry.

The main outcomes from this project include:

- Reduction of waste streams through utilisation of waste materials to produce nickel and cobalt sulfate for precursors of battery manufacture.
- Review of the current nickel cobalt processing techno-economics including company reports, plant data and published literature.
- Reports on recovery through heap leaching with lab scale columns, reagent loss through adsorption, biodegradation or oxidation, leach solution purification and recovery through solvent extraction and ion exchange and mass transfer and reactive transfer models for a heap leach.
- Generalising of experimental findings to industrial scale to establish process economics.
- Piloting and flowsheet development, demonstrating practical application.

PROJECT LEADERSHIP

Elsayed Oraby is a Senior Research Fellow in the WA School of Mines with 17 years' experience in extractive metallurgy (industry and academic). Dr Oraby holds a PhD in Extractive Metallurgical Engineering (Hydrometallurgy) of using eco-friendly lixiviants for gold and copper leaching. He is the co-inventor of the novel processes using alkaline glycine for the extraction and processing of base and precious metals and has been the chief investigator in more than 20 research projects in gold and base metals industry, co-authored 32 published journal papers, is a named inventor for 4 patents families, co-authored 15 conference papers and co-supervised 6 PhD students. Dr Oraby's research focus is on the optimisation of cyanide alternative lixiviants for gold leaching such glycine, thiosulfate, thiourea and halides, and currently on the recovery of gold and copper from different gold-copper resources and on the base metals recovery from ores, concentrates and waste materials. His research team focuses on novel techniques to recover precious, base and PGMs metals from different resources.

STATUS

The Innovative Nickel and Cobalt Extraction Technologies project was approved to commence Stage 1 - planning by the FBICRC Board in December 2019. This project is currently in the final stages of contracting to undertake Stage 1, which includes the full-scale budget and project planning for four years. This stage of the project will also undertake a literature review and state-of-play for the Nickel and Cobalt industry, describe potential source materials, range of final product specifications and investigate potential processes against techno-economic evaluations of current processes. Initial sighter tests will be conducted on participant samples using the glycine leaching system to provide evidence for progression to the lab-scale leach program.

Indicative Full Budget – to be finalised during Stage 1

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$3,929,369	$1,699,000	$5,628,369
Target Allocation	$1,964,685*	$7,858,738**	-
Current Allocation	$0	$1,699,000	-
Allocation Required	$1,964,685	$6,159,738	-

Note
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Enhancing Lithium Extraction

Improved technology for the extraction of lithium minerals and refining of battery grade lithium chemicals in Australia

While Australia owns about 17% of the world lithium resources, it dominates the lithium market with its hard rock operations currently providing more than 60% of the world supply of lithium source material. This lithium is produced by a very small number of suppliers, including a single major mine in Western Australia but several new operations are ramping up production which should ensure ongoing world dominance in this sector. Currently, Australian mining companies export the lithium minerals mainly as a concentrate and only achieve limited profit margin.

By testing new and improved process options for lithium extraction, recovery and purification, and processes to manage waste streams that generate by-products, this project aims to deliver integrated processing solutions that will allow lower cost production of battery grade lithium, with lower environmental impact, increased ability to create jobs and growth for the local communities. Areas where significant opportunity for improvement exist is in the improved calcination of spodumene concentrates utilising advances in flash calcination technology, particularly to improve operability and availability of equipment, minimise clinkering and enhance recovery from fines, while obtaining high phase conversions. Reagent recovery and recycling, and effluent and waste repurposing pose additional challenges to reduce the overall cost of production.

Battery-grade lithium chemicals produced and available in Australia will pave the way for their use as battery precursor ingredients in local production of electrode materials and electrolytes for lithium-ion batteries, which will contribute to the emerging battery manufacturing industry in Australia. Moreover, the developed processing technologies in this project will minimise the energy consumption, achieve high extraction rate of lithium from lithium minerals, and dramatically reduce environmental pollution.

This 4-year project comprises 12 sub-project topics in four main themes across the lithium processing flowsheet:

- Comminution and beneficiation
- Extraction
- Impurity separation and purification
- Reagent recovery from liquors

COLLABORATION AND IMPACT

Led and managed by Murdoch University in collaboration with University of Technology Sydney, Curtin University, University of Western Australia, University of Melbourne and Deakin University, this project is has interest from 7 industry partners. The project will support one Doctor of Philosophy scholarship and 10 Master of Philosophy scholarships across the university partners.

This research meets the rising demand for lithium ion batteries which has led to rapid development of new mines in Australia. As these mines have ramped up, one common theme has persistently emerged, the issue of the processing plants struggling to meet design recovery rates and achieve cost effective production. Finding solutions to these challenges is hindered by the fact that expertise in designing and operating processes and plants for lithium production is still very limited. Globally the lithium refining plants tend to be semi-batch, and significant internal inventories are maintained. Conversion of plants to fully continuous plants pose additional challenges from an operability perspective.

The lack of the sound understanding of the underlaying metallurgical process mechanisms is seen as the main obstacle to the development of optimised and alternative processes, such as have been developed over the years for the more established commodities in Australia. This project will address this gap and deliver tangible benefits to the industry. This project also aims to set a new value for the waste streams and development of downstream opportunities towards zero liquid discharge technologies.

OBJECTIVES AND OUTCOMES

The primary objective of this project is to develop improved technologies for the production of lithium.

The objectives and outcomes from this project include but are not limited to:

- Establish the impact of hard rock breakage mechanism on liberation characteristics of lithium minerals and tantalum minerals by using various crushing techniques.
- Develop more energy efficient grinding technology and grinding additives to effectively break and grind lithium ore to fine powders with desired size and optimised size distribution.
- Optimise coarse particle processing by wet and dry separation methods (gravity, magnetic and flotation).
- Develop new collectors for fresh and saline water flotation of hard rock lithium minerals.
- Develop more efficient calcination processes for spodumene and petalite to achieve high Li extraction efficiency with lower cost and energy consumption, whilst minimizing clinkering and fines losses.
- Develop technology for direct hydrometallurgical Li extraction from hard rock minerals.
- Establish the mechanochemical processing of hard rock lithium bearing minerals.
- Develop improved understanding of guiding principles for effective impurity separation and by-product recovery from leach liquors by precipitation and ion exchange processes.
- Develop processes for production of high purity battery grade lithium by crystallisation using alternative new approaches and reagents.
- Develop technology to produce $LiOH.H_2O$ from different product liquors using electrodialysis.
- Develop technology for the regeneration of caustic and acid from Na_2SO_4 waste liquors by bipolar membrane electrodialysis.
- Develop technology for the recovery of reagents such as fluorine from final liquor by precipitation.

PROJECT LEADERSHIP

Professor Aleks Nikoloski is an expert in the electrochemistry of leaching and the reduction processes used in the hydrometallurgical treatment of metals and minerals and is the Academic Chair of Extractive Metallurgy at Murdoch University.

Professor Nikoloski completed his PhD in Metallurgical Engineering (Hydrometallurgy) at Murdoch University and has over twenty years of teaching and research experience in Extractive Metallurgy, as well as several years' experience in industry. During his time in industry, Aleks conducted cutting-edge research, leading several research projects some of which have led to established commercial operations.

He has significant experience in the metallurgical process development using pilot plant scale test work and investigates the kinetics and thermodynamics of metallurgical processes for the treatment of non-ferrous metals, in particular nickel, cobalt, copper, gold and the platinum group metals.

STATUS

This project was approved by the FBICRC Board in December 2019 and is currently in the final stages of contracting to undertake Stage 1. Stage 1 will determine the current State-of-Play across the lithium extraction flowsheet, define the benefit of improved technologies to Australian battery industries, including the potential economic impact and develop a commercialisation pathway plan in conjunction with industry participants. Initial medium/large calcination trials, in collaboration with Calix Ltd will be undertaken to determine optimal calcination operating parameters for lithium beneficiation at their pilot flash calcination facility in Victoria.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$4,527,100	$5,020,000	$9,547,100
Target Allocation	$2,263,550*	$9,054,200**	-
Current Allocation	0	$5,020,000	-
Allocation Required	$2,263,550	$5,020,000	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Cathode Precursor Production Pilot Plant in Western Australia

Increasing the value chain of battery manufacturing in Western Australia by developing Pilot Plant and establishing technical and processing capabilities to manufacture nickel-rich cathode active material precursors.

Western Australia (WA) has the potential to supply all the commodities required by the battery manufacturing industry. Battery Precursor manufacturing is a crucial step to add and increase the value of battery production for industry partners.

Manufacturing of battery grade lithium Nickel-Manganese-Cobalt (NMC) and lithium Nickel-Cobalt-Aluminium (NCA) oxide precursors in Australia will provide the cost-effective, sustainable production of superior quality battery precursors for cathodes whilst minimising processing wastes. The success of this project will bring significant social, environmental and economic benefits to local communities and the nation, including potential production of fertilizer as a by-product (reduction of waste streams), job creation and placing Australia as an exporter of value-added products rather than raw materials. The project will also facilitate research training in high-quality research environment and international research collaborations.

Lithium ion batteries are widely considered as the most advanced power sources for the next generation of electric vehicles and smart grids to reduce the reliance on non-renewable energy sources. The cathode accounts for about one third of the total cost of a lithium ion battery and nickel-based cathodes provide economic and environmental advantages while delivering batteries of high energy density.

This project will deliver the design, construction and operation of a batch pilot plant for manufacturing various cathode precursors. The electrochemical and materials quality standards performance of the final precursors will be delivered through battery production and testing. This project will also investigate performance enhancement methods such as surface coating, layering and doping and the performance of new cathode material combinations. At scoping study level, process modelling and scale-up verification of final process design will be completed along with capital and operating costs to prove the viability of the production of ultra-stable NCM/NCA cathode materials with a clear path to commercialisation, along with analysis of environmental, safety and business benefits/risks.

This 4-year project will progress through a staged project approach as a pathway to commercialisation and highlight the key benefits and risks associated with precursor production:

- Project planning and small-scale process verification.
- Pilot Plant construction and commissioning.
- Process scale-up and pilot campaigns.

COLLABORATION AND IMPACT

The Cathode Precursor Production Pilot Plant project will be led and managed by Curtin University in collaboration with Queensland University of Technology, University of Technology Sydney, CSIRO. To date, 15 industry participants have indicated interest in this project.

This project will support 3 Master of Philosophy research candidates, with one student based at each of the university participants.

Collaborations between the research and industry partners will enhance the international competitive profile of Australia in the field of energy storage. The key outcome is to generate patentable technologies and to confirm the operability, ability to quality control, and provide the techno-economic foundation for a cathode precursor materials plant which will attract investment to Australia from other influential international organisations and corporations. In addition, this multidisciplinary investigation will create several high impact publications in peered journals and deliver trained staff.

Commercialisation pathways will be dependent upon the cathode precursor markets and the research outcomes from this project; commercialisation opportunities will be identified through demonstrating economic drivers for manufacturing battery precursors in Western Australia and setting and achieving technical goals for cathode precursor production at the pilot scale. Techno-economic analysis of processes and commercialisation strategies will be developed in line with these outcomes throughout the life of the project.

OBJECTIVES AND OUTCOMES

The main objectives of this project are to increase the value chain of battery manufacturing in Western Australia while minimising the environmental impact of production.

The intended outcomes from this project include but are not limited to:

- Establishment of technical and processing capability in Australia to produce cost effective high-quality precursors on a production scale.
- Detailed engineering design and construction of a precursor pilot plant that lays the foundation for specification for the development of industrial scale plants.
- Allow production of ultra-stable hydroxide co-precipitated Ni-Co-Mn/Al-OH precursors from their salts and with the ability to control the particle size distribution.
- Establish Lithiation of Mixed Hydroxide co-precipitated Ni-Co-Mn/Al-OH precursors.
- Investigate the potential to remove sulfate generated in the hydroxide co-precipitation process as a potassium-ammonium sulfate that can be used as a product in the fertiliser industry.
- Conversion of the mixed hydroxide precursor to cathode active material for qualification testing.
- A verification and qualification of the final precursor with regards to electrochemical and materials quality standards.

PROJECT LEADERSHIP

The project will be led by Dr Mark Aylmore with Ms Erin Ireland as Theme Lead. Dr Aylmore is a Senior Research Fellow at the John de Laeter Centre, Curtin University, and currently managing several critical mineral ore assessment projects. He is a Fellow of the Australasian Institute of Mining and Metallurgy. Mark has extensive technical experience in extractive metallurgy, process mineralogy, mineral processing and process engineering, including scoping through to feasibility level studies on a number of commodities. He has numerous publications and reports, including several patent lodgements. His early work established him internationally as a leading authority in the fundamentals and practical use of alternative leachates to cyanide in the gold industry.

Mark has held senior roles in managing industry and government funded projects and has worked for various international mining companies, institutions and consultancy firms over his 27 years in industry and academia.

STATUS

The Cathode Precursor Production Pilot Plant project was approved to commence Stage 1 - planning by the FBICRC Board in December 2019. This project is currently in the final stages of contracting to undertake

Stage 1, which includes the full-scale budget and project planning for four years, stock take of pilot plant components, identification of cathode materials, small scale process verification and process modelling and production cost estimates. Participant allocations to this stage need to be firm commitments, allocations to later stages can be indicative and confirmed during contracting for these further stages. The Stage 1 and estimated full project budget are indicated below.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$6,841,943	$6,420,000	$13,261,943
Target Allocation	$3,420,971*	$13,683,886**	-
Current Allocation	$0	$6,420,000	-
Allocation Required	$3,420,971	$7,263,886	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Super Anode

Developing Australian capability across the anode material value to chain to produce high power anodes

Australia can position itself to produce high power anodes utilising more environmentally sustainable processing methods to process natural graphite and novel applications of nanotechnologies and binder technologies.

Graphite based anodes are a core element of batteries, including lithium, and are typically manufactured from a blend of natural (flake) graphite and synthetic graphite. Current levels used in anodes are around 50:50, although the expected natural graphite is expected to increase to 70% over time as both cost and environmental pressures increase on battery manufacturers and end users. To compete with synthetic graphite, natural graphite must be processed via a complex set of processes, firstly to flake graphite and then with further processing to produce spheroidised particles of the require particle size distribution, shape and purity. Due to the significant number of process steps material losses are high (often in excess of 66%) which leads to significant wastage and increased cost.

Further, in a bid to increase the capacity of the anode, researchers and industry have begun to add silicon particles to the anode in a bid to further enhance the energy density of lithium-ion batteries. This presents significant challenges in both the electrode processing, mechanical and chemical stability of the electrode in operation and cycle-life, primarily due to the ~400 % volume change during cycling.

Australia has a significant capacity for Graphite production with an estimated resource of 7.14 MT and a market value for graphite estimated at 1.08 billion USD. The potential opportunity for Australian graphite is substantial but Australia currently has no industrial scale capacity to manufacture anode materials and/or assembled anodes. A capability is emerging that this project aims to support and accelerate to capitalise on Australia's natural graphite reserves and processing technologies.

The Super Anode project will focus on adding value to Australia's natural graphite reserves by the development of step change improvements in processing including the critical steps of spheroidisation and purification, formulation of electrodes, including silicon additives and binders, and the associated manufacturing processes. The project aims to develop an Australian capability in natural graphite processing to take advantage of the value to natural graphite by upgrading to improve performance and displace synthetic graphite with natural graphite flake by reducing cost without compromising performance.

The 4-year project timeline is comprised of 4 sub-project topics:

- Production and upscaling silicon:natural graphite spheronised composites
- Coating and production of high energy density anode materials
- Preparation of hybrid natural/synthetic graphites
- Life cycle and cost/benefit analysis

COLLABORATION AND IMPACT

This proposed project will be led and managed by the University of Melbourne in collaboration with University of Technology Sydney, CSIRO, Deakin University and Queensland University of Technology, this project has interest from seven industry partners to date. The project will support one full Doctor of Philosophy scholarship, two top-ups, one Master of Philosophy scholarship and several Honours or 4th year engineering research projects.

Commercialisation of project outcomes will be via the industry participants. The step change improvements likely to result from the project will enable key points of differentiation (cost/performance) for Australian producers. The Super anode project will directly support the development of commercial capability and capacity in Australia by connecting relevant research and industry players and understanding current best practice in the production and testing of anode materials. Several key outcomes will support this including:

- Establish required testing protocols to compare the efficacy of different anode materials and production approaches.
- Optimise the sub processes of graphite purification, spheroidization and coatings, and overall system optimisation.
- Develop novel "composite" anode formulations, including the use of silicon and/or artificial graphite additives.
- Increase the Australian expertise base in anode battery materials.

These outcomes will directly support and accelerate industry to develop natural graphite and subsequent anode production capacity in Australia. The project team has access to a broad range of fabrication and characterisation tools as well as national computational facilities, all of which address specific objectives from industry and the FBICRC.

OBJECTIVES AND OUTCOMES

The project will seek to develop and implement a processing pipeline for silicon loaded natural graphite for anode production. This pipeline will include improved, environmentally friendly, and safe, processing of natural graphite through spheronisation, purification, coating, and silicon incorporation. Feasibility and full life cycle analysis of hybrid natural/graphite materials for anodes will be examined.

The Super Anode Project objectives and targets are to:

- Establish current best practice in graphite processing
- Develop capability in assessing natural graphite-based anode materials and anodes.
- Define and produce the optimal bimodal particle size distribution
- Reduce the wastage (particularly in spheroidisation) of natural graphite in anode production by 30%.
- Reduce the processing cost of anode materials by 25%.
- Improve the performance of anodes by 25%.
- Complete a full life cycle analysis of natural graphite (and composite) anodes.

PROJECT LEADERSHIP

Amanda Ellis is a Professor and Head of Department of Chemical Engineering at the University of Melbourne. She graduated with a Ph.D. (Applied Chemistry) from the University of Technology, Sydney in 2003.

After two postdocs in the USA, including Rensselaer Polytechnic Institute and New Mexico State University she secured a prestigious Foundation of Research Science and Technology Postdoctoral Research Fellowship at Industrial Research Ltd (now Callaghan Innovations). In 2006 she commenced at Flinders University, South Australia as a teaching/research academic in Chemical and Physical Sciences. During this time, she became a full professor (2013), an ARC Future Fellow (2014) and acting Associate Dean of Research for the Faculty of Science and Engineering (2016). In May 2017 she joined the Chemical Engineering Department at the University of Melbourne. She has been an ARC College of Experts for the MCPE panel (2017-2019) and Board member of the Royal Australia Chemical Institute (RACI) (2016-2019). She has secured over $20 M in funding from the ARC and non-ARC sources on projects involving novel polymer coatings, DNA nanotechnology, functionalised carbon nanotubes and graphene, nanocellulose, and plastic and biomass gasification.

STATUS

The Super Anode proposal is currently under development and is expected to be submitted to the FBICRC Board in June 2020.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$4,122,156	$2,009,250	$6,131,405
Target Allocation	$2,061,078*	$8,244,312**	-
Current Allocation	$750,000	$2,009,250	-
Allocation Required	$1,311,078	$6,235,062	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Whole of Systems Approach for Assessment of Battery Investment Options

A software platform for improved decision-making of investment and operation of batteries

This project will deliver a software platform as a mechanism for network providers and retailers to assess and understand the costs and benefits of installing different battery types and sizes for various purposes at different locations over an asset base.

Many battery technologies, different in type and scale, have been developed for industrial and power engineering use; they offer a large range of capabilities to support electricity production from residential households, communities and commercial enterprises. Appropriate choices of energy storage battery provide substantial benefits to regional or national electricity grids as intermittent energy generation comes on-line. However, choosing the type, location and timing to invest in batteries is difficult in this relatively new energy environment. This is partly due to the lack of confidence in battery systems performance in specific environmental and operational conditions, and the lack of analysis tools that can capture the impact of perturbation in one part of the system to the system overall.

This project will deliver a software platform for utilities/retailers to assess investment options of battery storage installations over their network. The software implementation will be based on data-driven models using data from case studies selected from a high/medium (HV/MV) network in Queensland and Western Australia, with potential to expand to other regions. The intention of this project is to demonstrate study feasibility in the first instance, with plans to extend the methods and models to other areas in SA, VIC and NSW within the NEM, as well as to a broader range of revenue models and commercial opportunities.

By considering the physical infrastructure, the impact of the operation of proposed battery installations on the network will be quantified. This will highlight constraints and benefits both in terms of physical operation and revenue opportunities. Additionally, focusing on a limited area of a HV/MV network in the first instance reduces the parameter space to a small set. This will result in simulation and analysis output that are cognitively manageable, providing decision-makers with an ability to draw conclusions and get strategic values quickly and with greater confidence. This has further advantages in terms of demonstrating the suitability of the approach with greater confidence when later applied to larger areas and over LV networks.

This data- and user-centric software platform will improve decision-making of investment and operation of batteries. A successful project will contribute towards the development of long-term strategies for utilities to reduce electricity supply costs and increase affordability of electricity. This approach will also lead to greater confidence regarding battery investments through the development of realistic operational conditions for battery systems using trial data and expected growth in the market. The methods and tools developed during this demonstration project are generic and can be used at other locations and over larger areas than the project case studies.

This 2-year project will be divided into 2 main sub-projects:

- Development of a whole of system analysis tool for the selection of the type, location and timing of battery systems
- Predictive location and purpose-specific operational performance of battery systems

COLLABORATION AND IMPACT

This project will be led and managed by Queensland University of Technology in collaboration with Murdoch University. Opportunities with the University of Adelaide and University of Melbourne are currently being explored. To date, 5 industry participants have indicated interest in this project including 2 energy retailers. This project will support 2 Master of Philosophy research candidates based at QUT.

Without a whole of system assessment when investigating battery network investment, it is difficult to identify fluctuation in flows of electricity over a network subject to new forces (e.g. uptake of new technologies, shut down of some generation types) as well as capture investment return opportunities with sufficient confidence. Investors need to gain confidence not only in the technology but also in their suitability for the application and for their return on investment.

By experimenting with different scenarios of battery placement, operation and remuneration schemes, the stakeholders will gain confidence in terms of return on their investment, as well as electrical safety and reliability of their network. This will in turn lead to greater investment in batteries, leading to a more secure, environmental and affordable electricity supply and a stronger battery industry.

Economic impacts of successful investment planning for state and national level power networks have been well described by the Finkel Report (2017) and other studies by consulting firms. In short, a stabilised and secure energy network that is resilient to technology innovations and additions as well as to more intense external events (e.g. extreme weather/climate change) has immense economic and social value. More effective and efficient use of energy generation and distribution using strategically planned battery installations will also reduce the demand for larger-scale, longer-term investments in generation technologies that may have unsustainable environmental impacts.

OBJECTIVES AND OUTCOMES

This project will extend an existing generic prototype model for a distributed regional network to address the following core research questions:

- Given a range of battery investment options, what is the most sustainable option for a system overall?
- Where do the costs and benefits lie for different battery types/sizes/purposes/locations with respect to generators, network operators and retailers?
- How can confidence increase when investing in networked batteries?

The intended objectives and outcomes from this project include:

- Deliver a software platform for utilities/retailers to assess investment options of battery storage installations over their network
- Extend models from a previous QUT-industry project that evaluates the impact of trajectories of consumption over many years and locations, and suggests optimised solutions for network planning.
- Extend models of network assets structure to include assets at the HV level with large generators and supply constraints in the wholesale market.
- Develop new models for battery operation using data gathered from battery trials at various locations and for different operation modes.
- Implemented new and extended models in the software to increase accuracy of battery assessments under specific conditions.
- Provide ranking of battery investment options (against key criteria of economic, environmental and social value) from applying ranking theory and multi-criteria analysis using simulations output to determine most sustainable outcomes for the system overall (optimal location, type and timing of battery installation).

PROJECT LEADERSHIP

As a research fellow in the Science and Engineering Faculty at Queensland University of Technology (QUT), Dr Fanny Boulaire applies her knowledge in analytics, modelling, and software development to research projects seeking answers to a variety of challenges in the energy sector.

Fanny has developed her technical expertise over twenty years, since she started her undergraduate studies in mathematics, modelling and computer science. Her knowledge deepened as she worked as a project officer at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), in the domains of building and construction, bushfire and water asset management. There she developed software tools in Java, Java3D, and Python, as well as statistical models for different applications.

In March 2011, Fanny joined QUT to work on a collaborative research project between QUT, two Australian and three German universities, and Ergon Energy. The project investigated the impact of introducing renewable energy sources on electricity grids. It focused on quantifying electricity usage of assets with a view to finding alternative solutions to address costly network upgrades. In this project, Ergon Energy provided the case studies and data, while she applied complex system science techniques, namely agent-based modelling, to the modelling of the different factors affecting electrical power distribution systems. At the same time as she was working on the Ergon Energy project, Fanny undertook and successfully completed a Doctor of Philosophy (PhD). Her PhD work provided a flexible and extensible software environment on which the models were developed. This was a very enriching experience, combining the research objectives with Ergon Energy needs in order to produce rigorous and high quality project outcomes.

After she completed her Doctorate, her novel and practical approach to developing modelling and software platforms gained industry interest. Fanny has since worked with Energy Queensland on two research projects, assisting them in bringing together their data with a view to developing a complete network model of Queensland, and developing a bayesian network that describes their customers' relationship with electricity.

STATUS

The Whole of Systems Approach for Assessment of Battery Investment Option project Expression of Interest was submitted to the FBICRC Board in March 2020 and was invited to submit a full project proposal for assessment in June 2020. The project team is exploring expanding the project team to South Australia and Victoria.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$570,223	$590,000	$1,160,223
Target Allocation	$285,112*	$ 1,140,446**	-
Current Allocation	$0	$590,000	-
Allocation Required	$285,112	$550,446	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Electrochemical Testing of Li-ion Battery Materials in Standard Cell Formats

Establishment of fabrication and electrochemical testing facility for lithium-ion battery materials

This project will fabricate industry standard lithium-ion battery cells from materials developed in Australia and provide representative electrochemical data to validate the performance and quality of these materials.

The industry accepted process for validating lithium-ion battery materials is to produce battery cells and test their electrochemical performance. While it is important to test and characterise the individual components, it is how the materials perform when combined in a full cell that provides the true electrochemical performance of the materials. Feedback from these tests can then be provided to the materials developer for the iterative optimisation of their product.

A key outcome of this approach is the creation of an accessible database from the iterative feedback of progressive improvements to the battery cell materials by identifying factors such as;

- standardised materials production for best performance
- preferred materials properties that relate to performance such as particle size, morphology composition and coatings
- identification and impact of impurities
- control of solid phases formed during the manufacturing processes
- the nature of the solid-electrolyte-interface (SEI) layer formed during cell formation.

This project is an essential link between other FBICRC projects including Cathode Precursor Production Pilot Plant, Super Anode and Future Electrolyte Systems by providing validation data for cathode, anode, electrolyte and separator performance in a final cell format. It builds upon QUT's existing cell fabrication and electrochemical capability, which includes Australia's only purpose-built Dry Rooms for lithium-ion cell fabrication. Specific outcomes will include an improved the testing capacity and wider range of industry-representative cell types that can be fabricated. Formation equipment will be added to the current facility to assist with understanding the solid-electrolyte-interface (SEI) that develops in a cell during initial charging and discharging. Optimisation of this SEI layer improves the quality, cell longevity and reproducibility. Collection of data regarding improved cell safety through the development of high purity alumina (HPA) coatings of separator membranes will also be an important aspect of this project.

COLLABORATION AND IMPACT

The 4-year project timeline comprises 4 key work packages and has a cash component of $3.7M and $2M in-kind for a total project value of $5.7M. Key equipment purchases include;

- A double-sided electrode coater
- Electrode stacker for producing standard pouch cells.
- Pouch cell fabrication equipment; electrode cutter, pouch former and heat sealer

- Electrochemical cell formation equipment
- Cell cycling equipment

The project will be led by the Queensland University of Technology in collaboration with Deakin University and the University of Melbourne. Industry participants have been included in the research team to maximise feedback between the research group and industry participants. The project team also supports three higher degree students and will work closely with the local TAFE to train a workforce with specialised skills to support industry-based quality control of value-added battery materials development in Australia.

The cell performance database will also provide valuable information to the National Battery Testing Centre including safety data and information that will inform battery module builders in the development of safe operating standards.

OBJECTIVES AND OUTCOMES

Key objectives include:

1. The establishment of a facility for fabricating and electrochemically testing lithium-ion battery materials.

2. The creation of an interactive database to inform materials developers of;

- best practice processing
- raw materials specifications related to effects of impurities
- impurity phases that can occur during processing
- materials and cell standards related to safety of cells and cell modules
- electrochemical performance of materials in combination with other cell components in a complete cell
- electrochemical performance of materials in cells under a range of charge/discharge and environmental conditions
- cycle life and reproducibility of performance

PROJECT LEADERSHIP

Professor Jose Alarco (Institute for Future Environments, QUT) has been involved in R&D of battery and other nanotechnology materials for over two decades, both within academic and commercial organizations. He has co-developed and holds numerous patents in generic processes for the manufacture of nano-scale complex, metal oxides and for applications in catalysis, batteries, electronics, and other chemical/physical processes. Much of his work has involved translating manufacturing processes from lab to pilot plant scale at tonnes per week level. He has an undergraduate degree in Physics from National University of Engineering in Peru and a PhD in Materials Science from Chalmers University of Technology in Sweden.

He has been involved in collaborations with international chemical and battery companies such as BASF, Engelhard, Valence Technology, Sud Chemie, Degussa, Phostech Lithium, Lishen Battery Co and A123. He was a Chief Investigator in the Auto CRC Project led by Professor Peter Talbot, with over $4 million awarded to QUT for R&D on lithium-ion battery production scale-up for energy-efficient vehicles in Malaysia and Australia.

Jose is also a Co-Investigator in the S7.7M ARENA H2Export Project on Cost Effective Renewable Hydrogen through Materials, Modelling and Process Innovation. In this project, Jose is part of the team developing high energy density battery materials with improved cyclability and building battery packs as back-up power for the electrolyser operation at the “plug and play” renewable microgrid facility at Redlands. He is currently a Theme Leader for Battery Safety and Security in the Future Battery Industry (FBI) CRC.

STATUS

This proposed project is currently under development with the intent to submit a full project proposal for the June 2020 CRC Board meeting.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$3,724,805	$1,965,000	$5,689,805
Target Allocation	$1,862,402*	$7,449,610**	-
Current Allocation	$188,000	$1,965,000	-
Allocation Required	$1,674,402	5,484,610	-

Note
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Key Techno-Economic Solutions to Drive Mass-Uptake of Australian Manufactured Battery Systems

Facilitating cost reduction throughout the battery energy management value chain for Australian battery manufacturers

Australia leads the world in residential rooftop solar uptake with one in every five houses having an installed photovoltaic (PV) system. On the back of a growing number of residential roof top solar, battery storage uptake was expected to boom, however, Electricity Statement of Opportunities produced by AEMO in 2018 suggests less than half the uptake forecast reported in its 2017 document due to longer pay-back periods for batteries. This highlights a need to minimise the cost and maximise the economic benefits of both stationary and mobile battery systems to ensure mass uptake of Australian-made battery energy storage systems (BESSs).

In this context 3 key barriers to mass uptake of grid-connected batteries have been identified:

- The power electronics that grid-connect battery systems are not sufficiently scalable or sufficiently robust to optimise their cost across a range of market segments;
- A coordinated control approach for battery systems to provide interoperability and electrical stability in microgrids must be developed and standardised;
- Lack of clear value proposition of Virtual Power Plants (VPPs) to generators, retailers and customers, and the associated business and electricity pricing models that maximise the financial benefit of batteries to all participants.

This project aims to develop next-generation power electronics for battery applications. In addition to providing significant battery performance, safety and lifetime improvements these systems will modularise deployment and create a simplified, mass-producible building block. The project also aims to develop and optimise the individual and coordinated control of modular battery energy storage systems to enhance grid stability and energy reliability in microgrids. New technology and business models will also be developed that co-optimise the utilisation and benefits of batteries in a VPP, which will ultimately drive increased uptake of battery systems.

This 3-year project will be split across three key work packages to address these challenges:

Grid-Interfacing Power Electronics

This subproject will develop modular and scalable power electronics that are based on multilevel converter technology and will be mapped into advanced electric vehicle battery chargers. It will facilitate cost-effective deployment of battery chargers and establish pathways for Australian battery charger manufacturers to monetise their contribution to grid stability and energy availability, through incentivised use of mobile batteries to buffer energy demand.

Batteries as Microgrid Enablers

This subproject aims at solving some pressing industry problems in using battery energy storage systems to provide grid-forming functionality in microgrids. Project outputs will be integrated into participant products, which can be found supporting numerous Australian industries including, hospitals, substations, oil rigs, airports and mines as well as on Australian warships both in Australia and overseas.

Battery Enabled Virtual Power Plant for a Residential Housing Complex

Development of artificial-intelligence (AI)-based energy management system for community-size battery in a newly established VPP and implementing the optimal battery energy management system on a hardware level. This will be integrated into the overall energy management stratagem of the entire VPP and finally, developing an optimal business model.

COLLABORATION AND IMPACT

This project will be led and managed by the University of Western Australia in collaboration with Murdoch University and the University of Adelaide. To date, 8 industry participants have indicated their support this project which will also support two Doctor of Philosophy scholarships, with students based at Murdoch and Adelaide.

This project will facilitate significant cost reduction throughout the battery value chain and thereby help overcome barriers to mass uptake of grid-connected battery systems into the Australian power grid. This will be achieved by undertaking research that proposes, develops and constructs modular, reliable and mass-producible battery charger building blocks. The modular nature of the building blocks will result in reduced engineering effort, onsite installation, reduced maintenance, and high-volume production/economies of scale.

A key advantage of the proposed project is that the main technical contributions span from integration of the smallest constituent battery modules all the way up to utility-scale deployment and coordination of grid-connected batteries. With the targeted deliverables, the project can design battery systems that meet required grid support functionality, and simultaneously develop control and economic modelling strategies that best utilise the performance characteristics of these battery systems. This will provide the Australian battery manufacturing, integration and utilisation industries a key competitive edge in both domestic and international markets.

Further, uncoordinated power-electronic controlled BEMS represent a significant stability risk to microgrids as fossil fuel based synchronous generation is retired. Intelligent coordination of battery systems is capable of increasing the value-add of batteries and is therefore crucial to future Australian battery industries. Therefore, this project will also develop and standardise control approaches for modular battery systems deployed in microgrids.

The concepts developed for battery enabled VPPs will be directly scalable to an entire power grid made up many thousands of interconnected VPPs. Such concepts will contribute to new power generation and retail business models, to minimise electricity cost and maximise the utility of energy assets. A novel market model will include energy pricing, control and trading, and be suitable for a future renewable integrated power grid and technically ready to replace the current energy business models.

OBJECTIVES AND OUTCOMES

The intended objectives of this project are split across the 3 subprojects and include:

Grid-Interfacing Power Electronics

- Design and prototype a mass-producible and standardised building block for a 10kW electric
- vehicle battery charger;
- Prototype the printed circuit board for modular 10kW battery charger;
- Series and parallel scaling of blocks to form a 100kW battery charger system;
- Develop standardised modulation, control and communication techniques to provide grid to vehicle and vehicle to grid charging/discharging services from the battery charger system.

Batteries as Microgrid Enablers

- Develop and integrate power electronic models that describe the transient behaviour of a broad range of microgrid equipment sourced from various vendors.
- Identify, develop and analyse control schemes that maintain electrical stability and energy security in battery-enabled microgrids with high renewable-penetration levels;
- Address the steady-state and transient control and coordination of modular battery systems deployed in microgrids, enabled by next generation communication systems such as 5G WiFi;
- Identify the optimal system architecture for battery-enabled microgrids deployed in either community or remote off-grid applications;
- Prototype a modular battery energy storage system in a 50kW microgrid.

Battery Enabled Virtual Power Plant for a Residential Housing Complex

- Aggregate distributed PV solar panels and behind the meter community battery storage from a residential complex located in South Lake (WA) to form of an industry-scale VPP;
- Coordinate individual household energy consumption, production, storage profiles and energy pricing within this VPP;
- Develop suitable energy business models for electricity retailers to serve the Australian energy market;
- Develop a strategy to co-optimise between (1) the VPP controller that aims to maximise economic benefits of the entire community and (2) individual household energy usage preferences.

The expected flow on benefits of this project include job creation in the emerging Australian BEMS manufacturing industry and job retention through increased economic viability of grids. Cheaper and more reliable electrical power for Australian energy consumers will reduce negative societal effects on low socio-economic members of society and the superior utilisation factor of electrical infrastructure coupled with lower cost of renewable generation will leading to increased uptake and reduced greenhouse gasses due to higher efficiencies gained by lower transmission and distribution losses.

PROJECT LEADERSHIP

Tyrone Fernando is a professor of electrical engineering at the University of Western Australia and leads the Power and Clean Energy research group which focusses on grid integration of clean/renewable energy sources, microgrids and energy storage systems, which are all related to modernising the electric grid. Tyrone is the Chair of Power and Energy technical committee of the IEEE Circuits and Systems Society, and have served in editorial boards of several journals related to the disciplines of power and energy. Tyrone has published extensively on topics related to electric grid modernisation with renewable energy sources and battery energy storage systems. Tyrone collaborates with Western Power on a number of projects including building an optimal electric network in the South West Interconnected System through identifying locations for stand-alone power systems with energy storage systems (see weblink: https://www.westernpower.com.au/community/blog/cost-saving-innovation-for-electricity-networks/)

Building on the collaborative research with Western Power, Tyrone is the lead chief investigator of the research project "Microgrid Architectures for Efficient Use of Renewable Energy Sources" currently funded by the Australian Research Council under the Discovery Projects scheme. Recently, Tyrone provided consultancy services for Cape Bouvard Technologies (Australia) on a liquid cooling technology for battery energy storage systems, and is also involved in a number of other industry related research projects in energy related topics with Magellan Power (Australia), Tritium (Australia), Ultra Power Systems (Australia), GemTek (Australia), Synergy (Australia), Horizon Power (Australia), Water Corporation (Australia), and Eco Power (Sri-Lanka).

Professor Fernando obtained his Bachelor of Engineering with honours and PhD degrees, both from the University of Melbourne in 1990 and 1996. He has been with the University of Western Australia since 1996 where he is currently a professor of electrical engineering. He has served as Associate Head/Deputy Head of the electrical engineering department at UWA during 2008-2010. During his sabbatical leave periods from the University of Western Australia, he has worked at Deakin University and Eco Power (Sri-Lanka). He is a senior member of IEEE society.

STATUS

The Key Techno-Economic Solutions to Drive Mass-Uptake of Australian-Manufactured Battery Systems project Expression of Interest was submitted to the FBICRC Board in March 2020 and invited to submit a full project proposal for consideration in June 2020.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$1,821,000	$3,580,000	$5,401,000
Target Allocation	$910,500*	$3,642,000**	-
Current Allocation	$900,000	$3,580,000	-
Allocation Required	$10,500	$62,000	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Chemical Processing of Vanadium and Manganese Ores for Battery Materials

Developing new and improved processes for vanadium and manganese extraction and purification, and the optimisation of vanadium bearing electrolytes of Vanadium Redox Flow Batteries (VRFBs)

VRFBs offer significant advantages for electrical energy storage where volumetric or specific power delivery is of lesser concern, but where safe, non-flammable, long life storage is paramount, such as for stationary grid and microgrid applications.

This project will develop and demonstrate new and improved processes for vanadium and manganese extraction and purification that involve lower capital and operating costs, produce highest purity products with lower environmental impact, and recover valuable by-products. The cost-effective production of battery grade manganese sulfate and vanadium pentoxide is targeted in order to produce cathode and new generation electrolyte materials respectively.

This project will address industry research questions to improve vanadium and manganese recovery, reduce energy and reagent consumption and impurity levels in products, optimise recovery of by-products and manage waste streams. Theme 1 will seek to improve vanadium extraction from primary and secondary sources, including methods to reduce the reagent consumption, optimise product purity and recovery of by-products, and develop processes for direct leaching to lower cost of production. Theme 2 will focus on the energy storage applications – the Vanadium Redox Flow Battery (VRFB) which will be demonstrated on a closed grid. Optimal electrolyte and operating parameters for use in VRFBs will be identified. Theme 3 will seek to develop cost-effective and selective approaches to extract

manganese from high-iron ores and from waste materials, including both reductive roasting options and alternative processes for direct hydrometallurgical extraction of manganese from ores and

waste tailing, and optimisation of impurity separation and purification processes to enable production of the highest purity manganese products.

The 4-year project timeline is comprised of three key themes addressing industry research questions to improve vanadium and manganese recovery, reduce energy and reagent consumption and impurity levels in products, optimise recovery of by-products and manage waste streams.

Theme 1 - Vanadium resources processing

- Characterisation of vanadium ores in Australia: Supporting diversity in Australian battery minerals
- Roast-leach and direct leach processing options for the extraction of vanadium from iron and titanium oxide ores and waste materials
- Design and operation of a pilot plant for the novel VanadiumCorp-Electrochem Processing Technology process for multi-commodity recovery from titanomagnetite vanadium ores

Theme 2 Vanadium Redox Flow Battery (VRFB) development and application:

- Application of a 100kWh VRFB (CellCube FB10) in the Murdoch Smart Grid to demonstrate VRFB technology and performance, and in-place evaluation
- Optimal electrolytes and operating parameters for use in full scale Gen 3 and Gen 4 vanadium redox flow batteries

Theme 3 - Manganese resources processing

- Development of improved processes for pyro-hydrometallurgical and direct hydrometallurgical extraction of manganese from common manganese minerals
- Development of impurity separation and purification technology for production of high purity manganese products (MnO2 and MnSO4)

COLLABORATION AND IMPACT

This project will be led by Murdoch University in collaboration with Curtin University, University of Western Australia and CSIR - Institute of Minerals & Materials Technology (India) and has indicative support from 7 industry participants. This project plans to support 5 Doctor of Philosophy and 3 Master of Philosophy scholarships, with the majority anticipated to be joint institution students across the university partners.

The proposed program is designed to assist in the development of commercial technology and processes for safe, effective and efficient treatment of ores, and developing improved and new types of redox flow batteries. The findings from the research will be relevant to industry interested in producing high grade vanadium and manganese products for use in batteries, including related by-products. For example, there is a significant opportunity to develop alternative types of electrolytes for redox flow batteries, utilising cerium which is currently produced in oversupply and could greatly lower the cost of the current VRFB type electrolytes.

OBJECTIVES AND OUTCOMES

Each research theme within this project has key objectives and outputs including:

Theme 1

- Identify the best processing options for the dominant roast-leach technology
- Develop new direct hydro processes allowing rapid take up by industry
- Design and operate a pilot plant to validate the VEPT technology
- Identify the key characteristics of V-hosted deposits that may impact processing characteristics

Theme 2

- Matching of vanadium battery systems to operating requirements (e.g long energy duration, unlimited cycling, 100% depth of discharge, high ambient heat tolerance)
- Electrolyte optimisation to enable improvements in the design and operation of the most modern VRFBs.
- Deliver a better understanding of the operational characteristics of hybrid V/Ce or V/Br type redox flow batteries and effective solutions to possible maintenance issues.

Theme 3

- Establish the conditions for selective extraction of the manganese from iron oxide ores from roast-leach and direct leach process options
- Deliver a cost-effective method to recover high purity manganese
- Develop an integrated process flow sheet for segregation of manganese (and potentially other valuable elements) from impurities

PROJECT LEADERSHIP

Professor Aleks Nikoloski is an expert in the electrochemistry of leaching and the reduction processes used in the hydrometallurgical treatment of metals and minerals and is the Academic Chair of Chemical and Metallurgical Engineering, and Extractive Metallurgy at Murdoch University.

Professor Nikoloski completed his PhD in Metallurgical Engineering (Hydrometallurgy) at Murdoch University and has over twenty years of teaching and research experience in Extractive Metallurgy, as well as several years' experience in industry. During his time in industry, Aleks conducted cutting-edge research, leading several research projects some of which have led to established commercial operations.

He has significant experience in the metallurgical process development using pilot plant scale test work and investigates the kinetics and thermodynamics of metallurgical processes for the treatment of non-ferrous metals, in particular nickel, cobalt, copper, gold and the platinum group metals.

STATUS

The Chemical processing of vanadium and manganese ores and development of redox flow batteries Expression of Interest was submitted to the FBICRC Board in December 2019 and invited to submit a full project proposal for consideration in June 2020.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$3,773,000	$2,750,000	$6,523,000
Target Allocation	$1,886,500*	$7,546,000**	-
Current Allocation	$0	$2,750,000	-
Allocation Required	$1,886,500	$4,796,000	-

Note
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Future Electrolyte Systems

New electrolyte systems to improve Li-ion device performance in niche applications

Despite recent development in solid state and other battery types, lithium ion batteries remain the foreseen default battery technology for the medium term, supported by an industry with significant vested interest in its sustained deployment. However, lithium-ion batteries face limitations in energy-density, power-density, safety, and high temperature stability which can diminish their usefulness or prohibit their application for operation in hot, remote areas. In these respects, the electrolyte is the most critical component of the cell which often limits performance.

The current choice of electrolyte system leads to the poor safety, poor stability over 40^{0}C, insufficient electrochemical stability (limiting energy-density), while the 'soft' materials (binder and separator) impact cell rate performance and stability. Implementing alternative electrolyte chemistries in combination with compatible binder and separator materials is thus the most effective strategy to overcome these limitations.

This project seeks to bring together a wide network of materials expertise to focus on the 'soft' battery components, specifically the electrode binder, separator, and the electrolyte. Through the research and development of battery materials, an Australian battery manufacturing capability and supporting industries can be established based on IP developed during this project. To achieve this, advanced soft electrolyte systems that are superior to current Li-ion technology will be developed for targeted device chemistries.

Building on previous successful research at Deakin University, this project will seek to overcome the Li-ion performance limitations through manipulating electrolyte components by developing more robust separators and binders that are compatible with the new electrolytes and have higher temperature stability, and controlling the bulk electrolyte ion transport and Solid Electrolyte Interphase (SEI) properties through modifying the electrolyte formulation and formation steps. All electrolyte systems will be designed with improved safety and high temperature stability as the first priority, targeting the set of applications where conventional Li-ion cannot compete.

This 4-year project is split into 2 key R&D themes:

- Improve upon existing commercial technologies by employing locally generated materials IP that can be rapidly optimised and implemented at scale.
- Developing new materials for advanced electrolyte systems (high power, high energy, low cost and/or solid state).

COLLABORATION AND IMPACT

The Future Electrolyte Systems project will be led and managed by Deakin University in collaboration with University of Technology Sydney, Queensland University of Technology and CSIRO. To date, nine industry participants have either expressed interest or have considered to collaborate on this project.

This project will support three Doctor of Philosophy scholarships, with a student based at each of the participating university partners with students and post-Doctoral team co-supervised across broad teams of academic and industry supervisors.

Currently, there is a unique opportunity to develop new technologies that meet the demands of smaller scale, high value Australasian markets that are currently not sufficiently served by the global Li-ion battery manufacturers due to the inherent technological limitations. This project aims to stimulate the involvement of ancillary battery industries around chemical and electrode manufacture and of nickel mining industry in the production of electrode materials for emerging Li-ion and Na-ion technologies.

This project aims to drive growth, productivity and competitiveness in the future battery market by championing advances in:

- Materials, chemical and polymer electrolytes synthesis at scale using newly developed methods;
- Manufacture and fabrication of devices with cylindrical prototyping capabilities.
- Upscaling of large format pouch cells by engaging with a pouch cell manufacturer
- Device integration/end-user application

The outcomes of the project will include new products, allowing for participants to compete in the energy storage technology manufacturing market on a global scale as well as growing a future workforce capable of adapting to Australia's future energy needs.

In addition to augmenting the performance and suitability of commercial Li-ion electrode materials, this project will complement and work with the Super Anode and Cathode Precursor projects to develop safe, high performance, high stability electrolyte systems. It will also provide a pathway for CRC electrode materials to be incorporated into an optimised electrolyte system, allowing for more rapid feedback to electrode materials production efforts and providing prototype batteries to be deployed within the CRC for further field testing and documentation.

OBJECTIVES AND OUTCOMES

The Super Anode project will generate IP and know-how around the development of new electrolyte systems and incorporation into devices based on advanced high energy electrode materials. The intended objectives and outcomes from this project include but are not limited to:

- Market analysis and feasibility study to identify the potential markets where Li-ion batteries are unable to effectively operate and determine the performance requirements for target markets.
- Identify and/or develop new compatible separator and binder materials designed for use with high energy Li-ion electrodes and new safe electrolytes at elevated temperatures.
- Identify and/or develop new compatible binder materials designed for use with high energy Li-ion electrodes and new solid polymer-gel based electrolytes at elevated temperatures.
- Develop an electrolyte system with enhanced safety and stability for application with CRC high voltage NMC cathode materials and Super Anode materials.
- Demonstrate pouch cell and cylindrical cell prototypes at Ah scale.
- Foster Australian battery industries through the development and scale-up of advanced soft components and electrolyte systems targeted for niche battery markets.
- Increase Australian capability and expertise in the use, design and application of electrolyte materials in advanced batteries.

PROJECT LEADERSHIP

Professor Maria Forsyth "FAA" (Fellow Australian Academy of Sciences), is the Deputy Director of the Institute for Frontier Materials (IFM) at Deakin University in Australia, an Ikerbasque Professor at POLYMAT in UPV and Director of an ARC Industrial Transformation Training Centre. She also is the Associate Director in the ARC Centre of Excellence in Electromaterials Science (ACES). Sine 2018 she has joined POLYMAT at UPV in San Sebastian as an Ikerbasque Professor where she collaborates with Innovative Polymers group and supervisors research projects related to sustainability. Specifically, she is an expert in ionic materials including ionic liquids, organic ionic plastic crystals, polymer gels and composites with applications to several areas including materials for CO2 absorption, electrowinning of metals and energy storage. Her work has also focused on understanding the phenomenon of charge transport at metal/electrolyte interfaces and within novel electrolyte materials. NMR techniques have featured strongly in Professor Forsyth's research where she has applied pulsed field gradient NMR to measure diffusion of ionic species in electrolytes, variable temperature solid state wide line NMR and MAS to investigate structure and dynamics in solids and, most recently, NMR imaging of electrochemical processes. She leads collaborative projects in lithium and sodium battery technologies funded through recent Australian Research Council grants. Her team collaborates very productively with colleagues within academia, CSIRO, DSTO as well as industry to design new materials and processes to control and optimise these phenomena in two key areas - corrosion (e.g. Corrosion Science 2006, Surface and Coatings Technology, 2007) and electrochemical devices (eg., Nature 1999, Science 2002, Science 2008, Journal of Applied Electrochemistry 2008). Specifically, her work has focused on understanding the phenomenon of charge transport at metal/electrolyte interfaces and within novel electrolyte materials. Such materials have included a range of novel ionic liquids, polymer electrolytes and plastic crystals.

Professor Forsyth is a co-author of over 550 journal and conference publications attracted more than 20000 citations. She has delivered more than 25 invited and plenary talks in the past 5 years. She has served on several editorial boards and is currently senior editor for Journal of Physical Chemistry letters. She has received the Galileo Galilee award for her contributions to the Polymer Electrolyte and energy storage field and awarded to The Victorian Prize for Science and Innovation (VESKI).

STATUS

The Future Electrolyte Systems project Expression of Interest was submitted for consideration to the FBICRC in March 2020. It has been invited to submit a full project proposal for the June 2020 Board meeting and is currently under development.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$3,824,396	$1,860,000	$5,684,396
Target Allocation	$ 1,912,198*	$ 7,648,792**	-
Current Allocation	$0	$ 1,860,000	-
Allocation Required	$ 1,912,198	$ 5,788,792	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Battery Material Provenance

Ethically Sourced, High-grade Battery Material Provenance Authentication for the Next Generation Battery Supply Market

Provenance information, based on the identification of key geochemical and mineralogical signatures, will allow Australian battery materials to have a market advantage over uncertified competitor products. The project will provide greater assurance for end users/consumers around ethical, social, and environmental sustainability through the future battery industry value chain through the development of blockchain supported battery material certification.

Ethically sourced premium grade products will have more value to downstream manufacturers in the face of growing public awareness and consumer expectation. To provide certainty of supply, quality, reliability, affordability, and sustainability of batteries, it is important to ensure that battery precursor materials have well-characterized standards, universal certificates and traceability systems through a Chain-of-Custody (CoC) process.

The FBICRC is commissioning a scene setting project that will focus on 3 key topics to inform the scope and objectives of the anticipated full project:

- Project opportunity context, market need and the advantage to Australia
- Performance review and feasibility evaluation for available blockchain platforms
- Certification/compliance needs of end users

The scene setting project will achieve this through engagement with local and international stakeholders in battery supply chains to determine the value proposition for a provenance tool to verify Australian exports, review the technological aspects of existing blockchain solutions and define and standardize data measures: source, batches, dates, actors, metrics such as chart of accounts (COA) etc. The project will also review existing compliance requirements such as the US Frank-Dodd Act and the OECD Due Diligence Guide. This scene setting project will also inform the scope and outcomes of a full project proposal.

As the importance of ethical sourcing of battery materials increases across the entire battery supply chain ecosystem, especially for end-users of electric vehicle, it is anticipated that a full project will develop accurate tools to verify Australian battery material exports based on the integration of chemical fingerprinting and blockchain traceability and certification technologies. The impact will be Australian producers of battery materials acquiring a competitive market advantage over products with uncertain provenance and will provide greater assurance for end users/consumers around ethical, social, and environmental sustainability throughout the future battery industry value chain.

A geochemical “fingerprinting” database is the foundation of such project; and the necessity in the database is outlined by industry across the battery supply chain, including a range of issues such as:

- Geochemical characterisation of battery mineral provenance;
- Identification and quantification of contaminant impacts;
- Quality control and quality assurance practises in the production of battery grade materials; providing international ‘responsible/ethical production processes; and
- Supply chain transparency and traceability to provide transformative information from production to customer along different points of the supply chain.

To address these problems, the trace element content, isotopic composition, and elemental speciation of a wide range of battery materials would be analysed. This will provide the basis for defining premium grade battery materials and supply chain integrity and provide systems to ensure that battery minerals, metals and materials are responsibly sourced and traded using blockchain technology. The ledgers in the blockchain will record provenance information and responsible production certificates at the suitable supply chain points in a decentralised, transparent, encrypted, and immutable database. The information can be shared in a controlled manner with downstream customers and relevant third parties.

The intended outputs of the proposed full project include:

- Detailed characterisation and understanding of Australian battery mineral resources;
- Guidelines for a new Australian standard for premium quality battery grade materials in terms of chemical composition and contaminant characterisation throughout the mining and processing stages;
- A mechanism to trace a quality assurance through CoC digitisation;
- A commercial private blockchain platform based on traceability mechanism; and
- Suggestions for integration of provenance data into LCA, certification and battery passport schemes contemplated in other project/s.

COLLABORATION AND IMPACT

Led and managed by Curtin University in collaboration with Murdoch University, this project will be comprised of an international team of experts in the field of ore geology, geochemical analysis, extractive metallurgy, energy storage, sustainable policy and data science with the aim of quantifying and tracing specific elements and interelement ratios that may be beneficial or detrimental to the production and certification standards. The full project is expected to support 3 Doctor of Philosophy scholarships.

The potential impacts of this project include economic, social and environmental.

The development of purity standards and 'best practises' for both Li-ion component precursor mineral feeds and battery materials will provide the tools needed to improve battery performance, lifetime, stability and safety. The transparent and traceable nature of the product will provide a template for responsibly produced materials and drive sustainability demands. Public concern regarding ethical supply will be alleviated with detailed and reliable information around social and environmental impacts for the entire battery supply chain. Socially responsible production can be incentivised, based on the standards and compliance to social regulation. End users/consumers will have the ability to trace the provenance of concentrates, battery precursor materials, and batteries based on source and process-specific fingerprints that can be used to verify ethical and sustainable production, providing an economic and socioeconomic market advantage over uncertified products.

This project will also limit the risk of fraud due to the immutability and decentralisation of blockchain, empowering upstream producers and downstream buyers with trustworthy data to support the proof of sustainably and ethically source of batteries, from mine to market to recycling. In addition, this project underpins the integrity of responsible production certificates that demonstrate sustainability.

These outcomes will promote and stimulating Australian battery chemical markets and enable Australia to establish a competitive advantage and increase market share in battery industries.

STATUS

An Expression of Interest for this project was submitted to the FBICRC Board in December 2019. The Board is commissioning a 3-month scene setting project to articulate the certification needs of end users, review current software/develop a state-of-play report and define the end-users, market need and advantage to Australia. The project will be conducted in close collaboration with the Circular Economy and Life Cycle Analysis project.

The scene setting project will inform the scope and aims of a full project proposal.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$4,248,693	$2,403,400	$6,652,093
Target Allocation	$2,124,346*	$8,497,386**	-
Current Allocation	$0	$2,403,400	-
Allocation Required	$2,124,346	$6,093,986	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Demonstrating market advantage through certification and life cycle analysis for Australian battery materials

A quantified environmental basis to ensure traceable, sustainable production of Australian battery minerals, metals and materials.

Batteries (including lithium-ion and vanadium flow batteries) are an important part of the transition towards a sustainable energy sector. Australia has some of the largest reserves in the world for battery minerals (e.g. lithium, nickel, cobalt, vanadium, and graphite) and the Western Australian (WA) state government has recognized the importance of ethical and sustainable production standards to provide a differentiator in a competitive market.

The CRC is taking a leadership position regarding environmental management strategies from extraction of material through to the end of life. We are providing and researching a designated circular economy approach across the whole value chain from resources extraction, through processing, battery production, deployment and reuse/recycling.

For Australian battery minerals, metals and materials producers to be competitive in a global market, it must be transparent about its environmental impact along the battery materials supply chain. To do so, it needs to provide quantitative tools to measure, model, calibrate and qualify the environmental footprint of Australian produced battery materials in alignment with global customers' needs that would value this information and associated certainties.

Quantitative analysis of Australian battery material production systems does not exist, and this limits the ability to demonstrate the relative environmental performance to the market and to consider the full life cycle of a battery. This proposed project aims to fill this gap and provide the underlying research to support market differentiation of Australian production along the battery supply chain. This includes research to support certification framework development to assess and benchmark the environmental and social impact of Australian production, as well as to develop both certification and process optimisation tools for continuous improvement towards a circular economy.

The FBICRC will commission a scene setting project to develop the scope, context, state of play and feasibility of the broader project topic, including consideration of the connections to the proposed project on battery material provenance. All three research programs of the CRC are interdependent, and each contain challenges relevant to establishing a leadership position regarding environmental strategies.

The scene setting study will address the following questions to set the scene for an intended full project proposal:

- Define and identify international state-of-the-art for the circular economy for FBI with focus on design with the goals of reduce, reuse and recycle.
- Provide a basis for a circular economy approach for leadership through engagement of industry, agencies, society and researchers.
- Collate and consolidate technical and policy results to test the circular economy approach.
- Provide/advise first pathways to circular economy best practice for Australian industry.
- Collate and overview of the FBICRC results at a higher circular economy systems level.
- Suggest leadership in environmental management strategies that provide national and international recognition.

- Confirm if a certification framework will be created, its requirements and nature, and to confirm the administrative costs, and who will bear the costs and how the framework will be deployed;
- Confirm and define what data is required by end users for their certification;
- Determine the data format required to be accessible to end users;
- Consider the value of a “battery passport”, outline the role for Australian industry to play in the scheme;
- Outline the value for Australia of a circular economy approach, certification and battery passport schemes;
- Map and reconcile to the requirements of the battery materials provenance project, with a clear pathway to capture environmental life cycle attributes in the provenance ledger;
- Clearly map the methodology to provide source-calibrated environmental attributes and supporting models to be captured at every custody transfer point.

The proposed full project will seek to address 3 key research questions:

- How can a certification framework and underpinning life environmental cycle analysis be developed to position Australia in the global market as a responsible source of sustainable battery minerals and materials?
- What data and models are required to support the certification and life cycle analysis; and, how does it support reducing the environmental and social impact over the battery life cycle?
- How can certification and life cycle data for Australian battery supply chains be leveraged through the development of tools to drive process improvement and quantify the benefits of technology and policy interventions on environmental and social performance over the coming decades?

The objective of the proposed project is to provide the Australian battery industry with resource and methodology to access relative performance against economic, environmental and social impact benchmarks, identify best-in-class sustainable practice. It aims to develop a certification framework through life cycle analysis for ensuring and demonstrating that the standard of Australian battery industry is a world leader in social and environmental management practices and governance. Implementing the proposed certification framework across the battery value chain will position the Australian industry as a sustainable source for battery mineral and material production and management over the product life cycle. The project will use internationally accepted methods for quantifying and labelling performance to communicate the Australian brand in the international market.

The proposed project consists of four main subprojects:

- Project establishment and research co-design;
- Certification framework development;
- Quantitative assessment for certification piloting and benchmarking;
- Development of tools for
  a) Certification and benchmarking
  b) Impact mapping and process optimisation.

COLLABORATION AND IMPACT

Led and managed by the University technology Sydney in collaboration with the University of Melbourne, Curtin University, University of Western Australia and Murdoch University, this project will integrate with other FBICRC projects by providing data to demonstrate performance, provide the testing ground for assessment of the benefits of new production processes and recycling initiatives. This provides a bank of data and experience that will maximise the impact of other projects by leveraging the expertise of the project team in both mining/processing as well as sustainability assessment.

This proposed project allows industry to identify and develop a comparative advantage in the marketplace as a sustainable source of battery minerals and materials. It aims to provide a certification framework to demonstrate the environmental and social responsibility of Australian battery supply chains to the market. In conjunction with detailed life cycle assessment to benchmark and develop tools for use in evaluating process improvements and policy development, this will improve the global competitiveness and sustainability outcomes of the sector.

PROJECT LEADERSHIP

Damien Giurco is Professor of Resource Futures at the Institute for Sustainable Futures, University of Technology Sydney. He holds Bachelor degrees in Science and Chemical Engineering from The University of Melbourne and a PhD from The University of Sydney on Life Cycle Assessment in the resources sector. He leads a dynamic team of researchers at UTS working to create change towards sustainable futures in partnership with government, industry and the community. He has published widely in academic journals, including Nature, and has written for The Conversation. Damien has undertaken research funded by Cooperative Research Centres and industry, such as IGO, Newcrest, Rio Tinto and by local, state and Australian governments, for example on international best practice in circular economy as input to the development of the NSW Circular Economy Policy Statement. Last year, he represented Australia at the APEC Forum on SME innovation and the circular economy. Damien has received the UTS Vice-Chancellor's Award for Research Excellence through Partnership and the Institute Service Award from the Australasian Institute of Mining and Metallurgy, after establishing their Community and Environment Society. He led the Wealth from Waste Cluster and co-chaired the inaugural World Resources Forum Asia Pacific, launching an *Action Agenda for Resource Productivity and Innovation: Opportunities for Australia in the Circular Economy* and is passionate about championing industry-government-research collaboration on resources and the circular economy.

Damien has collaborated with the Steel Stewardship Forum and chaired the energy storage working group of the Australian Battery Recycling Initiative. He is currently Editor-in-chief for the journal *Resources*, chairs the advisory group for Ewaste Watch and leads a theme on Battery Supply Chain Integrity within the Future Battery Industries Cooperative Research Centre.

STATUS

An Expression of Interest for this project was submitted to the FBICRC Board in December 2019. The Board will commission a 3-month scene setting project to define the full project scope and aims, as well as address early research questions. The scene setting project will be conducted in close collaboration to ensure coherent information flow with the Battery Materials Provenance scene setting project.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$2,082,120	$6,492,120	$8,511,240
Target Allocation	$1,041,060*	$4,164,240**	-
Current Allocation	$0	$6,492,120	-
Allocation Required	$ 1,041,060	$0	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Recycling, Reuse and Repurposing of Spent Batteries

Reduction of battery waste for a more sustainable and circular economy for Australian battery industries

The rapid growth of end-of-life lithium-ion batteries (LIBs) in Australia and globally is already a significant and rapidly growing environmental problem. Currently, LIBs are not well-recycled (2-5% in Australia) and predominantly disposed of in landfill. With State bans on batteries in landfill, without a viable recycling-infrastructure, an immediate problem is present. Australia has existing recyclers that handles collection, sorting and disassembly, but further chemical / metallurgical processing to recover cell materials is currently done abroad, despite Australia being a world leader in extractive metallurgical expertise.

The FBICRC aims to assist companies and state governments to grow a sustainable, traceable and responsible Australian battery repurposing and recycling industry based upon collection, repurposing, sorting and metallurgical recycling with back-integration into the resources processing value chain of the circular economy. The recycling of batteries have numerous challenges, including in both the collection and processing stages, but also the lack of harmonised policy between Federal Government and State Governments and requirements placed on collecting and processing companies.

Establishing the interrelationship between technical, economic and regulatory factors is critical and to this end the FBICRC is engaging with governments, industry and researchers to understand the greatest potential for new industry activity in Australia. A 3-month scene setting project will be commissioned to build on previous work completed by CSIRO in 2018 and serve as a foundation for a flagship project in this theme to build a LIB repurposing and recycling industry in Australia.

The project will commence with an initial scene setting project to evaluate:

- The regulatory landscape in Australia, including the incoming Battery Stewardship Scheme being introduced by the Federal government, identify gaps
- Best practice in government (all levels) policy setting area, harmonisation, recommendations to Government policy
- Industry perspective, aassessment of best practices, identify battery manufacturing opportunities
- Economic and business model considerations including a solution/s fit for Australia, fit to overseas supply chain
- Using a value chain approach as the backbone to identify technology gaps in Recycling, Reuse and Repurposing LIB's
- Technology gaps for effective and efficient (competitive) Recycling, Reuse and Repurposing of LIB's in Australia
- Economic modelling and cost benefit analysis
- LCA of reuse/repurpose EV batteries for stationary energy storage
- Infrastructure gaps

This project will approach this by building on previous research, interviewing relevant industry participants and groups and canvas best practice at all levels of government. This will evaluate technology readiness to support Recycling, Reuse and Repurposing of LiB's in Australia and advise key enablers to extend this and ensure maximum impact of a full project.

The main focus of the proposed full project will be to systematically recover all internal components of spent LIBs (cathode and anode materials, electrolyte and associated solvents) for reuse or repurposing in other applications or for safe disposal or destruction. It aims to provide a practical and commercially viable approach to recover and reuse spent LIBs with high recovery efficiencies and promote the sustainable development of the emerging Australian battery industry. This project complements existing research in Australia around the recycling of electrical and electronic waste, which is important as the battery pack contains, in addition to the cells, the printed circuit boards that constitute part of the battery management system, and other materials which adds to the complexity of dismantling and recycling, due to the presence of non-battery metals and plastics.

Further research (to be confirmed in the scene setting project) may include:

- Options for non-destructive assessment of discarded batteries for potential reuse of working constituent cells
- Physical or chemical treatment for the extraction and recycling of the contained chemical elements
- Mapping of pollutants contained in batteries, such as fluoride, heavy metals and other toxins or hazardous compounds that could be emitted during the collection, beneficiation and extraction processes
- Processes needed to prepare the spent batteries for subsequent hydrometallurgical extraction of the valuable elements.
- Evaluation of different beneficiation, thermal and chemical processes to develop:
    a) sorting and beneficiation schemes that can be applied to spent batteries; and
    b) develop effective physicochemical pre-treatment techniques of the spent batteries
- Developing an effective technology for the hydrometallurgical extraction, purification and recovery of cobalt, nickel, manganese, lithium, copper and aluminium and other by-products from spent lithium ion batteries, focussing on processes that are environmentally less harmful and which would allow processing in the vicinity of urban environments and light industrial areas, and processes that are scalable to allow processing smaller amounts of material closer to source.
- Niche purification process options relevant to LIBs
- Re-synthesize and back-integrate next-generation cathode-materials (i.e. NMC) from the recovered solutions of spent-LIBs using low-cost and scalable methods
- Working with recyclers to pilot small scale processing facilities to recycle LiBs and evaluate the potential and basis to commercialise the technology.

This project will also collaborate with other FBICRC projects to testing of synthesized materials, cell manufacturing and safety standards to provide iterative feedback on research progress and applications, as well as collaborating with the Provenance and Life Cycle Analysis projects.

COLLABORATION AND IMPACT

It is anticipated this project would be managed by an industry partner, drawing on research expertise across university partners for the various sub-projects, to ensure close collaboration and iterative feedback, allowing for agile research that is responsive to developing industry needs. It is anticipated the core research team will be formed across Murdoch University, Queensland University of Technology, Deakin University, CSIRO, University of Adelaide, Curtin University and the Korean Institute of Geoscience and Mineral Resources.

This proposed project would support up to 3 Doctor of Philosophy and 3 Master of Philosophy scholarships across the research partners.

Successful completion and commercialisation of developed technology and implementation of insights will have numerous and significant impacts. LIBs are composed of several crucial elements (Li, Ni, and Co) and the recovery of these materials from spent LIBs is economically viable, in addition to the copper and aluminium current collectors. The use of recovered metal solutions as precursors to develop new metal oxides for portable-electronics will provide low-cost and better performing active-materials without new precursors.

From an environmental point of view, LIBs represent a significant hazard as these batteries contain reactive materials, organic and inorganic compounds that can explode at high temperature and pollute the environment. A recycling and re-purposing strategy will reduce the negative effects on the environment and promote the sustainable development of the battery industry. New clean energy generation and storage technologies developed through this project such as CO2- reduction and supercapacitors will significantly reduce CO2-emmission in the atmosphere, enabling environmental sustainability. Further, the recycling of LIBs will protect human health by avoiding fire risk and exposure to toxic compounds during current waste handling, stockpiling and disposal to landfill practises.

STATUS

The FBICRC Board noted this as a key area of research and the commissioned scene setting project will inform the full project scope and requirements. The scope of work for the scene setting project is currently being defined and is proposed to run from approximately June to September. The anticipated full project is open for expressions of interest from companies, state governments and FBICRC research participants.

Indicative Full Budget

	Cash	In-kind (2:1)	Total Project Value
Full Project Budget	$1,500,000	$2,500,000	$4,000,000
Target Allocation	$750,000*	$4,500,00**	-
Current Allocation	$0	$2,500,00	-
Allocation Required	$1,500,000	$2,000,000	-

Note:
*Target allocation for cash is 1:1 matching with FBICRC funding.
**Target allocation for in-kind is a 2:1 ratio of in-kind to cash based on cash required and may fluctuate.

Australian Battery Industry Hubs

Facilitating regional synergy and investment around downstream battery industry development

Australia has several industry hubs around the country which may lend themselves to become regional nodes for battery industries by building upon local strengths and existing infrastructure and businesses

Globally, mineral and metal refining, the production of battery chemicals, cell components, assembled cells and battery packs typically become cost effective when related industries are co-located in industrial precincts that are well supported by competitively priced transport, water, and energy infrastructure and available land and supported by regional communities, research and training institutions. Often, these hubs are situated on the coast with suitable access to port and rail infrastructure in the presence of existing refineries and chemical complexes, and investment is often, but not always, facilitated with favourable taxation or other attractive investment incentives. While there are several such hubs around Australia built around other chemical and manufacturing industries, this project proposes to investigate what regional, financial, and industrial attributes and policies would be required to facilitate a truly globally competitive battery industry hub.

In Western Australia, the Kwinana Industrial Area is a model 'hub' of industrial synergy that includes mineral and metal refining operations, oil and gas refining, chemicals and fertilizer manufacture, battery chemicals manufacture, cement production and advanced manufacturing for the defence and maritime industries, and battery and microgrid manufacturing. It is supported by its own port, as well as the nearby Fremantle container port, has a large local resident community and is in close proximity to advanced research and training facilities, as well as company head offices in or in the proximity of the Perth CBD. The Kwinana industrial area therefore provides a basis for a case study into what may constitute a successful industry hub and also offers opportunities for further optimisation.

This proposed project will aim to identify additional hubs, which are typically located along the coasts of Queensland, Western Australia and Victoria. Inland hubs such as Kalgoorlie and the Kalgoorlie-Esperance corridor will also be considered. Minimum criteria will be identified that would have to be satisfied for hubs to be classified as a Battery Industry Hub, such as supporting regional and state policies, existing infrastructure, existing industry, transport networks, investment incentives, regional community support and regional knowledge innovation networks. Global competitiveness criteria will need to be reviewed to optimally position Australia as a competitive manufacturer and innovator of battery materials and provider of associated services to the national and international market. A map of competing and cooperating industries, energy resources (fossil and renewable), by-and co-products, reusable waste products, and the flow of materials, energy, water (by type and quality), and existing businesses are foreseen to be developed for every hub to be considered.

COLLABORATION AND IMPACT

This project will initially be developed by the FBICRC leadership, in conjunction with organisations such as the METS Ignited Industry Growth Centre, Climate Knowledge-Innovation Community (Climate KIC) and participating State and Local Governments and industry associations.

It is expected that a good regional database and analyses of the regional hubs will allow companies to better position themselves with regards to investment opportunities in the industry hubs. It will allow State and Regional government to better plan for prospective battery industries and guide the development of policies in particular to promote foreign direct investment as well as economic growth in the local and existing companies and institutions.

OBJECTIVES AND OUTCOMES

The intended objectives of this project are split across a number of proposed subprojects which include:

Compilation of a common glossary of terms and definitions for industrial hubs

- Industry hubs, ecosystems, innovation clusters, precincts etc. all evoke different understandings amongst different parties and a common language is required to facilitate reporting and planning

Intent, economic benefit and evaluation methodology

- The intent of battery industry hubs needs to be clearly enunciated and the criteria to measure economic and regional benefit and the evaluation methodology are to be developed
- A common assessment framework is to be developed

Evaluation of the Kwinana Industries Hub as a case study

- Identification of success criteria
- Mapping of existing businesses and interactions
- Understanding of shortcomings, challenges and opportunities
- Identification of policy requirements to further grow this industry hubs to a globally competitive battery industries hub

Growing other regional battery industry hubs in Australia

- Examples of existing hubs
- Strengths and deficiencies of these hubs
- Economic contexts

Criteria for global competitiveness and positioning

- Infrastructure
- Port, rail and other transport infrastructure
- Water and Energy
- Resources raw materials and wastes
- Land
- Waste, effluents and gaseous emissions
- Treatment of co-product and by-products
- Communities
- Research, education and training
- Supporting businesses
- Taxation and financial incentives
- Geopolitical, jurisdictional and sovereign risks and stability
- Access to domestic and international markets

A tangible roadmap is foreseen that will aid government planning, land use planning and policy development and to promote regional positioning of the battery industry hubs for domestic and foreign businesses. The report should aid government to identify which “levers to pull” to accelerate rapid development of the regional hubs.

STATUS

This project is under development and will initially be led by the FBICRC executive to scope and confirm sufficient industry support before proceeding with development of a full project proposal.

Battery Supported Mine Electrification

A holistic systems approach to mine electrification with batteries deployed in stationary and mobile applications

Australia is a world class mining jurisdiction and leads globally in many areas of mining technology. The remoteness of mines, the readily available renewable energy sources, the drive towards decarbonisation and the elimination of diesel particulates are major drivers to electrify mines with support of batteries and/or hybrid energy generation and storage systems. The optimal deployment of batteries in mining is still at an early stage and many research challenges remain.

This proposal for an FBICRC project is under development and will commence with a survey, developed in conjunction with VCI who have created a national innovation platform (https://www.stateofplay.org/about/), to identify and delineate the priority areas in mine electrification. Given that a significant investment in these activities are already occurring at trial mine sites globally, it is the aim of this work to address those aspects that requires a collaborative approach between mining companies, OEMs, engineering companies, service companies, energy providers and utilities and research institutions. This project will offer an opportunity for the associated and affiliated industries to benefit from the leverage obtained through industry-wide collaboration of the mining companies and to grow the associated METS, OEM, services and engineering sectors, while entrenching deep knowledge and capabilities at the participating universities.

The survey will provide baseline information for project planning, mega-trend validation, and serves to set the scene for the research and development towards high impact outcomes.

A workshop will explore the opportunities, with a focus on Australian operations. The following areas will be considered:

- Mapping of challenges, opportunities in battery-based electrification (in equipment and in the mine site microgrid with renewables).
- Selection of appropriate cells, battery modules, and battery management systems and energy management systems.
- Appropriate deployment of correct size and type of battery in mobile and stationary equipment.
- Mapping of needs for equipment, service vehicles, haulage vehicles, earth moving equipment, retrofitting opportunities, telecommunications, lighting, refrigeration, ventilation, charging infrastructure, parts logistics and inventories, battery recycling, testing and maintenance, energy integration at site, integration in above ground metallurgical and mineral processing operations, batteries for emergency, batteries for autonomous vehicles and drones, integration needs with vehicle autonomy, storage of battery systems prior to deployment, modelling of safety incidents and dangerous underground events, asset management, etc.
- Mapping of the state of play in the industry and the essential participants to address prioritised areas.

The proposed project will initially develop and prioritise industry needs in relation to:

- A roadmap to mine electrification in Australia
- A prioritisation of key challenges and industry needs
- Mapping of optimal mix of companies and service providers to address the challenges / opportunities

- Requirements for field work testing, site trials and data gathering
- A framework for the evaluation of battery-enabled equipment, vehicles and devices
- Mathematical, statistical and economic modelling requirements
- Identification of major battery safety concerns and approach to research and development
- Impacts of mine electrification on mine design and mine planning

This is foreseen as potentially a multi-year project, which includes a scene setting portion that maps the detailed scope, opportunities, risks and investment requirement and the identification of foundation participants.

COLLABORATION AND IMPACT

The project will initially be developed by the FBICRC Executive, with the support of VCI. Subject to industry participant support, and funding approvals, an appropriate project manager would be identified, in discussion with the industry participants. The workshop and survey will set the context for the project development to ensure that high impact priorities of mutual interest are identified first.

STATUS

This project is under development and open for expressions of interest from companies, state governments and FBICRC research participants.