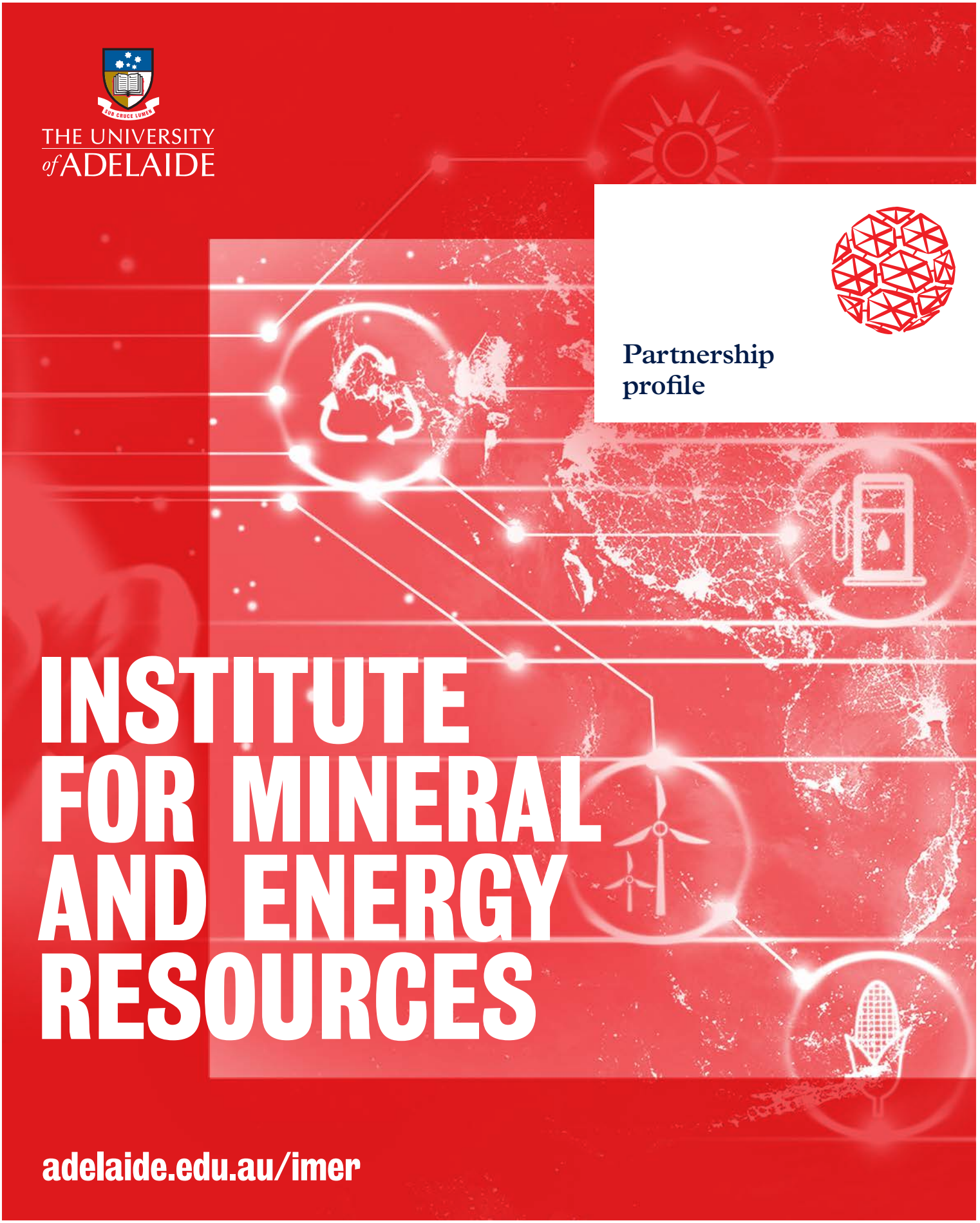
THE UNIVERSITY of ADELAIDE

Partnership profile

INSTITUTE FOR MINERAL AND ENERGY RESOURCES



adelaide.edu.au/imer

WELCOME.

OUR GOAL?
SUSTAINABLE ENERGY AND RESOURCES IN CLEVER NEW WAYS.

The Institute for Mineral and Energy Resources (IMER) focuses the University's engagement and collaboration efforts on opportunities critical to the energy and resources sectors. As one of six institutes, IMER develops cross-disciplinary programs and teams that transcend faculty boundaries. And it's co-chaired by an industry advisory board.

On the path to Future Making

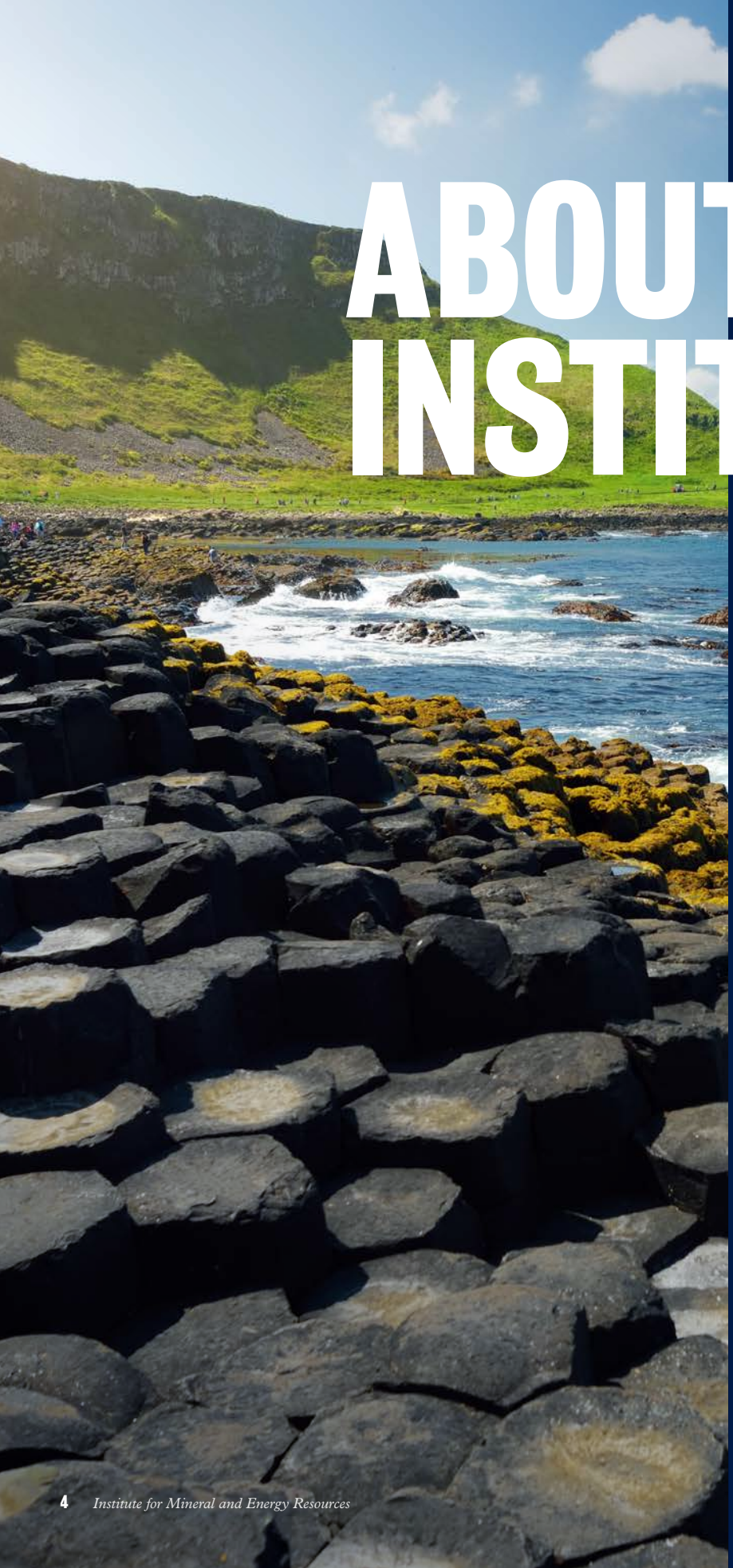
IMER is helping to shape South Australia and the University of Adelaide as a 'future maker'. In line with our 'Future Making' Strategy, IMER's activities help the University to be:

1. **Connected to the global world of ideas.** IMER's researchers are entrenched in global networks. Many were born overseas or hold dual citizenships, and are connected with the top universities across the globe.
2. **A magnet for talent.** IMER has become a focal point for the best and brightest globally to see Adelaide as an attractive professional destination.
3. **The place where research shapes the future.** IMER's research is rated well above world standard in all major areas, and combines this with a focus on industry-driven collaborations.
4. **A place for a 21st century education.** IMER researchers supervise more than 100 PhD and master students, plus many more honours students. We have, for example, one of the top mining schools in the world, and one of the world's leading renewable energy teaching locations.
5. **The beating heart of Adelaide.** IMER is proudly South Australian, and sits directly in the centre of a city that consistently rates as one of the most liveable in the world.

IMER helps create and deliver a vision for a more sustainable world, and reaches out across the globe to collaborate on delivery of this vision.

Professor Peter Rathjen

Vice-Chancellor and President
The University of Adelaide



ABOUT THE INSTITUTE

MISSION

Be the gateway to the University of Adelaide for collaborative and interdisciplinary research.

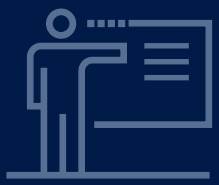
VISION

A world where agile and responsive research is key to the sustainable use and development of resources.

AIM

Maximise the impact of our research in energy and resources, to benefit industry, society and the environment.

$7.64m competitive funding (2018)



26 Research Leaders

240+ members

8 Research Priorities

8 Research Themes

COMPLETIONS IN 2018

15 Master Degree Students

85 PhD Students

PUBLICATIONS IN 2018

3 Books

220 Conference Papers

21 book chapters

700 Journal Articles

RESEARCH WITH IMPACT

Themes

Materials for energy and catalysts

Off earth resources

Heat, power and fuels

Energy and power systems transformation

Green hydrogen

Deep and automated mining

Complex processing

Energy geo-resources

Deep resources

Capabilities

Computer science

Artificial intelligence

Machine learning

Robotics

Robotic vision

Visualisation including 3D

Virtual and augmented reality

Sensors and sensor networks

Data science

Optimisation

Automation

Techno economics

Impact

Scientific Discoveries

New Jobs

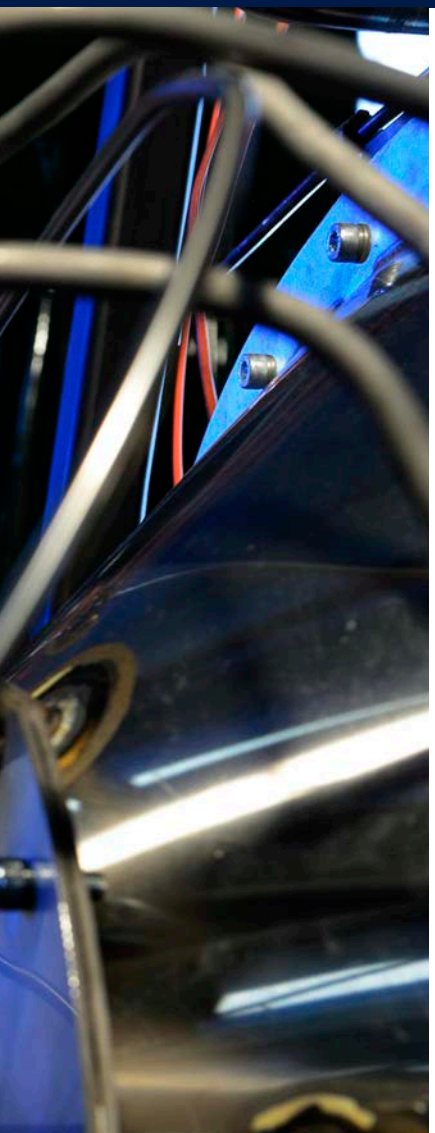
Training

Productivity Enhancement

Innovations

Advanced Products

Spin-Outs



How We Work

Create strategy with our researchers and partners, led by our Industry Advisory Board by:

- facilitating connections, including internationally
- communicating opportunities and providing resources
- preparing high quality and attractive proposals and expressions of interest
- hosting workshops and symposia.

What you can do: Come to our workshops, tell us about real-life industry challenges, or express interest in joining our Industry Advisory Board.

Research, innovate and engage in tailor-designed projects by:

- bringing together interdisciplinary teams
- leveraging new funding
- identifying and nurturing talent.

What you can do: Suggest a project idea, contribute cash or resources to a program, or host a postgraduate student in your workplace.

Make an impact by rolling out solutions to our partners by:

- establishing research leadership and growing our track record

What you can do: Provide access to data and sites for pilot tests, or host a postdoctoral researcher to tailor-fit solutions on-site.

Industry challenges

Energy

Australia, like the rest of the world, is seeking an orderly transition in its energy sources. A transition that is affordable, reliable and sustainable. We also seek enhanced productivity and low or zero-CO_2 energy exports.

Resources

Australia is lucky to be well endowed with both mineral and energy geo-resources like coal, oil and gas. But we are one of the highest cost and most regulated countries in the world. We strive for efficient exploration, extraction and processing for deeper and more complex minerals, and access to energy geo-resources.

Our outcomes

We work strategically with industry and government to deliver least cost, reliable and sustainable energy and support Australia's commitments to international agreements.

We deliver low cost, highly productive, and low impact resource projects with a focus on energy and water sustainability, low carbon materials and reduced emissions.

TO OUR PARTNERS, RESEARCH VIA IMER IS A WAY TO MAXIMISE PROFITS AND REDUCE COSTS.

Professor Michael Goodsite,
Interim Director

MEET OUR DIRECTOR

Professor Michael Goodsite
Interim Director

Browsing through this brochure, you will see that our goal is to improve industry, society and the environment with innovations in energy, minerals and petroleum.

Local and global end users, plus industry's key equipment and technology service companies, benefit from collaborating with IMER.

How we innovate

IMER's points of difference are our team's mix of research and industry backgrounds, and our ability to move quickly. We have mobilised teams involving as many as 35 different parties, forming consortia to bid for and successfully win millions of dollars in grant funding.

We know and understand the strengths and research goals of over 240 staff and students at our university, plus research organisations elsewhere, so that we can create the right team to solve any energy, minerals or petroleum dilemma.

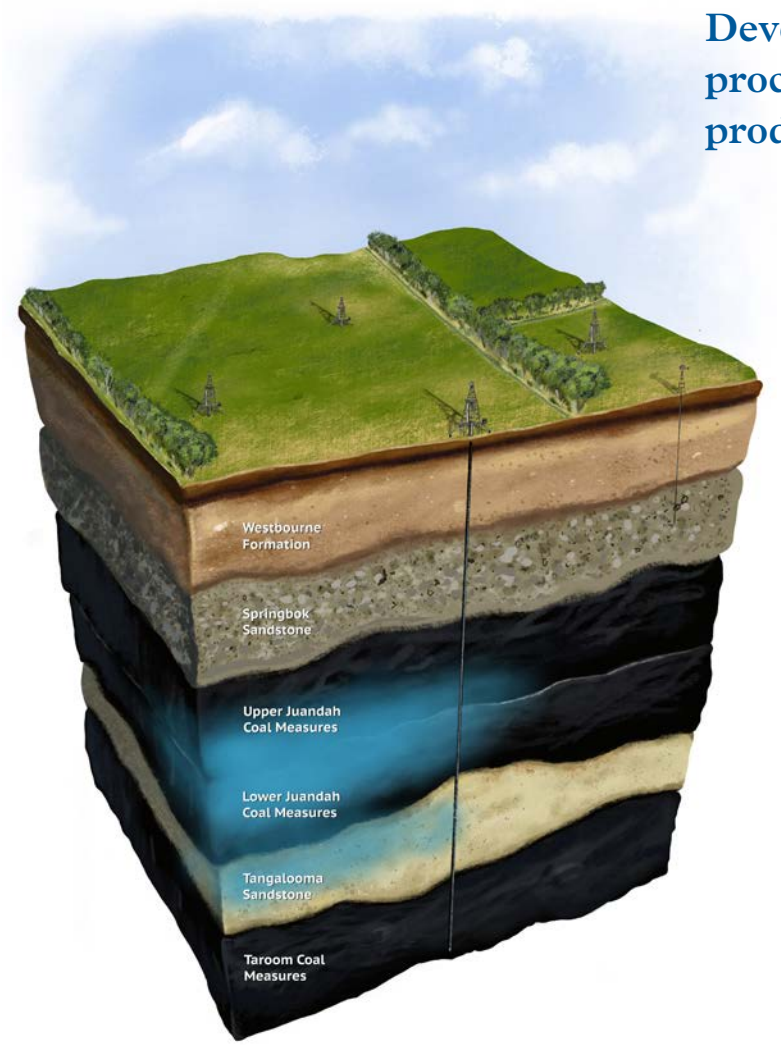
Background mix

My professional background includes roles in industry, government and academia. As well as being Interim Director of IMER, I am also the Head of the School of Civil, Environmental and Mining Engineering (CEME); and a member of the ECMS Faculty Executive as Director of Commercialisation. Since arriving at the University of Adelaide in November 2018, I have worked to champion and advance the minerals, energy and resources sectors together with staff and stakeholders. Prior to my appointment as Interim Director of IMER, I was Interim Head of the Australian School of Petroleum.

I am internationally engaged in the sector: as I am presently appointed to the Board of the Danish National Energy Technology Development and Demonstration Program (EUDP) and an advisor to the Peking University School of Economics Center for National Resource Economic Studies (CNRES). Prior to coming to Australia in 2018 I held positions as Director of the Nordic Centre of Excellence for Strategic Adaptation Research: a public private partnership which received significant industry funding and had hubs in all five Nordic countries and served as the Chief Operating Officer for Regional Development of the Region of Southern Denmark, where my portfolio included amongst other domains, mineral and energy resources in the Region.

I also am actively engaged locally: I sit on the SACOME Mining and Extractives Committee and the SACOME Energy Committee.

INNOVATIONS IN PLAY



Developing new techniques and processes that rethink how we produce energy and resources.

Fluid flow imaging with 4DMT

What's really going on during fracking

How do fluids such as water, gas and petroleum move in the earth? The answer is largely guesswork. We can't physically see fluid pathways, so we guess by sampling, drilling and modelling.

With IMER's 4DMT, that changes now.

IMER has created a geophysics technique, using magnetotellurics (MT), to observe how fluids move over a period of time, such as when pumped by an operator.

Geophysics has been used to map the earth and the minerals in it for a long time. But until now they have never been used continuously over time to provide dynamic information.

To refine the technique, which we call 4DMT, our researchers monitored the entire fluid flow cycle - a world first - in a Cooper Basin shale gas frack before, during and after hydraulic stimulation. They detected changes over time.

Next, they tested the technique in a coal seam gas field and mapped the variability in gas production across a well field. The low cost technique is still being refined, but the potential benefits to industry, farmers concerned about impacts on groundwater, regulators and environment groups are enormous.

Partners: Santos and QGC.

Mineral source discovery with DeepMT

Long-range geophysics to reconstruct the deep Earth in 3D

IMER has developed a way to locate the origins of mineral systems in the very deep Earth.

The finding was made after researchers left MT boxes at sites one to two kilometres apart for two weeks across the Olympic Domain in South Australia. The boxes recorded information about the Earth's magnetic field, and gave researchers enough data to reconstruct an image of the deep Earth in 3D.

They saw a clear link between deep (under the earth's crust) source rocks - 'footprints' of past events, where minerals are thought to have originated perhaps a billion or more years ago – and known, world-class mineral deposits.

When the team looked at the deep region below the Olympic Domain, they saw remarkable narrow structures that seemed to show where fluids containing minerals had moved from the source region to the surface. One structure led directly to Olympic Dam, one of the world's largest and most significant copper deposits. The fluid paths are at least partly supported by observations in seismic data.

DeepMT tells us something about the geology of the Earth that we can't otherwise access. It shows great promise for the use of MT for exploration under cover. We could apply this approach in different places to try to discover new mineral deposits. We could look for fluid paths from very deep structures, which could be new areas of high prospectivity.

IMER HAS DEVELOPED A WAY TO LOCATE THE ORIGINS OF MINERAL SYSTEMS IN THE VERY DEEP EARTH.

RESEARCH SPIN-OUTS

GREEN HYDROGEN

Carbon-zero hydrogen with solar thermal or photocatalysis

'Green' hydrogen is fast becoming a cost-competitive energy option for industry. IMER specialises in hydrogen production solutions, including:

- Bubble technology with molten metals using concentrated solar thermal (CST) and industrial waste heat. The metal could 'carry' hydrogen for future use or export.
- Photocatalysis to convert water and sunlight to hydrogen (and oxygen). IMER and partners have created materials with atomically-precise metal clusters that perform 'artificial photosynthesis'. The water doesn't even have to be pure.

Partners: US Army, University of Tokyo, ASTRI, Flinders University.

FERTILISER FROM AIR

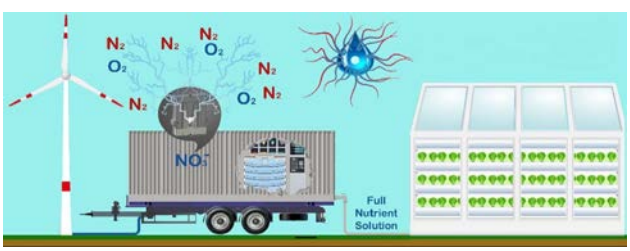
Tailor-made nitrogen fertiliser anytime, anywhere

For farmers, buying just the right amount of fertiliser in a country with unpredictable weather is a tricky business.

IMER researchers are working on a new way to create nitrogen fertilisers, using a new kind of plasma, catalysts and just air and water.

The technology, once fully developed and trialled, will enable farms to produce just the right amount of fertiliser for their exact needs, such as their soil acidity level. And it could be used anywhere – even on the back of a truck, where it could be put to work in remote areas.

Funded by a European Research Council Synergy Grant SCOPE. Partners: University of Warwick, University of Antwerp, Eindhoven University of Technology and University of Messina.



GEOVISION

Intelligent vision for mining and exploration

Vast amounts of collected rock cores are not analysed, or are analysed poorly long after drilling. The 'digital mine' of the future will require much smarter technology than used now.

Geovision combines multi-sensory core scanners, data fusion and machine learning to capture geological and structural data at the exploration or mine site.

The ultimate product? A portable unit that can be moved from site to site to provide to-the-minute information via a dashboard.

Funded by a CRC Project Grant, led by Boart Longyear, and supported by SRA IT and IMER researchers.

ENVIROCOPPER

Could minerals be unearthed without active mining?

EnviroCopper is assessing the potential to recover mineral deposits from the ground without digging them out. By creating a 3D hydrogeological model of the historic Kapunda copper-gold mine area, the team is devising an approach for in-situ recovery of copper and gold in an innovative new way.

IMER brings expertise in geomechanical and geological modelling, and geophysical site characterisation to the project. Once demonstrated at Kapunda, the approach could be extended to similar deposits around the world.

Funded under a CRC Project Grant, the team comprises Environmental Copper Recovery, Thor Mining, Terramin Exploration, Mining3, CSIRO and IMER researchers.

SMART INTEGRATION ACROSS THE MINING VALUE CHAIN

WHY ENHANCE COMPLEX ORE PROCESSING?

Complex ores contain two or more minerals and are difficult or costly to treat. They can contain base and precious metals such as copper, gold, nickel, lead, zinc, and PGM.

By 2023, global copper production from existing and proposed mines is projected to be about 270,000 tonnes short of demand. This is based on a year-on-year increase in demand for copper, and steady decline in existing mine production.

(CRU Group 2019)

Modern thinking and technologies to process minerals better

The mining value chain comprises many steps, from rocks in the ground to materials going to market. Each step is an opportunity to optimise with new thinking and technologies. And the whole chain could be integrated so that each step 'talks' to the others.

A consortium led by IMER is doing these things in a bid to make the chain much more efficient. The Integrated Mining Consortium is maximising value and reducing costs for mineral producers of complex ores in five ways.

Machine learning, artificial intelligence

Computer science technologies offer unparalleled ability to target resource attributes and therefore optimise downstream processing. At the same time, they can rapidly deliver feedback to operators, who can then alter the mine plan on the fly.

Modelling, simulation, digital twins

Modelling and simulation are key tools for decision makers to analyse and predict mining operations and plant performance. Recent advances in virtual and augmented

reality offer an unprecedented visualisation capability bringing the models close to reality. The operator can monitor the plant processes and their parameters in near real time being able to identify the problem on the spot and make a quick decision to address the problem.

The consortium team is developing sophisticated near real time models to track ore characteristics from mine to mill.

Advanced data analytics

Our program includes finding new ways to collect data at all points of the mining chain. Data can feed back along the chain to give real time knowledge of the orebody and allow the mine plan to be updated, and forward to allow steps down the line to be optimised based on real time knowledge of what is coming down.

Automation and robotics (remote operations and controllers)

Robots are replacing humans in mines, with huge safety and cost-saving results. From robotic drills to self-driving trucks, the opportunities for automation are many.

The consortium is partnering with the key vendors of automation and control systems and equipment to automate grinding and flotation circuits.

Sensing and monitoring

The problem with mineral deposits is heterogeneity. There is variability in mineralogy, grade, hardness, lithology and grain size. This erodes value. The resultant feed variability makes mining and mineral processing costly. Sensors will pick up and communicate aspects of the ore to other parts of the chain, erasing this problem.

How the consortium works

In a series of research and industry translation projects, the team is developing, trialling and commercialising technologies and techniques that promise to improve the process of gaining value from mineral deposits.

The idea is to reduce wasted and inefficient efforts, which can happen in complex ore processing, to drive up profitability. At the moment, value is being lost all the way along the chain, exacerbated by rising energy costs and a shortage of crossover technical skills in computer science, mining and processing.

Modern resource challenges are interdisciplinary. They are not just about mining and processing anymore.

Funded by the Premier's Research and Industry Fund (PRIF) Research Consortia Program

CLEANER, INEXPENSIVE HEAT FOR INDUSTRY

Concentrated solar thermal (CST) to heat the Bayer process in alumina refineries

Many industries require heat – in addition to electricity or fuel – to run their processes. Industrial heat accounts for 16% of the world's carbon emissions, and forward-looking companies are looking for and implementing solutions to cut this. At the moment, industry's need for heat is mostly met by natural gas.

One industrial activity that could be heated with renewable sources is the Bayer process, used in alumina refineries. Part of the process requires heat at very high temperatures, 1000°C or more. The team at IMER think they can provide this heat using CST.

To develop the technology, IMER is partnered with Alcoa, the world's largest alumina producer. Reducing their carbon footprint is a long-term strategic imperative of Alcoa, and CST technology could be retrofitted into its plants everywhere. The program is looking to introduce solar into three parts of the Bayer process.

Low temperature process heat

At alumina plants, about half the thermal energy used in the Bayer process is low temperature heat - for digestion, evaporation and pre-heating - up to about 280°C. The team is researching under what conditions CST can be integrated into these processes.

Solar reforming of natural gas

Researchers are checking whether generating syngas through solar reforming is economically feasible for the Bayer alumina process. This would be attractive to industry because existing plant equipment won't have to be radically altered and plant operators could easily switch between syngas and natural gas.

High temperature calcination

CST is one of the most promising technologies to cost-effectively decarbonise high temperature process industries. IMER is researching whether CST can be introduced directly to the reactor or indirectly by heating particles.

IMER researchers are most involved with the high temperature work, and progress has been significant. A laboratory-scale Solar Expanding-Vortex Receiver/Rector (SEVR) with optical accesses has been constructed and is being commissioned, while another three laboratory-scale SEVRs for high temperature operating conditions have been fabricated.

IMER's CST technology - and the method of incorporating it into the Bayer process - passed its first economic 'stage gate' at the project's half-way point, providing a strong initial indicator of commercial viability.

If successful, it will be the world's first commercially viable application of renewable energy into a high-temperature industrial process. If cost-effective, it could be applied to other processes like iron and steel making. That paves the way to value-add to Australia's iron ore, of which 95% is currently exported raw.

Funded by the Australian Renewable Energy Agency. Partners: Alcoa Australia, ITP, Hatch, CSIRO, University of NSW.

KEY TERMS EXPLAINED

Bayer process: The primary means of refining bauxite to alumina (aluminium oxide).

Concentrated solar thermal (CST) energy: Solar energy created by using mirrors or lenses to concentrate a large area of sunlight onto a small receiving unit. It is perfect for generating heat.

OUR PARTNERS

HOW WE CAN HELP

Innovate with us

In a world where change and disruption are almost the norm, there is a constant need to innovate. Often, this requires a multidisciplinary approach.

We invite you to make our team your team. We have more than 160 of the world's experts to help you innovate and push past challenges in your business. And we will work with you to attract funding and deliver results you can use.

Some of our large industry-led, grant-funded projects

- ARC Australian Copper-Uranium Transformation Research Hub
- ARENA Solar Thermal for Alumina Project
- ARENA Solar Thermal Research Initiative
- Australian Energy Storage Knowledge Bank
- CRCP EnviroCopper
- CRC ORE
- Fight Food Waste CRC
- Future Fuels CRC
- GeoVision CRCP
- Iron Oxide (FOX) Research Program
- MinEX CRC
- PRIF Research Consortia Program 'Unlocking Complex Resources through Lean Processing'

Centres that operate within IMER

- Centre for Energy Technology
- The Mawson Centre for Geoscience
- Centre for Radiation Research, Education and Innovation
- Centre for Sustainable Planetary and Space Resources
- Centre for Materials in Energy and Catalysis

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