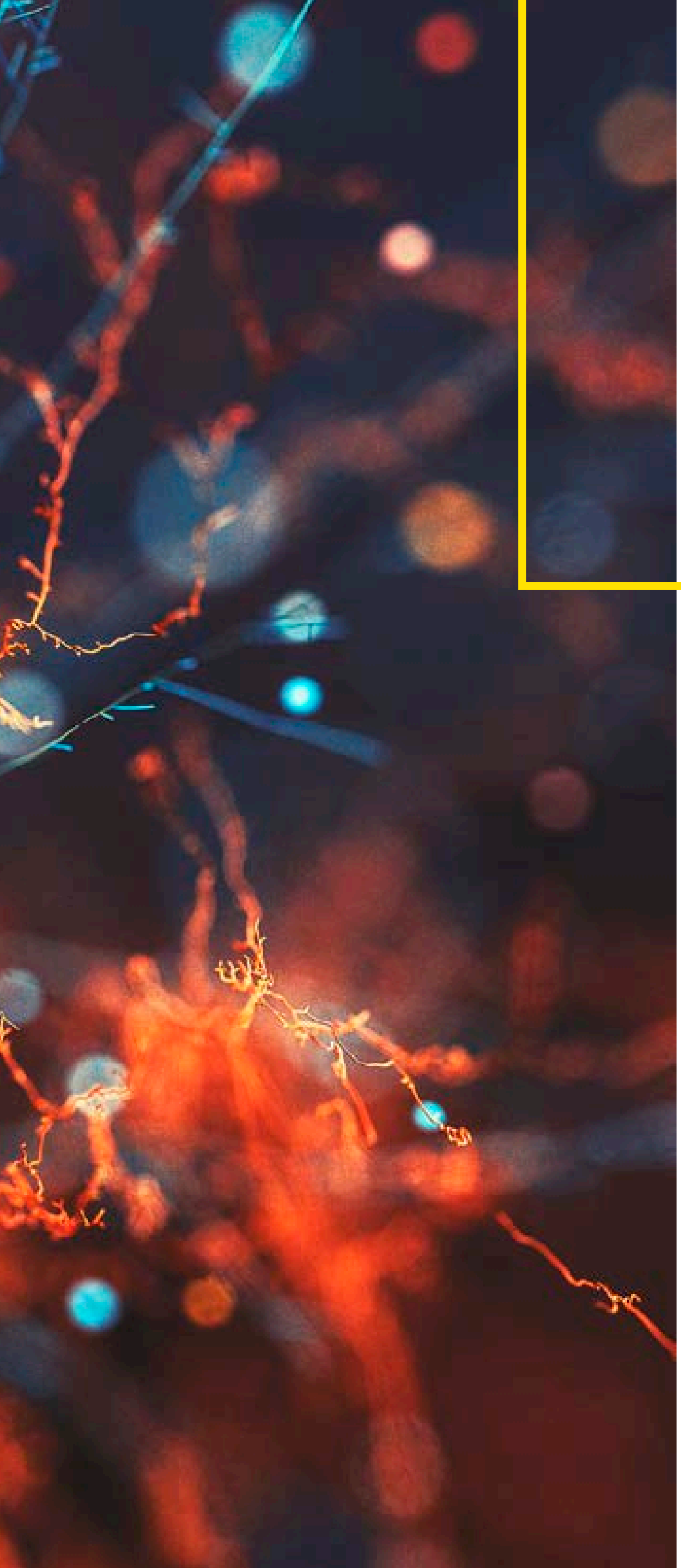
UNSW

Energy Storage

Capability Portfolio

UNSW Your Energy Research Partner



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FROM THE DEAN OF ENGINEERING

UNSW Sydney has carved a formidable reputation as one of the world's leading research and technology hubs for energy innovation over the last 30 years. Our Engineering Faculty is globally recognised for our multidisciplinary excellence in research and innovation and our contribution to energy and environmental issues. This is further supported by the UNSW 2025 Strategy which places social engagement and global impact at its core.

Energy storage is an increasingly important part of the energy value chain, and UNSW is ideally positioned to lead the development of more efficient, commercial and environmental storage solutions with expertise and collaborations spanning multiple faculties and six engineering schools.

This Energy Storage Portfolio illustrates the depth and breadth of expertise UNSW can offer. When coupled with our expertise in transport, energy systems and energy markets, we are uniquely placed to address the future energy storage needs faced by societies across the globe, from vehicles to small end-users such as home owners to complex energy supply and distribution networks.

This portfolio is a snapshot of our broad energy capability; it is reinforced by our world-class research facilities and by a range of complementary initiatives at UNSW, such as the Australian Government-funded national ARC Research Hub for Integrated Energy Storage Solutions, the UNSW Energy Institute, and the UNSW Digital Grid Futures Institute.

The portfolio highlights our work across academia, in partnership with government and industry. Our partnerships are strong, and we have close productive ties with our industry partners like Ausgrid, Aurecon, Lockheed Martin, Toshiba and Volvo, and we are the stimulus for numerous start-ups. We also enjoy close collaboration with local, state and Commonwealth governments and agencies.

We welcome new partners and collaborators who can leverage UNSW's investment into energy storage. Together we can shape the energy storage agenda and develop cutting-edge commercial solutions for the energy value chain of the future.

Professor Mark Hoffman
Dean, UNSW Engineering

FROM THE UNSW ENERGY INSTITUTE CHIEF EXECUTIVE OFFICER

The world is in the throes of an energy transition, driven by the imperative for decarbonisation, the ageing of existing energy facilities, the commercialisation of new energy technologies and the emergence of new business models. Australia is now faced with a once-in-a-generation opportunity to reshape its electricity system for the future and embrace the wave of technological change that will accompany this transition.

The electricity system of the future will be complex: increasingly variable as the penetration of renewables rises, increasingly distributed as homes and businesses adopt new technologies, increasingly electrified as electric vehicles become popular, and increasingly digitised and open to a variety of new market products. Without question, energy storage is key to realising this transition and supporting the complexities faced in managing our future electricity grid system.

Globally, widespread penetration of energy storage solutions has been impeded by a range of technical, economic and systemic barriers. The lack of cost-effective, mass-produced, and fully integrated energy storage solutions results in increased energy costs. Bespoke systems designed for specific applications bely a lack of standards. Novel battery and gas storage technologies have not yet been 'commoditised' to bring economies of scale. Energy storage technologies are spread across different sectors (electrical, gas, thermal, mechanical), chemistries and materials. Gas and electricity networks operate separately, without taking full advantage of their synergistic storage potential. And the energy value chain is typically split between wholesale markets, ancillary services markets, networks, retailers and energy service providers, making it hard to deliver system-wide benefits.

Ongoing technological developments mean the future shape of the energy storage sector has yet to be set. With its abundance of both conventional and renewable energy resources, its high penetration of rooftop solar PV, and its existing unique energy storage research expertise, Australia is exceptionally well positioned to play a major role in this race, shaping the future of key energy storage technologies and becoming a significant part of a vast global value chain.

Here at UNSW we are ideally positioned to address these problems. We have a reputation for excellence, backed by our extensive expertise spanning across the energy storage sector, we have already invested significant funding into energy storage research and facilities, and are keen to invest further. UNSW is committed to fostering an innovative and entrepreneurial environment with our external high calibre corporate partnerships. Addressing energy storage solutions is now critical and at the forefront of world economic policy and corporate investment. It is therefore of interest to governments at all levels, and consumers are demanding more – from electric vehicles to small scale energy storage solutions for homes and business. Together we have an opportunity to make this happen. UNSW looks forward to partnering with industry, government and the community to leverage our energy storage expertise to create social, environmental and economic impact.

Justine Jarvinen
Chief Executive Officer, UNSW Energy Institute

BATTERIES: DEVELOPMENT, CHARACTERISATION AND MANUFACTURING

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Electrically Conductive Nanocomposite Films

An industrially scalable method has been developed for synthesising polymer nanoparticles decorated with graphene oxide sheets via miniemulsion polymerisation. This enables preparation of electrically-conductive films using a simple method at ambient temperature. The resulting nanocomposite films exhibit high electrical conductivity and have a wide range of potential applications as conductive coatings.

Competitive advantage

- Technology represents first example of an approach for synthesis of electrically-conductive graphene/polymer films that form at ambient temperature
- Environmentally friendly process
- Amenable to industrial scale applications

Impact

- Potential for advanced coatings, sensors and nanomedicines

Capabilities and facilities

- Synthesis of polymer/graphene thin films with specified level of electrical conductivity
- Synthesis of hybrid polymer/graphene nanoparticles as hybrid materials
- Synthesis of polymer nanoparticles of various size, shape and internal morphology

More information

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Advanced Energy Materials

Recent advances in lithium-ion battery technology have seen them used in applications ranging from portable electronic devices to electric vehicles. In the future, developing energy storage applications for renewable resources will become increasingly important.

Competitive advantage

- Unique interdisciplinary research experience in battery engineering
- Expertise in synthetic organic chemistry, for developing next-generation energy storage systems
- Extensive research experience in design and fabrication of organic-based rechargeable batteries

Impact

- New and novel battery technologies for better and more efficient energy storage

Successful applications

- Bottom-up synthesis of redox-active compounds and fundamental understanding of the reaction mechanism in rechargeable batteries
- Pioneering work to demonstrate rechargeable aluminium-ion batteries using a redox-active organic compound as the active material

Capabilities and facilities

- Synthetic organic chemistry laboratory setup
- Battery analysis equipment

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Fire and Explosion Suppression for Newly Developed Electrochemical Storage Materials

MXenes are a newly discovered class of two-dimensional transition metal carbides, nitrides and carbonnitrides. They are emerging materials for electrochemical storage and possible use in lithium-ion batteries for applications such as cell phones and electric vehicles. However, their practical applications are currently limited by challenges with manufacturing, and fire and explosion safety.

Competitive advantage

- MXene is an emerging material with outstanding electronic properties and large surface areas ensure the inherent advantages as the electrode for electrochemical energy storage

Impact

- Enhanced safety of next generation electrochemical materials
- Rechargeable batteries with higher energy density

Successful applications

- Development of a highly thermally-insulated three-dimensional architectured composite structure comprising epoxy, graphene and hydroxylated boron nitrides nanosheets
- Reinforcing the fire resistance properties of glass fibre using phosphorous-containing silane coupling agent

Capabilities and facilities

- Collective fire testing facilities including cone calorimeter, horizontal and vertical fire spread (UL94) and oxygen index
- Access to neutron beam diffraction facilities of ANSTO to study molecular morphological structure of MXenes
- Application of novel computation codes to predict the structural, mechanical, electrical, magnetic and thermoelectric properties of MXenes

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Electrolytes and Thin Films for Solid State Batteries

Battery safety is a key challenge, as is the practical implementation of batteries over a wide range of temperatures without additional heating or cooling. Solid state batteries present a solution to these challenges, providing inherently safe batteries that are stable over applicable temperature ranges.

More information

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Competitive advantage

- Expertise in materials development
- Analysis of conductivity and diffusion at bulk and atomic scales
- Spectroscopic and crystallographic methods for characterising materials
- Working towards development of all-solid-state thin film batteries

Impact

- Understanding the role of grains and grain boundaries on bulk diffusion
- Evaluating the type of atomic-scale diffusion
- Linking structure to local and long-range diffusion
- Using in situ methods to elucidate phase evolution

Successful applications

- Developed a testing apparatus for the operando study of thin film batteries using synchrotron X-ray diffraction during operation

Capabilities and facilities

- Materials synthesis
- Pulse laser deposition growth of certain electrodes
- Access to key analytical techniques such as solid-state NMR, surface analysis and electron microscopy
- Use of unconventional techniques such as quasi-elastic and inelastic neutron scattering

Our partners

- CEA

Materials Development for Next Generation Batteries

Batteries of the future will need to supply more energy. To make this happen, new materials and new concepts are required for alternative battery chemistries, such as lithium-sulfur and potassium-ion.

Competitive advantage

- Flexible materials development capacity
- Ability to work with and examine a range of battery chemistries
- Full structural, spectroscopic and electrochemical characterisation

Impact

- The next generation of batteries, providing a step change to current technology

Successful applications

- Development of new cathodes for lithium-sulfur batteries and potassium-ion batteries

Capabilities and facilities

- Materials synthesis
- Access to key analytical techniques such as solid-state NMR, operando X-ray and neutron diffraction, surface analysis, and electron microscopy

More information

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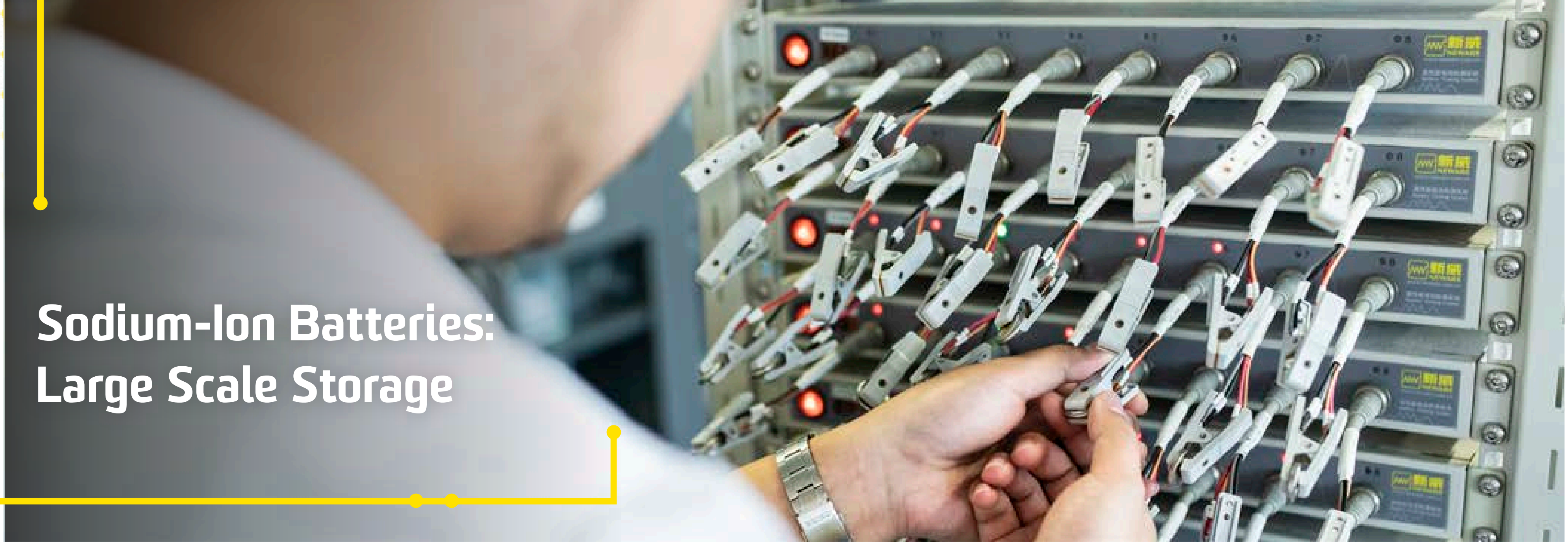

Sodium-Ion Batteries: Large Scale Storage

Sodium-ion batteries are a potential candidate that can either supplement or replace lithium-ion batteries for specialised applications such as renewable energy storage. Making sodium-ion batteries commercially viable requires developing components for these batteries and understanding their structure-property relationships.

Competitive advantage

- Development of environmentally friendly cheap electrode materials
- Use of a range of analytical techniques, particularly operando synchrotron X-ray diffraction, to elucidate structure-property relationships
- Using waste as a source for electrodes for sodium-ion batteries, potentially making them even more environmentally friendly and cheaper
- Rationale design of new materials

Impact

- The development and understanding of materials for potential commercial sodium-ion batteries
- Understanding structure-property relationships to design better materials

Successful applications

- Evaluating the chemical compositions of electrodes and their performance
- Combining a range of analytical methods to understand materials properties in devices

Capabilities and facilities

- Battery materials development to research-scale cell development
- Access to key analytical techniques such as operando synchrotron X-ray diffraction, solid state NMR, surface analysis and electron microscopy

Our partners

- CIC Energigune

More information

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Lithium-Ion Batteries: Atomic Scale Know-How

Lithium-ion batteries are currently used extensively across a range of applications. Their increasing uptake in larger-scale applications requires an understanding of degradation mechanisms at the atomic scale and developing new materials or concepts for these batteries.

Competitive advantage

- Access to non-destructive methods to assess battery degradation and failure modes for research and large-scale batteries
- Variety of analytical tools to determine degradation, in particular in situ or operando neutron and synchrotron X-ray diffraction, and solid-state NMR
- Knowhow for analysing data from a range of analytical techniques to build a picture of degradation
- Directed materials design for optimised performance
- Ability to develop materials, characterise, examine electrochemical performance and understand the chemical reasons behind performance

Impact

- Development of the next generation of materials for higher performing or specialised lithium-ion batteries
- Ability to non-destructively assess battery degradation
- Understanding failure and degradation modes to help design next generation batteries

Successful applications

- Non-destructively examined the state-of-health of batteries used in testing by Volvo
- Non-destructively examined the role chemical composition of the cathode plays on cycling and high voltage stability
- Investigated new chemical doping regimes and their influence on electrochemical performance
- Investigated batteries in different form factors; e.g. thin film and all-solid-state
- Investigated new cathodes, anodes and electrolytes

Capabilities and facilities

- Access to in situ/operando neutron diffraction
- Access to in situ/operando synchrotron X-ray diffraction and X-ray absorption spectroscopy
- Solid state NMR
- X-ray photoelectron spectroscopy, Raman, XRD, electron microscopy
- Battery materials development to research-scale cell development

Our partners

- Volvo
- Valence Technologies

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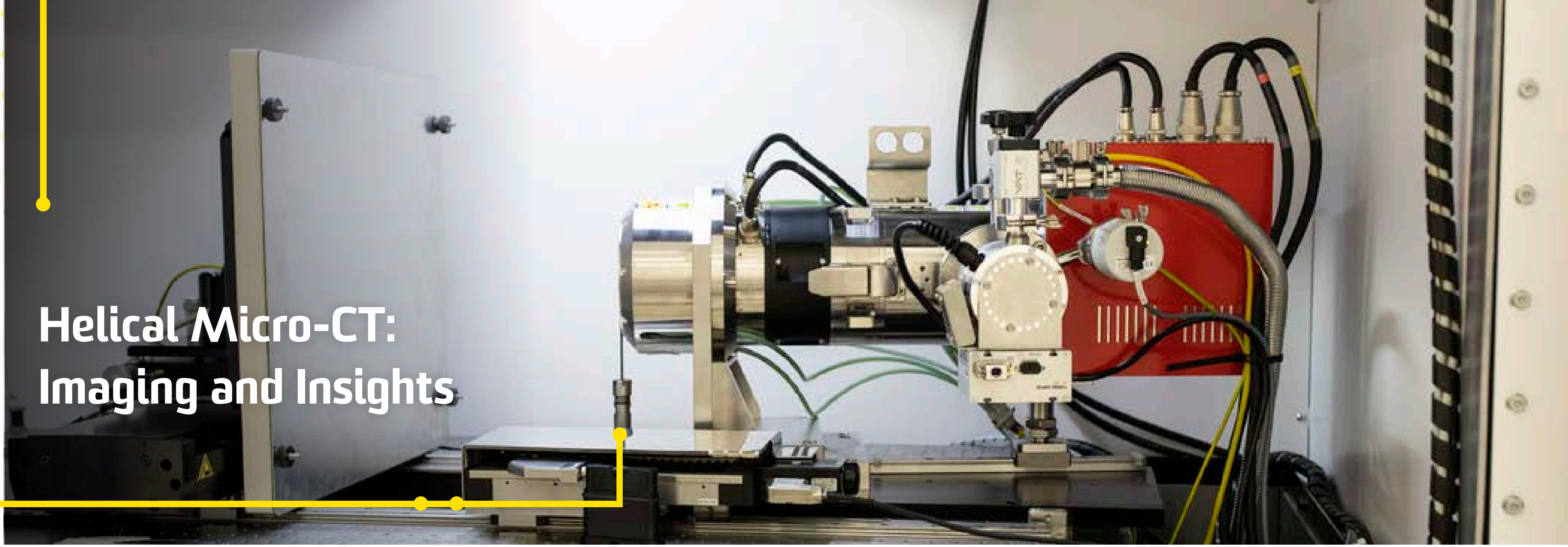
Helical Micro-CT: Imaging and Insights



High-resolution imaging combined with image analysis, physical property calculations and measurements. A rare combination of instrument capacity and people skills provide unparalleled insights into microstructural behaviour.

More information

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Competitive advantage

- Award-winning analysis outperforms conventional X-ray computed tomography
- Very high resolution allows imaging at submicron scale
- High speed method allows dynamic imaging; e.g. tracking of multicomponent fluid flows

Impact

- Imaging of battery materials for degradation studies
- Imaging of flow in 3-dimensional electrode materials
- More efficient oil and gas recovery
- High resolution biomedical imaging

Successful applications

- Technology commercialised through spin-off company Digital Core, which merged with Numerical Rocks AS to form Lithicon. In 2014, Lithicon was acquired by FEI for A$76 million.

Capabilities and facilities

- Facility housed in a dedicated, temperature-stabilised, lead-lined room
- X-ray source (180 kV/20 W) with diamond windows
- High quality flatbed detector (3072 × 3072 pixels, 3.75 fps readout rate)
- Helical and circular scanning mode
- Pressure and flow cells for various sample sizes

Structural Supercapacitors and Batteries

Lightweight energy storage is vital to environmentally friendly transport, including electrical vehicles, electrical drones, and wearable devices. Structures that can simultaneously carry load and store electrical energy while simultaneously providing an energy density equivalent to the current state-of-the-art supercapacitors are critical enablers for these new technologies.

Competitive advantage

The current bottleneck preventing the production of structural energy storage devices is the development of a stiff and strong material which also exhibits the high ionic conductivity needed to facilitate the electrochemical processes inherent in common energy storage devices such as batteries and supercapacitors.

- Development of structurally strong batteries and supercapacitors
- Ability to integrate energy storage into the load bearing capability of a transport structure, eliminating the need for a traditional energy storage device and its weight from the platform
- Significant weight savings in autonomous vehicles leading to improved energy efficiency for direct energy requirements, and embedded communications and sensing technologies enabling energy to serve other capabilities leading to greater capabilities

Impact

- Light weight energy storage devices for Defence applications where high energy storage density is required

Successful applications

- The first generation of structural batteries has been demonstrated by embedding flexible lithium ion batteries into laminated fibre composites. The resulting structure can simultaneously store electricity and carry load

Our partners

- Defence Science and Technology (DST)

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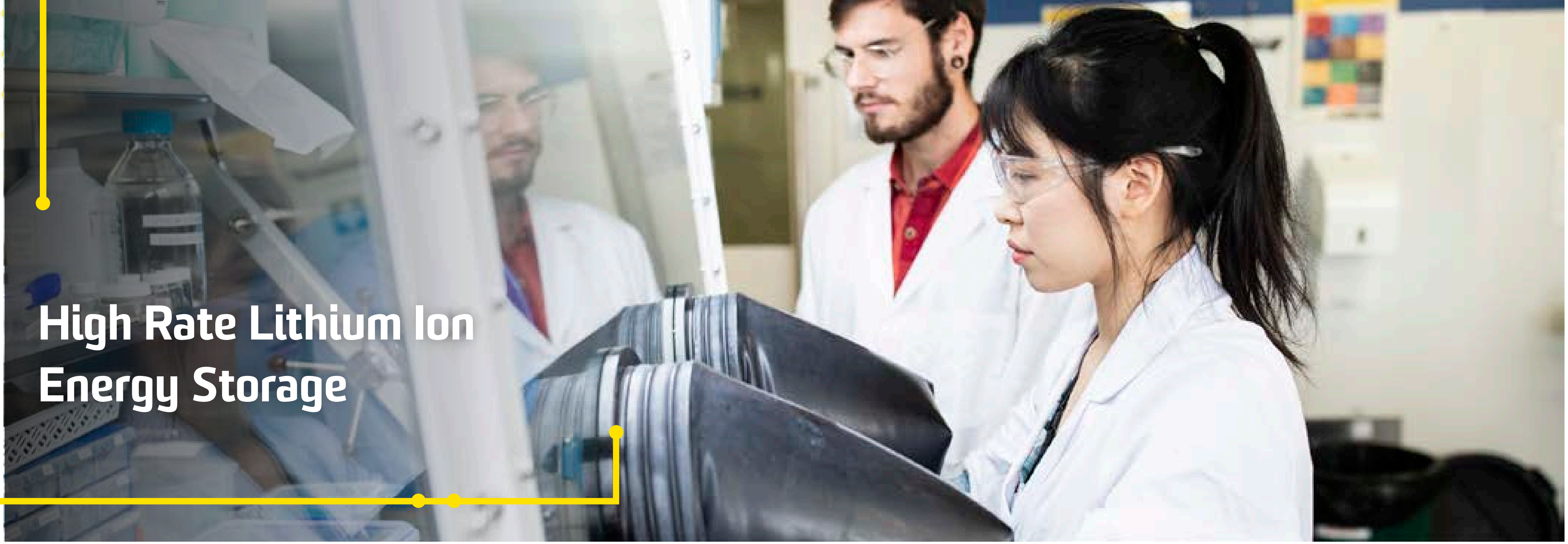

High Rate Lithium Ion Energy Storage

Lithium ion batteries that can be charged and discharged at high rates can play a critical role in stabilising electricity grids with a high proportion of renewable energy generators. These devices blur the distinction between supercapacitors and batteries, and may also find applications in electrical power buffering for mass transport systems.

Competitive advantage

- Expertise in fabrication of binder-free 3D electrodes for high rate electrodes and amorphous metal oxide electroactive materials
- New electrochemical modelling methods that can be used to distinguish between double layer storage and Faradaic charge storage
- Integrated experimental-modelling approach

Impact

- High rate electrochemical storage will be critical for electrical grid stabilisation
- Potentially lower cost alternative to electrochemical capacitors in mass transport applications

Successful applications

- 3D porous electrodes using metal foams and 3D printed current collectors
- Anodic titanium oxides binder-free electrodes for high-rate anodes

Capabilities and facilities

- State of the art electrochemical fabrication and characterisation facilities
- Expertise and access to PFG NMR and solid state NMR facilities
- Expertise in atomic scale modelling of electrode materials and electrochemical processes

More information

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Energy Storage For Integrated Energy Systems

UNSW's world first developments in energy storage and flow battery technology including the vanadium redox flow battery provide opportunities for maximising renewable energy power plant performance and improvements in electricity quality and supply. Advancements made on flow battery technology have been utilised globally in large scale demonstration and commercial projects.

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Competitive advantage

- Redox flow batteries offer lower cost and longer cycle life than conventional battery systems with no thermal issues
- Up to 200,000 cycles for a vanadium flow battery demonstrated in commercial wind system
- Lower risk than Li-ion technology – no emissions or fire hazards
- Advanced battery control approaches based on mechanisms of electrochemical reactions to improve efficiency and flexibility of battery operation
- Use of vanadium batteries for simultaneous electricity quality control and power demand/supply balance (without supercapacitors) to reduce the capital and maintenance costs of systems

Impact

- The vanadium flow battery developed at UNSW is currently manufactured commercially by companies in Japan, China, USA, UK and Germany. A 200 MW/800 MWh VRB is currently being installed in Dalian, China.

Successful applications

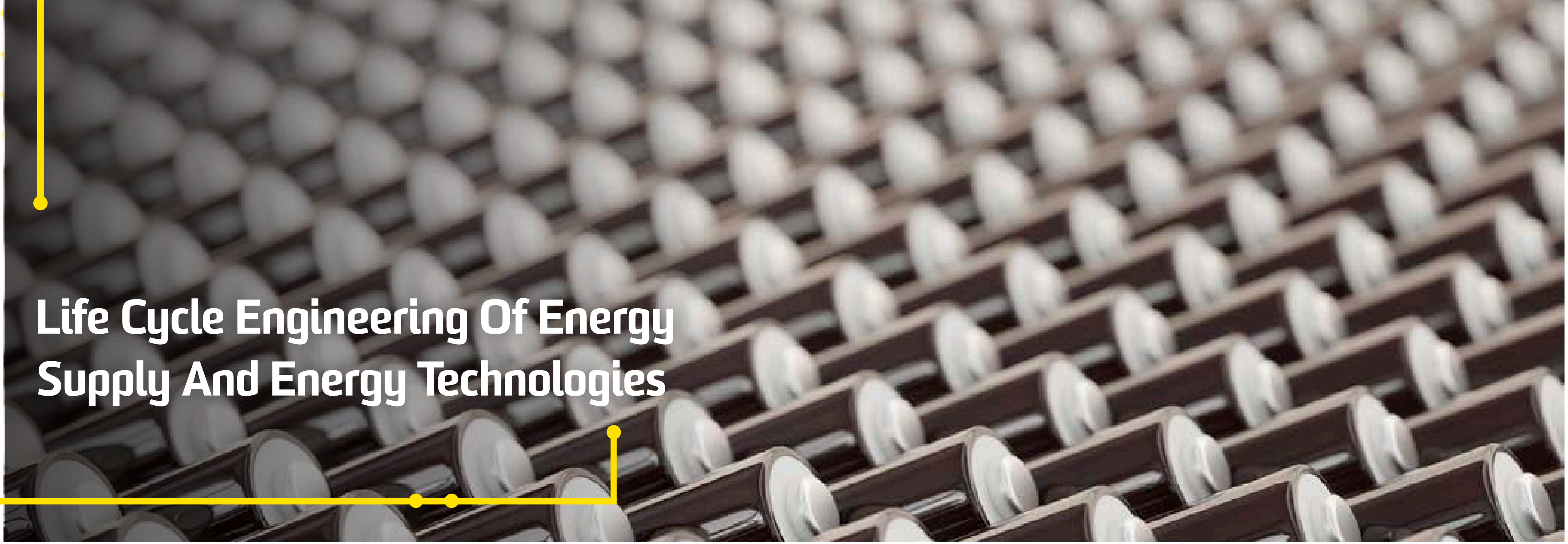
- Vanadium flow battery developed at UNSW now manufactured commercially.
- Licensing of vanadium battery technology to international sponsors.
- Development of a vanadium oxygen laboratory scale fuel cell system.
- Scale-up of an iron slurry flow battery system

Capabilities and facilities

- 30 kW/130 kWh commercial VRB system
- Dedicated computation laboratories for advanced simulation modelling and associated facilities for validation studies.
- Extensive state of the art electrochemical and mechanical laboratories.
- Advanced additive and automated manufacturing facilities

Our partners

- Fraunhofer ICT
- Fusion Power Systems



Life Cycle Engineering Of Energy Supply And Energy Technologies

Expertise across sustainable manufacturing, sustainable product development, life-cycle engineering and manufacturing, and closed-loop manufacturing. Extensive experience implementing renewable energy and energy storage solutions for the manufacturing industry.

Competitive advantage

First in Australia and one of the first in the world developing hands-on capability in:

- Holistic energy efficiency assessment in manufacturing
- Renewable energy integration into factories through micro-grids
- Management of energy supply and demand in factories
- Cradle-to-cradle battery supply chain sustainability, integrity and transparency
- Environmental impact assessment of battery supply chains

Impact

- Saving of millions of dollars for the manufacturing industry

Successful applications

- Implementation of energy efficiency technology
- Achieving industry-wide impact through helping NSW government as an invited expert advisor for energy efficiency program
- Contributing technical expertise in the Australian Government industrial energy efficiency program

More information

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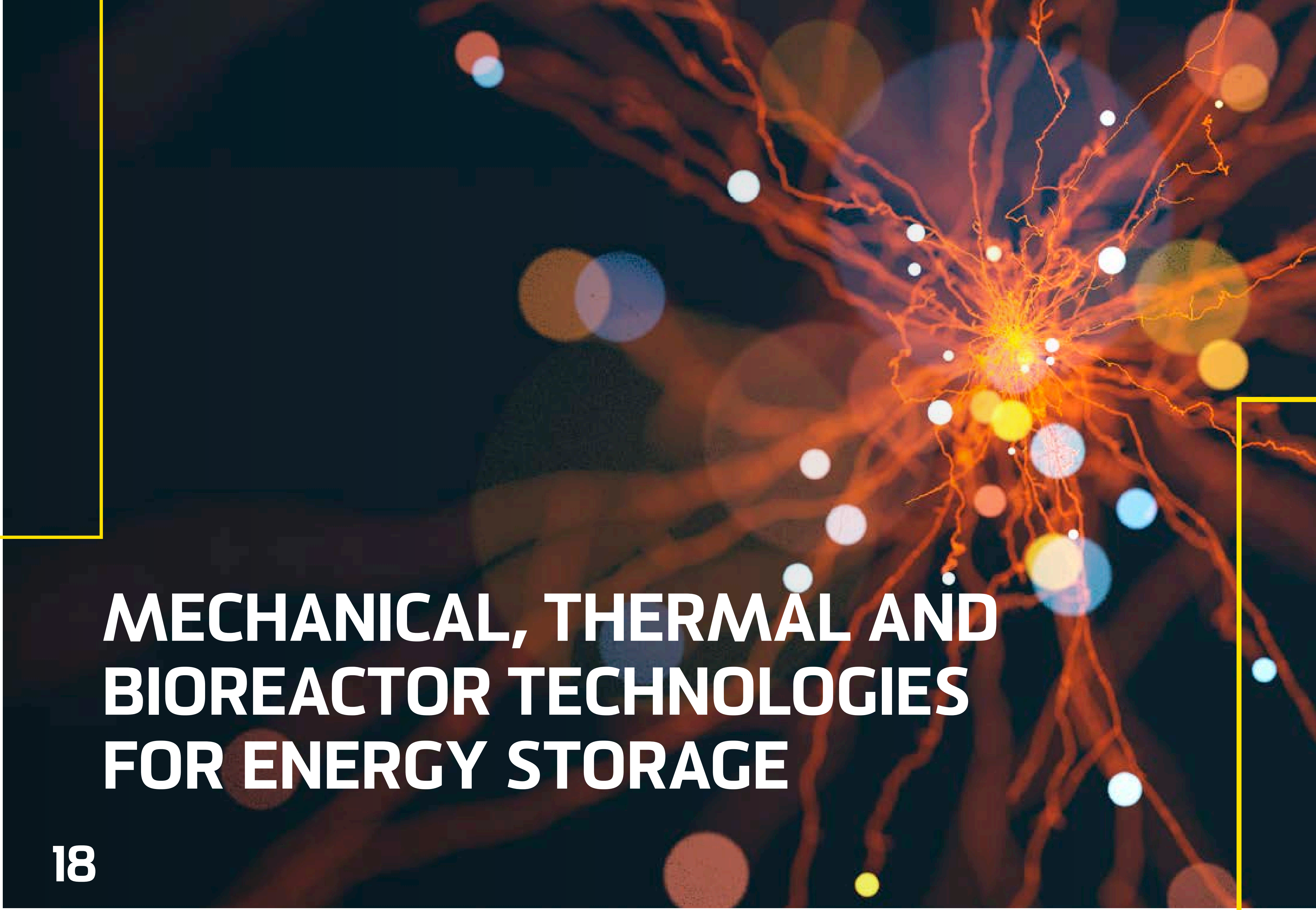
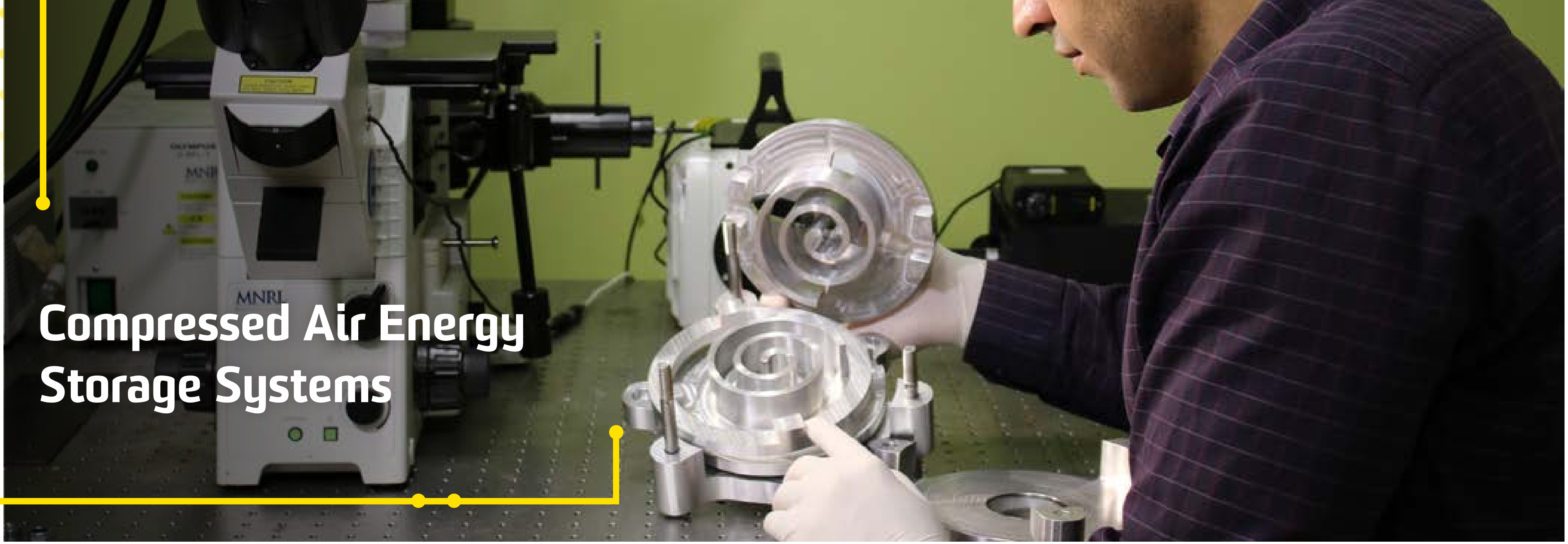


MECHANICAL, THERMAL AND BIOREACTOR TECHNOLOGIES FOR ENERGY STORAGE



Compressed Air Energy Storage Systems

Small-scale energy storage plays a critical role in managing mismatch between loads and renewable energy supply. In recent years, micro compressed air energy storage (CAES) systems have gained significant attention, as they can potentially overcome these issues and provide hybrid electric-thermal storage for buildings and plants that require significant amounts of heating and cooling in addition to electricity.

Competitive advantage

CAES systems are a scalable technology that use mechanical compressors to convert electricity into potential energy stored as pressurised air, with the pressurised air expanding to generate power when needed. Unlike electrochemical batteries, this technology does not rely on toxic, resource-limited or degradable materials. Conventional CAES systems generate a large amount of heating and cooling energy, which is wasted during compression and expansion, resulting in a low round-trip storage efficiency.

Impact

- Better small-scale integration of intermittent renewable energy sources into commercial and residential buildings

Successful applications

- On-going prototype development of a new type of compressor for use in a CAES system for residential or small-scale applications, Cyclonas Pty Limited

Capabilities and facilities

- Two LDA systems (including a Dantec 3D LDA/PDA system)
- Five PIV systems (including tomographic capability)
- Flow visualisation lasers
- Computational facilities, including in-house clusters and access to NCI shared clusters
- Software, including unlimited site license for ANSYS products and open-source codes such as OpenFOAM
- In-house developed code

Our partners

- Cyclonas Pty Limited

More information

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Design and Control of Permanent-Magnet Synchronous Machines for Flywheel-storage

Specialists in permanent magnet (PM) type electric machines and drive systems. Strong capabilities in designing and optimising high-speed PM machine geometries and developing advanced control techniques to further improve performance for emerging applications such as flywheel storage.

Competitive advantage

- Expertise in PM machine design and control
- Mechanical sensorless control for PM machine
- Expertise in designing very high-speed PM machine drives suitable for applications such as flywheel storage
- Developing advanced on-line parameter identification techniques

Impact

- Permanent magnet motor-generators of rated speed in excess of 50,000 rpm
- Advanced control schemes and drivers for smooth energy conversion

Successful applications

- Sensorless control techniques for PM motor drive
- Development of novel interior-type PM motors with speed capability >50,000 rpm

Capabilities and facilities

- Finite-element packages, including Magsoft and ANSYS, with optimization tools developed in-house
- Simulation platforms (Matlab–Simulink, PSIM), FPGA and DSP systems with high-performance signal acquisition, estimation and switch gate-drive interfaces
- Two and three-level inverters
- Several machine drive set-ups complete with shaft position sensors, torque sensors and highly dynamic loads
- Four-quadrant dynamometer for testing direct-drive wind generators
- High-speed (>50,000 rpm) PM machine test bed

Our partners

- CSIRO
- Wisconsin Electric Machines and Power Electronics
- Toshiba
- Regal Beloit

More information

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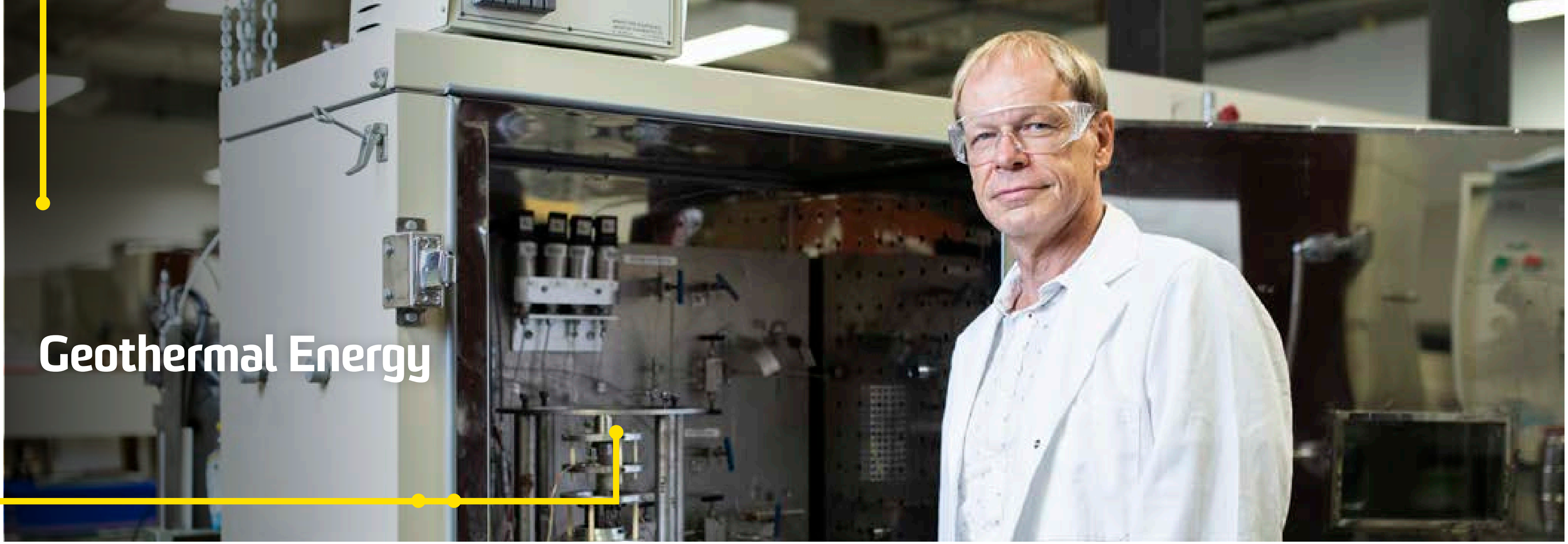

Geothermal Energy

Geothermal energy can provide the cheapest, cleanest and most abundant source of baseload power. Innovative solutions for cascaded heat use and direct heat applications are scalable and can provide clean power for industrial and domestic applications.

Competitive advantage

- International expertise in geothermal energy
- Experience in coordinating geothermal initiatives in Germany, New Zealand and Australia
- Providing innovative solutions for cascaded heat use and direct heat applications
- Enhanced geothermal stimulation strategies for high temperatures
- Novel drilling technologies for hard basement rocks
- Patented technology in desalination, advanced geothermal cooling technology and low temperature geothermal refrigeration

Impact

- Cheap and abundant baseload power

Successful applications

- Implementation of novel groundwater heat rejection concept for cooling a supercomputer
- Innovative geothermal solutions for developing countries
- Lithium co-production from geothermal brines

Capabilities and facilities

- Advanced rock characterisation laboratory
- High temperature/high pressure triaxial geomechanics testing facilities
- Thermal infrared laboratory

Our partners

- Green Rock Energy Limited
- Geodynamics Limited

More information

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High Concentration Solar Furnaces

High concentration solar furnaces involve highly efficient interconversion of energy from sunlight to produce electricity, heat and fuel. Each form of energy has different storage challenges; for example, spectrum-splitting photovoltaics can produce electrical power, hybrid PV–thermal systems produce electricity and heat, while ultra-high solar concentration furnaces can be used to manufacture solar fuels.

Competitive advantage

Development of novel optical systems applied to industrial-scale solar concentrators opens up new possibilities for high temperature solar furnaces. Integration of fluid lens optics and optic fibre provides a versatile platform for deployment of new high temperature reactors, as well as retro-fitting to existing systems.

Impact

- Enabling a range of high-temperature thermochemical cycles that may be used for the production of renewable solar fuels
- Extraction of metals from their ores using solar energy could position Australia as an exporter of clean and high value raw materials

Successful applications

- High efficiency photovoltaic devices
- High concentration solar cell architectures
- Development of new modelling tools for solar concentrators
- Design integration with concentrating solar power technology for deployment at scale

Capabilities and facilities

- 3D freeform optical surface growth for optimal non-symmetric optical concentrators
- Heliostat field integration and solar receiver optimisation
- Spectrum-splitting optics and high-efficiency photovoltaics
- Concentrating solar receiver design
- Thermodynamics of the interconversion of heat, electricity and light
- Characterisation of optical materials

Our partners

- Heliosystems Pty Limited
- Peritar Pty Limited
- Raygen Resources Pty Limited

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Solar Thermal Energy Harvesting and Storage

Extensive expertise in development of new solar thermal and thermal energy storage technologies with testing capabilities to understand the performance of existing technologies, with an emphasis on real-world experimentation 'on-sun', where appropriate.

Competitive advantage

- World-class testing facilities for outdoor testing of prototype solar collectors and thermal storage devices that run on liquid or gaseous working fluids.

Impact

- Improve technologies for solar thermal and thermal energy storage

Successful applications

- Lead investigator on two ARC projects
  - » Superhydrophobic/nanotechnology, micro solar collectors
  - » Waste heat recycling for desal in solar thermal power plants
- Chief Investigator on four ARENA funded projects in solar thermal areas
  - » Aluminium processing with solar energy (current project)
  - » Hydrogen production via solar thermal/ PV system (in collaboration with the School of Chemical Engineering)

Capabilities and facilities

- Two outdoor solar laboratories
- An indoor lab for fluids and heat transfer measurements (includes a differential scanning calorimeter, IR cameras, and other thermal characterisation equipment

Our partners

- Vast Solar (CSP Engineering)
- Apricus (Solar Hot Water)
- GREE (HVAC manufacturer)
- Solar and Thermal Energy Solutions (consulting)

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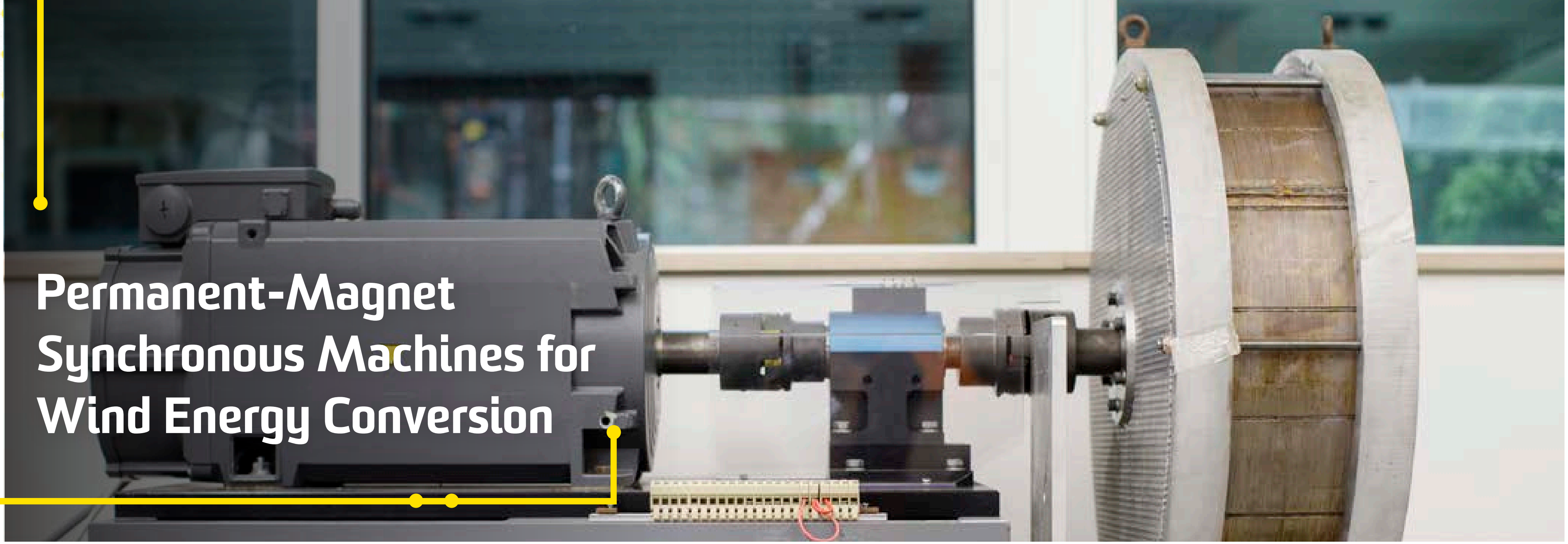

Permanent-Magnet Synchronous Machines for Wind Energy Conversion

Specialists in design and control of permanent magnet (PM) type electric machines. Strong capabilities in design optimisation and control of various PM machine geometries for low-speed, high torque applications such as direct-drive wind energy conversion.

Competitive advantage

- Expertise in designing direct-drive PM generators with compact size and negligible cogging torque.
- One of the world's first to develop fractional-slot concentrated wound interior PM machine for direct-drive wind energy conversion
- Advanced control techniques for the generator-side converters of Wind Energy Conversion
- Advanced techniques for on-line parameter identification with the possibility to use in remote condition monitoring of off-shore generators.

Impact

- Direct-drive PM generators of compact size and with negligible cogging torque
- Cost-effective controller suitable for roof-top applications.

Successful applications

- Advanced control techniques for the direct-drive PM generators
- Patented Fractional-slot Concentrate Wound PM machine technology
- Pending patent application—design optimisation package for PM machine

Capabilities and facilities

- Finite-element packages, including Magsoft and ANSYS, with optimization tools developed in-house
- Simulation platforms (Matlab–Simulink, PSIM), FPGA and DSP systems with high-performance signal acquisition, estimation and switch gate-drive interfaces
- Two and three-level inverters
- Several machine drive set-ups complete with shaft position sensors, torque sensors and highly dynamic loads
- Four-quadrant dynamometer for testing direct-drive wind generators

Our partners

- CSIRO
- Wisconsin Electric Machines and Power Electronics
- Toshiba
- Regal Beloit

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Net Negative CO_2 and Methane Producing Bioreactor

A bioreactor that uses sunlight and CO_2 dissolved in seawater to simultaneously generate methane from the decomposition of algae and sequester CO_2 in the coccoliths of growing algae.

Competitive advantage

CO_2 dissolved in sea water is at 20x the concentration atmospheric CO_2. Algae growing in seawater use sunlight and this CO_2 to produce energy rich lipids and calcium carbonate rich coccolith skeletons. The bioreactor provides the appropriate conditions for good algae growth in an aerobic environment on its surface and at the base of the reactor, the right condition for anaerobic archaea to breakdown the algal lipids to produce methane that is removed as a fuel. The remaining cocolyths are removed in a batch process and stored as sequestration of CO_2 (the precursors of limestone). The Biorector provides methane as a renewable fuel and sequests CO_2 as calcium carbonate or limestone.

- A bespoke bioreactor
- A combination of expertise to leverage existing technology in a combined approach to achieve net negative CO_2 production and produce a renewable energy source (methane) from solar energy

Impact

- Production of renewable fuel
- Capture of CO_2 to reduce the atmospheric concentration of greenhouse gases

Successful applications

- Design and commissioning of a bespoke bioreactor for net negative CO_2 and algal methane production
- Proven methane generation from methanogenic archaea decomposing algae and of CO_2 incorporation in algal coccoliths

Capabilities and facilities

- Lab facilities biogas experiments
- Bioreactor for algal growth and methanogenic archaea decomposition

More information

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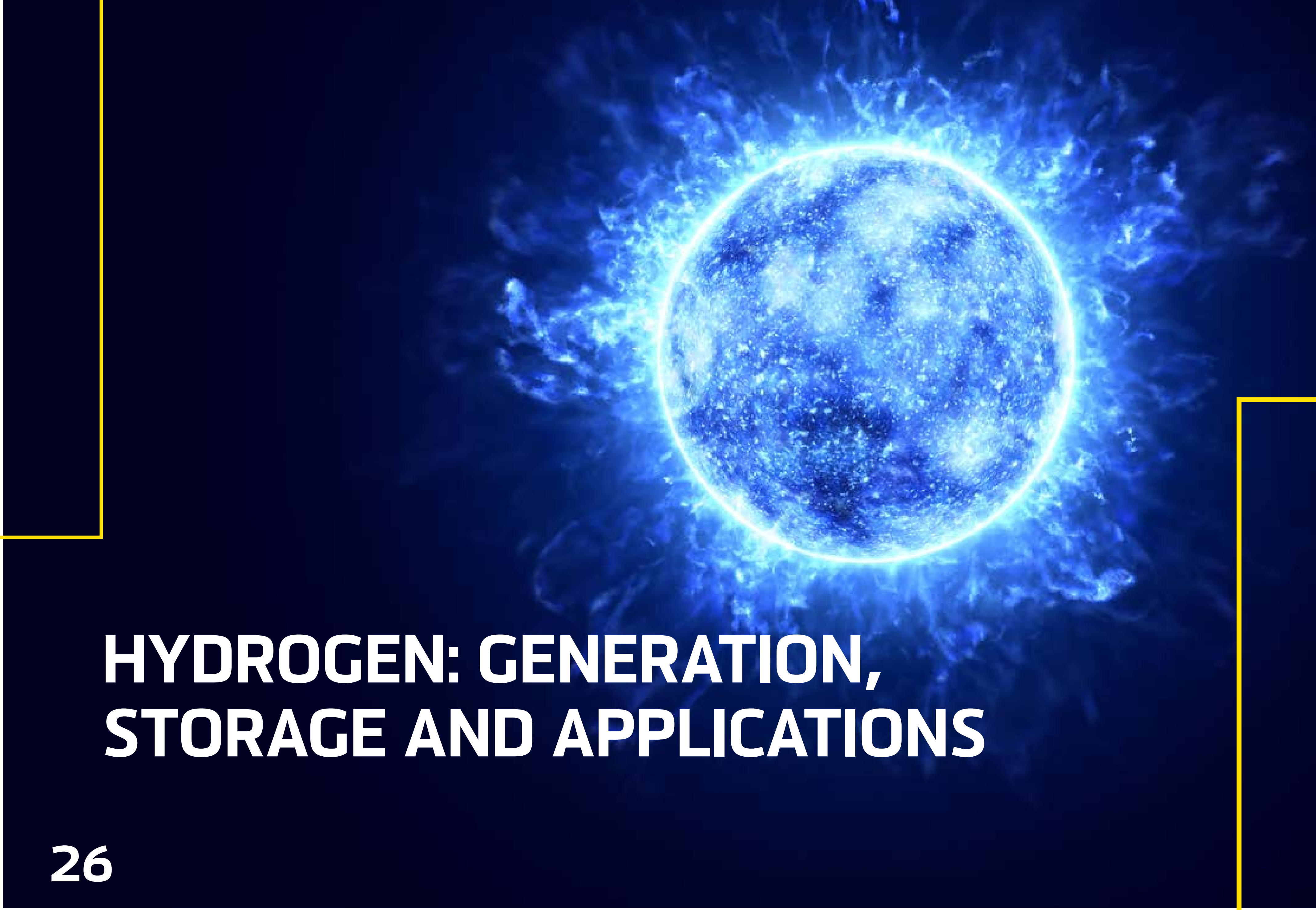
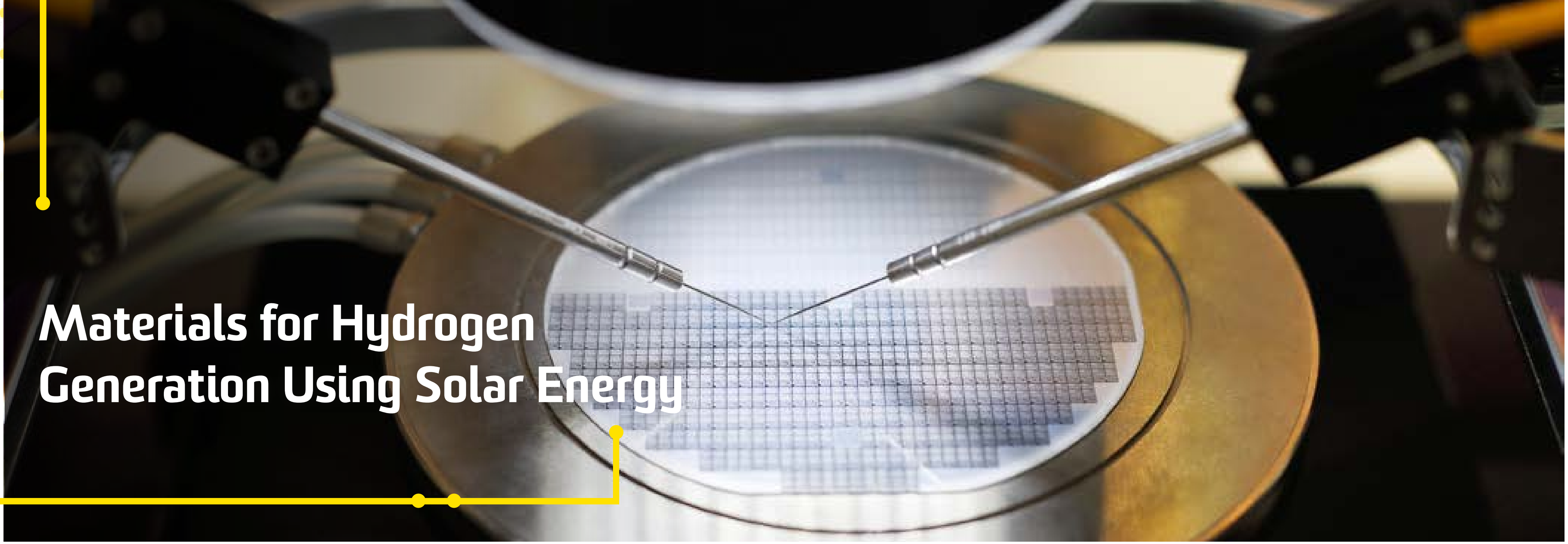


HYDROGEN: GENERATION, STORAGE AND APPLICATIONS



Materials for Hydrogen Generation Using Solar Energy

Design and development of novel semiconducting materials systems for efficient, direct conversion of solar energy to hydrogen allows solar energy to be stored and transported in the form of a chemical fuel, so that it can be used on-demand.

Competitive advantage

The team integrates expertise across computational materials design, a range of materials fabrication techniques, advanced characterisation and device testing. This allows a holistic approach covering all stages from design to testing, thus accelerating materials development.

Impact

- New materials that can absorb energy from sunlight and convert it to hydrogen
- Atomic-level understanding, derived from computational studies, of the light absorption and surface catalytic properties of novel materials

Successful applications

- Prediction and confirmation of a new materials system with photoactivity extending to longer wavelengths than most existing materials

Capabilities and facilities

- High-performance computing capabilities
- Expertise in applying computational materials science to designing new materials and understanding materials performance across a range of applications, including photocatalysis, photovoltaics, battery materials and catalysis

More information

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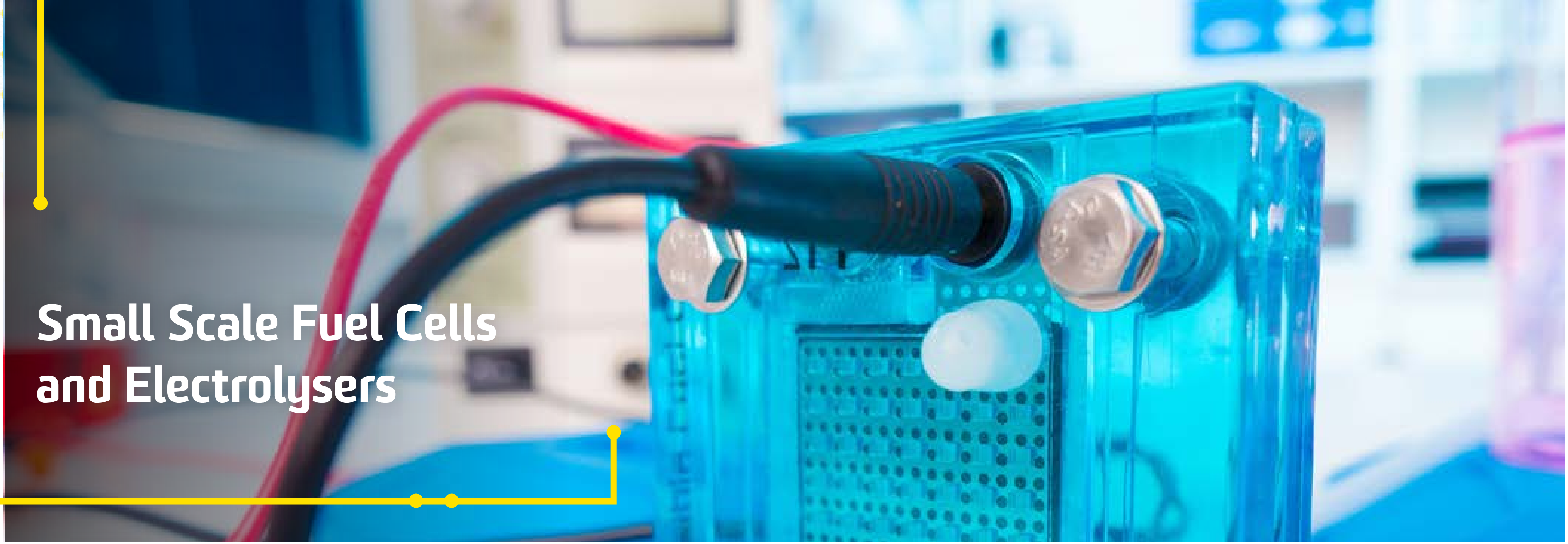

Small Scale Fuel Cells and Electrolysers

Hydrogen is a clean energy vector that can enable zero emission and a decarbonised economy. Development of suitable technology to enable the general public to produce and utilise hydrogen safely has the potential to revolutionise the way energy is generated and used.

Competitive advantage

Unique world class expertise in the design of planar fuel cells and electrolysers for small scale applications.

- Small scale fuel cells (< 300 W) with a planar design (light and thin) to enable application in a range of portable and mobile electronic appliances and devices
- Small scale plug and play electrolysers to enable on-site generation of hydrogen to power small devices or recharge small hydrogen canisters.
- Robust and simple technology

Impact

- Potential to revolutionise the way hydrogen can be produced and used in everyday life. By enabling the utilisation of hydrogen across the entire energy sector, the general public can become prosumers, generate and use their own hydrogen.

Successful applications

- Planar fuel cell to increase the efficiency of electrical bicycles
- Plug and play electrolysers to self-recharge hydrogen canisters

Capabilities and facilities

- State of the art research facility for designing and testing of small scale fuel cells and electrolysers
- Prototyping and optimisation capability

More information

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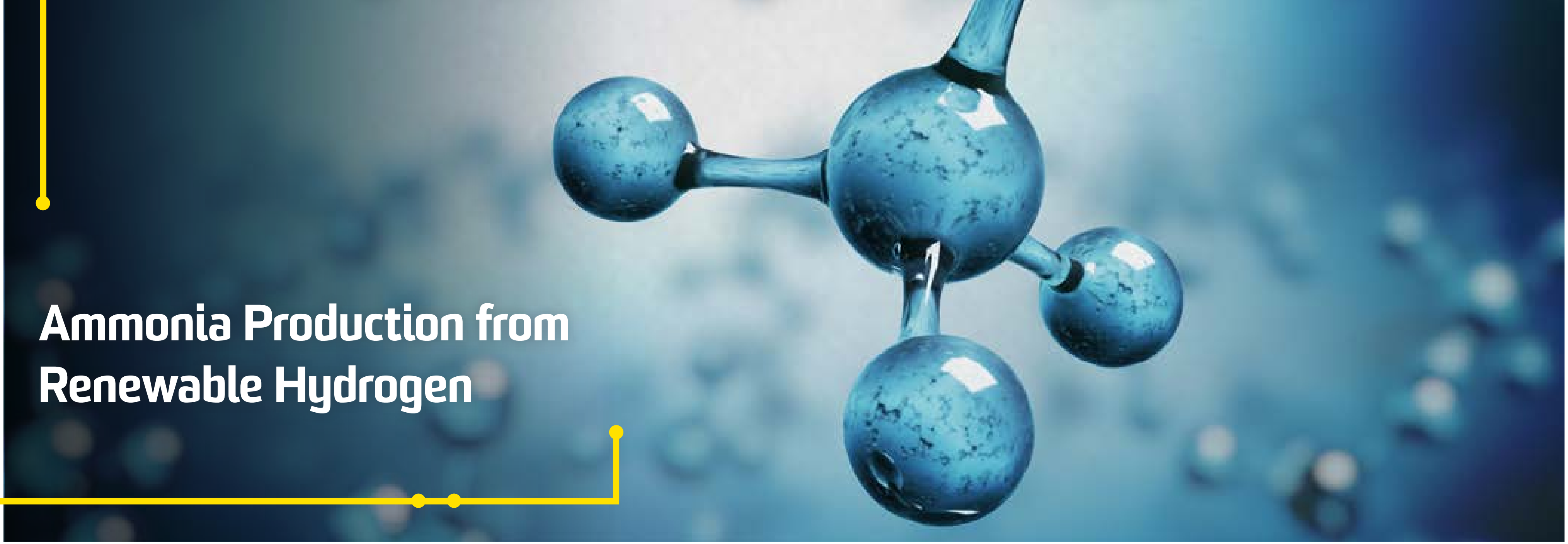

Ammonia Production from Renewable Hydrogen

Development of a high efficiency single-stage electrocatalytic ammonia synthesis reactor to produce ammonia at lower cost than via the traditional Haber-Bosch process.

Competitive advantage

Ammonia is produced using PV electrolysed hydrogen from photovoltaic electrolysis and atmospheric nitrogen. A number of innovations are used to increase efficiency: nitrogen activity is increased by ionising the molecule; nitrogen selectivity over oxygen is achieved using tailored ionic liquids as electrolytes and the nitrogen reaction is catalysed using tailored electrodes.

- In-house expertise exists across all engineering requirements to solve problems and design and test a working prototype

Impact

- Cheaper and more energy efficient process for the production of ammonia

Successful applications

- Photovoltaic electrolysis of water to produce renewable hydrogen
- Demonstration of selective transport in ionic liquids.

Capabilities and facilities

- Extensive lab facilities for PV electrolysis and characterisation
- Expertise and analysis facilities for studying the application of ionic liquids and the ability to assess the increased nitrogen activity

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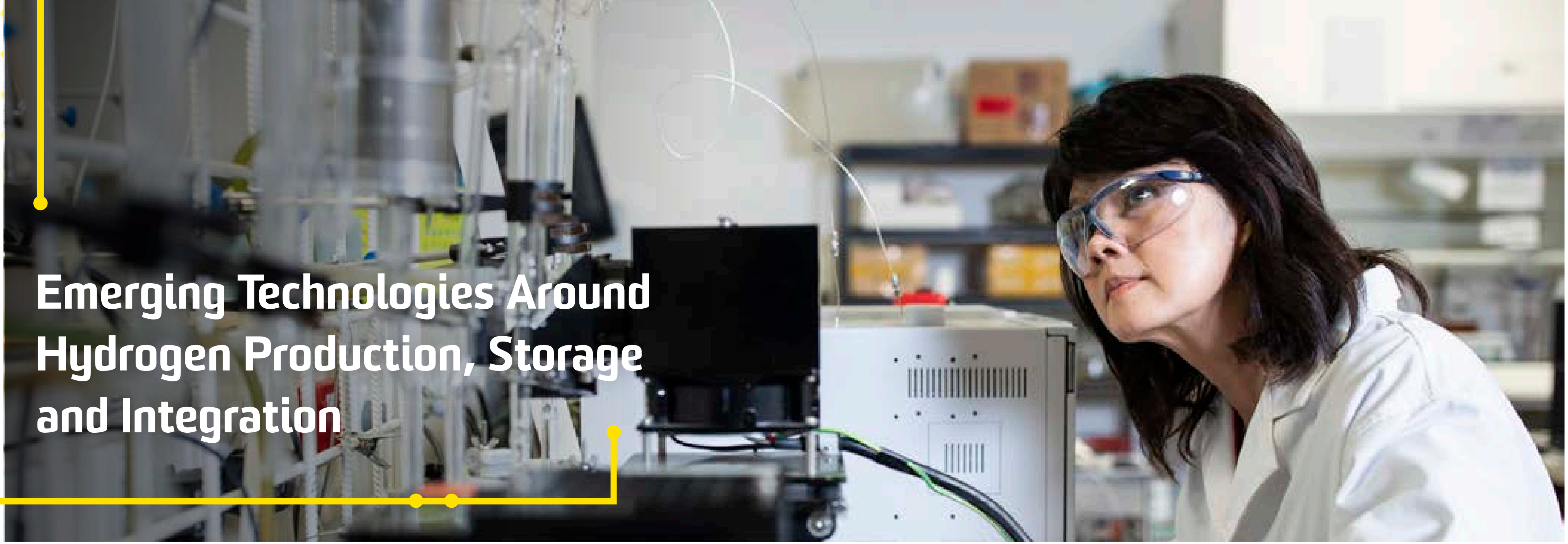

Emerging Technologies Around Hydrogen Production, Storage and Integration

A leading photo(electro)catalysis and nanomaterials research group with expertise and focus around catalysis processes that are thermal, electrochemical, photothermal and photoelectrochemical. The group has a highly efficient and low cost Photovoltaic-Electrolysis (PVE) system to produce renewable fuels by harvesting the full spectrum of sunlight.

Competitive advantage

- Production of renewable fuels (e.g. H_2, CO, ethanol) using cost-effective and active electrolysers powered by photovoltaic cells
- Electrodes are comprised of earth abundant elements without using any expensive noble metals
- Electrolysers can use natural seawater as the electrolyte to produce chlorine on the anode and hydrogen on the cathode

Impact

- Enhanced Australian energy security by using infinite and diffusive solar energy
- Alleviate global warming by reducing the carbon footprint
- Off-grid fuel generation in remote strategic sites

Successful applications

- PVE electrolysis for Hydrogen generation

Capabilities and facilities

- Wide range of nanomaterials development techniques
- State-of-the-art instrument for particle and material characterisation
- Several electrolysers for testing catalyst performance
- In-situ studies capability

Our partners

- RayGen Resources Pty Ltd
- Shenzhen Kohodo Sunshine Renewable Energy Co. Ltd
- Beijing Zhongchao Haiqi Technology Co Ltd

More information

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Waste Biomass to Renewable Hydrogen

The production of renewable hydrogen from preconditioned biomass is an important source of energy and a key component of Australia's future energy offerings for the generation and exporting of hydrogen. It is economically viable and environmentally friendly, with zero carbon dioxide emissions.

Competitive advantage

- Preconditioned biomass (from raw biomass stream) can be obtained at very low cost
- Electrocatalytic hydrogen extraction from pre-conditioned biomass is generally easier than water electrolysis
- It is selective, delivers zero carbon dioxide emissions and can produce value-added organic products with potential to be used as precursors for plastic fabrication

Impact

- Competitive energy production by utilising waste to produce renewable hydrogen
- Alleviate global warming by reducing the carbon footprint
- Resource recovery and new materials

Successful applications

- A zero-emission tandem array for transforming biomass into renewable hydrogen

Capabilities and facilities

- Access to technical expertise and facilities dedicated to sustainable technology development

Our partners

- Origin Water International Pty Ltd
- Apricus Energy Pty Ltd

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Solar Thermal CO_2 Methanation

A state-of-the-art integrated photothermal system for carbon dioxide conversion to methane and facilities for catalyst synthesis for large scale production

Competitive advantage

- Integrated system incorporating photothermal technology to run the methanation reaction
- Uses solar heating as the main driving force to heat up the catalyst for CO_2 conversion
- A very high CO_2 conversion can be achieved using a Ni-based catalyst, with virtually 100% selectivity towards methane

Impact

- Alleviate global warming by recycling CO_2 into synthetic fuels
- Effective use of abundant and free energy from the sun

Successful applications

- The construction and commissioning of a Solar Thermal Plant for integrated CO_2 methanation with hydrogen production via catalysed water electrolysis

Capabilities and facilities

- Access to expertise and state-of-the-art facilities for catalyst synthesis for large scale production
- Characterisation and testing of catalyst performance
- In-situ testing to understand conversion mechanisms

Our partners

- CSIRO Energy

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Dry CO_2 Reforming of Methane

Advanced expertise in the design, development and testing of cost-effective dry reforming catalysts for the conversion of common greenhouse gases (carbon dioxide and methane) into syngas.

Competitive advantage

- Highly active methane dry reforming catalyst based on cheap active metals (Ni and Co) which can be synthesised rapidly in a single step method, and is readily scalable
- High conversion of methane (up to 90%) is achievable at a relatively low operating temperature of 700 °C
- Catalyst support (using SiO_2 and Al_2O_3) modification to enhance catalyst stability

Impact

- Alleviate global warming by conversion of CO_2 and methane into synthetic fuels
- Large scale production of active and stable catalyst

Successful applications

- The construction and commissioning of a Flame Spray Pyrolysis reactor to fabricate high surface area metal oxides and catalysts

Capabilities and facilities

- Access to expertise and state-of-the-art facilities for catalyst synthesis for large scale production
- Characterisation and testing of catalyst performance
- In-situ testing to understand conversion mechanisms

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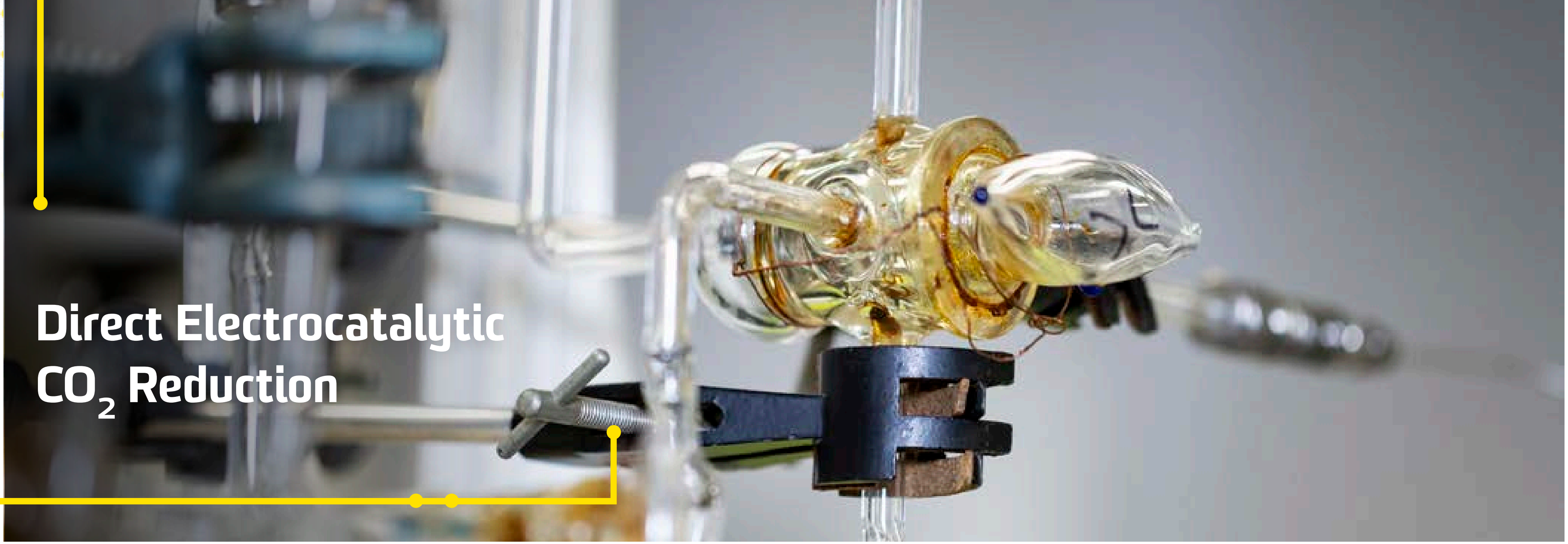

Direct Electrocatalytic CO_2 Reduction

Expertise in the direct conversion of carbon dioxide into high value liquid products, which is important for combating climate changes and energy efficiency challenges

Competitive advantage

- The electrochemical CO_2 reduction reaction (CO_2RR) can be carried out at ambient conditions by applying an external bias
- Possibility to couple with electricity generated from renewable energy resources to close the carbon loop
- Simple, scalable and cost-effective catalysts for CO_2RR in the gas phase to deliver liquid products

Impact

- Alleviate global warming by direct conversion of CO_2 into high value liquid products
- Creation of a sustainable cycle of carbon-based fuel that will promote zero net CO_2 emissions

Successful applications

- Mesoporous tin oxide (SnO_2) electrocatalyst for large scale conversion of CO_2 to formate with high selectivity and current density

Capabilities and facilities

- Access to expertise and state-of-the-art facilities for electrocatalyst fabrication, characterisation and testing of performance

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Simulation and Modelling of Solid-State Hydrogen Storage Tanks

Hydrogen is a clean energy vector that can enable storage of any form of energy, including renewable, with high density. Development of suitable models to enable the design of effective solid-state hydrogen storage tanks will enable the transition to a new economy based on the use of hydrogen.

Competitive advantage

Unique world class expertise in the modelling of solid-state hydrogen storage tanks for the effective recovery of the hydrogen storage and the associated heat and hydrogen flow management.

- Optimisation of hydrogen storage solution for high energy efficiency
- Most advanced simulation packages for the design and optimisation of hydrogen storage tanks and their integration into existing infrastructures

Impact

- Potential to revolutionise the way energy is generated, distributed and used at small, intermediate and large scales

Successful applications

- Design of solid-state hydrogen storage tanks integrated to electrolysers and fuel cells

Capabilities and facilities

- State of the art research facility for designing and testing solid state hydrogen tanks and verification of simulation models
- Prototyping and optimisation capability

More information

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Cryogenic Testing of Advanced Fibre Composite

Lightweight storage vessels are important for the transportation and storage of hydrogen in vehicles such as spacecraft, satellites, cars and marine ships. Existing carbon-fibre reinforced composites suffer matrix cracking that leads to leakage and lower strength. Techniques to eliminate matrix cracking by nano-scale engineering of polymer matrixes are being developed.

More information

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Competitive advantage

Lightweight and strong fibre composites that can safely operate at cryogenic temperatures without microcracking are urgently needed to reduce the weight of future aerospace craft, launch vehicles, fuel storage, and other space missions. This need is being addressed with extensive expertise in:

- Nano-engineering of fibre reinforced composites to simultaneously improving mechanical, electrical and other functionalities such as gas permeability
- Design and manufacturing of carbon fibre composites for extreme operating conditions, such as high mechanical stress and super cold temperatures
- Automated manufacturing processes, such as fibre placement and filament winding to reduce the cost of production

Impact

- Significant improvement of mechanical properties and permeation leakage in cryogenic tanks
- Lighter fibre-composite tanks for transporting and storing liquid hydrogen as a fuel source.

Successful applications

- Prototype development of carbon fibre composite tank for storing liquid hydrogen, Lockheed Martin

Our partners

- Lockheed Martin

Solid-State Hydrogen Technology for Advanced Energy Storage

Hydrogen is a clean energy vector that can enable storage of any form of energy, including renewable, with high density. Development of suitable technology to store hydrogen safely and with high efficiency will enable the transition to a new economy based on the use of hydrogen.

Competitive advantage

Unique world class expertise in solid-state hydrogen storage from fundamental material design to implementation in the field. Hydrogen is a versatile energy carrier that can provide both heat and electricity.

Commercialisation of solid-state hydrogen solutions

- The most effective energy storage solution enabling both high volumetric and gravimetric energy density (6 times that of Li-ion batteries)
- Long cycle life (> 30,000 cycles of hydrogen uptake and release)
- No memory effect and recoverable stored hydrogen > 90%
- Simple and robust technology enabling increased safety in the use of hydrogen
- Pre-commercialisation cost comparable to existing technologies such as batteries
- Solid-state materials heat and cool upon hydrogen uptake and release. This provides additional energy in the form of heating/cooling owing the unique properties of solid state hydrogen storage materials

Impact

- Potential to revolutionise the way energy is generated, distributed and used at small, intermediate and large scales.

Successful applications

- Storage and transport of renewable energy
- Integration to the grid for load levelling or long term electricity storage
- Heat and/or cooling for applications that require both energy storage and heat recovery

Capabilities and facilities

- State of the art research facility for designing and testing solid state hydrogen materials
- Prototype solid-state hydrogen tanks design and optimisation capability
- Integration of solid-state solutions in existing infrastructures

More information

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Hydrogen Based Appliances

Hydrogen is a clean energy vector that can enable zero emission and a decarbonised economy. Development of suitable technology to utilise hydrogen safely and with high efficiency will enable the transition this a new economy based on the use of hydrogen.

Competitive advantage

Unique world class expertise in the design/conversion of common appliances effectively using hydrogen as a fuel to generate electricity or heat. Expertise for the integration into existing infrastructures.

- Hydrogen can be used with a fuel cell to generate electricity with high efficiency and with water as the sole emission
- Hydrogen can be catalytically burnt to generate heat to do work.
- Robust and simple technology based on the most advanced innovative solutions developed at UNSW

Impact

- Potential to revolutionise the way hydrogen can be used in everyday life and facilitate the transition to a hydrogen based economy

Successful applications

- Hy-cycle, hydrogen powered bicycle demonstrating the effective use of hydrogen with a fuel cell to generate electricity on-board a bicycle
- H2Q, a hydrogen powered BBQ, catalytically burning hydrogen without any flame

Capabilities and facilities

- State of the art research facility for designing and testing appliances/devices effectively using hydrogen
- Prototyping and optimisation capability

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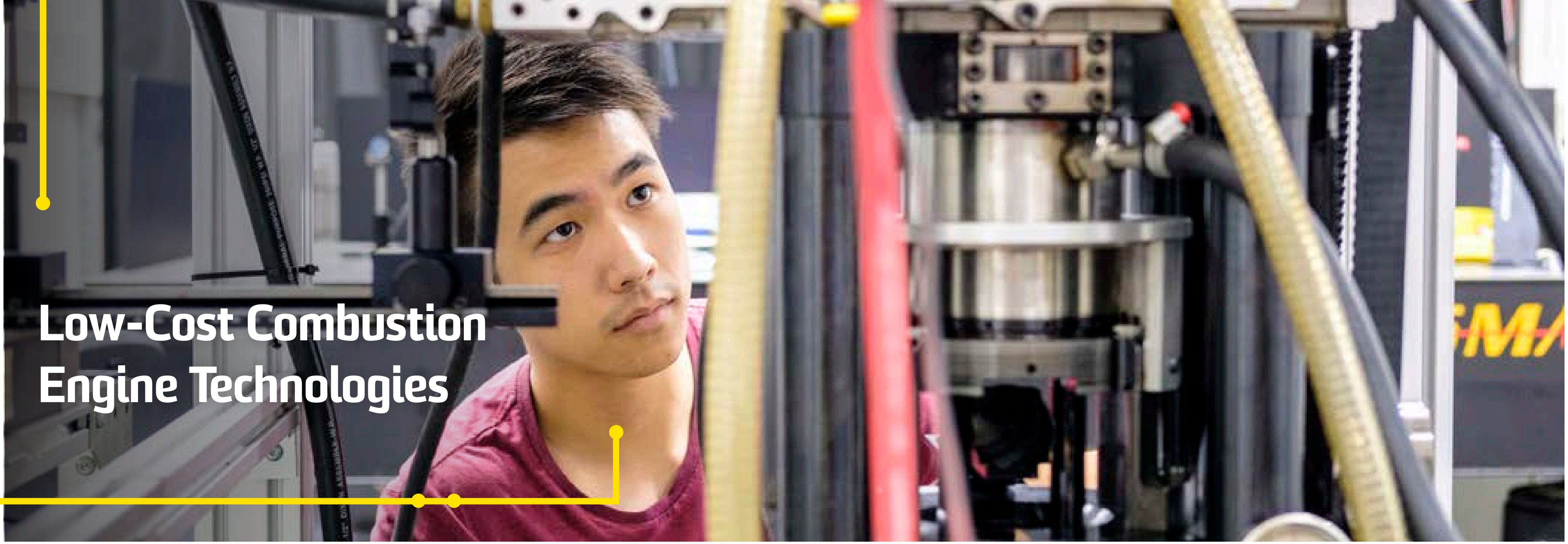

Low-Cost Combustion Engine Technologies

Efficient, robust and low-cost combustion engine technologies for hydrogen end use in transportation and power generation

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Competitive advantage

- Focus on renewable hydrogen use in highly efficient compression ignition engines and gas turbines
- Thermal efficiencies comparable to real-world efficiency of a fuel cell, at much lower cost, while allowing flexibility to operate on industrial-grade hydrogen or to switch to conventional fuels
- Unique combination of capabilities and expertise including in-cylinder measurements in optically-accessible engines and combustion chambers together with high-fidelity computational fluid dynamics models

Impact

- Low-cost and robust near term technologies for efficient hydrogen end use in power-to-gas systems and in transportation

Successful applications

Demonstrated renewable fuel engine technology through:

- Successful development of a renewable ethanol fuelled compression ignition engine using port injection system for retrofitting applications
- Development of a highly efficient compression ignition engine through direct injection of renewable ethanol

Capabilities and facilities

- Optical engines and advanced imaging systems
- Engine performance/emission testing facility
- High fidelity CFD engine models
- High performance computing

Our partners

- MAN Energy Solutions
- Haltech Engine Management Systems
- Imagineering

ENERGY STORAGE FOR VEHICLES

Safety-Critical Electric Drives

Expertise in design and control of novel, power-dense multi-phase electric drives for safety-critical applications, including rail transportation, electric vehicles, marine propulsion drives and aerospace.

Competitive advantage

- Novel five-phase generator technology, using fractional-slot, concentrated-wound electric machines, provides best-in-class power density for permanent magnet machines
- Drives that also incorporate novel multi-phase designs that enhance torque production, smooth ripple-free torque, and provide tolerance to faults

Impact

- More efficient, safer transport solutions

Successful applications

- Open winding multi-phase drive system for fault tolerance

Capabilities and facilities

- Four-quadrant dynamometer
- Bidirectional grid simulators
- High-speed load machines
- Medium-voltage testing

More information

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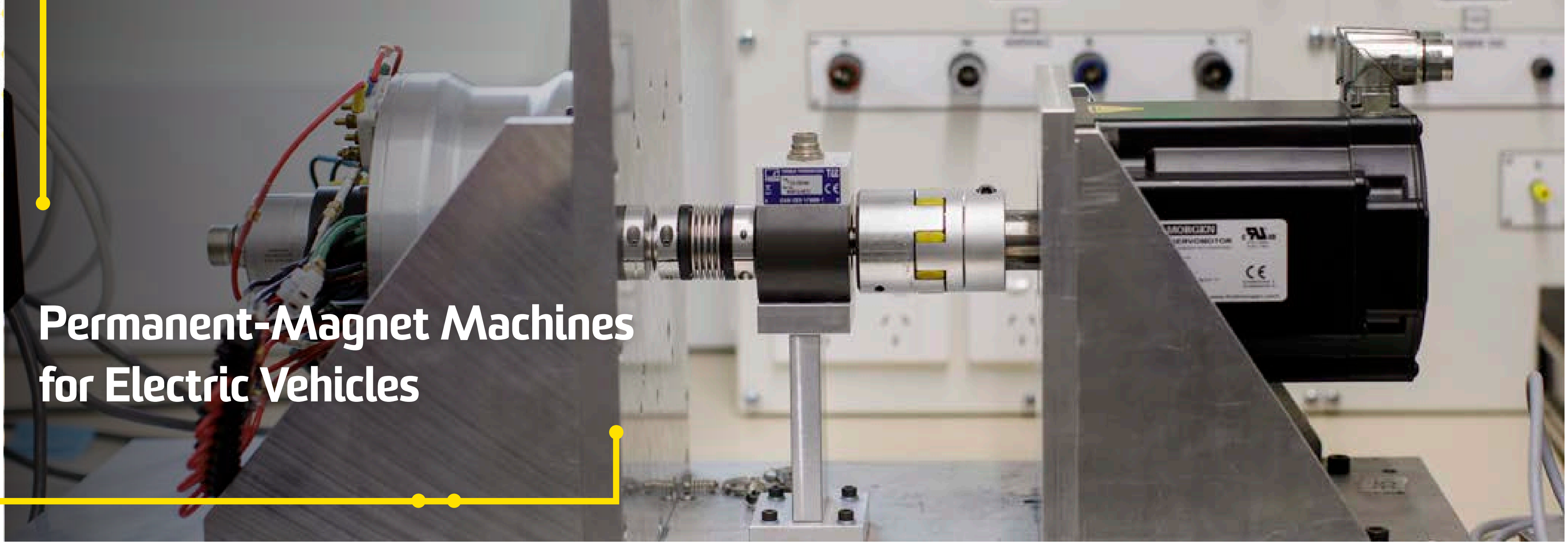

Permanent-Magnet Machines for Electric Vehicles

Strong capabilities in designing and optimising various PM machine geometries and developing advanced control techniques to further improve performance of electric vehicles

Competitive advantage

- World-class expertise in PM machine design and control
- One of the world's first to develop mechanical sensorless control for an interior-type PM machine and a fractional-slot concentrated wound interior PM machine
- Patented PM machine technologies with wide flux-weakening range—a requirement for traction drives in electric vehicles
- Developing advanced on-line parameter identification techniques

Impact

- Electric machines with higher efficiency and better performances for EV-powertrain
- Motors with wider constant power operation for traction applications.

Successful applications

- Sensorless control techniques from zero to full speed for PM motor drives
- World's first experimental verification of fractional-slot concentrated wound stator with Interior-type PM rotor
- Development of PWM-based sensorless control and high-speed Interior PM machines
- Patented technologies of fractional-slot Interior PM machines
- Patent application—Novel multi-objective optimisation techniques for PM machines

Capabilities and facilities

- Finite-element packages, including Maxwell 2D/3D, Magsoft and ANSYS, with optimization tools developed in-house
- Simulation platforms (Matlab–Simulink, PSIM), FPGA and DSP systems with high-performance signal acquisition, estimation and switch gate-drive interfaces
- Two and three-level inverters
- Several machine drive set-ups complete with shaft position sensors, torque sensors and highly dynamic loads
- Four-quadrant dynamometer for testing direct-drive wind generators
- High-speed (>50 krpm) PM machine test bed (work-in-progress)

Our partners

- CSIRO
- Wisconsin Electric Machines and Power Electronics
- Toshiba
- Regal Beloit

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Micro-Supercapacitors for IoT

Micro-supercapacitors offer energy densities comparable to micro-lithium-ion batteries, but with one hundred times more power density and an ability to be recharged in 3 seconds. These devices have a range of potential applications, including electric vehicles and wearable electronics.

Competitive advantage

- Bulk intercalative charge storage allows high energy density and low self-discharge
- Dual-carrier transfer renders high power capability
- Based on neutral aqueous electrolyte with high environmental compatibility

Impact

- Improved lifetime, stability and power density for electric vehicle applications
- Facilitating maintenance-free biosensors, mobile environmental sensors, wearable electronics and nanorobotics

Successful applications

- Lab-demo coin-type cell developed

Capabilities and facilities

- High-end electrochemical materials and device evaluation system
- In-situ electrochemical cell diagnosis (structural, chemical, and thermal)
- Advanced materials fabrication platform
- Versatile printing technologies for cell development (roll-to-roll, spraying, bar coating, doctor blade, etc.)

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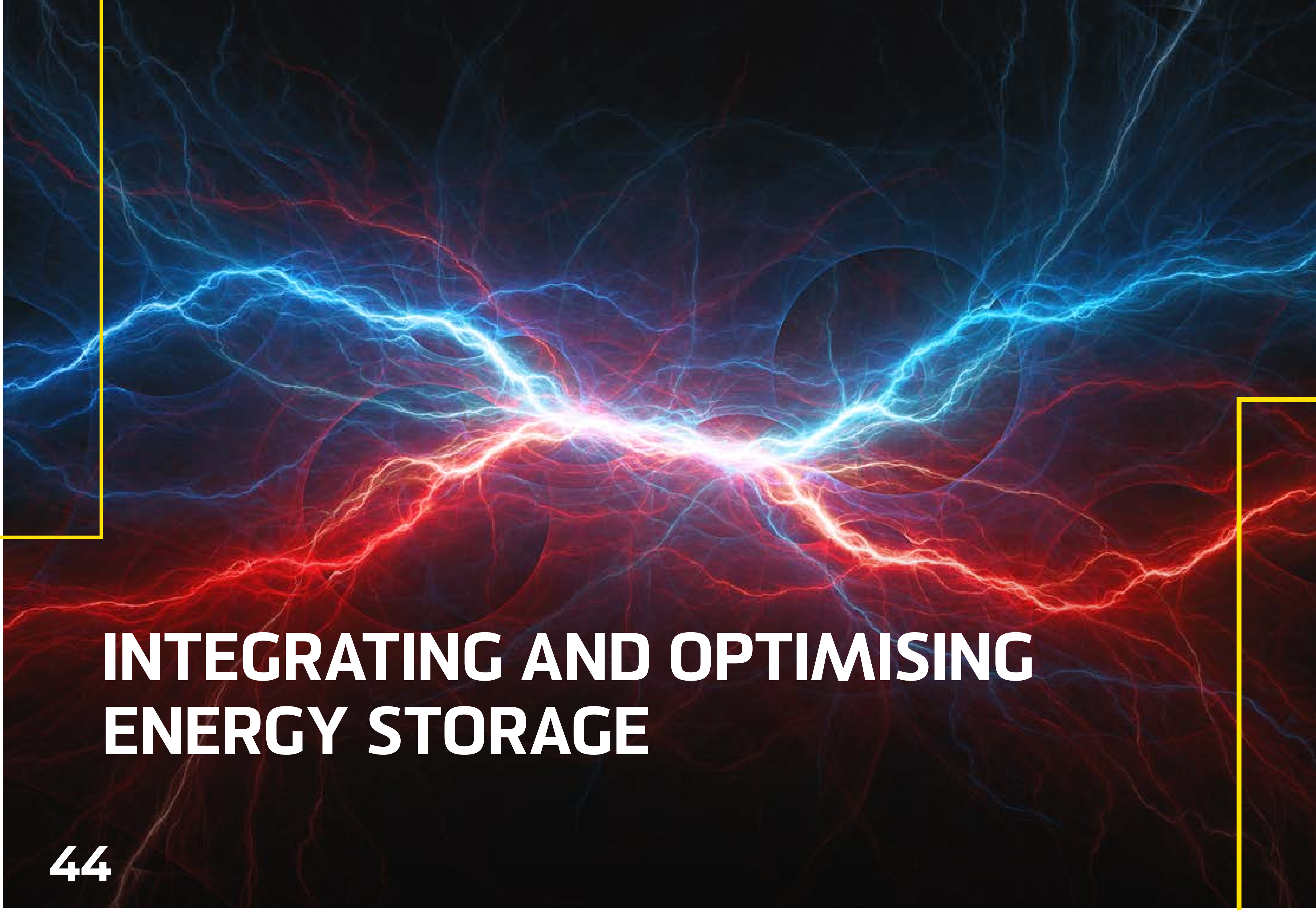
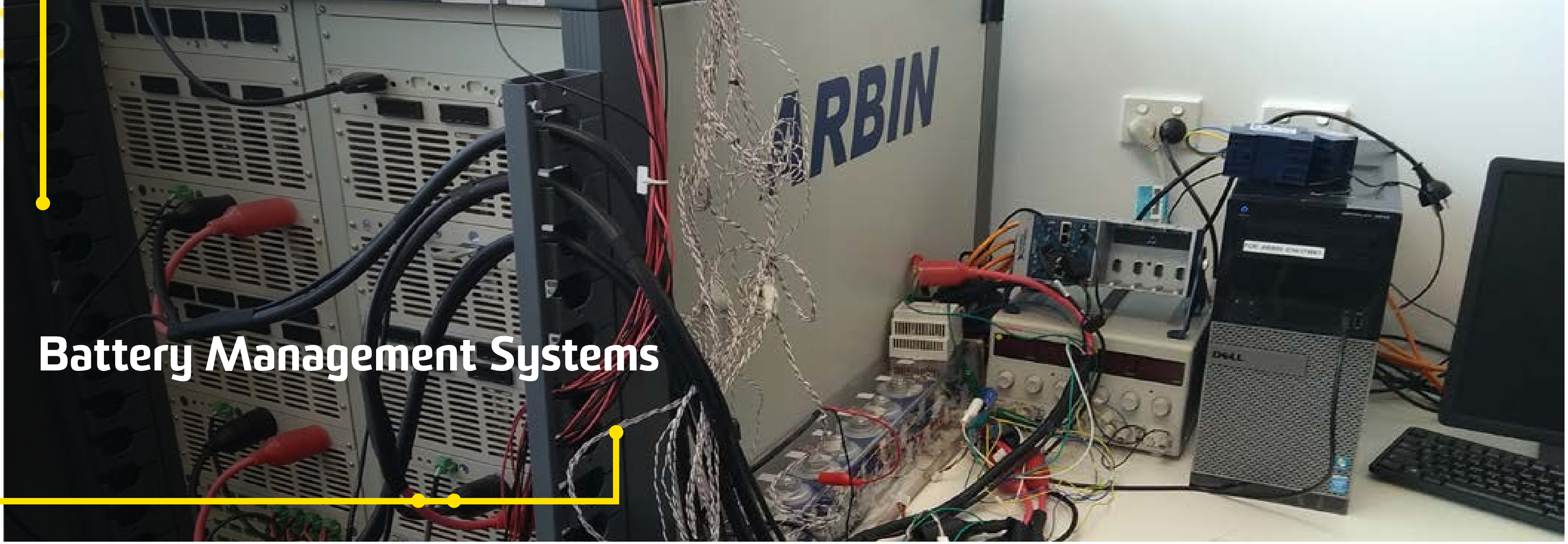


INTEGRATING AND OPTIMISING ENERGY STORAGE



Battery Management Systems

Expertise in battery management systems including the ability to monitor temperature, state-of-charge, and maintain the system within safe operating limits to improve battery life.

Competitive advantage

- Cooperative state of charge balancing
- Advanced state-of-charge, state-of-health estimation algorithms
- Monotonic charging/discharging of battery packs
- Temperature monitoring using limited number of temperature sensors
- Reduction of battery current variation

Impact

- Extended lifetime of batteries
- More efficient and reliable battery products

Successful applications

- Direct AC linked hybrid (battery/ultracapacitor) energy storage system with second order harmonic current reduction
- Distributed cooperative balancing system for reconfigurable battery systems
- Modular multilevel battery storage system with second order harmonic current reduction
- Temperature monitoring system for ultracapacitor strings using limited number of temperature sensors

Capabilities and facilities

- Power Electronics Laboratory
- Arbin Instruments battery tester
- Prototypes of hybrid (battery/ultracapacitor) energy storage system, reconfigurable (hybrid) energy storage system and temperature monitoring system for supercapacitors strings

Our partners

- ABB

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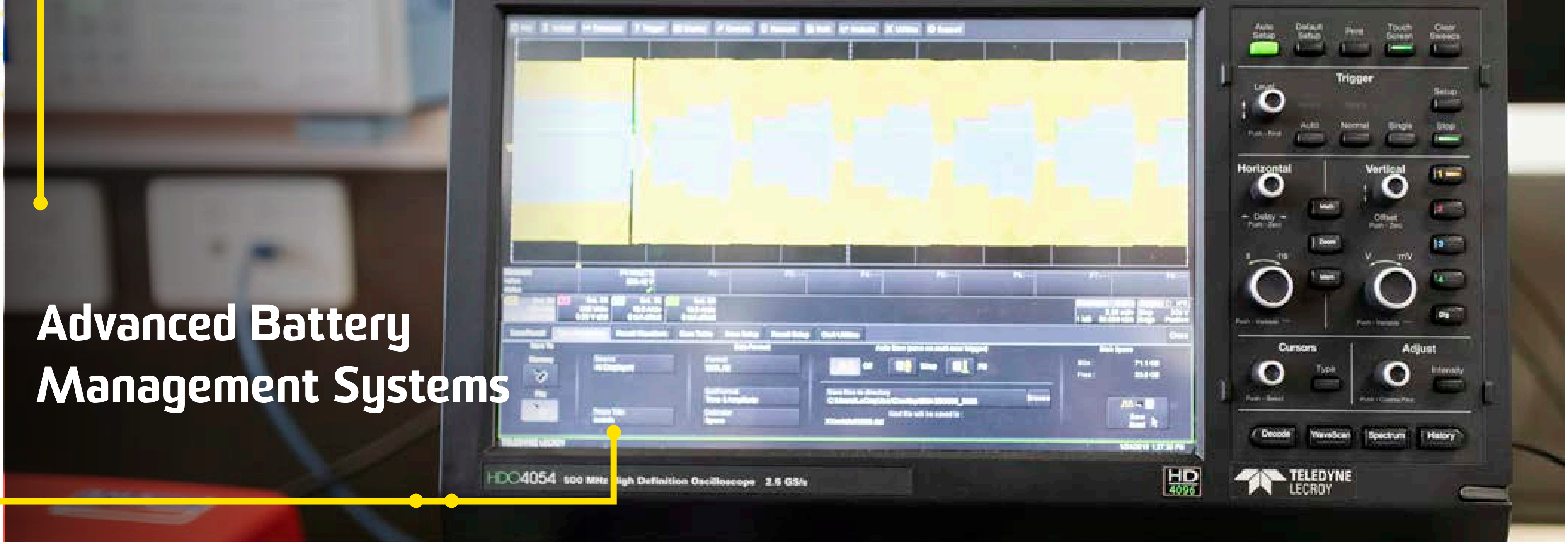
Advanced Battery Management Systems



Battery management systems (BMS) for managing both charge and discharge of individual or groups of cells is essential for safety and increasing performance of the system. Balancing can be a simple passive circuit that normalises voltages in the steady-state or highly complex, using networks of active converter circuits that provide balancing function in both transient and steady-state.

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Competitive advantage

- A range of technologies from low-cost cell balancing technologies to complex management systems that utilise ultra-low power IOT/wireless technologies to simplify the gathering of cell parameters and control the cell charge using novel dc-dc converter technologies.
- A high-power density dc-dc converter technology that decreases the size and volume of the battery management system
- An IOT/wireless interfacing that decreases the complexity of the system, improving reliability and security.
- Ability to provide lab-scale development with interface capability up to 50kVA

Impact

- Development of advanced BMS technologies that improve safety, reliability and lifetime whilst ensuring cell performance at optimum levels.

Successful applications

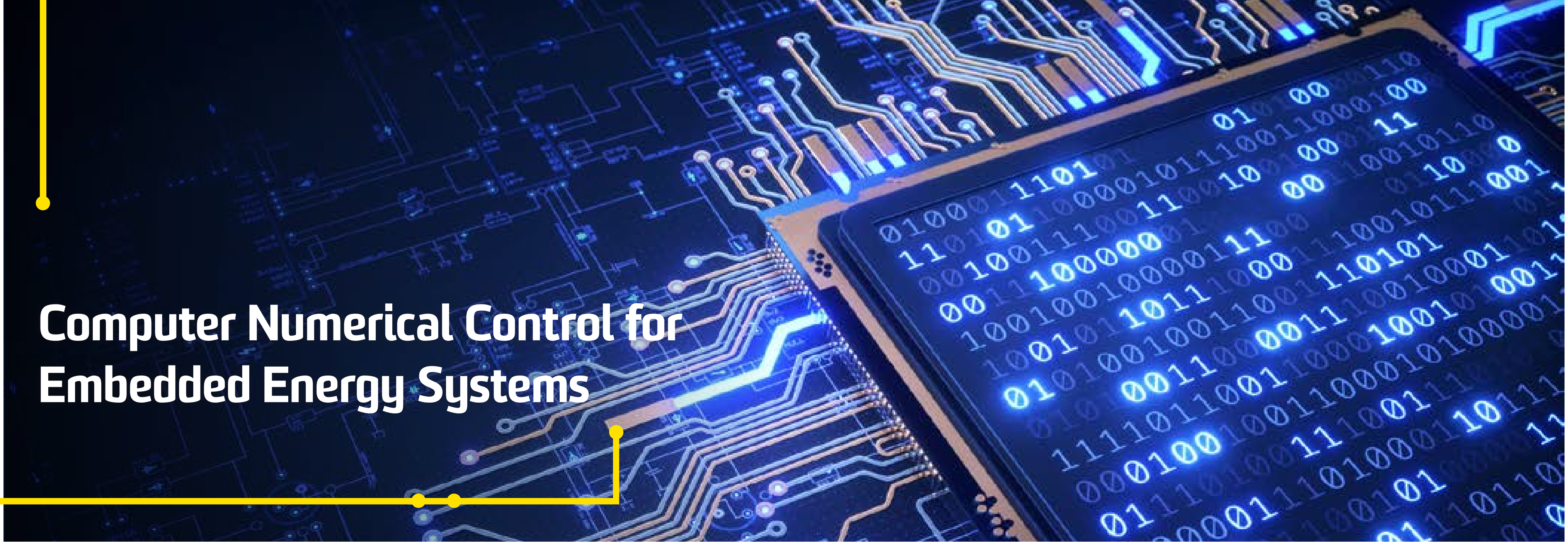
- Solar car battery management systems
- Pipeline ‘pig’ applications
- BMS systems for traction drives

Capabilities and facilities

- Hardware-in-loop simulation for rapid assessment of control techniques
- Hardware testing capability up to 50kVA, 1kV, 400A
- Arbin battery and supercapacitor tester with environmental chamber

Our partners

- RST Projects
- Taipei Locomotives



Computer Numerical Control for Embedded Energy Systems

Expertise in embedded system design for various systems, including computer numerical control (CNC) systems, wireless sensor networks, and high performance, low energy embedded systems.

Competitive advantage

- Lifetime-aware wireless sensor networks
- Secure wireless sensor networks
- High performance CNC systems
- High performance, low energy, fully predictable embedded systems

Impact

- Embedded systems with better performance and greater security

Successful applications

- Aerospace I CNC system—core technology for founding Wuhan Huazhong Numerical Control Co Ltd (HNC), one of the world's leading CNC providers
- Lifetime-aware data collection in wireless sensor networks
- Secure data collection and distribution in wireless sensor networks
- Energy-aware task scheduling on MPSoC-based embedded systems
- Optimizing compilers for clustered VILW processor-based embedded systems
- Integrating cache locking and task scheduling for fully predicable embedded systems

Our partners

- Wuhan Huazhong Numerical Control Co Ltd

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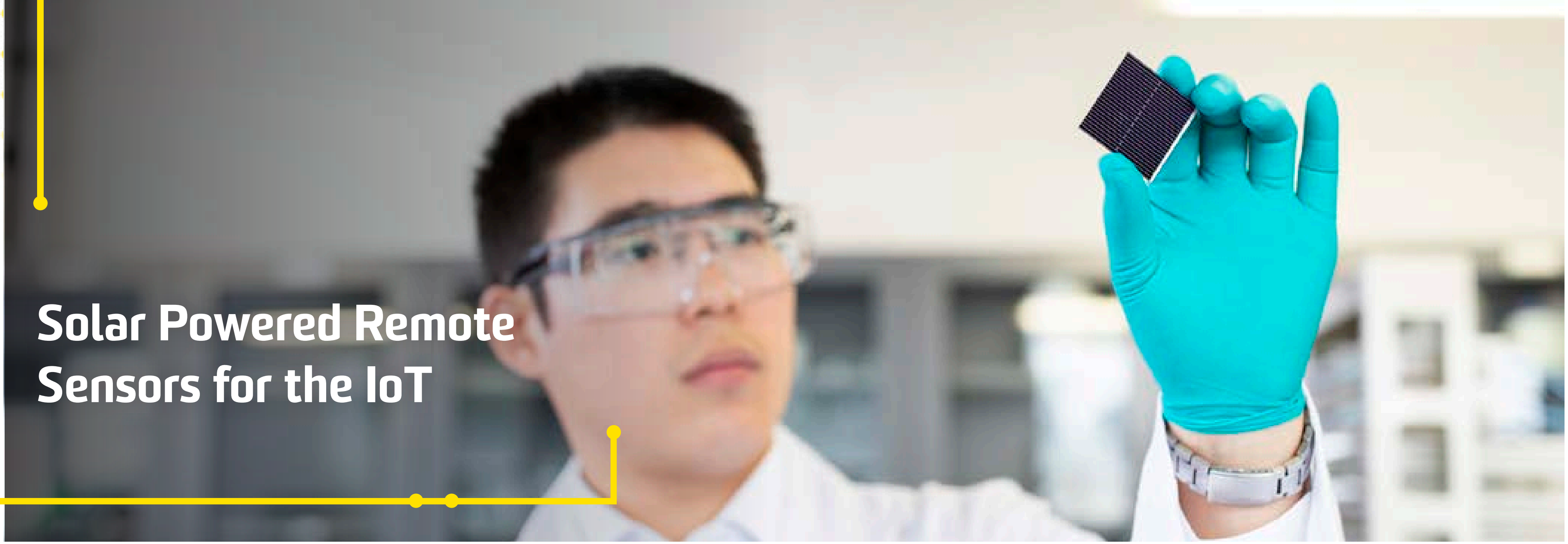

Solar Powered Remote Sensors for the IoT

Solar powered hybrid devices with on-board energy storage can enable compact remote sensing devices that collect and transmit field data to the cloud to support 24/7 monitoring and surveying applications.

Competitive advantage

- Expertise in photovoltaics and energy storage
- Practical experience in fabrication of hybrid devices
- Knowledge/experience in durable device encapsulation
- Circuit and device modelling/simulation expertise

Impact

- Self-powered sensors and devices to enable monitoring and/or survey data to be collected from remote areas and assimilated via cloud computing into historical and/or predictive models
- Hybrid photovoltaic and storage functionality for solar-powered devices and tools, and medical implants

Successful applications

- Demonstrated hybrid device based on a commercially-produced silicon solar cell

Capabilities and facilities

- Extensive expertise in both photovoltaics and energy storage research
- State-of-the-art laboratory facilities for both photovoltaics and energy storage research and fabrication of hybrid devices

More information

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Energy Storage Modelling and Forecasting

Leaders in research of renewable energy and energy storage for stand-alone, microgrids and grid connected systems, using state of the art simulations based on machine learning models. Analysing and understanding electricity demand, solar irradiance and weather variables leads to the development of accurate models to forecast electrical loads and photovoltaic power generation.

Competitive advantage

World-class modelling and energy forecasting for the analysis and technoeconomic optimisation of thermal and electrical storage. Expertise and capability to accurately simulate the operation of storage systems in detail and as part of larger systems (like a grid or a microgrid), to understand their performance, operation and value proposition in different scenarios, including demand management, renewable energy smoothing and firming.

Impact

- Optimised deployment of storage systems
- Optimised dispatch of storage systems
- Analysis of degradation of storage systems
- Better understanding of the value generated by storage systems over time

Successful applications

- Optimization of the energy use for a residential hot water system with PV using forecasting and storage modelling

Capabilities and facilities

- Research storage systems from 30 kWh to 500 kWh
- Microgrid research facilities
- World class capability to optimise grid systems and storage using machine learning
- Access to real data for renewable energy and storage systems

Our partners

- Solar Analytics

More information

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Hybrid Battery Storage for Microgrids and Solar Farms

Battery storage plays an important role in microgrids and solar farms, improving grid reliability and resilience while facilitating effective operation of critical and frequency-sensitive loads. Battery storage is critical both for daily operation of a microgrid, as well as providing for grid redundancy in extreme events.

Competitive advantage

A complete test bed and procedures for assessing battery storage performance under different grid events to:

- improve the reliability and resilience of grid supply using coordinated microgrid battery storage
- improve continuous supply for electricity demands and demand side management
- provide reliable and economical reserve
- -provide firming capacity and reduce DC losses for solar farms

Impact

- More reliable and efficient microgrid performance

Successful applications

- Development of a hybrid portable mobile microgrid station system
- Microgrid planning tools and capability for urban and remote area
- Hybrid portable mobile microgrid station for Australian Defence Force—a project focussed on hybrid battery storage systems for mobile and reliable power supplies for remote operation activities

Capabilities and facilities

- Energy and power research group with industrial standard software.
- Hardware-in-the-loop testing bed for energy storage systems with programmable grid simulations on real time digital simulators (RTDSs)

Our partners

- Remote energy users including farmers, mining sites and army forward bases
- Solar farm owners for field trials

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Cooperative Distributed Energy Storage Systems

Massive penetration of energy storage systems presents new opportunities for power network operators and individual customers. Innovative cooperation of distributed energy storage systems can improve power quality while bringing additional capacity, flexibility and redundancy into power networks. It can also avoid costly power network upgrades and increase power-supply security.

Competitive advantage

Expertise in developing distributed multi-agent control strategies for energy storage systems. Distributed multi-agent control strategies provide improved performance compared with decentralised control strategies and have advantages in terms of robustness, scalability, security and flexibility over centralised control strategies.

Successful applications

Development of multi-agent control strategies for both homogeneous and heterogeneous distributed energy storage systems that allow:

- cooperative state-of-charge balancing with no circulating currents
- plug-and-play capability
- monotonic charging/discharging, and
- network topology independent dynamic optimal power flow.

Capabilities and facilities

UNSW houses one of the largest Real Time Digital Simulators (RTDS) in academic and research institutions globally.

- The RTDS allows real-time verification of algorithms and simulation of power networks together with accurate models of energy storage systems and power converters.
- RTDS allows hardware-in-the-loop simulation, which is the final step before field verification.
- This presents the opportunity for rapid research, development and verification necessary for translating theoretical advances in multi-agent cooperative control into new strategies suitable for deployment in power system networks.

Our partners

- ABB Corporate Research, Sweden

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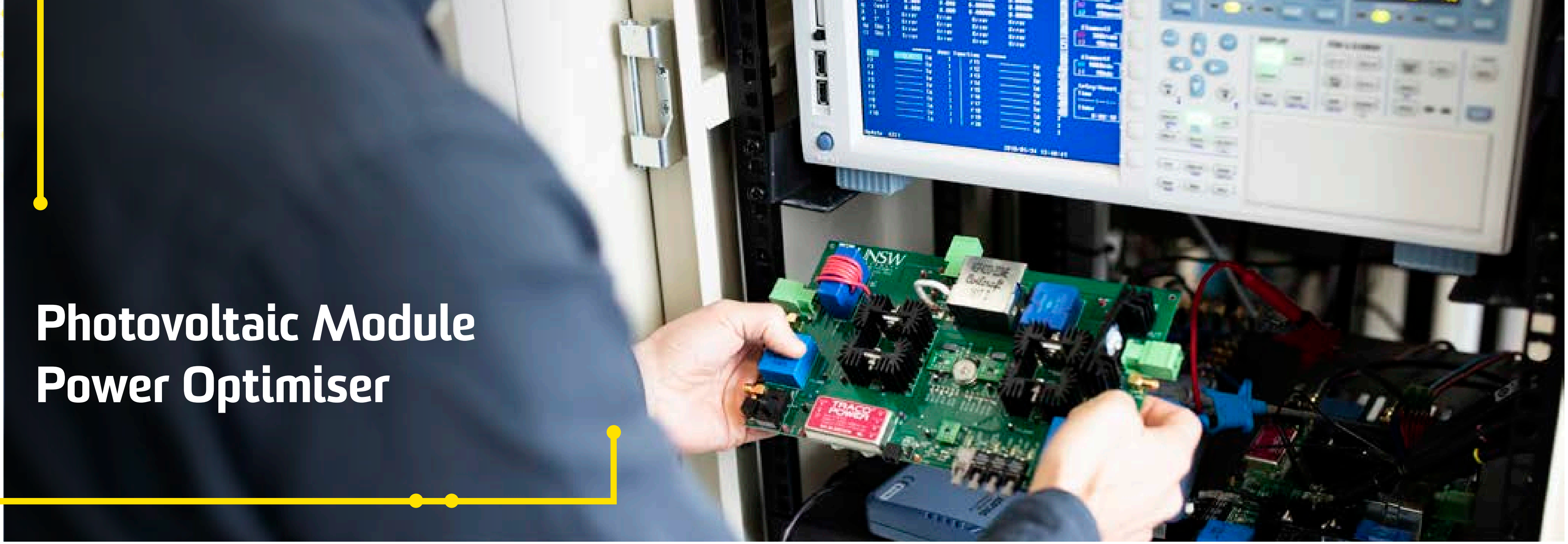
Photovoltaic Module Power Optimiser



A low-cost universal converter that can act as either a power optimiser or a micro-inverter for photovoltaic (PV) modules would maximise the energy output of photovoltaic systems by constantly extracting the maximum power from each photovoltaic panel separately.

Competitive advantage

- High frequency and intelligent design that can detect potential faults in PV modules and ancillary equipment, thereby avoiding costly downtime
- Allows flexible installation design with multiple orientations, slopes and PV panel types in the same string
- String voltages can be kept constant, providing greater flexibility with longer strings and strings of different lengths to design optimal solar PV systems

Impact

- More efficient photovoltaic power systems
- Improved safety functionality
- Improved energy yield and reduced energy loss due to shading effects

Capabilities and facilities

- State-of-the-art test facilities including accelerated testing
- First class instrumentation and measurement
- Prototyping and testing solutions
- Realtime simulation

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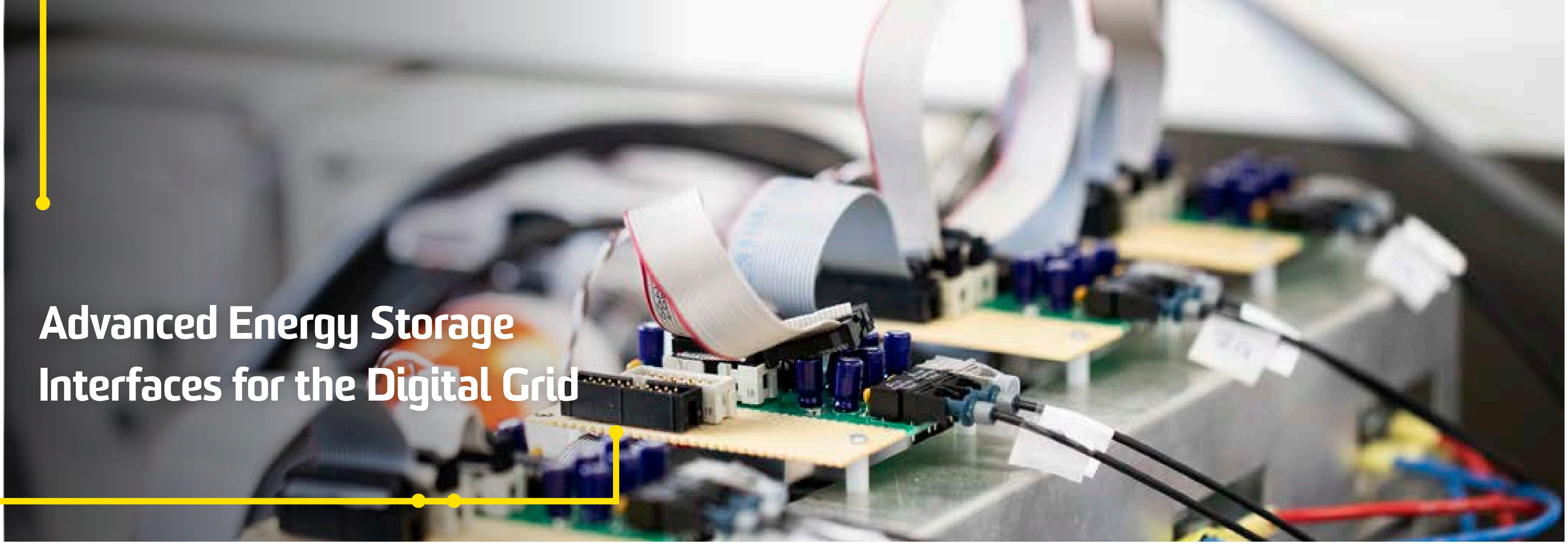

Advanced Energy Storage Interfaces for the Digital Grid

Advanced energy storage techniques require advanced grid interfaces. Such advanced interfaces ensure that bidirectional inverter or converter technologies are capable of harnessing the benefits of the storage technique, helping unlock the advantages of new storage technologies.

Competitive advantage

- Capabilities across all areas related to energy storage
- Novel interfaces for single- and three-phase AC systems reduce costs and improve storage utilisation
- Unique research and demonstration of hybrid energy storage systems and reconfigurable energy storage systems that can be adapted online to fulfil different operating modes
- Lab-scale development with grid simulation up to 50 kVA

Impact

- Extending the lifetime of energy storage systems

Successful applications

- Application of technology at laboratory-scale to include both DC and AC microgrid systems
- Supported development of energy storage solutions for NSW rail networks

Capabilities and facilities

- Realtime digital simulation with power hardware-in-the-loop capability up to 50 kVA
- Best in class laboratory equipment including PV simulation, three- and single-phase grid simulation, and load emulation
- Five-node AC microgrid with 5 kVA node capability
- Arbin battery and supercapacitor tester with environmental chamber

Our partners

- ARUP
- RES
- Transport for NSW
- AEMO
- TransGrid
- Ausgrid

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Grid Connection Studies for Conventional and Renewable Generators

Extensive expertise in both conventional and non-conventional power generation and provider of a wide range of power system engineering consultancy services to clients in generation, energy storage, transmission and distribution. These services include commercial and technical advice, assistance and strategic guidance for grid connection.

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Competitive advantage

- Model structure review, generator performance standard study, dynamic model acceptance testing, and benchmark studies
- Synchronous generator modelling, parameter identification and control system design
- Automatic voltage regulator, speed governor and power system stabiliser tuning
- Power system simulation studies (RTDS, PSS/E, PowerFactory, PSCAD, Python)

Impact

- Better grid integration of conventional and renewable generators

Successful applications

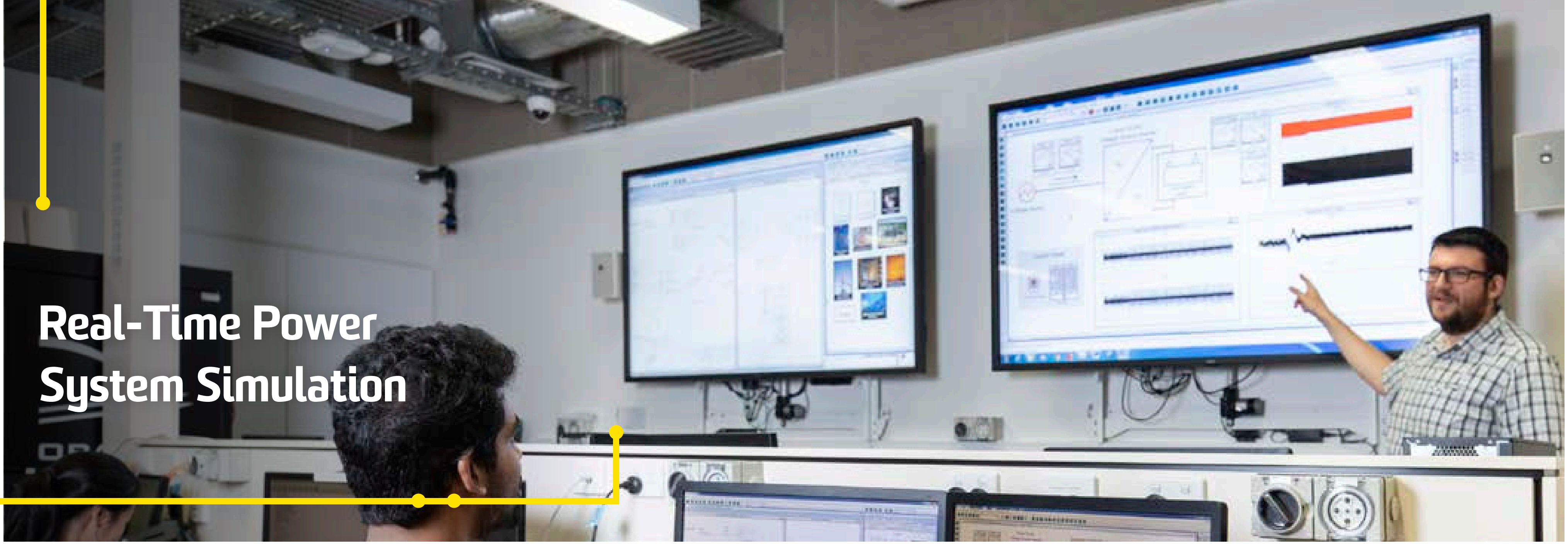
- Strategies for grid connection and risk assessment on conventional generator connections and renewable farm grid connection studies
- Guidance on regulatory issues and system modelling with a number of wind farms

Capabilities and facilities

- Real-Time Digital Simulators (RTDS)
- Power System Simulator for Engineering (PSS/E)
- DIgSILENT Powerfactory
- PSCAD/EMTDC
- Matlab, Python, AMPL

Our partners

- GoldWind Wind Farm
- CSIRO
- Ausgrid
- Aurecon
- Solar farm owners for field trials



Real-Time Power System Simulation

Real-time digital simulation of power electronics and power systems in real-time with sufficient resolution (20–50 µs) allows for accurate modelling and studies of large and complicated power systems. Digital and analog input and output functions facilitate interfacing with control hardware-in-the-loop (HiL) or power hardware-in-the-loop (PHiL), rapid prototyping and batch testing.

More information

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Competitive advantage

- Expertise in comprehensive modelling and real-time digital simulation of power systems and power electronics
- Experience with high-voltage direct current (HVDC) and multi-terminal DC (MTDC) transmission systems
- Expertise in power electronics and power systems interaction, large-scale renewable energy system integration, HiL testing, rapid controller development and testing, closed-loop testing of protection and control equipment, and microgrid simulation

Impact

- Electricity network support and power quality enhancement from energy storage systems
- Energy storage system integration, optimisation and balance of power.
- Energy storage modelling for real-time simulations
- Battery management systems

Successful applications

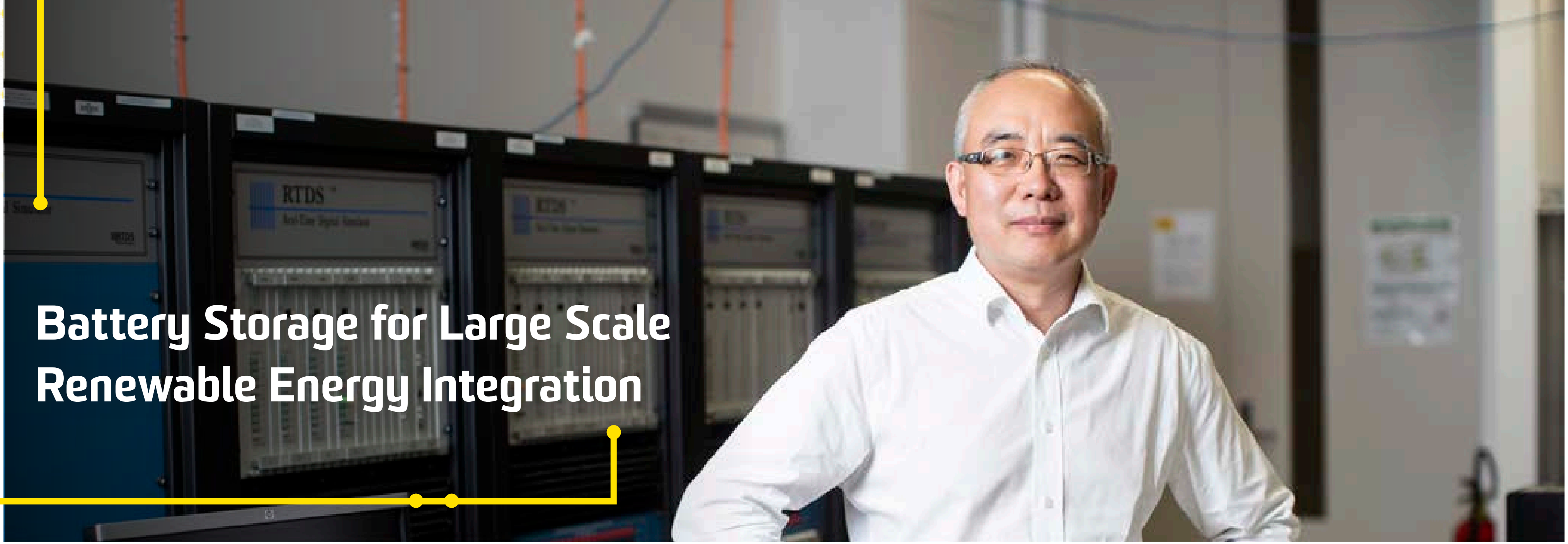
- High-voltage DC grids for flexible and efficient electricity transmission
- ElectraNet Heywood Interconnector distance protection relay hardware-in-the-loop testing
- ElectraNet Heywood Interconnector series compensation protection testing

Capabilities and facilities

- 18-rack, 90-processor board RTDS real-time digital simulator
- 1 × OPAL-RT OP5607 real-time digital simulator
- 4 × OPAL-RT OP4500 real-time digital simulators
- 4 × Omicron CMS100 power amplifiers
- Interface with Regatron DC/AC supplies for power hardware-in-the-loop testing

Our partners

- AEMO
- AEMC



Battery Storage for Large Scale Renewable Energy Integration

Battery storage provides significant advantages for integrating intermittent renewable energy systems into the electricity grid. Battery storage has the potential to become standard in new renewable energy installations, increasing their competitiveness and greater deployment of renewables.

Competitive advantage

- Expertise in grid-integration of battery storage and renewable energy systems
- Experience in mitigating the stability impacts of intermittent renewable generation using battery storage—ensuring stable and reliable power is delivered to consumers, overcoming issues such as network congestion and potentially deferring network capital upgrades.

Impact

- More reliable electricity networks with lower carbon emissions
- Better economic return for renewable farm owners
- A higher level of firming capacity

Successful applications

- The Future Grid Research Program—a $13 million research collaboration between CSIRO and four leading Australian universities that aims to develop Australia's capacity to plan and design an efficient and low emission electricity grid
- Grid planning and co-optimisation of electricity and gas networks
- Improved understanding of impacts of different loads, generation sources and energy storage on electricity system security

Capabilities and facilities

- Cross-platform modelling tools for grid studies of the impacts of loads, generation sources and energy storage on system security
- Energy and power research group with industrial standard software
- Grid planning and co-optimisation of electricity and gas networks
- Hardware-in-the-Loop testing bed for energy storage systems with programmable grid simulations on real time digital simulators (RTDSs)

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Fault Ride Through Testing Facility to Support Grid Stability

A facility to test the ability of non-synchronous power plants to maintain continuous uninterrupted operation when a power system is subjected to a voltage disturbance. This is a fundamental requirement to maintain system security and prevent wider frequency collapse.

Competitive advantage

- Full suite of low voltage ride-through (LVRT) and high voltage ride-through (HVRT) testing services
- Ability to simulate different depths of voltage dips and rises, ranging from 0% to 140% with a step of 1% of the rated voltage, lasting from 1000 ms to 3000 ms.
- Ability to simulate different grid faults, including line to line (L-L), double line to ground (LL-G), and line to line to line (L-L-L)
- Test generating plants up to 8 MVA in grids and up to 40 kV system
- Compliance with the IEC6400-21

Impact

- Validate simulation model against onsite test in R2 test
- Demonstrate fault ride through performance on site
- Support grid stability and improve security of supply
- Full-scale field testing with no adverse impact on the network

Successful applications

- Successfully commissioned 30 LVRT tests on 10 different wind turbines

Our partners

- Goldwind
- DNV GL

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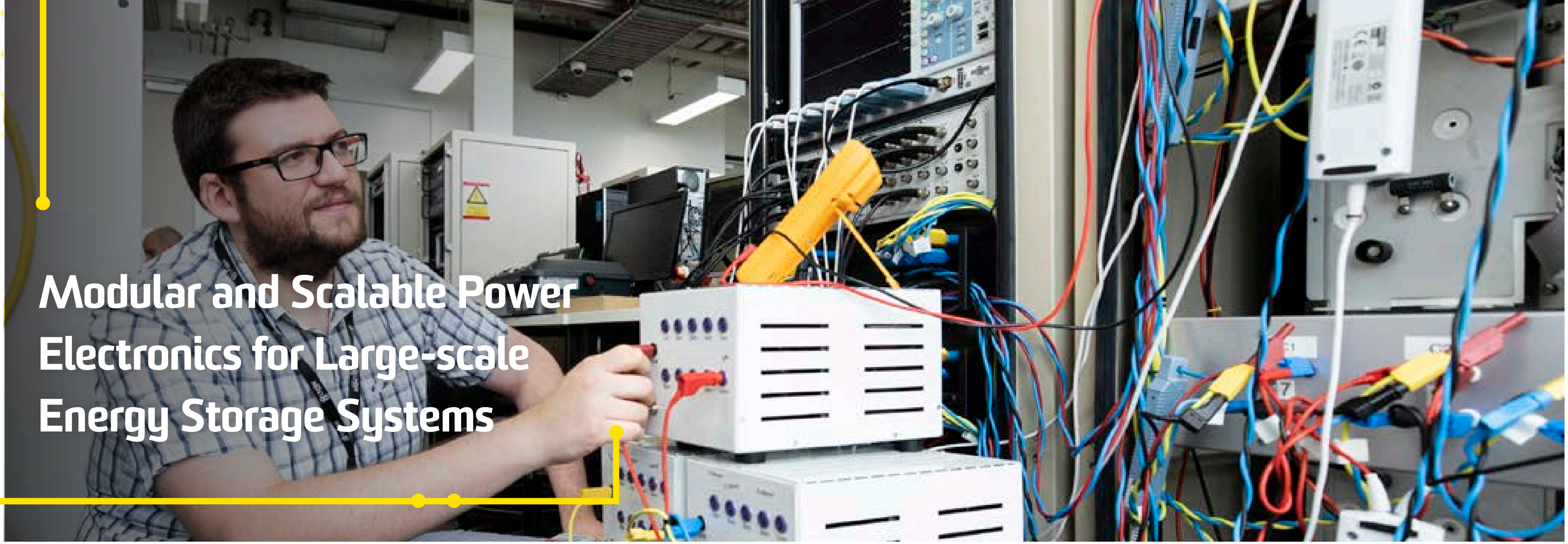

Modular and Scalable Power Electronics for Large-scale Energy Storage Systems

Unlocking the benefits of large-scale energy storage systems requires advances in power electronics topologies for interfacing and supporting the electricity grid. Multilevel converters can provide optimised, reliable, modular and cost-effective solutions for large-scale multi-megawatt energy storage systems across a range of energy storage technologies.

Competitive advantage

- Next-generation, modular and scalable power electronics for multi-megawatt energy storage systems
- Highly efficient and reliable redundant solutions
- Extensive range of multilevel power electronics converter prototypes
- State-of-the-art measurement and grid emulation facilities
- Hardware and software validation and testing

Impact

- Next-generation power electronics topologies for large-scale energy storage
- Advanced grid support functions
- Redundant and fault-tolerant implementations
- Technology and cost optimisation, irrespective of energy storage solution

Capabilities and facilities

- Multilevel converters (scaled-down laboratory prototypes)
- Measurement and grid simulation facilities
- State-of-the-art real-time simulators for grid integration validation, hardware and controller testing, and power hardware-in-the-loop capabilities

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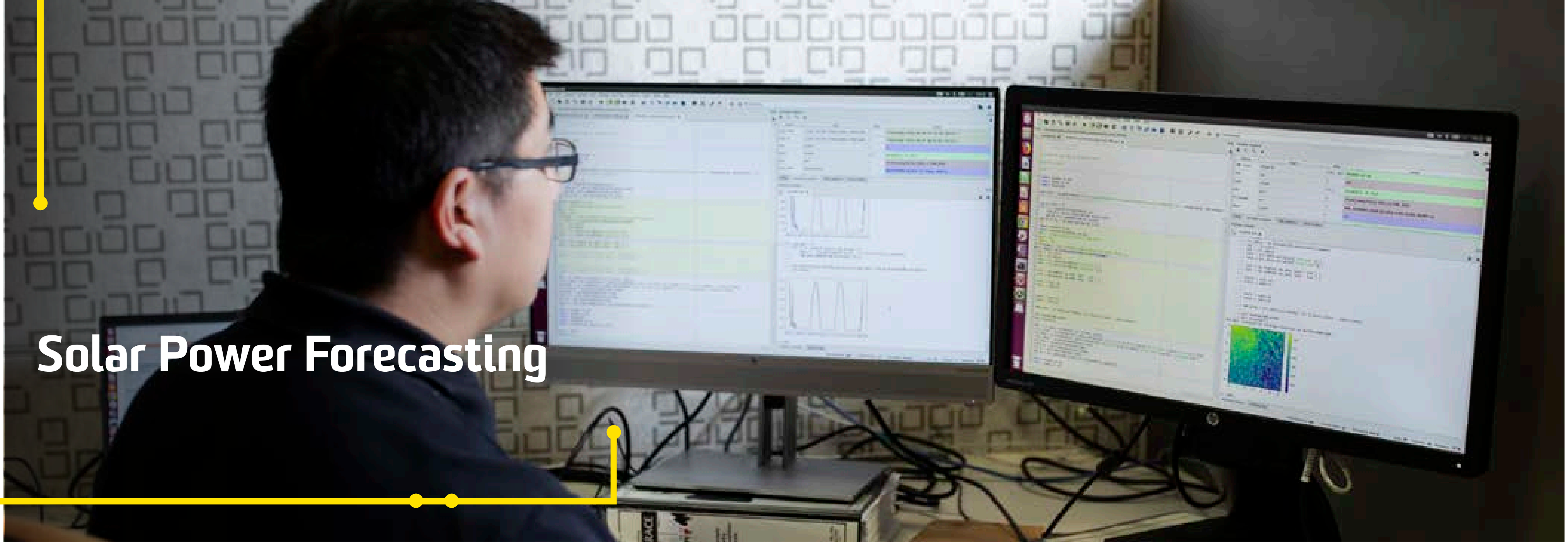

Solar Power Forecasting

Accurate solar forecasting is essential for managing and increasing adoption rates of grid-connected solar systems. Forecasts for regionally-distributed PV systems and individual solar power plants can be provided based on a proprietary PV system modelling methodology and expertise in combining Numerical Weather Prediction (NWP) and real-time observations with artificial intelligence techniques.

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Competitive advantage

This capability can be provided as an API-based software-as-a-service (SaaS) product, which can:

- Optimise dispatch and operating reserve requirements for grid operators
- Meet compliance requirements and reduce risks for solar power plants
- Make energy-management system (EMS) smarter in micro-grid and storage systems

The product features:

- Advanced solar system modelling
- Sophisticated data processing with artificial intelligence methods, and
- Reliable and flexible data delivery through web services.

Impact

- Increased safety and efficiency of grid operation by facilitating grid operators to better optimise dispatch while managing the intermittency and ramp-rate of solar power plants
- Increased adoption rate of solar by overcoming the challenges from high penetration and reduced reserves
- Optimised storage management to reduce required battery sizes and increase battery lifetimes

Successful applications

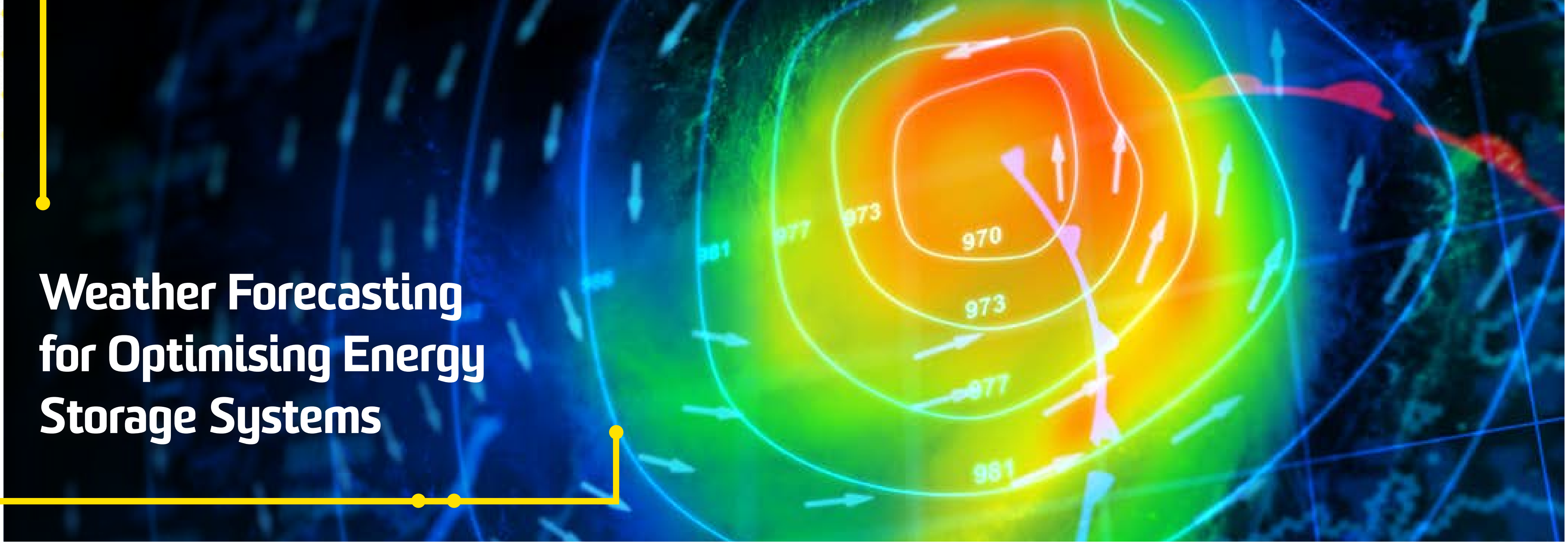
- The PV system modelling methodology has been used in evaluating and optimising new solar module designs for commercial partners. It has also been integrated into a commercial home battery storage product.

Capabilities and facilities

- Solar system forecasting
- Meteorological data processing
- Artificial intelligence
- Web service development

Our partners

- LONGi Green Energy Technology
- Hebei Sizhuo Photovoltaic Tech
- DSM Advanced Solar
- Energy research Centre of the Netherlands (ECN)



Weather Forecasting for Optimising Energy Storage Systems

Renewable energy power plant performance is maximised using an advanced suite of weather and climate-based optimisation and control strategies for hybrid systems that incorporate energy storage. Risk mitigation strategies are developed that can be used by operators to ensure generation is secure and optimised and ensures maximum returns in the competitive energy market.

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Competitive advantage

Extensive expertise in advance weather forecasting strategies across fundamental research to industrial-scale applications delivering:

- Integration of new forecasting models with the latest insights on the impacts on output from grid events and charge/discharge regimes for energy storage in hybrid systems.
- Development of key insights into the impacts of weather events on wind and solar operation, particularly extreme weather events, as well as the interplay of different battery technology performance in system response.
- Interrogation, development and strategies and integration of new technologies into industrial-scale applications

Impact

- Development of novel approaches to energy storage control in hybrid renewable energy systems using a combination of weather forecasting and machine learning

Successful applications

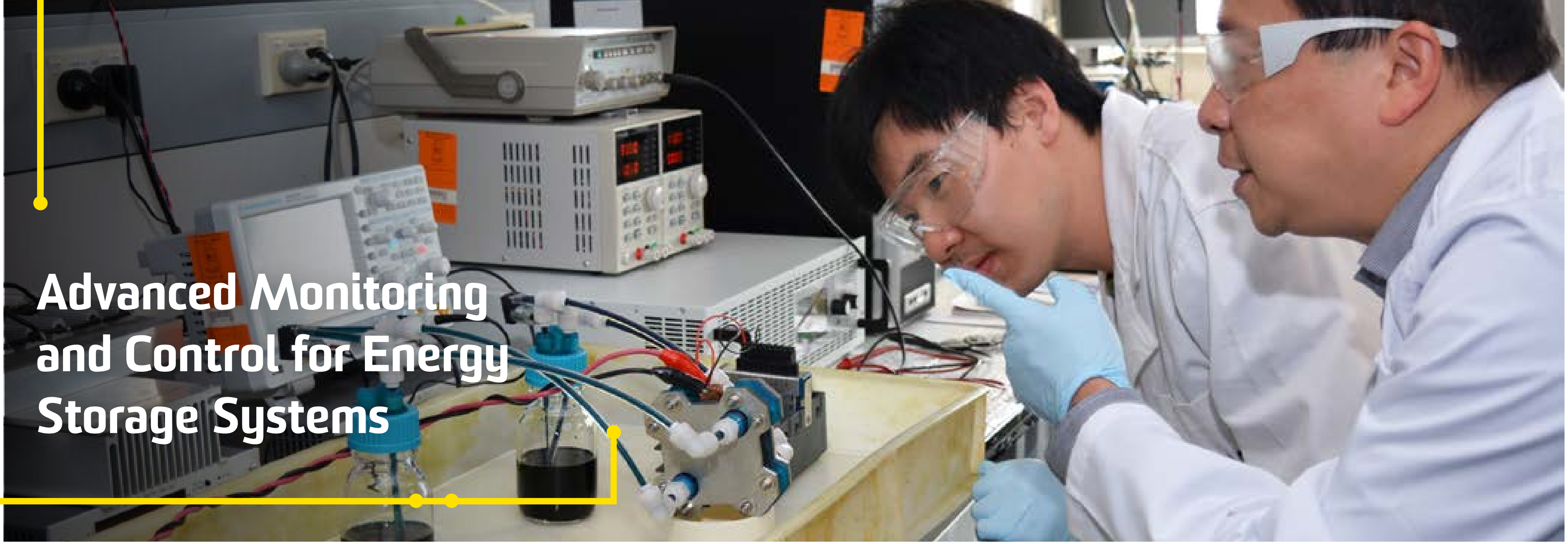
- Optimisation of battery size and type for hybrid systems based on weather forecasting

Capabilities and facilities

- 30 kW/130 kWh commercial vanadium redox battery system in Tyree Building for energy storage and micro-grid research.
- Dedicated computation laboratories for advanced simulation modelling and associated facilities for validation studies.
- Climate controlled chambers for evaluating effects of environmental parameters on energy storage system performance.

Our partners

- Fraunhofer ICT



Advanced Monitoring and Control for Energy Storage Systems

World-leading development of advanced control systems and maximising performance of energy storage system technologies including the vanadium redox flow battery. The expertise extends across energy systems to maximise renewable energy power plant performance to improve quality and demand and supply.

Competitive advantage

- Novel scalable distributed control approach (using advanced control theory integrated with advanced flow battery designs) to control and coordinate distributed energy storage systems and load management for enhanced reliability and flexibility.
- An integrated approach to the design and control of flow batteries based on the dynamic mechanisms of the electrochemical reactions to achieve optimal efficiency and flexibility of battery operation.
- Advanced monitoring systems to monitor the state of charge, flow channel blockage, capacity loss and imbalance of electrolyte, with online fault detection techniques based on dynamic battery models.
- Use of flow batteries as a multi-functional energy storage system for voltage stability and power quality improvement without complementary energy storage devices to reduce system costs and improve reliability

Impact

- Significant improvement of flow battery systems
- Greater flexibility in battery operation to allow optimal charging and discharging with time-varying input/output power for integration with renewable power sources
- Improved voltage stability and power

Successful applications

- Vanadium flow battery developed at UNSW now manufactured commercially.
- Installation of a 200 MW/800 MWh VRB, Dalian, China.

Capabilities and facilities

- 30 kW/130 kWh commercial VRB system
- Extensive state of the art electrochemical and mechanical laboratories.
- Climate controlled chambers for evaluating effects of environmental parameters on energy storage system performance.

Our partners

- Fraunhofer ICT

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Centre for Energy and Environmental Markets

The Centre for Energy and Environmental Markets is devoted to studying the challenges and opportunities of clean energy transition within market-oriented electricity industries. Key aspects of this transition are the integration of large-scale renewable technologies and distributed energy technologies (generation, storage and 'smart' loads) into the electricity industry.

More information

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Competitive advantage

- The Centre for Energy and Environmental Markets (CEEM) is unique in that it brings together experts across engineering, business, social sciences and law
- One of Australia's leading research groups on restructured electricity industries with more than a decade's experience delivering expert solutions on market design, regulatory arrangements and related policy framework development
- Extensive expertise in electricity market and distributed energy modelling, data science applications to energy problems and the development of open source tools

Impact

- Increase the understanding of the role of storage in the transition of electricity systems and markets to integrating high penetration renewable energy, both centralised and distributed

Successful applications

- Open source tools including market dispatch, tariff design and distributed energy sharing and aggregation models
- Interdisciplinary frameworks for policy, market and regulatory assessment and design
- Analysis of impacts and value of storage and demand response on networks and power systems, over a range of timeframes
- Assessment of the potential and value of storage and demand response for integration of variable renewable energy

Capabilities and facilities

- High performance computing
- Access to the National Computational Infrastructure, Canberra

OUR CENTRES AND FACILITIES

UNSW Energy Institute

UNSW Energy Institute coordinates energy activities across UNSW and collaborates with industry, government, community stakeholders and other research institutions. The Institute draws on the vision and work of UNSW's energy researchers based in the Tyree Energy Technologies Building and the Faculty of Engineering, working together with colleagues around the University from faculties such as Arts and Social Sciences, Science, Built Environment and Law. This allows the space to contribute to the development of new technology, policy advice, and the public's understanding of the challenges and opportunities facing Australia as it undergoes major energy transition. This coordination allows UNSW to take a 'system of systems' multi-disciplinary view of energy.

Tyree Energy Technologies Building (TETB)

Tyree Energy Technologies Building (TETB) is a showcase, award-winning, six-star energy efficient building costing over $130 million. The TETB houses the School of PV and Renewable Energy Engineering, Petroleum Engineering, the Centre for Energy and Environmental Markets, the Cooperative Research Centre for Low Carbon Living, the Particles and Catalysis Research Laboratory, the Real Time Digital Simulation Lab, a vanadium redox flow battery and an 800kW trigeneration plant. TETB is also a "living lab" for researchers studying the building's power production and consumption, water utilisation and human interaction. More than 300 students, academics and researchers use the building each day.

ARC Research Hub for Integrated Energy Storage Solutions

ARC Research Hub for Integrated Energy Storage Solutions, formally launching in 2019, is a 4-year, $12m nationally significant program in partnership with industry and other research institutions. Research projects include: novel and conventional batteries and supercapacitors; novel fuel cells; power-to-gas; virtual storage (demand response); and systems control and optimisation.

UNSW Digital Grid Futures Institute

UNSW Digital Grid Futures Institute launched in 2018 to future-proof global electricity systems, ensuring reliable, secure, affordable, sustainable electricity for economic advancement and transport. Research addresses five key priorities for the electricity grid of the future, including: energy storage; the electrification of transportation; robust physical connections across the grid; open yet secure cyber connections, and supportive socio-political, economic, regulatory and legal frameworks.

Real-Time Digital Simulation (RTDS) Laboratory, UNSW

Real-Time Digital Simulation (RTDS) Laboratory, UNSW is the largest RTDS laboratory in Australia, and one of the largest in the world, with extended simulation capabilities in the areas of high-voltage DC networks, power system protection testing, smart grids, microgrids, renewable energy systems, distributed generation, power electronics, control system testing, and hardware-in-the-loop testing.

Particles and Catalysis Research Laboratory (PartCat), UNSW

Particles and Catalysis Research Laboratory (PartCat), UNSW is one of the best catalyst/photocatalyst fabrication and characterisation facilities available in Australia. It hosts state-of-the-art equipment dedicated to heterogeneous catalysis/photocatalysis research. It has been funded over $25 million by the ARC programs and industries for research centred on particle and catalysis projects.

Materials Energy Research Laboratory in Nanoscale (MERLin)

Materials Energy Research Laboratory in Nanoscale (MERLin) is an energy research laboratory used to research use of hydrogen as a clean energy vector, and fully equipped for the development and characterisation of hydrogen storage materials and fuel cells.

The Mark Wainwright Analytical Centre (MWAC)

The Mark Wainwright Analytical Centre (MWAC), UNSW houses contemporary instruments for materials characterisation, including vibrational spectroscopy, SEM, TEM, XRD, XPS etc. It features world-leading magnetic resonance facilities, including high-resolution solid-state NMR up to 700 MHz and X-band EPR.

The German-Australian Alliance for Electrochemical Technologies for the Storage of Renewable Energy

A joint international research alliance for stationary energy storage (CENELEST) has been established by UNSW and The Fraunhofer Institute for Chemical Technology (ICT). The alliance aims to strengthen the world-class expertise in redox flow batteries, and concurrently develop other types of batteries and fuel cells in order to cover the entire range of electrochemical energy storage needs for renewable energy.

The Centre for Energy and Environmental Markets

The Centre for Energy and Environmental Markets is devoted to studying the challenges and opportunities of clean energy transition within market-oriented electricity industries. Key aspects of this transition are the integration of large-scale renewable technologies and distributed energy technologies (generation, storage and ‘smart’ loads) into the electricity industry.

Flow Battery Research Laboratory, UNSW

Flow Battery Research Laboratory, UNSW is a world leading facility for research into vanadium and other flow battery technologies.

Vanadium Redox Batteries

Vanadium Redox Batteries (30 kW/120 kWh) are installed in the Ground Floor of the Tyree Energy Technologies Building, UNSW.

UNSW laboratory facilities of Chief Investigator Da-Wei Wang

The UNSW laboratory facilities of CI Da-Wei Wang for battery testing, demonstration and integration including lab-scale coin cell and pouch cell fabrication.

ARC Training Centre for Fire Retardant Materials

ARC Training Centre for Fire Retardant Materials aims to create knowledge in novel green flame retardants, advanced fire models, innovative fire suppression technologies and new flammability fire tests. It gears to accelerate the transformation of Australia’s industries in producing new fire-retardant materials, high-value products and engineering services.

UNSW Electric Vehicles

UNSW has three electric vehicles and electric vehicle charging equipment and research.

WORKING WITH UNSW

UNSW works with a variety of partners including government, high-calibre corporate partners, small-medium enterprises and community groups in Australia and overseas.

UNSW operates at the forefront of global science and technology to help deliver transformational innovations that advance Australia's energy capabilities and are instrumental in defining the future energy landscape.

By partnering with UNSW, your organisation will gain opportunities to access innovative research, ground-breaking discoveries and the very best students – the next generation of leaders in the energy sector.

We offer a broad range of engagement models and have decades of experience partnering with small and large organisations to deliver:

- Multidisciplinary expertise at the centre of leading and emerging research
- Access to world class technologies and infrastructure
- Dedicated industry-facing and government-facing organisational units, such as the UNSW Energy Institute, UNSW Knowledge Exchange and UNSW Division of Enterprise
- Highly effective partnership models including research strategy advice and support
- Collaborative research leveraging third party and government funding
- Access to our national and global research partners including Group of Eight Australian Universities; the international PLuS Alliance with Kings College London and Arizona State University; the New South Wales NUW Alliance with the University of Newcastle and University of Wollongong; the joint venture with Western Sydney University; and participation in the Energy Research Institutes Council of Australia.
- Access to students through professional development programs, projects and our industry placement program
- Customised and bespoke initiatives

We look forward to working with you to develop real world applications in energy storage.

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