THE UNIVERSITY of ADELAIDE

# Energy Capability

Institute for Sustainability, Energy and Resources

make history.

# DELIVERING FULL-SPECT
# ENERGY SYSTEM EXPER

## MODERN ENERGY SYSTEMS

Transportation and Infrastructure
Pipelines, Ports and Powerlines
Domestic and International Infrastructure
Waste to Energy and Circular Processes

## ENERGY NETWORKS

System modelling and design
Autonomy and AI
Monitoring and control
Modelling and optimisation
Smart Grids and VPP

## ENERGY MATERIALS

High performance energy storage
Catalysts
Molecular modelling
Semiconductor technologies

## ENERGY POLICY

Environmental Decision Making
Climate Change

## MOBILITY

Electric vehicles (EVs)
Fleet management and optimisation
Consumer behaviour and safety
EV technologies
Mass transportation

## ENERGY MARKETS

Market modelling
Accounting and finance
Reliability
Circular Economy
Global Trade
Energy workforces

## ENERGY SECURITY

Network security
Resilience modelling for critical infrastructure
Threat modelling and assessment
Communication and connectivity

## CLEAN ENERGY

Carbon capture, utilisation and storage

## CRITICAL

Discovery, mineral
Isotope Ge

## FUTURE

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## RENEWABLES

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fuels

## STORAGE AND MATERIALS

Batteries
Catalysts
Semiconductors
Critical minerals

## HYDROCARBONS

Petroleum engineering
Geoscience
Electrical earth imaging
Tectonics

## DATA AND CYBER

Data analytics
Software engineering
Optimisation and logistics
IoT and computer security

## SUSTAINABILITY

Decarbonising industry and mining
Clean combustion
Carbon capture and storage
Electric vehicles
Environmental responsibility
Social licence

## ECONOMICS AND POLICY

Market analysis and modelling
Policy analysis and impact assessment
Circular economies
Systems thinking and mapping
Techno-economic evaluation

# WELCOME

The energy sector's importance to planetary sustainability is difficult to overstate.

Clean energy and associated technologies are crucial to overcoming multiple challenges: decarbonising utilities, transport, heavy industry and mining; reducing air pollution and its health and environmental impacts; expanding developing countries' and remote communities' access to reliable electricity; the list goes on.

The University of Adelaide is a research, development and education leader in the energy fields as presented in this capabilities statement. We are continuing to invest significant human, technological and financial resources to ensure we remain at its cutting edge to help society meet the grand challenge of net zero by 2050.

We invite you to partner with us in providing the next generation of energy solutions to improve our environmental, economic and social sustainability—including through creating jobs for the future.

**Professor Peter Høj AC**
*Vice-Chancellor and President*
*The University of Adelaide*

# MEET OUR TEAM

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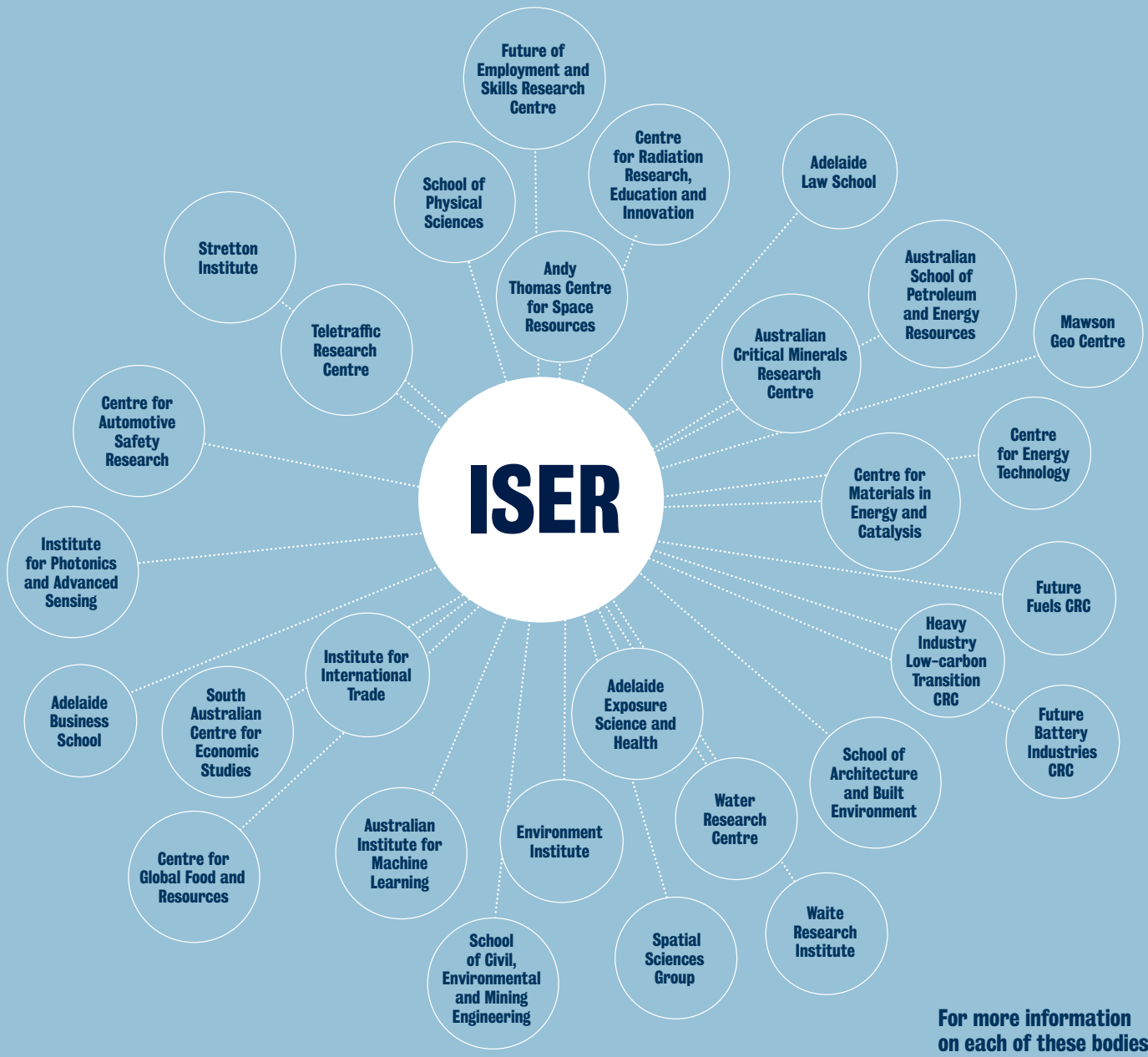
# ONE POINT OF CONTACT ENDLESS POSSIBILITIES

The Institute for Sustainability, Energy and Resources (ISER) is your conduit to the University of Adelaide's full spectrum of world-class, energy-related expertise.

We operate at the sector's international forefront, focusing our University's finest, multidisciplinary talent. Our size, capability and experience equip us to take on collaborative projects of any scale or complexity. We can absorb high levels of risk.

Plus we're fiercely committed to ensuring our work has positive impact—for our partners, our community and our planet.




**For more information on each of these bodies, visit: www.adelaide.edu.au**

# 2021 HIGHLIGHTS

**South Australian Scientist Of The Year**
**Professor Shizhang Qiao**

**STEMM Educator of the Year Finalist –**
**Dr Richard Lilly**

**HILT CRC awarded to accelerate a low carbon future for heavy industry**

**Launch of the Australian Critical Minerals Research Centre**

**Total Income**

**$16m**

**Australian School of Petroleum and Energy Resources teams up with Chevron Australia to create a new state-of-the-art facility for carbon storage research.**

# SUPPLY AND ENGINEERING

**As the world's appetite for intermittent renewable energy increases, so too does the need for expertise in its generation and distribution at scale. It must be safe, it must be secure and it must be intelligent. The University of Adelaide can deliver all three.**

## Grid planning and reliability

The University has significant, proven capability in optimal grid planning, including energy storage and demand management systems, wholesale and local energy market design, and network development.

We advise on—and lead—projects relating to:

- optimal power system and resources planning and operation—to integrate increasing amounts of renewable resources securely and reliably, including in very weak systems
- control system design and development—to address asynchronously connected sources' significant technical challenges
- power system modelling and simulation
- power system performance, operating limits and storage analysis
- system components' quality and condition monitoring
- mine-site electrification
- flexibility aggregator simulation-tool development
- future-grid technologies, including electric vehicles infrastructure
- power system security analysis, including addressing Internet of Things (IoT) vulnerabilities.

## MOVING INDUSTRY FORWARD

### Power Systems Dynamics Group

The University of Adelaide Power Systems Dynamics Group (PSDG) has worked in partnership with the energy industry for over two decades, undertaking technically challenging projects to help ensure power system security and reliability.

#### Industry benefits

The group's R&D expertise has directly benefited companies and organisations such as the Australian Energy Market Operator (AEMO), Powerlink Queensland, TransGrid, VENCorp, Transend Networks, Hydro Tasmania and ElectraNet. For example, its:

- *Mudpack* (MUltimachine Dynamics PACKage) commercial software package helps AEMO—and most domestic power system transmission network service providers—analyse and optimise system dynamics and control-system design
- *AULimit* software helps ElectraNet define the South Australian power system's secure technical operating envelope in all conditions, by calculating maximum secure interregional power-transfer limits.

#### Further information

To learn more about our PSDG, or to discuss a possible R&D collaboration, contact:

Professor Nelson Tansu
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School of Electrical and Electronic Engineering
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## Australian Institute of Machine Learning

The University of Adelaide's Australian Institute of Machine Learning (AIML) is the largest machine learning and computer vision group in the nation—and a key contributor to our energy-related R&D.

Established in early 2018, AIML has over 100 members and boasts outstanding research expertise, state-of-the-art facilities and global recognition.

The institute's specialised staff are highly experienced in tailoring R&D proposals to help organisations better compete in an AI-enabled economy, with past project partners including the likes of Bayer, Facebook, Google, Microsoft and Canon.

### Key areas of focus

AIML's talented researchers can work with you to provide practical solutions in areas such as:

- identifying patterns in large, complex data sources
- predicting future behaviour of people and systems
- optimising complex systems
- automating the interpretation of video and imagery
- producing computer vision and robotics applications
- natural language processing
- visual question answering
- AI innovation strategies.

**'THE AUSTRALIAN' NEWSPAPER'S 2021 RESEARCH MAGAZINE SUPPLEMENT RANKED OUR UNIVERSITY #1 IN AUSTRALIA FOR HIGH ENERGY AND NUCLEAR PHYSICS RESEARCH; AND OUR PROFESSOR PENG SHI AS AUSTRALIA'S #1 RESEARCHER IN AUTOMATION AND CONTROL. PROFESSOR SHI WAS ALSO RECOGNISED AS A 'SUPERSTAR OF RESEARCH' FOR LIFETIME ACHIEVEMENT.**

www.theaustralian.com.au/special-reports/research-magazine-2021

### Waste-to-energy

The University's waste-to-energy research investigates new, more efficient and effective ways to harness energy from waste and renewable resources, and store it for reliable, later use.

Our capabilities here include:

- assessing waste streams' potential value and capacity for fuel conversion, such as for agricultural and wastewater industries
- incorporating solar energy into existing industry processes—or designing new processes—and assessing its carbon-emissions impact
- assessing solar intermittency's impact on industrial processes
- hydrothermal carbonisation and liquefaction—to produce sustainable solid fuels and biocrude
- $CO_2$ capture and conversion to fuels
- laser diagnostics for reaction and multiphase non-isothermal flows—to enable the cost-effective optimisation and scale-up of high-temperature thermal energy processes
- ammonia, for use as fuel, hydrogen storage, mobility (diesel additive), and fertilliser
- biomass solar gasification.

# VECTORS AND RENEWABLES

**In the transition to low- or zero-emissions energy there's no single answer. Hydrogen, solar and wind all have roles to play; so too methane, tidal and bio-fuel. The University of Adelaide is progressing them all.**

## Hydrogen

### Water-splitting photocatalysis

Our expertise in this area centres around using the most active photocatalysts available in various extreme conditions to extract hydrogen from water through photocatalysis (a chemical reaction accelerated by the absorption of light).

This includes conducting photocatalysis to produce hydrogen fuel in:

- remote locations, such as islands or deserts
- extraterrestrial conditions, such as on asteroids or the moon.

In these conditions, photocatalysis has important advantages over other hydrogen production methods:

- sunlight is abundantly available in situ
- production efficiency increases with temperature, light intensity and UV illumination.

### Urea oxidation

The University has developed a new urea oxidation reaction (UOR) catalyst with the potential to make globally abundant wastewater a viable source of hydrogen fuel.

Compared to using existing UOR catalysts in wastewater electrolysers, our novel nickel ferrocyanide compound, which can easily be made in large amounts:

- makes the UOR significantly faster and more efficient
- requires less energy input
- produces more hydrogen.

The process also has the added benefit of removing urea from wastewater, the presence of which can be harmful to human health and the environment.

We're now refining electrolyser designs to up-scale the technology.

## MOVING INDUSTRY FORWARD

### Scaling Green Hydrogen CRC Bid

The University of Adelaide is sponsoring the Hydrogen CRC bid, which brings together key stakeholders to build a national hydrogen production capability that will progressively make hydrogen an affordable energy source for Australian industry, including the mining sector.

#### Industry benefits

The CRC will help Australia become a leading global player in the hydrogen industry. It will accelerate hydrogen's commercialisation by:

- growing domestic demand
- driving production
- building export capabilities.

#### Our key areas of focus

If successful, through the Hydrogen CRC, the University will drive innovation in hydrogen:

- production
- storage
- distribution
- utilisation.

Our work will also lead workforce upskilling to facilitate the transition to a hydrogen economy. A dedicated education and training program will utilise 7.5% of the CRC's budget for delivering applied programs, vocational skills development and community education.

#### Further information

To learn more, or to join the Hydrogen CRC bid, contact:

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### Underground hydrogen storage

Integrating our geoscience and engineering expertise, our subsurface hydrogen storage research enables the temporary and large-scale storage of green and blue hydrogen.

Our key capabilities include:

- assessing and characterising potential geological storage sites and systems through desktop, laboratory and numerical modelling studies
- assessing subsurface storage's geochemical and geomechanical impact
- subsurface storage sites' reservoir modelling and engineering
- determining site seal capacity
- assessing well and reservoir injectivity during subsurface gas storage
- hydrogen-water-rock interactions' geochemistry
- modelling and simulating coupled wellbore-reservoir systems
- multiscale modelling of geochemical and bio-reactive transport in sedimentary rocks.

### Blending hydrogen and natural gas

The University has completed a number of projects within the Australian Government's Future Fuels Cooperative Research Centre focused on ensuring the safe distribution and use of a 1:9 hydrogen–natural gas blended fuel for domestic and industrial use.

This includes:

- testing in-service and older domestic appliances
- assessing emissions safety issues
- testing a wide range of commercial and industrial appliances and burners, such as package burners
- performance modelling.

We'll also be testing the use of more hydrogen-rich fuel in several industrial and commercial appliances, and developing 100% hydrogen cookers and ducted space heaters.

## MOVING INDUSTRY FORWARD

## Informing Australia's hydrogen roadmap

A University of Adelaide research team has taken the lead on two important hydrogen-focused projects through the Australian Government-funded Future Fuels Cooperative Research Centre (see page 11).

The first, completed in 2019, was an in-depth global hydrogen roadmaps review, analysing the various paths being taken around the world to introduce 'green' hydrogen into economies. The second, started in 2020 and still ongoing, is building a massive, highly detailed model of the entire Australian economy to predict the likely impact of emissions-reduction measures, including the introduction of green hydrogen.

### Industry benefits

The global hydrogen roadmaps review was submitted in 2021 to the Australian Government to help inform its National Hydrogen Strategy, launched in November 2019. The review:

- included nuanced analysis of hydrogen strategies being implemented in 19 different regions, nations and major cities, including the US, European Union, South Korea and China
- looked at how each entity is approaching all aspects of building and strengthening their hydrogen infrastructure, industry and use
- identified key takeaways that are particularly pertinent for Australia.

The economy-wide modelling project is building Australia's capability to assess the likely economic, societal and greenhouse impact of every conceivable emissions-reduction measure—and their timing relative to each other—right across the country.

It even enables emissions hotspots, like Western Australia's Pilbara and South Australia's 'iron triangle', to be modelled independently.

# WIND POWER

## Optimising wind farm design

University of Adelaide researchers have developed a genetic algorithm-based optimisation method for wind farm design.

Our innovative software enables users to maximise their farm's reliability and minimise its costs by:

- rapidly testing hundreds, or even thousands, of potential cable network options for standard on-shore layouts
- quickly optimising their design rather than having to go through a time-consuming iterative manual calculation process.

Importantly, it also:

- enables selection from a range of design components, including underground, overhead, single- or triple-core cables
- allows for inaccessible areas of a site, such as rivers, or locations with ownership or access issues.

The software is already saving industry significant time and money.

### Turbine wake analysis

Another way we're helping wind farm developers improve their site layouts is by reducing turbines' impact on each other to maximise their efficiency.

This is achieved by precisely staggering the turbines' placement and/or deflecting their wakes.

Using the University's high-performance computing facilities and large-scale wind tunnel, our team can simulate, assess and advise on:

- individual turbines' wake characteristics
- wake interaction impact
- near- and far-wake dynamics
- turbulence intensity
- blade loading and performance.

## Wave and tidal energy

University of Adelaide researchers are involved in a number of projects investigating the vast potential of ocean energy.

For example, we're partnering with Carnegie Clean Energy to optimise their submerged hydraulic heaving buoy system's power generation with our non-linear control systems.

This involves specialist capabilities such as:

- modelling an electro-mechanical system coupled to incoming waves
- impedance matching to maximise power transfer.

## Concentrated solar thermal (CST)

### Solar expanding-vortex particle receiver-reactor

The University of Adelaide has developed a patented solar expanding vortex reactor (SEVR) with the potential to deliver higher temperatures and efficiency than traditional CST system tubular receivers.

The most promising of any particle receiver-reactor proposed to date, our SEVR addresses this technology's two key challenges: uneven particle heating and energy destruction; and particle deposition on the receiver-reactor window.

Compared to its competition, it:

- reduces particle deposition rate by more than 10 times
- generates a well-established vortex flow pattern within the cavity
- reduces swirl intensity at the aperture plane by up to 10 times
- preferentially recirculates larger particles within the chamber relative to smaller particles
- can achieve prolonged particle residence times
- has >85% calculated thermal efficiency (ratio of useful heat absorbed to power input), depending on particle size.

### Heliostat design

The University has significant research capability in the aerodynamic design and performance of heliostats, the mirror-holding structures that follow the sun to focus solar energy on a receiver in concentrated solar thermal (CST) power-tower systems.

This includes expertise in:

- wind load testing and reduction
- assessing turbulence characteristics.

With our guidance, heliostats can be:

- constructed with lighter materials
- manufactured and installed at lower cost.

## MOVING INDUSTRY FORWARD

### Australia-China Joint Research Centre of Offshore Wind and Wave Energy Harnessing

**Jointly funded by the Australian Department of Industry, Innovation and Science and the Chinese Ministry of Science and Technology, the Australia-China Joint Research Centre of Offshore Wind and Wave Energy Harnessing is co-led by the University of Adelaide and Shanghai Jiao Tong University.**

**The virtual centre involves more than 10 partners across the two nations, including the CSIRO, China University of Mining and Technology, and Carnegie Clean Energy.**

#### Industry benefits

**The centre is developing lower-cost, sustainable combined wind and wave power generation technology, which will lead to:**

- **improved energy security**
- **reduced fossil fuel emissions**
- **economic growth**
- **job creation.**

**The centre is also offering PhD scholarships in related disciplines, including: computer science; wave science; and power conversion engineering.**

## Solar Energy Journal Best Paper Award 2021

University of Adelaide researchers were recognised with the Solar Energy Journal Best Paper Award 2021 by the International Solar Energy Society (ISES) for their work on CST heliostat design.

### Key areas of focus

Our research team characterised atmospheric boundary layer turbulence's likely impact on full-size heliostats' maximum wind loads by investigating aerodynamic wind loads on scale-model heliostats.

They found that heliostat components' structural cost becomes increasingly sensitive to terrain roughness with increasing heliostat size.

### Industry benefits

The results reported in our team's paper are now reflected in the International Energy Agency SolarPACES Task III working group's Heliostat Wind Load Design Guidelines.

These guidelines provide a useful engineering tool for heliostat designers to estimate the loads on full-scale heliostats and reduce structural costs.

**'THE AUSTRALIAN' NEWSPAPER'S 2021 RESEARCH MAGAZINE SUPPLEMENT RANKED THE UNIVERSITY OF ADELAIDE #1 IN AUSTRALIA FOR THERMAL SCIENCES RESEARCH.**

www.theaustralian.com.au/special-reports/research-magazine-2021

# BIOMETHANE

## Grid-connection viability assessment

The University of Adelaide has strong capabilities in the assessment of projects designed to connect biomethane to Australian gas grids.

Working with key industry partners in the Future Fuels Cooperative Research Centre, our researchers have used system-dynamics modelling to perform pre-feasibility techno-economic viability assessments for two hub-scale biomethane projects.

The first looked at the role biomethane could play in a renewable energy hub in Griffith, New South Wales. Collaborating with electricity and gas provider Jemena, we explored:

- centralised and decentralised biogas production
- a possible alignment with hydrogen production to boost biomethane yields from agricultural feedstock.

The second study, conducted in partnership with AGIG (Australian Gas Infrastructure Group) and SA Water, investigated the potential for biomethane production from recovered organic waste in South Australia.

### Conceptual framework for end users

As an extension of this work, we've also delivered an easy-to-use conceptual framework to help end users:

- navigate the process of determining gas-grid-connected-biomethane project viability
- understand which aspects of projects to adjust for increased viability.

## Methanol and methane

### CO2-reducing solar photocatalysis

The University has developed breakthrough catalyst technology that enables the efficient, low-temperature creation of solar fuels—and reduces atmospheric $CO_2$ in the process.

Effectively a form of artificial photosynthesis, the process uses a novel catalyst and co-catalysts to accelerate the solar-induced photocatalytic conversion of $CO_2$ and water into methanol and methane fuels.

Our researchers' unique combination of a titanium dioxide ($TiO_2$) catalyst and embedded nanoscale gold-cluster and ruthenium co-catalysts enables:

- up to 40 times greater conversion efficiency than traditional platinum catalysts
- the production of methanol and methane at just 80°C—significantly lower than the 200–250°C required by current commercial catalysts.

This simple, purely chemical approach to creating solar fuel is also highly space-efficient, scalable, and can be built anywhere in sunlight.

## Syngas

### Hybrid solar gasification

Adelaide researchers have developed a unique hybridised solar dual fluidised bed (SDFB) gasification process to enable the production of low-cost, low-carbon jet fuel and diesel from biomass residues.

The process combines the use of inert particles in the solar receiver with sensible thermal storage of bed material to deliver a constant rate of syngas production despite solar variability.

The syngas generated is suitable as:

- a general-purpose and industrial fuel
- feedstock for liquid fuels and petrochemicals.

## Future Fuels Cooperative Research Centre

Established in 2018, the Future Fuels Cooperative Research Centre (FF-CRC) is an industry-focused R&D partnership developing solutions to prepare Australia's industry infrastructure, pipelines and utilities for future carbon-neutral fuels.

In addition to the University of Adelaide, the seven-year, $81m program involves over 60 companies, five other universities, the national energy market operator, and two energy regulators.

### Industry benefits

The FF-CRC's research is identifying:

- more efficient and cheaper ways to produce and distribute renewable fuels, such as hydrogen, biogas, methanol and ammonia.
- viable options for maximising the re-use of existing infrastructure assets, including domestic, commercial and industrial gas appliances.

### Our key areas of focus

The University of Adelaide is involved in both the techno-economics of future-fuel generation, and the technology development needed for its widespread distribution and use.

### For more information

Visit: futurefuelscrc.com

## Bio-fuels

Biomass—organic matter from living, or recently living organisms—could be one of the world's largest primary energy sources. Agricultural and horticultural waste, in particular, is a potentially plentiful and economic resource for the Australian agricultural industry.

Up until now, however, its low energy density and high transportation costs have limited uptake. But the University of Adelaide is helping to overcome these challenges in numerous ways.

### Hydrothermal liquefaction (HTL)

HTL is one of the leading methods to convert complex organic feedstocks, such as biosolids from wastewater treatment and other waste biomass, into valuable products such as transport fuels and their precursors.

The process involves using water to break down biomass macromolecules at average temperatures and high pressures.

Our HTL capabilities and expertise include:

- determining HTL reacting mixture viscosity, with temperature-time reaction histories
- identifying continuous HTL reactor heat-transfer characteristics
- computational fluid dynamics modelling, to support HTL up-scaling and optimising
- parameter sensitivity analysis, to inform biocrude oil quality and yield optimisation.

### Torrefaction

Torrefaction is a biomass energy densification process. It involves thermochemically treating biomass in the gas phase of a mild thermal decomposition process, operated at 200-300°C in an atmospherically inert environment.

The University has developed a superior torrefaction process that results in biomass with increased value as a fuel source. Its characteristics include:

- higher calorific value
- lower moisture content
- water resistivity (hydrophobicity)
- uniform properties.

This enables producers to:

- generate and use their own biomass-derived fuel on-site for heat and power generation
- lower their waste disposal and energy costs
- reduce their carbon footprint.

# STORAGE AND MATERIALS

**Designing innovative new materials and processes is key to developing sustainable and cost-effective energy generation, storage and conversion. Our University's world-class interdisciplinary capabilities in these fields puts us at the forefront of industry advancement.**

**CHINESE MANUFACTURER ZHUOYUE POWER NEW ENERGY LTD HAS COMMITTED AUS$1 MILLION TO DEVELOP OUR NEW HIGH-ENERGY BATTERY TECHNOLOGY AND HOPES TO HAVE A PRODUCT AVAILABLE IN 2022.**

## Batteries

### High-energy, high-density

The University of Adelaide has designed and patented technology to develop high-energy, high-power-density batteries that are:

- safer
- cheaper
- more reliable than any existing battery on the market.

The technology is ideal for applications where battery weight, size and safety are critical factors, including:

- automotive and aerospace
- domestic and commercial buildings
- all vehicle types, from small scooters to diesel-electric trains.
- large solar and wind farms
- grid-scale energy storage.

### Superior physicochemical interactions

The key to our high-energy-battery technology's improved performance lies in optimised physicochemical interactions at the electrode-electrolyte interface.

Our approach uses non-toxic zinc and manganese—both abundant in Australia—and incombustible aqueous electrolyte.

### Low costs

The cost of this new electrolytic Zn–Mn battery is estimated at less than US$10 per kWh—significantly lower than that for current lithium-ion (US$300 per kWh), nickel-iron (US$72 per kWh), and lead–acid batteries (US$48 per kWh).

Recycling will also be easier than for existing batteries of comparable energy density.

## MOVING INDUSTRY FORWARD

### Australian Energy Storage Test Facility and Knowledge Bank

The University of Adelaide led the Australian Renewable Energy Agency-funded Australian Energy Storage Test Facility and Knowledge Bank project from 2015 to 2019.

The project involved building and deploying state-of-the-art energy storage test facilities, and establishing an online knowledge bank to host Australian energy storage expertise. Project partners included SA Power Networks, Zen Energy, and the South Australian Government.

#### Industry benefits

The Knowledge Bank now accelerates energy storage systems' development and use around Australia by providing industry and researchers with:

- a central online source for up-to-date performance data and case studies about energy storage trials in a range of applications and conditions, both in Australia and internationally
- world-class mobile and micro-grid platforms to independently test and trial entire energy storage systems, both under lab conditions and grid-connected in the field.

This helps energy storage innovators create new solutions tailored to users' specific needs, settings and locations.

#### For more information

Visit: aeskb.com.au

### Instant-charging quantum-powered

The University is working to harness the unique properties of quantum mechanics to build the world's first quantum battery—a new 'super battery' with the potential for instantaneous charging.

Unlike ordinary batteries, which always take the same amount of time to charge, quantum batteries will theoretically charge faster the more you have of them. If one quantum battery takes one hour to charge, then two would take 30 minutes, three would take 20 minutes, and so on.

If you had 10 thousand batteries, they would all charge simultaneously in less than a second.

### Harnessing quantum entanglement

This instant- and instantaneous-charging capability is due to a remarkable quantum mechanics phenomenon known as entanglement.

When electrons are 'entangled' their individual properties are always and instantaneously shared, regardless of their distance apart. Hence, when entangled electrons are distributed across numerous batteries, charging one charges them all.

### Enormous market potential

Small quantum batteries could replace conventional batteries used in electronic devices, such as watches, smart phones, tablets and computers, or any other product that relies on stored energy.

Larger versions could also provide opportunities for the renewable energy sector.

## Next-gen sulphur chemistry

Another highly promising new approach to batteries being developed at the University of Adelaide is based on cutting-edge sulphur-oxidation processes.

Our researchers have developed an aluminium–sulphur battery that, when compared to current commercial lithium-ion batteries:

- delivers significantly more power
- can be made at much lower cost
- has less environmental impact.

Testing has shown our battery achieves the highest voltage output of any aluminium–sulphur battery yet made: approximately 1.8 volts of steady power, which is more than double lithium-ion's approximate 0.6 volts.

Our research could also lead to other metal-sulphur battery designs.

### Energy management systems

Our team's battery expertise also extends to energy management—an area in which we've had significant international commercial experience.

This includes collaborating on residential and commercial battery energy management system development with:

- the California Independent System Operator, widely considered to be the world's most pioneering wholesale electricity market operator
- NEC Laboratories America, a leading Silicon Valley R&D lab.

Our work with these entities has led to four US patents so far.

## MOVING INDUSTRY FORWARD

### Future Battery Industries Cooperative Research Centre

Launched March 2020, the Future Battery Industries Cooperative Research Centre (FBI-CRC) is a six-year research and development program targeting all segments of the battery value chain.

In addition to the University of Adelaide, the centre brings together almost 60 industry participants—including BHP Nickel West, IGO Limited, Energetics Pty Ltd, and Galaxy Resources Limited—another seven universities, the CSIRO, and the federal and state governments.

#### Industry benefits

The FBI-CRC's R&D will:

- position Australia as a leader in battery industries
- accelerate our battery industry's expansion
- create a new generation of highly skilled domestic workers equipped to deliver the energy materials, systems and accreditation processes of the future.

#### Our key areas of focus

Participating University of Adelaide researchers will be developing:

- new high-value battery products
- battery manufacturing control systems
- machine-learning optimisation techniques
- efficient power-grid integration methods.

#### For more information

Visit: fbicrc.com.au

**'THE AUSTRALIAN' NEWSPAPER'S 2021 RESEARCH MAGAZINE SUPPLEMENT RECOGNISED THE UNIVERSITY OF ADELAIDE'S DR NGHIA NGUYEN-TRONG AS A NATIONAL 'RAISING STAR' AMONG EARLY-CAREER ELECTROMAGNETISM RESEARCHERS.**

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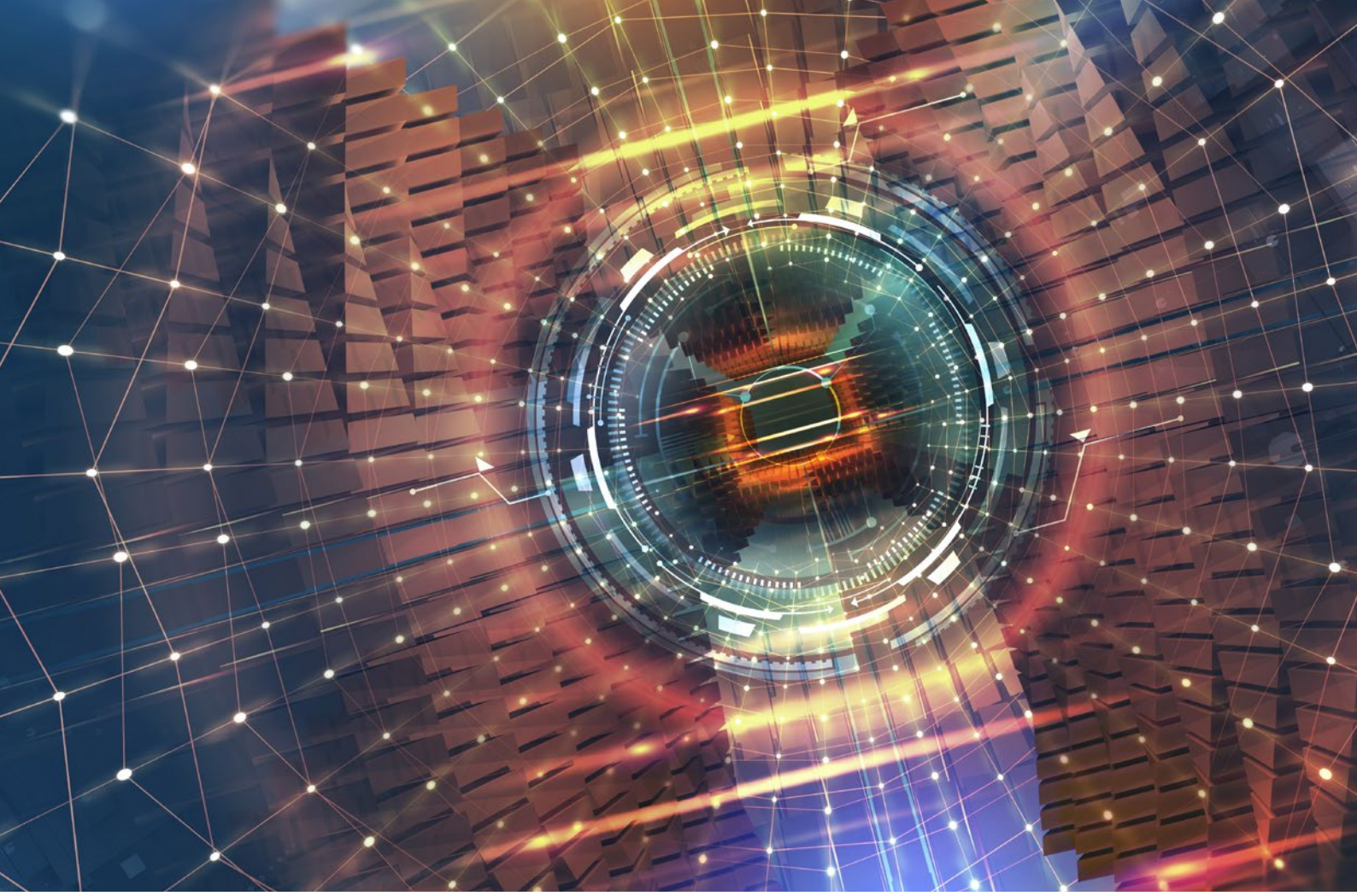


# CATALYSTS

## High-performance electrocatalysts

Efficiency in fuel cells, water-splitting cells and batteries depends strongly on the rate of a series of electrochemical reactions that occur on the surface of electrode catalysts. To get the best performance out of an electrochemical device, it's crucial to choose an appropriate electrocatalyst.

The University of Adelaide is helping with this.

### Innovative designs for greater efficiency

Using computational theory and electrochemical experiments, we've developed a design principle for effective catalysts that simultaneously considers an energy material's chemical components and physical structures.

This means we can now design of a wide variety of new high-performance catalysts offering increased efficiency in:

- oxygen reduction reactions, such as in fuel cell cathodes
- hydrogen evolution reactions, such as in water-splitting (electrolytic) cell anodes
- oxygen evolution reactions, such as in metal-air battery charging processes.
- $CO_2$ reduction reactions, to transform $CO_2$ into a range of hydrocarbons
- nitrogen reduction reactions, to enable room-temperature ammonia synthesis, oxidative nitrogen fixation from air to NOx and nitrates.

### Photocatalysts

Photocatalysts are materials that can absorb energy from light and then pass that energy on to another substance to trigger a desired chemical reaction.

The University has extensive capabilities in the design of semiconductor and carbon-based photocatalysts for:

- photovoltaic solar energy production
- solar water splitting, to produce hydrogen and oxygen
- photocatalytic $CO_2$ reduction
- photocatalytic synthesis of organic substances
- solar gasification.

### Catalyst modelling

Our catalyst modelling expertise includes the development of:

- molecular models for catalyst materials, to investigate their activity for various reactions and applications
- mathematical modelling of materials synthesis, from laboratory to pilot to commercial production.

### For more information

Visit **www.adelaide.edu.au/iser/our-capabilities**

## National research leadership recognition

'The Australian' newspaper has recognised the University of Adelaide's national standing in energy-related chemistry and materials engineering fields in its 2021 Research magazine supplement.

**Rankings in chemical kinetics and catalysts:**

- University of Adelaide, #1 research body in Australia
- Professor Shaobin Wang, #1 researcher in Australia today, and a 'Superstar of research' for lifetime achievement
- Dr Xiaoguang Duan, a national 'Rising star' among early-career researchers.

**Rankings in dispersion chemistry:**

- Professor Shaobin Wang, #1 researcher in Australia today

**Rankings in chemical and material sciences:**

- Professor Shi Zhang Qiao, #1 researcher in Australia today, and a 'Superstar of research' for lifetime achievement
- Dr Anthony Vasileff, a national 'Rising star' among early-career researchers.

**Rankings in materials engineering:**

- Dr Dongliang Chao, a national 'Rising star' among early-career researchers.

### For more information

Visit: theaustralian.com.au/special-reports/research-magazine-2021

## Advanced Materials Research Facility

Launched in 2021, the University of Adelaide's dedicated Advanced Materials Research Facility is the first of its kind in Australia.

### Industry benefits

The facility's specialised technology allows our advanced materials researchers to go from the design of a new material at the virtual molecular level, to its growth, and final application in an actual device—all in one location.

### Our key areas of focus

We'll be using the Advanced Materials Research Facility to make innovative materials for a range of energy-related applications, including to:

- increase the efficiency of making green hydrogen from water
- make safe, non-flammable, next-generation aqueous batteries
- act as catalysts in solar-to-fuels production technology.

### Nanocatalysts

The University can develop nanocatalysts for:

- hydrolysis, carbonisation and liquefaction of organic feedstocks
- catalytic cracking of hydrothermally produced oils.

We also have expertise in:

- novel nanostructured semi-conducting catalysts, for antibacterial applications and water disinfection
- biocompatible and biodegradable nanostructures, to immobilise protein-based or biomimetic biocatalysts for organic/polymer synthesis, biomass conversion, and $CO_2$ looping.

## Critical minerals (CM)

The University of Adelaide has nation-leading capabilities in the discovery, mineralogy and processing of mineral resources considered critical to modern energy and electronics technology. These resources include:

- lithium, nickel, cobalt, manganese and graphite—crucial to battery performance, longevity and energy density
- rare earth elements (REEs)—essential for the permanent magnets in wind turbines and electric vehicle motors
- copper and bauxite (for aluminium)—needed in huge quantities for electricity networks and all electricity-related technologies.

### Discovery

Our key focus in CM discovery is on developing new, more effective exploration tools and methods. This involves such capabilities as:

- novel isotope geochemistry
- mineral geochemistry
- geophysics.

### Mineralogy

Many CM resources aren't found in high-grade ore deposits, but rather occur in trace amounts in other ores. And several CMs, such as indium, cobalt and germanium, rarely reach economic concentrations of their own.

The University's comprehensive knowledge of CM mineralogy and chemistry, however, allows us to successfully develop the industry and identify opportunities for CM recovery as economic by-products.

Our specific capabilities here include advanced microanalytical and spectroscopic techniques and facilities.

### Processing

CMs are mined in one of two ways: as primary products, such as REEs and lithium; and as by-products in the production of other minerals, such as indium from zinc concentrates, or cobalt from copper and nickel ores. Processing is often sub-optimal, and significant opportunities can go unrecognised.

The University's CM experts are working to overcome this challenge—and help industry fully realise the value of Australia's rich CM endowment—by developing new techniques for:

- CM processing using frontier technologies
- CM processing sustainability.

**THE UNIVERSITY OF ADELAIDE HAS NATION-LEADING CAPABILITIES IN THE DISCOVERY, MINERALOGY AND PROCESSING OF MINERAL RESOURCES CONSIDERED CRITICAL TO MODERN ENERGY AND ELECTRONICS TECHNOLOGY.**

*Associate Professor Carl Spandler, Director (right) and Professor Nigel Cook, Deputy Director, Australian Critical Minerals Research Centre, University of Adelaide. Image: Sam Le Gallou*

## MOVING INDUSTRY FORWARD

### Silanna partnership

In 2017, the University of Adelaide initiated a strategic partnership with Silanna Group to undertake collaborative semiconductor research in purpose-built joint facilities.

### Key areas of focus

The first facility established was **picoFAB**—a multimillion-dollar research space providing world-leading capability in growing advanced silicon carbide (SiC) and gallium nitride (GaN) wide-band-gap semiconductor materials.

Following **picoFAB's** success, the University entered into a second joint initiative with Silanna in 2019: **microFAB**. Also involving the federal government's Defence Science Technology (DST) group, the **microFAB** facility will add the capability to grow gallium arsenide (GaAs) materials.

### Industry benefits

SiC and GaN devices are disruptive technologies for power electronics on today's grid and poised to play a major role in global electrification, enabling significantly more efficient power switches and inverters.

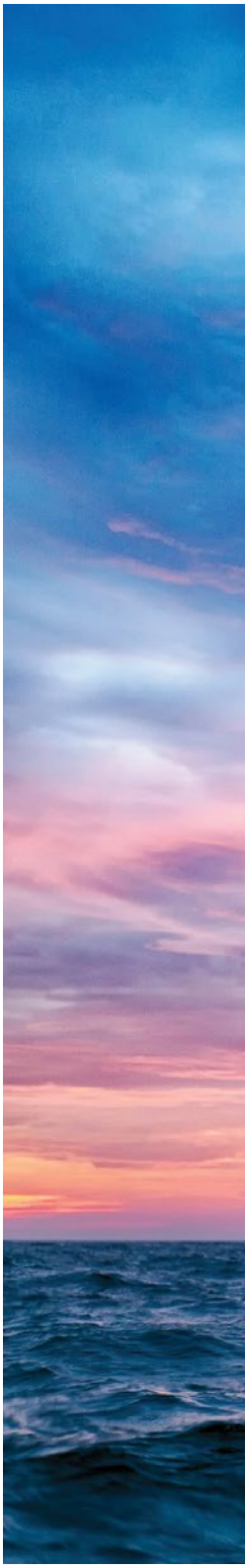
GaAs materials have exciting applications in high-efficiency, triple-junction solar cells and power converters in the lower power range.

### For more information

Visit: ecms.adelaide.edu.au/silanna

# HYDROCARBONS

**As long as hydrocarbons remain part of the world's energy mix, it's critical that they're discovered, extracted and processed with maximum efficiency and minimal environmental impact. The University of Adelaide is showing the way.**



## Petroleum

### Engineering

Our petroleum engineering research capabilities reflect real-world industry needs.

With particular strengths in water flooding, reservoir simulation, and enhanced oil and gas recovery for conventional and unconventional resources, our expertise includes:

- recovery from mature water-flooded reservoirs
- low-salinity water injection
- stochastic processes simulation and data analysis
- tight sands wettability alteration
- flow-back recovery
- assessing fracture roughness impacts on fracture propagation
- coal-seam gas (CSG) productivity and onset production prediction for well stimulation in CSG fields
- energy recovery from geothermal fields
- oil and gas field behaviour prediction and exploration planning
- aquifer contamination laboratory-based modelling
- drilling fluids particle sizing
- integrated reservoir studies
- hydraulic fracturing design and simulation
- well log and well test interpretation
- laboratory testing of reservoir rocks to estimate gas and oil well productivity
- oil recovery design in specific oil and gas fields
- unconventional energy sources planning and design, including field studies and reservoir simulation
- chemical- and microbial-enhanced oil recovery
- shale-gas field development
- water-production control in gas and oilfields
- suspension-colloidal-nano transport in porous media
- exact and asymptotic solutions for flow in porous media
- nanotechnologies in oil and gas production
- well injectivity and productivity
- formation damage and skin
- oil and gas secondary migration.

### Commercial applications

The University's findings are frequently adopted and adapted across industry to produce competitive advantage through enhanced processes and cost-efficiency. For example, our:

- Beach Energy and Santos use our gas-inflow profile determination method in their shale-gas and CSG fields
- Wintershall (Germany) uses our low-salinity water flooding analytical models to plan and design enhanced oil recovery projects
- Chevron uses our lab-based fines migration prediction method for well management in the Gulf of Mexico
- Petrobas uses our three-point-pressure formation-damage assessment method.

## Geoscience

Petroleum geoscience concerns the exploration, recovery, development and management of subsurface energy resources. The University has extensive expertise, including in:

- fundamental geological processes
- geophysical methodologies for discovering and producing hydrocarbon resources
- development of fundamental technical and workflow advances
- structural geology, geomechanics and permeability
- structural and stratigraphic-focused interpretation of 3D seismic data
- sedimentary basin analysis, including the impact of volcanic activity on hydrocarbon exploration and development
- identifying and predicting heterogeneities in shallow, marginal marine, and deep-water reservoirs
- contemporary and ancient reservoir analogues for continental, marginal marine and deep-water environments
- constraining and understanding contemporary and ancient stress fields, including in situ stress-related analyses
- sedimentology and shallow diagenetic processes
- deep-water depositional processes' bio-mediation
- continental strata correlation and sequence stratigraphy
- novel geochronological techniques
- 4D geological modelling.

**‘THE AUSTRALIAN’ NEWSPAPER’S 2021 RESEARCH MAGAZINE SUPPLEMENT RANKED THE UNIVERSITY OF ADELAIDE’S DR CRISTIANA CIOBANU AS AUSTRALIA’S #1 RESEARCHER IN GEOCHEMISTRY AND MINERALOGY.**

www.theaustralian.com.au/special-reports/research-magazine-2021

### Commercial applications

We regularly provide geoscience guidance, insight and project leadership in a wide range of petroleum exploration and production contexts. For example, we have:

- contributed to international multi-company consortia that have informed prediction of, and production from, reservoirs deposited in dryland and marginal marine environments
- produced workflows for exploration in basins impacted by volcanic activity, which have been implemented in sedimentary basins worldwide
- revealed the state of crustal stress across the Australian continent, aiding the development of unconventional geothermal reservoirs
- led the identification of Great Australian Bight drilling sites, in collaboration with the International Ocean Discovery Program.

## Electrical earth imaging

University of Adelaide researchers are highly skilled and experienced in sophisticated electrical earth imaging methods, including 3D and 4D magnetotellurics, for:

- crust and mantle imaging
- deep resource exploration
- identifying and monitoring underground water bodies
- highlighting areas likely to be earthquake-prone.

Magnetotellurics involves measuring the earth's electric and magnetic fields down to depths of hundreds of kilometres.

This enables the construction of remarkably informative 3D images of lithospheric 'architecture', which can provide an excellent indication of where hydrocarbon and ore deposits may have formed under sedimentary cover.

## Tectonics

Complementing and integrating the University's geological, geochemical and geophysical expertise is our significant capability in tectonics—the study of forces and how they change the earth.

Our hydrocarbon-relevant expertise here includes analysis and understanding of:

- how forces created by continental collisions, seduction zones and upwelling zones deform and move the earth's surface
- continental evolution—how today's continents evolved and interacted with each other over the past 4.6 billion years
- the evolution of continental terranes (distinctive crust fragments fused across two separate tectonic plates) and orogens (ancient folded and thrust mountain belts)
- the crustal and lithospheric architecture of continents and oceans.

## MOVING INDUSTRY FORWARD

### Australian Lithospheric Architecture Magnetotelluric Project

**The Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) is providing the first whole-country, 3D picture of the lithosphere—Earth's rigid upper plate–underneath Australia.**

**Funded by Geoscience Australia, the National Collaborative Research Infrastructure Strategy facility AuScope, and state and territory government geological surveys, AusLAMP aims to record data at around 3,000 geophysical stations in approximately a 55km grid across the entire country. Work began in 2013 and is expected to finish around 2023.**

**The University of Adelaide is a driving force.**

### Industry benefits

**AusLAMP is informing deep, under-cover resources exploration, and providing valuable insight into Australia's geological hazards and history.**

**Our key areas of focus**

**The University's researchers, working closely with the South Australian Government Geological Survey, have been responsible for all South Australian data stations, as well as some in New South Wales and Western Australia.**

### For more information

**Visit: ga.gov.au/about/projects/resources/auslamp**

**THE UNIVERSITY OF ADELAIDE HAS PUBLISHED MORE PAPERS AT TOP-TIER INTERNATIONAL COMPUTER SECURITY CONFERENCES THAN ALL OTHER AUSTRALIAN RESEARCH UNIVERSITIES COMBINED.**

# DATA AND CYBER

**Data science, digital capability and information security are now critical to success in the energy sector, as they are throughout the economy. The University of Adelaide stands ready and able to elevate these business functions to world-best-practice.**

## Data analytics

The University's data analytics research operates at the intersection of mathematics, statistics and information technology. We specialise in analysing real-world data—'big' and 'small'—to gain insights and drive performance improvements.

Our energy-relevant expertise includes:

- predicting future outcomes from historical data using machine learning
- testing alternative business scenarios and A/B comparisons using statistical methods
- building system and network models to optimise performance
- supporting decision-making by generating data visualisations to reveal patterns, structures and trends
- end-to-end product development and operational deployment
- targeted statistical consulting
- mathematical- and statistical-model agile prototyping
- fast iteration using the scientific method
- custom web application development for real-time data analytics in production environments.

### Commercial applications

The University's data analytics R&D has had significant impact in the energy sector. Our models are being developed with utility companies to quantify and improve their time-critical service delivery.

## Software engineering

University of Adelaide software engineering researchers apply computer science and engineering principles to develop and maintain high-quality software, including for the energy sector.

Our capabilities include developing and evaluating:

- tools that support software-intensive systems' design, analysis and evolution
- data analytics systems that uncover new information from large-scale software repositories
- custom software that better meets both functional and non-functional requirements, such as security.

### Commercial applications

Our software engineering R&D has a variety of real-world applications. This includes helping energy-sector organisations:

- leverage virtualised, Internet of Things and 'big data' technologies to design and evaluate secure, 'softwareised' infrastructure and services
- navigate large amounts of textual and quantitative data.

## High-performance computing

The University launched its 'Phoenix' supercomputer in 2016.

With a 700-terabyte storage capacity and 450-teraflop processing speed, Phoenix enables our researchers to solve large-scale and/or complex problems quickly and efficiently through big-data analysis, and complex modelling and simulations.

### Commercial applications

University energy researchers have used Phoenix to:

- model predicted wind turbine wake development, enabling wind farm designers and decision-makers to optimise wind farm layout for maximum energy generation
- simulate and model wave energy technologies, enabling optimal buoy and power-take-off-system designs.

## Optimisation and logistics

The University's optimisation and logistics researchers apply specialised computing techniques to solve complex and restrained process-optimisation problems, and enhance efficiencies.

Some energy-sector-relevant examples include: designing wind turbines and farms; informing long-term mining decisions; and customising program code for energy consumption. We have strong capabilities in:

- integrated planning
- scheduling-decision support systems relating to supply-chain operations
- developing new algorithms for renewable energy and software engineering
- mechanism design and social choice
- developing new approaches for dealing with game-theoretic problems
- linear programming
- branch-and-bound algorithm design
- genetic algorithms and programming
- evolution strategies
- ant colony optimisation
- particle-swarm optimisation
- local search.

### Commercial applications

Our optimisation and logistics research has led to the creation of three spin-off companies:

- NuTech Solutions, which creates technology solutions to predict business changes and help companies prepare for them
- SolveIT Software (acquired by Schneider Electric), which uses AI to manage complex operations
- Complexica, which develops AI software to help organisations increase revenue, margin and productivity through automated analytics.

**OUR RESEARCH HAS BEEN APPLIED IN MANY REAL-WORLD SETTINGS, INCLUDING TO IDENTIFY VULNERABILITIES IN COMMONLY USED SOFTWARE AND HARDWARE, SUCH AS THE HIGH-PROFILE PC PROCESSOR FLAWS 'SPECTRE' AND 'MELTDOWN' IN 2018.**

## IoT and computer security

Our Internet of Things (IoT) and computer security research explores important issues surrounding the ownership, use and protection of often-sensitive Internet-connected data.

We have particular expertise in:

- using machine learning algorithms to analyse time-series data on wirelessly powered IoT devices
- realising security services in the absence of operating-system control, and under device constraints
- understanding how hardware and operating system services support confidential-information management
- analysing cryptographic algorithms to identify potential data leaks.

### Commercial applications

The University regularly collaborates with software and hardware providers, such as Intel, AMD and OpenSSL. We also work closely with Australian defence agencies, including the Defence Science and Technology (DST) group, and Australian Signals Directorate.

Our researchers provide solutions to fundamental problems in pervasive computing, such as:

- making sense of noisy, continuous and sometimes untrustworthy data streams
- authenticating familiar security services and IoT devices' veracity-sensor measurements
- securing store keys with limited IoT hardware
- keeping sensitive information confidential.

# SUSTAINABLE ENERGY

**In addition to developing and optimising new sustainable energy sources, materials and technologies, there is much work to be done incorporating them into our world. And much of it is happening at the University of Adelaide.**

## Decarbonising industry

This is a big mountain to climb. In 2016-17, transport, manufacturing and mining—all heavily reliant on fossil fuels—represented 65% of Australia's total energy consumption (27.5%, 27.5% and 10.0%, respectively).

For this reason, we're directing significant effort towards developing and supporting the innovation required to transform these industries.

### Integrating concentrated solar thermal (CST)

CST systems are gaining popularity in industrial processes due to their low emissions, high efficiencies, ability to generate the high temperatures necessary for efficient plant operation, and their potential to hybridise with existing conventional thermal plants.

The University has extensive expertise in the design and application of CST technology for industry, including:

- process integration and optimisation
  - retrofitting CST into existing plants
  - plant electrification
  - new process development for greenfield sites
- process/system modelling
  - using our own in-house code, or ASPEN
  - modelling high-temperature thermal/chemical/electrical energy storage
  - process scale-up
- techno-economic analysis
- reactor development for mineral process, energy production or conversion
  - proof of concept
  - reaction rate measurement
  - heat transfer modelling
  - particle thermo-physical-chemical properties
  - scaling up from bench to laboratory to pilot scale.
- chemical production, such as sulphuric acid (used in concentrate leach and tails leach for copper), oxygen (smelting and refining), and hydrogen (metallurgy, heat, power and mobility)
- optimising solar vortex reactor performance, through reduced window particle-deposition
- innovate and lead sustainability assessment and metrics.

## Hybrid solar receiver combustor

The University of Adelaide has developed an innovative hybrid solar receiver combustor (HSRC) that can help industry transition to a renewable future by increasing solar share and hybridising methane or syngas with solar thermal.

### Capabilities and benefits

Our HSRC unit can supply:

- baseload power from a single unit
- around-the-clock hot air at up to 800°C.

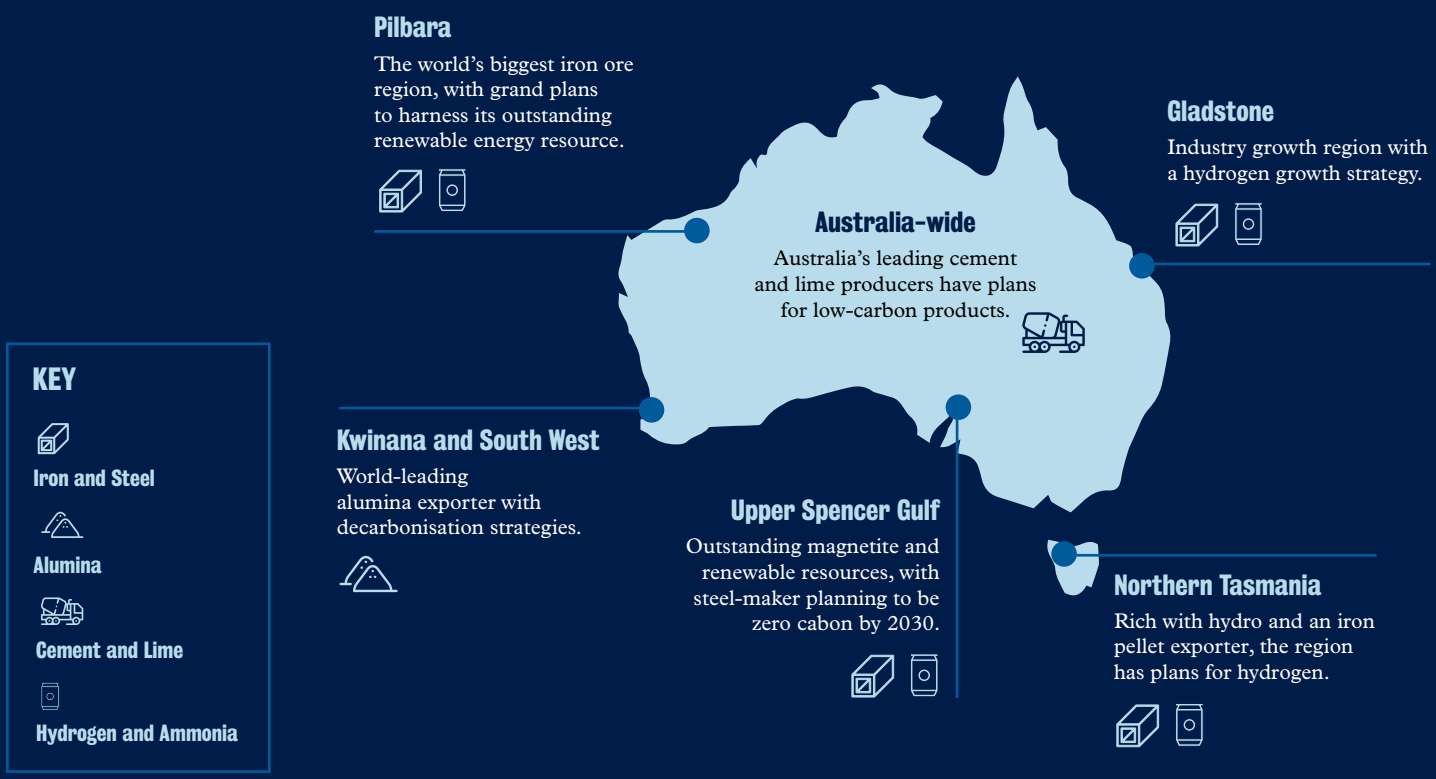
Our testing has shown that, when compared to standalone solar and combustion systems, it will reduce:

- levelised electricity costs by 24%
- net fuel consumption by up to 45%
- overall powerplant capital cost by 51%
- significantly reduce $CO_2$ emissions through faster start-up and much greater solar share.

### Multiple applications

Our HSRC can be fitted to various industrial process heat and electricity generation systems, and is ideally suited to:

- smelting
- limestone, alumina, and magnesium calcining




- integration with current CSP towers to supply steady, continuous electricity.

It can also supply energy for:

- biomass solar gasification
- liquid fuel manufacturing from biomass in remote settings.

### Like to get involved?

The University is now looking for project and partnership opportunities to:

- demonstrate the HSRC at pilot, small and large scales
- integrate the HSRC into a solar cavity receiver to reduce infrastructure costs and heat losses.

**To learn more or express interest, contact:**

Professor Gus Nathan
Research Director, HILT-CRC

Director, Centre for Energy Technology

e: gus.nathan@adelaide.edu.au
t: +61 (0)8 8313 5822
m: +61 (0)410 477 411

## Heavy Industry Low-Carbon Transition Cooperative Research Centre (HILT-CRC)

The University of Adelaide has been awarded the federally funded HILT-CRC, the Australian Government's largest collaborative R&D body for domestic heavy industry's sustainable transformation.

Industry partners include Alcoa, Boral, Fortescue and Adelaide Brighton Cement.

### Industry benefits

The centre will help Australia's heavy industry sector:

- dramatically reduce its carbon footprint
- capitalise on growing global demand for green materials
- protect and grow its operations, currently worth around $180 billion p.a., or 9% of the national economy
- create an 'early mover' advantage to maximise investment opportunities.

### Our key areas of focus

Working closely with our HILT-CRC partners, we will:

- develop and demonstrate key low-carbon heavy-industry technologies
- address heavy industry's broader challenges relating to:
  - policy and regulatory frameworks
  - market transformation
  - social licence
- develop $CO_2$ mitigation technologies.

### For more information

Visit: hiltcrc.com.au

**THE UNIVERSITY IS PARTNERING WITH THE GERMAN AEROSPACE CENTER (DLR) AND CSIRO TO DEVELOP NOVEL TECHNOLOGY FOR CO-PRODUCING HYDROGEN, OXYGEN AND SULPHURIC ACID FOR APPLICATION IN HIGH-TEMPERATURE INDUSTRIES.**

## Hybrid solar chemical looping combustion system

The University has created a world-first hybrid solar chemical looping combustion (Hy-Sol-CLC) power plant that can provide steady power generation—and significantly reduce costs—even with variations in solar thermal energy input.

The system has the potential to contribute to step change in integrating renewable energy technologies into conventional power generation systems.

### Vastly increased solar share

While current-generation solar hybrid technologies operate at around 3–10% solar share, the Hy-Sol-CLC power plant can achieve up to 60% solar share, while still maintaining base-load power generation.

In addition to storing solar energy, our Hy-Sol-CLC system can also be run as a conventional CLC system during extended periods of low solar radiation.

## Moderate or intense low-oxygen dilution combustion

We have significant expertise in moderate or intense low-oxygen dilution (MILD) combustion technology, which holds great promise for reducing pollutant and greenhouse gas emissions in multiple industries.

MILD combustion uses recirculated heat and exhaust gases to achieve:

- stable volumetric combustion at moderate temperatures
- reduced pollutant production, particularly nitrogen oxides
- increased thermal efficiency.

It can also be readily adapted to different fuel types, including non-conventional fuels like biomass and bio-derived fuels (e.g. biogas and bioliquids), which are traditionally more difficult to combust.

Our MILD capabilities include:

- experimental and computational research to increase understanding, applicability and adaptation of MILD combustion
- advanced laser-based techniques and computational fluid dynamics modelling to understand stable flame structures
- optimising fuel type, dilution and mixing pattern for combustion stability and low emissions.

### Enhancing hydrogen flame radiation

Our researchers are also investigating ways to increase the radiant heat generated by 100% hydrogen flames for industrial use, such as in alumina calciners and cement kilns.

These processes rely on a combination of radiant and convective heat transfer, and hydrogen flames naturally provide much less radiation than natural gas. We're using a combination of experimental and computational fluid dynamics modelling.



## Solar thermal in the Bayer alumina process

The University of Adelaide is leading collaborative Australian Renewable Energy Agency-funded research into the incorporation of concentrated solar thermal (CST) technologies in the commercial Bayer alumina process.

Project research and industry partners include Alcoa, Hatch, ITP, the CSIRO, and the University of NSW.

### Industry benefits

This ongoing project could potentially lead to CST's incorporation into high-heat-industry's existing large-scale processes—including iron and steel production—and reduce their greenhouse emissions by up to 50%.

### Our key areas of focus

The University has designed a CST system that:

- generates and stores heat on-site
- carries very low ongoing costs
- can be affordably retrofitted into existing plants.

### For more information

Visit: adelaide.edu.au/cet/solar-alumina

# DECARBONISING MINING

## MOVING INDUSTRY FORWARD

### Mining electrification tools development

The University of Adelaide is leading a Future Battery Industries Cooperative Research Centre (FBICRC) project to support the Australian mining industry's transition to battery-supported electric vehicles (BEVs) and electric stationary machinery.

#### Industry benefits

Transitioning to electric vehicles and machinery, combined with partial or stand-alone renewable-energy-powered microgrids, will enable mining operations that are:

- more efficient
- more sustainable
- lower cost
- safer.

#### Our key areas of focus

Together with our project partners, we'll be providing the Australian mining industry with a broad suite of vehicle and machinery electrification decision-making tools and guidelines.

### Decarbonising mining

Currently contributing around 4% to 7% of the world's greenhouse gas emissions, mining presents another significant challenge for global sustainability. With this in mind, the University of Adelaide is devoting considerable resources to meeting that challenge.

#### Mine electrification

The University has significant expertise in the complex, interdisciplinary task of mine electrification. This includes in:

- renewable-energy-powered microgrids
- power system operation
- mathematical modelling and optimisation
- battery energy storage
- power electronics
- transitioning to battery-supported electric vehicles (BEVs).

The move to BEVs is particularly important, with diesel-powered mining vehicles typically accounting for 30% to 50% of total mine-site energy usage.

#### How we go about it

Our approach to mine electrification involves conducting and/or developing:

- a detailed site assessment to identify electrification opportunities
- a comprehensive electrification plan
- tools for optimal charging scheduling of:
  - mobile fleets for material movement
  - stationary machinery for mining operations.
- techno-economical tools to design the backbone energy infrastructure to run the system smoothly and seamlessly 24/7
- workforce training materials.

### Incorporating thermal energy

Thermal energy is a highly promising vector for many industries that require high temperatures, including mineral processing.

The University has world-class expertise in the development of novel thermal storage technologies, spanning sensible, latent and chemical energy. These technologies can provide sufficient heat to power:

- mineral processing
- steam production for ore concentration
- hot air for mineral drying
- rock crushing and grinding.

Our researchers in this field have been involved in related projects with both the Australian Solar Thermal Research Institute and the Australian Renewable Energy Agency.

## Emissions reduction, capture and storage

### Solar-aided power generation (SAPG)

The University of Adelaide has considerable capabilities in the integration of solar thermal energy into coal-fired power plants (solar-aided power generation, or SAPG) to:

- increase plant efficiency
- reduce greenhouse gas emissions.

SAPG is an important transition point for industry until more advanced and independent solar power generation systems are developed.

### Sooting flames modelling

The University's researchers are helping to enable the development of clean combustion systems by providing vital new understanding of how soot evolves in flames.

Soot emissions from combustion systems are highly undesirable; fine particle emissions are a leading cause of death, and soot is the second biggest global warming contributor after $CO_2$.

Clean combustion systems are expected to be an important component of future affordable, secure and sustainable energy systems, particularly for key applications such as:

- air transportation
- peaking power
- process heat.

Our team is working in collaboration with the International Sooting Flames Workshop, a biennial open forum held immediately prior to each meeting of the International Symposium on Combustion.

## Carbon capture and subsurface storage

Our University has a long history of research in carbon capture, utilisation and storage (CCUS). Working with state-of-the-art facilities, we have strong capabilities in:

- analogue studies for subsurface gas storage
- chemical gas-water-rock interactions (laboratory studies and petrological investigations)
- drilling engineering (salt caverns and cavities)
- the geomechanics of subsurface gas storage
- formation damage and fines migration (laboratory studies and mathematical modelling)
- multiscale mathematical modelling (fluid flow in porous media)
- reactive transport modelling
- storage site assessment and selection
- well completion and repurposing
- well injectivity and integrity.

### Commercial applications

Our CCUS findings so far have:

- underpinned and demonstrated carbon capture and storage (CCS) through the Otway International Test Site (OTIS) in Victoria, Australia—one of the world's best characterised CCS demonstration sites
- contributed to Geoscience Australia's nationwide assessment of $CO_2$ storage capacity and feasibility
- highlighted the enhanced $CO_2$ storage potential of volcanic rocks present in some of Australia's sedimentary basins.

## Electric vehicles (EVs)

### Motor drives and power electronics

The University has significant capabilities and experience in:

- EV motor design, analysis and prototyping
- assisting with the development of more efficient machines for EVs, including through novel efficiency-mapping techniques
- reducing or eliminating the need for feedback devices in EV motor-control loops, to improve performance, reduce system cost and increase reliability
- EV motor testing and condition monitoring
- power quality monitoring in power systems.

### Alternative magnetic materials

We have a strong interest in developing alternative magnetic materials, including:

- soft composites—ideal for high-volume, low-cost applications, such as appliance motors
- amorphous material—useful where efficiency is important, such as in pumps.

### Commercial applications

- Our research in EV power electronics and motor drives has direct industry impact. This includes, for example, through:
- constructing various prototype machines using scalable manufacturing techniques, with the potential for commercialisation
- developing a range of sensorless motor-control software, applicable to variable-speed pump applications.

## MOVING INDUSTRY FORWARD

## APPEA Best Extended Abstract Award 2021

**University of Adelaide researchers shared the Best Extended Abstract Award at the 2021 Australian Petroleum Production and Exploration Association (APPEA) Conference and Exhibition for their collaborative work on CO2 storage in buried volcanoes.**

**They led the research in partnership with the universities of Aberdeen and Canterbury.**

### Industry benefits

**The results reported in the team's abstract show that certain volcanic rocks' chemical reactivity promotes CO2's permanent storage through natural mineral carbonation.**

**This suggests large volumes of CO2 could be securely stored in buried volcanic rocks in major gas-producing Australian regions such as:**

- **the Northwest Shelf**
- **Gippsland Basin**
- **Cooper Basin.**

## Chevron carbon capture partnership

The University of Adelaide is partnering with Chevron Australia to create a new state-of-the-art carbon capture and storage (CCS) research facility to accelerate Australia's transition to cleaner energy sources and net-zero emissions.

Chevron is contributing more than AUD$2.45 million to support the new laboratory, a five-year senior academic position in carbon storage engineering, and a three-year Senior Research Fellow position in carbon storage science.

### Our key areas of focus

Located at the University, the new facility will enable cutting-edge research on:

- permanent $CO_2$ storage within geological formations after its injection into subsurface reservoir rocks
- $CO_2$ flows through, and interacts with, rocks and pore waters on a microscopic scale.

### Industry benefits

Fundamental and applied research undertaken at the new facility will produce engineering and geoscience outcomes that will:

- help to tackle one of society's most pressing challenges
- provide training opportunities to ensure Australian students are equipped to contribute solutions to the energy transition.

### EV batteries and charging

We have considerable expertise and experience in EV batteries and charging systems. This includes:

- battery modelling, for faster detection of state of charge
- battery efficiency optimisation and safety enhancement
- coordinated EV charging to reduce peak demand
- vehicle-to-grid and grid-to-vehicle power/energy transfer (including algorithm development) and its impacts
- battery charging systems for photovoltaic systems, using wide-band-gap devices for high power density (high-temperature environment and high efficiency)
- on-board fast/intelligent charging systems using wide-band-gap devices for high power density (volumetric and weight)
- optimising charging management with AI and machine learning
- integration with remote-community autonomous microgrids and battery infrastructure, such as for fast-charging E-Buses from renewable sources
- 2nd- and 3rd-life battery applications and environments
- end-of-life uses for EV components, and battery recycling.

# ENVIRONMENTAL RESPONSIBILITY

**Ensuring our environment's ongoing health is not only a vital component of securing social licence, but of maintaining life on Earth. From preserving unique flora and fauna, to protecting groundwater, human habitability, and entire ecosystems, we can guide your responsible custodianship of it all.**

## Monitoring and management at all scales

The University of Adelaide is internationally renowned for its capability in all scales of spatial imaging and environmental management, from unmanned aircraft to satellites and spatial big-data analysis.

We can use remote sensing, geographic information systems, ecological modelling and multi-objective decision support systems to help you understand and manage any environment of interest—natural or managed, terrestrial, aquatic or marine.

Our strengths and experience include monitoring and assessing:

- spatial variations in landscapes, establishing what's occurring where and why
- biodiversity and landscape composition
- land, habitat, vegetation, soil and water condition
- environmental change over time.

We're also highly capable in the areas of:

- natural resource and wildlife management planning and decision support
- environmental and resource mapping.

**WE'RE NOW ABLE TO PINPOINT THE AGE, ORIGIN AND INTERCONNECTIVITY OF YOUR SITE'S GROUNDWATER—AND HOW IT HAS MOVED THROUGH SPACE AND TIME—USING STATE-OF-THE-ART ATOM TRAP ANALYSIS. THIS TECHNOLOGY CAN ALSO BE USED TO DETERMINE GAS TIGHTNESS FOR UNDERGROUND STORAGE.**

### Optimising our most precious resource: water

The University is widely recognised for multidisciplinary expertise in water and water systems management, and highly experienced in focusing it for the energy sector.

We're able to develop bespoke technology and applied scientific solutions to optimise—both environmentally and commercially—water use, supply and treatment. This could involve:

- water supply and distribution system planning, design and operation
- risk analysis and system resilience assessments
- rainfall runoff modelling
- tracing water pathways—including using four-dimensional magnetotellurics (4DMT)—nutrient pollution and recharge
- predicting and modelling water demand and availability
- predicting and testing water quality in source and distribution systems
- soil settlement prediction and microbiology studies
- river health prediction and management
- stream mesocosm experimentation
- water management guidelines for mineral extraction and processing, dams and reservoirs
- wastewater treatment, contaminant removal and transport
- environmental remediation.

### Protecting people's health

We can assemble a specialist team of qualified, experienced professionals to assess your workforce's occupational and environmental exposure to chemical, physical and biological hazards. Our experience sector-relevant expertise includes:

- community exposure studies and health impact assessments
- environmental health risk assessments (i.e. air, water, soil, food and consumer goods)
- hazardous chemicals audits and risk assessments
- heat-stress surveys
- indoor air quality investigations
- lighting surveys
- noise assessment and control
- ultrafine particles (i.e. dust, mist, fumes, gases)
- vapour intrusion assessments
- ventilation assessments.

As a matter of course, our detailed reports also include practical recommendations for improvement.

# SOCIAL LICENCE

**Obtaining and maintaining legitimate social licence is not only essential for individual energy projects, but a fantastic opportunity to strengthen the entire sector's future. The University of Adelaide can help you make it happen.**

## Backed by robust social science

The University's world-class social science researchers bring a wealth of knowledge and experience in rigorous community engagement surrounding complex issues relating to science, technology and the environment.

With a focus on engagement rather than communication, we will conduct robust, culturally sensitive social science research to determine your situation-specific basis for social licence, identifying all possible drivers and potential impediments.

We will then help you formulate and execute a strategic way forward.

### Tailored programs

Our approach to obtaining and maintaining social licence can be shaped to achieve any objective(s), including to:

- assess community concerns and help build community confidence regarding a proposed project's short- and long-term impacts—social, cultural, environmental and economic
- build collaborative relationships with previously negatively impacted communities or stakeholders
- address concerns raised by stakeholders, and establish bases for mutual understanding
- strengthen links between government, industry, academia and the community
- lay solid foundations for future collaborations/ projects in the region
- help identify and create win-win pathways to a low-carbon economy.

# ECONOMICS AND POLICY

**However large or small the venture, however complex the issues you face, the University of Adelaide's outstanding economists and policy experts can help you move forward with sound strategy and commercial confidence.**

## Vast energy industry experience

The University's economic and social policy experts have conducted numerous analyses and appraisals of various energy industry organisations, projects and policy decisions, to assess their actual or likely:

- gross economic contribution
- employment creation and skills requirements
- growth opportunities and constraints
- value-added production impacts.

Our key capabilities include:

- skills and workforce profiling and projections
- energy sector modelling
- policy mechanism development, such as to encourage new technology innovation and uptake
- domestic and international energy market analysis
- policy impact analysis, including on utilities regulation, pricing and net costs
- whole economy modelling (computerised general equilibrium), including greenhouse gas emissions and hydrogen production
- environmental and social impact assessments
- analysis of the national and industry-sector implications of changes in global trade policy (including border carbon adjustment)
- behind-the-meter flexibility assessment and procurement
- power system and distribution network modelling and analysis
- game theory analysis of energy systems, local electricity markets, pricing mechanisms, and energy and ancillary services trading
- stochastic modelling of electricity demand behaviour in the presence of external factors.

### Current and past projects

- Hydrogen 2050: Four exploratory scenarios for Australia (in progress, prepared as part of the Future Fuels CRC)
- Advancing Hydrogen: Learning from 19 plans to advance hydrogen from across the globe (2020, prepared as part of the Future Fuels CRC)
- Economic Impact of Olympic Dam Operations and Sustainment Investment Activities in South Australia (2017, prepared for BHP).

### Valuable government insight

We also have considerable experience working with government in the energy sector, providing critical complementary insight. A recent project example:

- Potential Economic Contribution of South Australia's Energy and Mining Sectors (2020, SA Department for Energy and Mining).

## Systems thinking and mapping

The University of Adelaide's systems thinking expertise is applied: qualitatively, through the development of frameworks; and quantitatively, through system dynamics modelling.

We bring together a range of approaches to enable the conceptualisation, simulation and analysis of complex problems.

This has been beneficial to energy projects at the hub scale, as they involve many stakeholders who are domain experts in different realms (e.g. different technical processes, policy, etc.).

### Stakeholder engagement focus

Stakeholder engagement plays a crucial role in system dynamics modelling. Talking with industry experts builds a system-level understanding of the problem and enhances feedback and collaboration.

With this in mind we routinely host workshops with industry/government organisations, and maintain ongoing engagement with project end-users throughout all stages of research.

### Decision support

We also provide wider decision support around the outputs of quantitative modelling, including:

- sensitivity/uncertainty analysis
- identification of decision break-even points
- multi-objective optimisation and multi-criteria decision analysis.

This process can:

- give end-users more confidence in model outputs
- provide deeper project understanding
- identify trade-offs between competing objectives and potential solutions
- identify the conditions under which one energy system configuration is preferable to another.

## Techno-economic evaluation

We regularly integrate our specialist economics and technical expertise to perform techno-economic assessments of future fuels production technologies.

Our capabilities here include:

- developing system mass and energy balances
- assessing system efficiency
- predicting whole-system impact from process parameter changes
- optimising system conditions
- predicting process capital and operating costs
- analysing discounted plant cash flow and net present value.

### aspenONE engineering software

The University also holds a commercial licence for the use of the industry-leading aspenONE engineering package. aspenONE can be used to conduct or design:

- industrial project consultations
- special and custom chemical and mineral equipment
- energy integration
- capital and operating cost estimations
- staff training in process flowsheeting (steady state and dynamic modes).

## MOVING INDUSTRY FORWARD

### Flexible Aggregator Simulation Platform

The University of Adelaide is leading the development of a Flexible Aggregator Simulation Platform (FRESNO) to simulate, test and verify advanced smart-grid operation mechanisms at the distribution level.

Danish energy company SEAS-NVE is our industry project partner.

#### Industry benefits

FRESNO will enable governments and utilities to more rapidly and accurately predict the impact of integrating larger amounts of intermittent renewable energy into the grid, with a view to:

- providing a secure environment for the widespread adoption of electric vehicles
- avoiding excessive grid-upgrade capital costs.

The platform will be particularly beneficial for states with high behind-the-meter PV and storage penetration, such as South Australia.

#### Our key areas of focus

Three major research challenges will initially be addressed as sub-projects:

1.Optimal Bidding in the Wholesale and Local Markets (FRESNO A)

2.Prosumers' Price Response Modelling (FRESNO B)

3.Local Energy and Ancillary Services Markets (FRESNO C)

These will later be combined to form a full, end-to-end simulation platform.

#### For more information

To learn more contact:

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# TRAINING AND EDUCATION

**World-leading undergraduate and postgraduate degrees. Management and leadership courses. Specialist undercover exploration training. The University of Adelaide puts a comprehensive suite of educational offerings at your disposal—and workforce-wide professional development within reach.**

### One world-top-10 subject ranking

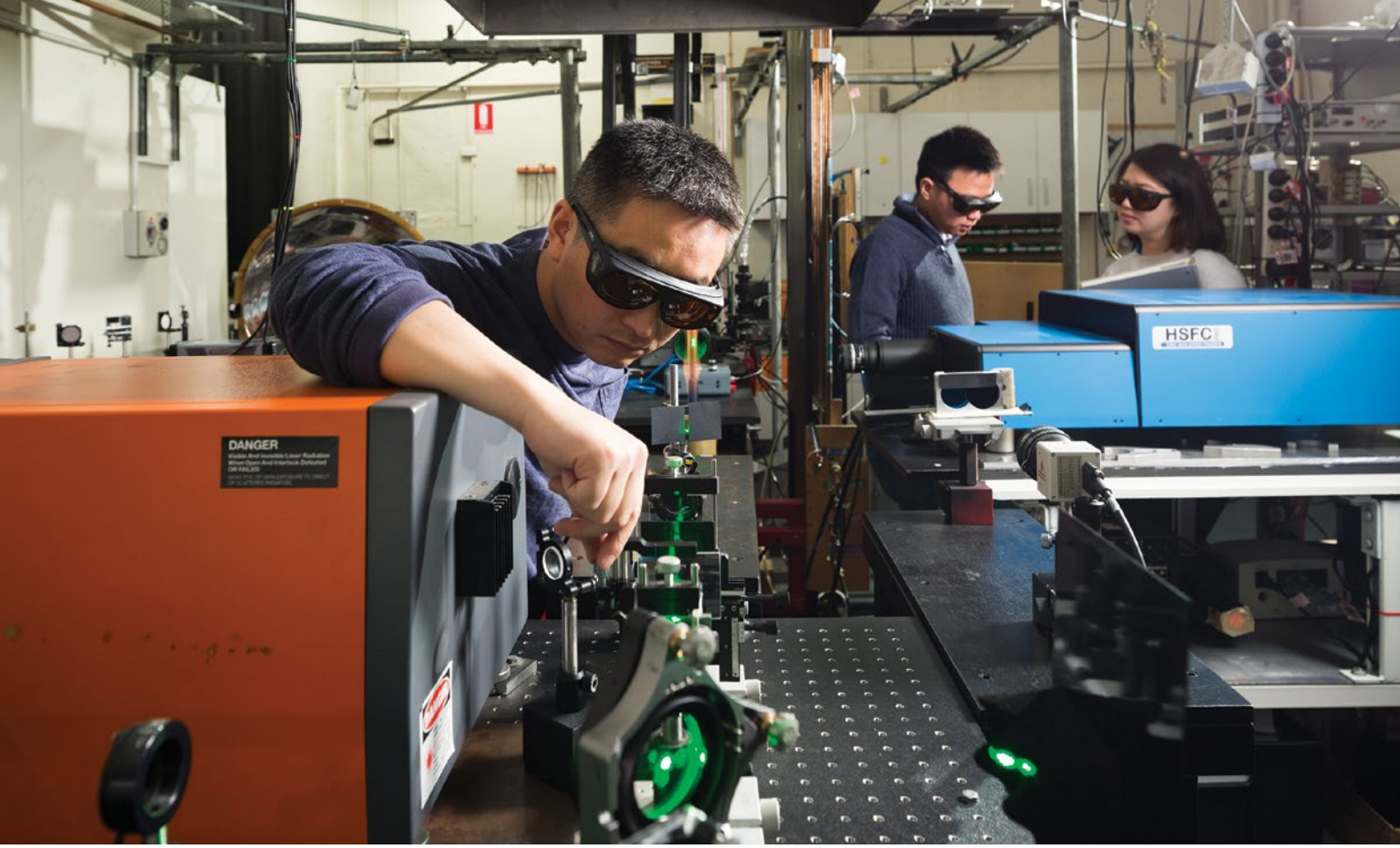
- Mineral and Mining Engineering*

### Another 6 energy-relevant world-top-50 rankings

- Automation and Control*
- Civil Engineering*
- Computer Science and Engineering*
- Electrical and Electronic Engineering*
- Petroleum Engineering†
- Water Resources*

### 10 more in the world top 100

- Accounting and Finance^
- Anthropology^
- Chemical Engineering^
- Earth Sciences*
- Energy Science and Engineering*
- Environmental Studies^
- Geology^
- Geophysics^
- Instruments Science and Technology*
- Mathematics^
- Mechanical Engineering*




### One of Australia's leading MBAs

The University's highly regarded Adelaide MBA has been rated second of all business school MBAs in the nation, according to the 2019 Australian Financial Review BOSS MBA Rankings. It also has a 5-star ranking from the Graduate Management Association of Australia (2017), Australia's peak body for MBAs.

## Multiple international accreditations

### Association to Advance Collegiate Schools of Business (AACSB)

AACSB accreditation is the largest and most recognised specialised accreditation worldwide for undergraduate and postgraduate business programs. AACSB-accredited schools must pass and maintain rigorous quality standards, and have been proven to provide the best in business education worldwide. Less than 5% of business educators globally have achieved this recognition.

### Accreditation Council for Entrepreneurial and Engaged Universities (ACEEU)

Adelaide is the only university in the world to receive dual ACEEU accreditation as being both an Entrepreneurial and an Engaged University**. Additionally, in 2019 we were ranked as Australia's number one university for entrepreneurship education and engagement (Maritz, 2019).

Supporting this standing, we have the longest operating Australian business incubator, ThincLab, and the longest running and most successful entrepreneurship pre-accelerator program, the Australian eChallenge.

### UN Principles for Responsible Management Education (PRME)

The University of Adelaide is a proud Advanced Signatory to the United Nations' PRME program. Founded in 2007, PRME aims to raise the profile of sustainability in schools around the world and equip today's business students with the understanding and ability to deliver change tomorrow.

## Transformative short courses and executive education

The University delivers an impressive suite of professional and personal development short courses that are practical, work-ready and goals-focused. As professional training experts, we can also meet your team's specific needs with highly customised courses—delivered at your premises or ours. Our extensive range of offerings spans:

- leadership
- strategic and design thinking
- business management
- career and wellbeing
- communication and writing
- customer experience
- digital media and marketing
- presentation skills.

## Climate Solutions engineering major

As our climate changes, developing solutions to ensure humanity's sustainability is crucial. In our Climate Solutions major, you'll study courses related to:

- sustainability
- the circular economy
- environmental and climate change and adaption
- climate risk and resilience
- renewable energy systems
- urban water systems
- natural hazard risks.

You'll also get first-hand experience learning from climate solutions experts in South Australia, and work on real-world projects throughout your degree.

You can major in Climate Solutions in our Bachelor of Engineering (Honours) (Environmental and Climate Solutions).

**Academic Ranking of World Universities, 2020.*
*^QS World University Rankings, 2020.*
*†QS World University Rankings, 2021.*
***Correct at time of printing.*

# LEGAL EXPERTISE

**The University of Adelaide has significant talent in contract law, mining and energy law, and international energy law. To determine where you're going, it's always wise to know where you stand.**

## Environmental and natural resources law

Our Environmental and Natural Resources Law research unit brings together a diverse range of scholars, enabling it to explore and advise on issues of law, policy and regulation relating to:

- the environment
- energy and natural resources, including renewable energy law and petroleum regulation
- climate change
- sustainability
- land use planning
- heritage protection
- human rights.

### Some important recent projects include:

- examining the general instruments required to encourage renewable energy generation in Australia
- conducting critical analyses of Australian states' planning systems in relation to off- and onshore wind energy
- investigating the adequacy of environmental protection laws and regulation in the mining and petroleum industries.

The unit is also committed to active community engagement, and regularly hosts public seminars, workshops and conferences.

# GENDER EQUITY

**The University proudly supports women's involvement and advancement in the energy sector through two key initiatives.**

## Women in STEM Careers Program

The University's Women in STEM Careers Program provides valuable professional development opportunities for young women studying in areas related to science, technology, engineering or mathematics (STEM). It's also complemented by our Women in STEM Society, which provides a friendly, supportive social network for women and other minority groups working and studying in STEM fields.

## Women's Professional Development Network

Supporting women across all professional disciplines, our Women's Professional Development Network is a 'grassroots' professional and personal development group. Participants are predominantly University staff, but membership's open to the entire community.

The network conducts events and activities to promote leadership, personal job satisfaction, a positive work attitude and career advancement.

## Ally Network

ISER is a member of the ALLY Network, which is a visible network of staff and students across the University who support the University's commitment to providing an inclusive and respectful university environment for people who identify as being lesbian, gay, bisexual, transgender, intersex and queer (LGBTIQ*).

ISER strongly supports and is an advocate in making the University an environment where all staff and students can safely work and study free of harassment or discrimination.

**HEAD OF THE AUSTRALIAN SCHOOL OF PETROLEUM DR KATHRYN AMOS WAS A STATE WINNER AND NATIONAL FINALIST IN THE 2020 DYNO NOBEL EXCEPTIONAL WOMAN IN AUSTRALIAN RESOURCES AWARD.**


AN EXCITING TOMORROW IS THERE FOR THE MAKING—MORE EFFICIENT, MORE PRODUCTIVE AND ENVIRONMENTALLY SUSTAINABLE.

## KAURNA ACKNOWLEDGEMENT

We acknowledge and pay our respects to the Kaurna people, the original custodians of the Adelaide Plains and the land on which the University of Adelaide's campuses at North Terrace, Waite, and Roseworthy are built. We acknowledge the deep feelings of attachment and relationship of the Kaurna people to country and we respect and value their past, present and ongoing connection to the land and cultural beliefs. The University continues to develop respectful and reciprocal relationships with all Indigenous peoples in Australia, and with other Indigenous peoples throughout the world.

## FOR FURTHER ENQUIRIES

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