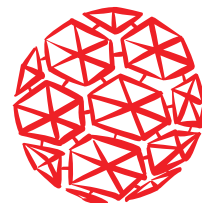




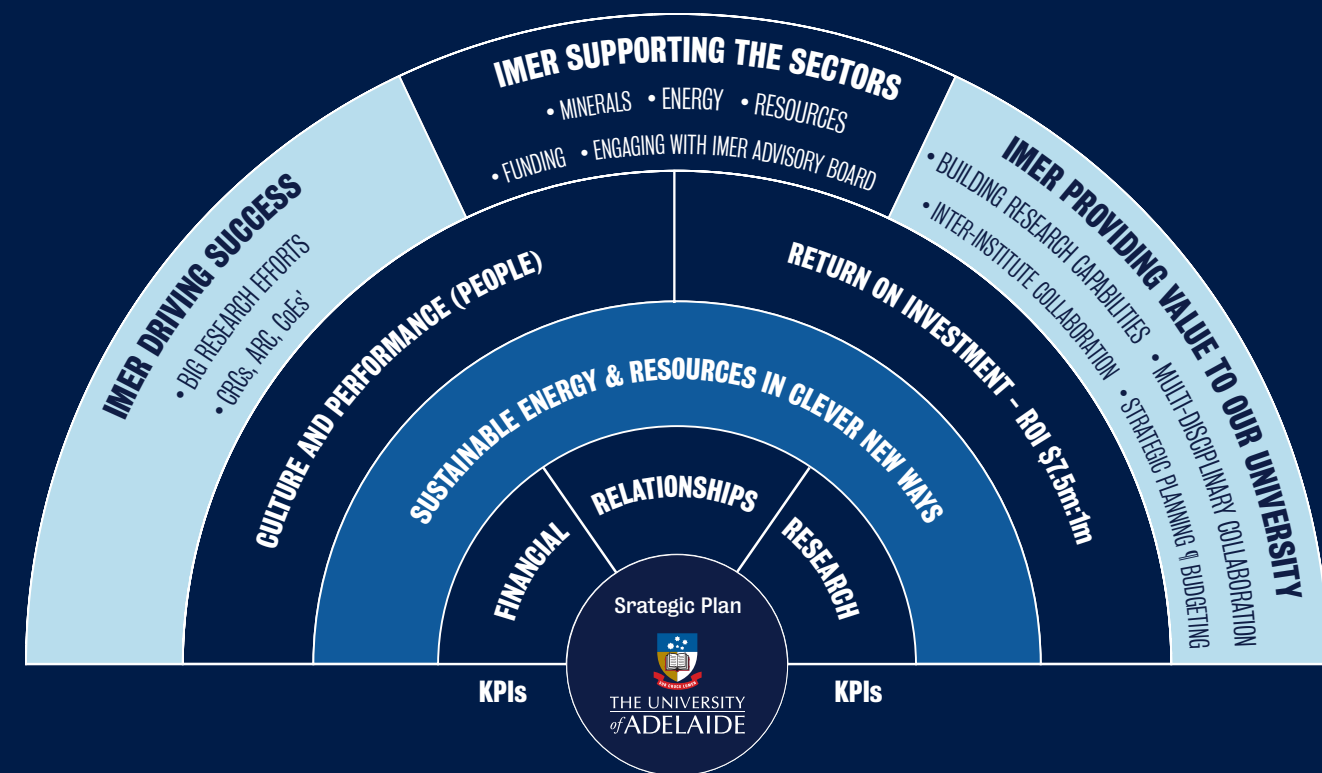
THE UNIVERSITY
of ADELAIDE



Annual Report 2019

INSTITUTE FOR MINERAL AND ENERGY RESOURCES

adelaide.edu.au/imer



THE IMER UNIVERSE

IMER operates at the international forefront of the mineral, energy and resource sectors, showcasing our finest talent in large-scale research and innovation outcomes, with the capacity to pursue higher-risk, cutting-edge projects catalysing the modern energy system.

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.

IMER fulfils the University of Adelaide's strategic plan and is driven by key performance indicators, influenced by its own culture and that of the University. It illustrates here the critical need for a return on investment and the interconnected nature of our business.

What is IMER?

IMER is the Institute for Mineral and Energy Resources, one of seven institutes at the University of Adelaide. IMER develops cross-disciplinary programs and teams that transcend school and faculty boundaries to work collaboratively with industry and government, focusing on opportunities critical to sustainability, productivity and global competitiveness for the energy and resources sectors, catalysing research-driving innovation for modern energy systems.

IMER is guided by an industry advisory board and contributes to the University's 'Future Making' strategy. This annual report contains required information and aims to add value for our stakeholders.

Who are IMER's stakeholders?

- The University of Adelaide
- Industry Advisory Board
- Academics and researchers
- Energy and resources sector industry groups
- Energy, resources and mineral companies
- The State Government of South Australia
- The Australian Government and funding bodies

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MISSION



Be the gateway both into, and out of the University of Adelaide, for collaborative and interdisciplinary research for modern energy systems

VISION



A world where agile and responsive research is a catalyst for the sustainable use and development of resources energising our future

AIM



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

DEPUTY VICE-CHANCELLOR (RESEARCH) REPORT

Professor Anton Middelberg



IMER exists to help us – as a state, as a nation and as a world – to transform the ways we create and use energy.

By finding ‘clever new ways’, IMER connects the people who have specialist knowledge and skills with those visionary companies and governments who have the resources, and the will, to travel the long road towards sustainable productivity.

By helping to shape South Australia and the University of Adelaide as a ‘future maker’, IMER is more relevant than ever.

As a vital institute at the University, IMER knows industry, and with energy and commitment to change, it creates the ongoing meaningful connections that are so essential to bridge the gap between academia and business.

With input from an industry advisory board, IMER focuses our engagement and collaboration efforts on opportunities critical to the energy and resources sectors.

IMER delivers on the University’s five pillars, specifically through being connected to the ‘global world of ideas’ and by catalysing ‘engaged research that shapes the future’. IMER works together with the University’s industry engagement priority in mining, energy and resources to ensure our university works for our stakeholders.

I would like to welcome Professor Michael Goodsite as IMER’s incoming Interim Director, who brings his own vision to the team of cross-sector expertise that the Institute has once again harnessed in 2019.

FIVE PILLARS TO EXCELLENCE

Five pillars define our Strategic Plan and will shape the trajectory of the University of Adelaide. These connect our research and teaching capabilities, manifest in our Faculties and Research Institutes, with the key challenges faced by our evolving world.

- | | |
|---|---|
| 1. CONNECTED TO THE GLOBAL WORLD OF IDEAS | 4. A 21ST CENTURY EDUCATION FOR A GROWING COMMUNITY OF LEARNERS |
| 2. A MAGNET FOR TALENT | |
| 3. RESEARCH THAT SHAPES THE FUTURE | 5. THE BEATING HEART OF ADELAIDE |

INTERIM DIRECTOR REPORT

Professor Michael Goodsite



THE FOUR TENETS OF RESEARCH, RESEARCH-BASED TEACHING, OUTREACH AND COMMERCIALISATION ARE WOVEN INTO IMER’S PURPOSE AND INTO THIS REPORT.

I am delighted to report that IMER has delivered on all key performance indicators for 2019. See page 6 for the full details. Our primary KPI is to deliver a 7.5-to-one ratio of financial return on investment.

We have achieved this by working strategically with industry and government to deliver least cost, reliable and sustainable energy and resources systems, while also helping our nation to meet commitments to international agreements.

Our job is to help the University and our partners to make a tangible difference in Australia’s ability to deliver affordable, highly productive, and low-impact resource projects, catalysing the innovation needed as we advance our energy systems.

We focus on energy and water sustainability, low-carbon materials and reduced emissions. Now, more than ever, in a post-pandemic world we need mineral and energy resources for the health and financial wellbeing of our economy. This is Australia’s global strength and we are confident that IMER will continue to generate excellent results for the University and society by significantly leveraging the investments it is entrusted with, and deploying our resources around activities that help stakeholders reach their strategic goals.

We have structured this fresh new annual report to be shorter and more concise. Most importantly, we want to communicate a real sense of the value we bring to the energy and resources sectors, and to the University, both in terms of directing and capitalising on useful research, which also adds value to teaching.

Our three main chapters explore, firstly, how we drive success both in terms of research outcomes for industry and society, and for the University’s programs, schools and reputation.

Our second chapter looks at how we have supported the resources, minerals and energy sectors, complemented by ‘case studies’ (or research impact stories) focusing on real-life examples of achievements and work in progress.

Our third chapter considers how IMER adds value to the University of Adelaide, focusing on building and directing research capabilities, collaborating across schools and institutes, financial return on investment, and collaborating with industry.

Chapter 4 expands on our vision for change which will be increasingly collaborative with the University’s other institutes and guided by the key ideals of transparency, value and commitment to the Future Making strategy.

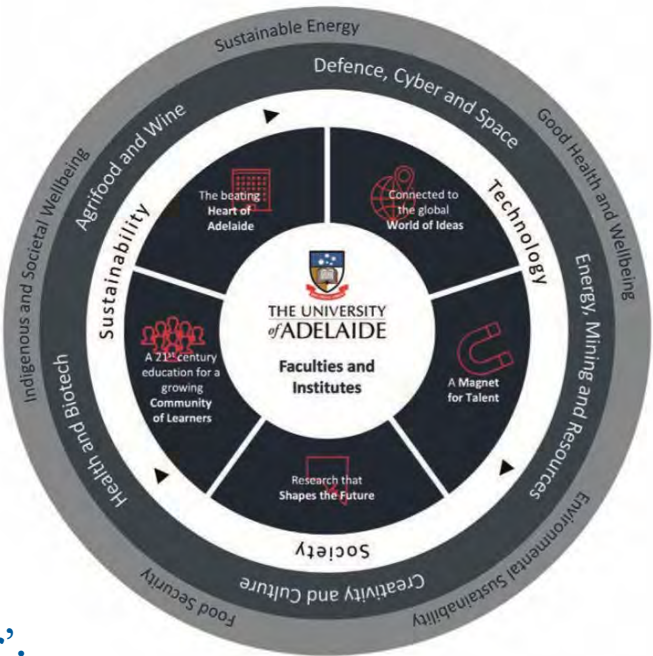
Finally, I would like to thank my team of talented and hard-working colleagues both within IMER and across the University, and within the businesses who have supported our ongoing challenge to ‘create sustainable energy and resources in clever new ways as we continue to be a catalyst for modern energy systems with our research and innovation’.

IMER ADVISORY BOARD CHAIR REPORT

John Anderson



- Five pillars
- Colleges of Expertise
- Industry Engagement Priorities
- Grand challenges



There is no doubt that IMER is helping to shape South Australia and the University as a ‘future maker’.

At IMER we work hard to align international research and development expertise with strategic know-how and vital funding through industry partners such as Santos, BHP, OZ Minerals, AGL and the state Department for Energy and Mining. (See page 23 for a full list of our valued industry collaborators.)

Building on strong foundations, 2019 was a transformative year for IMER. Under changed leadership, IMER is moving towards a new strategy addressing the University’s five pillars of focus.

Once again IMER deployed its limited discretionary resources extremely well, meeting KPIs despite significant challenges around sustainability and cost. The challenges of the COVID-19 pandemic will also be met with an appropriate mix of agility and robustness.

IMER has pursued a portfolio-management style of programs to balance risk and reward on value-generating activities. A summary of projects is listed on page 8.

Throughout 2019, the IMER Board has provided valuable input and advice leading to tangible results for industry.

The Board is pleased to see IMER continue as a respected voice in the strategic transformation of Australia’s minerals, energy and resources industries.

THE SOUTH AUSTRALIAN CONTEXT

Our State, in the context of modern energy systems, is already considered a leading centre in the world of renewables.

We may have fewer resources than Queensland or Western Australia, but through the Moomba gas fields for example, we punch well above our weight, supplying gas to much of the eastern seaboard, in addition to South Australia.

But we need energy to extract those precious resources that are becoming harder to find and more complex to extract or refine. This is why the synergy between cost-effectiveness, sustainability and productivity in energy and minerals/resources is so critical.

IMER exists due to support from the University, state and federal governments and industry partners that operate in all three sectors (minerals, resources and energy). Our combined future – indeed the future of the world as we know it – depends on transforming to a low-carbon approach.

The backdrop of our work includes federal and state hydrogen plans, 2030 emissions reduction targets, industry growth models and the Australian Government’s Technology Innovation Roadmap. These are all essential minerals and transition strategies that leverage state and University strengths.

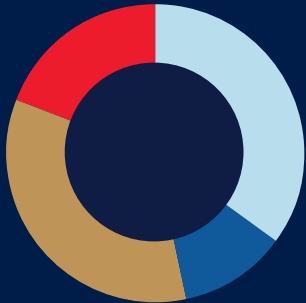
ACHIEVEMENTS IN 2019



ROI
\$11.6m:\$1m



**192 IMER
MEMBERS**



Category 1 **Category 3**
Category 2 **Category 4**

Total funding
\$11,676,685

RESEARCH PRIORITIES



Critical Minerals



Energy & Climate Change Policy



**Low Carbon Heavy Industry
including Hydrogen**



**Gas in the Transition
and CO2**



Sequestration



Storage



**Mining Chain Energy and
Optimisation and Power**



**Transmission and Renewable
Energy**



COMPLETIONS IN 2019

10 master degree students
60 PhDs



PUBLICATIONS IN 2019

5 Books 16 Book chapters
60 Conference papers
900 Journal articles

CATEGORIES OF FUNDING

Category 1

IMER teams are experts in how to attract funding, helping researchers play to their strengths.

Income is primarily from Australian competitive grants, which meet the conditions of a self-assessment system.

IMER helps researchers submit and win this most prestigious and highly competitive level of funding that is awarded to those projects with the highest risk and the highest reward. This category includes ARC hubs and training centres.

Category 2

Category 2 includes: research income received from government, and other public sector research income, eg state governments, such as the PRIF Research Consortium Industry Fund.

Category 3

Category 3 is for industry and other research income and includes contract research.

Category 4

This category specifically refers to Cooperative Research Centre (CRC) research income.

KEY PROJECTS ACTIVE IN 2019

Resource extraction

Unlocking Complex Resources through Lean Processing (see page 10)

The Integrated Mining Consortium is applying the ‘**industrial internet of things**’ (IIOT), **advanced** sensing, data analytics and machine learning to improve mining operations, mineral processing and recovery.

Sponsor: South Australian Premier’s Research and Industry Fund Research Consortia Program

Duration: October 2017 to June 2022

Funding: \$3.8m over four years

Director: Professor Nigel Cook

Chief Investigators: Prof Nigel Cook, Prof Peter Dowd, A/Prof Chaoshui Xu, Dr Tien-Fu Lu, Prof Chunhua Shen, Prof Frank Neumann, Dr Markus Wagner, Dr Lei Chen, Adjunct A/Prof Max Zanin

Schools: Civil, Environmental and Mining Engineering, Computer Science, Chemical Engineering and Advanced Materials, and Mechanical Engineering

Industry Partners: BHP and OZ Minerals

Research Partner: University of South Australia

More info: <http://integrated-mining-co-0.dev.openshift.services.adelaide.edu.au/imer/integrated-mining-consortium/>

Research Hub for Australian Copper-Uranium (see page 11, 15)

Hub researchers are developing and testing new, cost-effective ways to remove non-target metals from copper concentrates from ores in South Australia and beyond.

Sponsor: Australian Research Council, Industrial Transformation Research Hub

Duration: June 2015 to June 2020

Funding: \$4.8m over five years

Director: Professor Nigel Cook

Chief Investigators: Prof Nigel Cook, Prof David Ottaway, Prof Nigel Spooner

Schools: Civil, Environmental and Mining Engineering, and Physical Sciences

Industry Partners: BHP, OZ Minerals

Research Partners: Environmental Protection Agency SA, Flinders University, University of Queensland, Monash University, Defence Science and Technology Group

More info: <https://www.adelaide.edu.au/copper-uranium-research/>

Research Hub for Graphene Enabled Industry Transformation

This project is developing high-value products and innovative solutions for industries as diverse as agriculture, mining, construction, medical technologies and defence.

Sponsor: Australian Research Council, Industrial Transformation Research Hub

Duration: 2017 to 2021

Funding: \$3.5m over four years

Director: Professor Dusan Losic

Chief Investigators: Prof Dusan Losic, Prof Michael McLaughlin, Prof Christophe Fumeaux, A/Prof Reza Ghomashchi

Schools: Chemical Engineering and Advanced Materials, Electrical and Electronic Engineering, Mechanical Engineering, and Agriculture, Food and Wine

Research Partners: Monash University, University of Melbourne, University of South Australia, Royal Melbourne Institute of Technology

International Research Partners: Catalan Institute of Nanoscience and Nanotechnology, Spain; Cranfield University, UK; Natinal Physical Laboratory, UK

Industry Partners: NematiQ, Graphene Technology Solutions, Cleanfuture Energy, Archer Exploration Limited, First Graphene

More info: <https://arcgrapheneresearchhub.com.au/>

Concentrating solar thermal (CST) in the Bayer Alumina Process

This project is establishing a path to progressively integrate three CST energy technologies into the Bayer alumina process at the refinery plants of Alcoa of Australia, with a target of achieving 50% CST into the commercial Bayer process.

Sponsor: Australian Renewable Energy Agency – Emerging Renewables Program

Duration: 2016 to 2021

Funding: \$2.32m over five years

Chief Investigators: Prof Gus Nathan, Prof Bassam Dally, A/Prof Zeyad Alwahabi, Dr Woei Saw, Dr Philip Van Eyk, A/Prof Maziar Arjomandi, Dr Zhao Tian

Schools: Mechanical Engineering and Chemical Engineering and Advanced Materials

Research Partners: University of New South Wales, University of Newcastle, Australian Nuclear Science and Technology Organisation, Commonwealth Scientific and Industrial Research Organisation

International Research Partners: Swiss Federal Institute of Technology

Industry Partners: IT Power, Alcoa of Australia Ltd

More info: <https://www.adelaide.edu.au/cet/solar-alumina/research-program>

Mineral resources

Cooperative Research Centre for Optimising Resource Extraction (see page 14)

Project 1: Upconversion fluorescence of minerals for geo-sensing

Project 2: Resource scale heterogeneity evaluation

Project 3: Real-time fluorine mineral identification using novel fluorescence technology

Sponsor: Department of Industry, Science, Energy and Resources, Australian Government

Duration: 2016 to 2021

Funding: \$2m over five years

Chief Investigators: Prof Nigel Spooner, Prof David Ottaway, Dr Georgios Tsiminis, Dr Jillian Moffatt, Prof Peter Dowd, A/Prof Chaoshui Xu, Dr Exequiel Sepulveda

School: Physical Sciences and Civil, Environmental and Mining Engineering

More info: <https://www.crcore.org.au/>

Fox Project – Trace elements in iron oxides: deportment, distribution and application in ore genesis, geochronology, exploration and mineral processing

Studying iron oxides will help to develop novel exploration models by defining the signatures of different deposit types.

Sponsors: Government of South Australia’s Mining and Petroleum Services Centre of Excellence and BHP

Duration: June 2015 to June 2020

Funding: \$1.9m over five years

Industry Partner: BHP

Chief Investigators: Dr Cristiana Ciobanu, Prof Nigel Cook

Schools: Chemical Engineering and Advanced Materials, and Civil, Environmental and Mining Engineering

Research Partners: Curtin University, University of Tasmania

International Research Partner: British Geological Survey

AuScope A3.33 Earth Imaging

Investigating National Collaborative Research Infrastructure Strategy infrastructure for the earth imaging capability at the University of Adelaide.

Sponsor: Department of Industry, Science and Resources, Australian Government, National Collaborative Research Infrastructure Strategy

Duration: 2018 to 2019

Funding: \$795k over two years

Chief Investigator: Prof Graham Heinson

School: Physical Sciences

Intelligent vision, sensing and data fusion for mining and exploration

Sponsor: Department of Industry, Innovation & Science, Australian Government Cooperative Research Centre Project

Duration: 2017 to 2020

Funding: \$800k over three years

Chief Investigators: Prof Chunhua Shen, A/Prof Damith Ranasinghe, Prof Nigel Cook

Schools: Computer Science, and Civil, Environmental and Mining Engineering

Industry Partners: Boart Longyear, SRA

Energy

Future Fuels Cooperative Research Centre (see page 18)

An industry-focused research, development and demonstration partnership enabling the decarbonisation of Australia’s energy networks.

Sponsor: Department of Industry, Science, Energy and Resources, Australian Government

Duration: 2019 to 2023

Funding: \$1.65m over four years

Chief Investigators: Prof Gus Nathan, Prof Peter Ashman, Prof Holger Maier, Prof Michael Young

Schools: Mechanical Engineering, Chemical Engineering and Advanced Materials, Civil, Environmental and Mining Engineering, and Professions

Research Partners: Deakin University, Royal Melbourne Institute of Technology, University of Melbourne, University of Queensland, University of Wollongong

Industry Partners: Australian Pipelines and Gas Association, Australian Gas Infrastructure Group, Energy Networks Australia, Energysafe Victoria, Gas Appliance Manufacturers of Australia, Jemena, Government of South Australia

More info: <https://www.futurefuelscrc.com/>

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

Australian and Chinese researchers/engineers from both nations’ renewable energy industries working together to address the scientific challenge of developing combined wind and wave- power generation technology, including the translational challenge of commercialising research outcomes.

Sponsor: Department of Industry, Innovation and Science, Australian Government

Duration: 2019 to 2022

Funding: \$624,130 over three years

Chief Investigators: Prof Ben Cazzolato, A/Prof Boyin Ding

School: Mechanical Engineering

Research Partners: University of Western Australia, Swinburne University of Technology, Commonwealth Scientific and Industrial Research Organisation

International Research Partners: Shanghai Jiao Tong University, Dalian University of Technology, China University of Mining and Technology, Nanjing University of Aeronautics and Astronautics, National Ocean Technology Center

Tectonic Geography of the World’s Oldest Petroleum Play, the McArthur Basin

This project examines effective ways increasing the success of extracting McArthur Basin hydrocarbon deposits (plays), which cover northern Australia, estimated to be more than one billion years old; it will create a ‘roadmap’ to help develop techniques to understand ancient petroleum systems, build capacity and expertise, and support exploration.

Sponsor: Australian Research Council Linkage Project

Duration: 2017 to 2020

Funding: \$1.75m over three years

Chief Investigators: Prof Alan Collins, Dr Juraj Farkas, Dr Stijn Glorie, Prof John Foden

School: Physical Sciences

Research Partners: University of Wollongong, Northern Territory Geological Survey

International Research Partners: Czech Academy of Sciences

Industry Partners: Santos Ltd, Origin Energy

Converting Sunlight Innovation Challenge

A project building Australia’s international partnerships in solar fuels research and innovation.

Sponsor: Australian Renewable Energy Agency – International Engagement Program

Duration: 2018 to 2021

Funding: \$550k over two years

Chief Investigator: Prof Gus Nathan

School: Mechanical Engineering

Research Partners: Commonwealth Scientific and Industrial Research Organisation, Queensland University of Technology

International Research Partners: Arizona State University, Swiss Federal Institute of Technology, Niigata University, Sandia National Laboratories

RESOURCES DASHBOARD

Note: Figures relate to the PRIF Consortium



CASE STUDY #1

IMER brainchild to be launched in 2020

The commitment to the new ARC Training Centre for Integrated Operations in Mining to be based at the University of Adelaide was a major win in 2019 for the PRIF Consortium (South Australian Premier’s Research and Industry Fund Research Consortia Program), whose goal is to unlock complex resources through lean processing.

The PRIF Consortium is a collaboration between the University of Adelaide, the University of South Australia, major industry partners and 15 mining equipment, technology and services (METS) companies. It is a \$14.1m (including in-kind contributions) project funded over four years by the fund, as well as primary partners BHP and OZ Minerals Ltd.

The Consortium team currently has 22 experienced researchers across engineering disciplines and computer science.

“The ARC Training Centre – created jointly through extremely competitive Australian Government and industry

backing – began with a novel concept for a new generation of students to accelerate digital transformation in the mining sector,” says Professor Nigel J Cook, Consortium Director.

“The Training Centre is an IMER brainchild and will examine how to optimise and integrate operations end-to-end across the mining-processing cycle so that resource value across the entire mining chain can be maximised,” he says. The value and productivity of ore deposits now need to be increased to exploit complex minerals, which are harder to mine or process since ‘easier’ resources have been depleted.

The Training Centre is due to open its doors in July 2020 and will cater for some 16 higher-degree students, plus eight post-doctoral scientists.

“IMER offers a streamlined portal for engagement with industry, building and nurturing relationships that translate to a commitment to new research and innovation,” says Professor Cook.

“IMER keeps the momentum going, including working with the State and Commonwealth Governments, also critical partners, and bringing the necessary expertise, time and patience to put it all together.”

Professor Cook says that, like so much of IMER’s work, the Consortium and the ARC Training Centre focus on uniting multiple disciplines to solve a common problem, then integrating results.

“This doctoral training centre is a pioneering win for the University of Adelaide, involving industry interaction and mutual collaboration, deliberately seeking to avoid silo-type comfort zones. It’s bringing together professionals in an exciting, different way of working.”

“The University’s institutes are essential vehicles for achieving larger-scale projects that might otherwise not happen,” explains Professor Cook. “There’s been a whole string of wins for IMER. The interdisciplinary nature of its work bridges the gap between schools here.”

For further information see <https://www.adelaide.edu.au/imer/integrated-mining-consortium/about>, or contact nigel.cook@adelaide.edu.au.

The Research Hub for Australian Copper-Uranium, established by the Australian Research Council in 2015 as part of the Australian Government-funded Industry Transformation scheme, also completed its last full year of activity in 2019.

“Clean copper concentrates are a core requirement for the minerals industry to increase efficiency and maximise revenue,” says Professor Nigel Cook, who is also Director of the ARC Research Hub for Australian Copper-Uranium.

Although there are many different options to process and refine copper ores, complex ores containing small amounts of uranium represent an additional challenge.

“It’s been revolutionary to assemble a genuinely multidisciplinary group of people working closely together, focused on ores and concentrates in South Australia, and looking for solutions to longstanding, and previously intractable issues.”

Together with three other universities – Flinders University, Monash University, and the University of Queensland, BHP Olympic Dam and the Department for Energy and Mining in South Australia, the Research Hub has worked on:

- diagnosing mineralogy
- tracking radioactivity through the processing plant

- developing methods for detection of extremely small concentrations, including with sensors on site
- testing to produce treatment alternatives that can be tailored to the requirements of end-users.

The Hub’s work directly gives the Australian mineral industry a technological advantage.

“The research has also been a catalyst to create a new Centre for Radiation Research, Education and Innovation (CRREI) at the University of Adelaide.

Building on collective expertise, CRREI will offer radionuclide analysis, the opportunity for new research collaborations, and will be a nexus for education and training for the wider community.”

For further information see <https://www.adelaide.edu.au/copper-uranium-research/> and <https://crrei.com.au/> or contact nigel.cook@adelaide.edu.au or CRREI Director antony.hooker@adelaide.edu.au.

HOW IMER HAS DRIVEN SUCCESS

IMER operates from the belief that industry-led, challenge-based interdisciplinary research is fundamental to future sustainable use and development of the world’s natural resources.

As part of the University of Adelaide – a member of the ‘Group of Eight’, Australia’s leading research universities – IMER supports research projects that address scientific, technological and environmental challenges.

Through dedicated efforts to win highly competitive funding from government and industry, IMER drives success for the energy, minerals and resources sector, and the University of Adelaide through:

- big research efforts (multi-million-dollar funded projects for local, national and global benefits)
- working together with research bodies such as the Australian Research Council, Cooperative Research Centres and Projects (CRCs and CRC-Ps) and the Australian Renewable Energy Agency (ARENA)
- the formation of the new ARC Training Centre and other University successes.

“We closely monitor government policy and what the large resources, mining and energy companies are doing, with a view to assessing whether the University can help,” says IMER Manager, Dr Chris Matthews.

“IMER can then reach out directly to offer interdisciplinary solutions. The immense challenges around sustainability and cost need to be tackled through collaboration – the merging of ideas, talent and appropriate funding.”

IMER does not provide a project funding model, but instead operates from the unique position of “bringing people to solve problems,” says Dr Matthews.

“IMER brings the academic or research experts together with interested industry partners and then works to secure funding or bids. It’s a continuing process of engaging both across the University, and externally. We’re a sort of portal for both directions.”

Interim Director Professor Michael Goodsite explains that IMER is a business investment of the University, which must generate at least a 7.5:1 return on investment. “It’s vital that we consider transparency and inclusivity for the benefit of our investors – including big business and government – and the University of Adelaide,” he says.

“The great benefit of a commercially focused institute like IMER is that it brings the right people together to achieve results that will help South Australia and the nation’s energy, mining and resources industries.”

HOW IMER HAS SUPPORTED THE SECTORS

The natural resources, minerals and energy sectors play a critical role in the South Australian and Australian economy, with fuels, ores and precious metals/gems our top three exports.

According to [World’s Top Exports](#), Australia shipped \$448.5 billion worth of goods around the globe in 2019, a 42.5% increase since 2015 and a 7.3% gain from 2018.

For these industries to survive and thrive in a lower carbon future, cutting edge research is needed to break through technological, practical knowledge barriers.

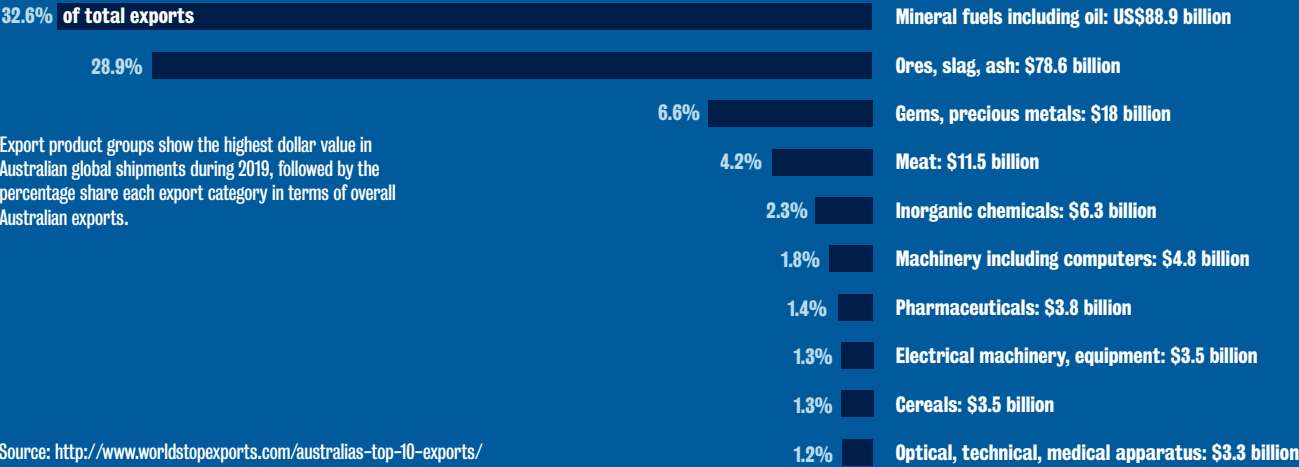
IMER brings to the University of Adelaide a strong focus on commercialisation, with industry connections and know-how.

“Teaching practice and research projects come out of this,” says IMER Manager, Dr Chris Matthews.

“IMER addresses the key challenges of the sectors through bringing new technology and ideas – the sorts of breakthroughs we share here in this report – to solve the ongoing challenges of depleting resources through lowering extraction costs, increasing productivity and efficiency,” he says.

“The mining industry needs to transform without losing time or disrupting work. Mining is a very expensive business, and although all companies worldwide want to ‘decarbonise’, research needs to have a direct and practical focus.

“There is now a universal mandate from shareholders that sustainability and lower carbon emissions are critical. Universities and commercially focused institutes like IMER play a fundamental role in bringing knowledge and clever new solutions to complex resources and energy problems.”





CASE STUDY#2

World-first capability with prototype in the University

Further breakthroughs with major impact for the mining industry

An exciting breakthrough was achieved in 2019 by the Fluorescence project supported by the Cooperative Research Centre for Optimising Resource Extraction (CRC ORE).

The centre is focused on optimising resource extraction with a goal to transform the minerals sector by developing innovative world-class technology to increase value across whole-of-mine systems.

Aiming for improving operational value and reversing the marked international trend of declining mineral productivity, other focus areas include reducing mining water and energy use, and CO₂ emissions by up to 20%.

“In 2019, we made strong progress, discovering ‘novel’ fluorescence signatures and showing their value in mining,” says Professor Nigel Spooner, Professor of Physics, and Head of the Prescott Environmental Luminescence Laboratory (PELL) at the University of Adelaide.

Professor Spooner leads the research collaboration, Environmental Luminescence Group, responsible for the breakthrough. His group has received funding from CRC ORE (for fluorescence), and the Australian Copper-Uranium Hub (for radionuclides in mineral processing).

The program sprang from a joint workshop held between IMER and the Institute for Photonics and Advanced Sensing (IPAS) in 2013, reviewing mining and mineral processing problems to raise awareness of opportunities for creating photonics-based solutions.

“The mining industry needs to know what minerals are in the rocks in order to process them,” says Professor Spooner.

“Light is playing a new role through our discovery of ‘novel’ fluorescence emissions from minerals – a process called ‘up-conversion’.

Our team at the University discovered that some minerals have a unique signature, so they can now be identified on a conveyor belt.”

This world-first capability has its prototype in the heart of the University, as a result of the 2019 special funding from CRC ORE. Industry partners, including mining companies and the Western Australian Government, have provided a further \$620,000 funding for a new project (CRC ORE P1-014) to develop this sensor as a prototype and test it in collaboration with local company, Scantech.

This important work also contributes to CRC ORE’s goal of maximising productivity to reduce the impact of the world’s declining ore grades.

“CRC ORE’s themes have been the subject of higher-degree studies here at the University through the contributions of scholarship and PhD programs, and a significant flow-on effect is the new ARC Training Centre. Lots of threads have come together to see the University of Adelaide recognised internationally as one of the strongest international training centres in mining.”

For further information see <https://www.crcore.org.au/>.

Professor Spooner says that two further exciting wins were achieved through the Research Hub for Australian Copper-Uranium. (See separate story on page 11).

“The first followed our breakthrough in detecting radioactive lead and polonium atoms on a micron spatial scale in mineral processing products, using a combination of alpha particle autoradiography and NanoSIMS.

“The second was the development of a new way of detecting alpha and beta radiation in real time in mineral processing solutions, using radiation-sensitive fibre-optic sensors,” he explains.

The team explored ideas hatched from old-school photography to discover a nuclear emulsion gel that shows the very low levels of radioactivity emanating from mineral samples.

“The impact of radioactivity in Olympic Dam and other sites around the world where crushed ores release multiple hazardous radionuclides has been a problem for decades,” says Professor Spooner.

“We revisited 1950s nuclear tracking technology and used photographic nuclear emulsion gel to ‘develop’ a 3D snapshot of alpha particles on the ore.

We achieved a ‘world first’ in imaging alpha particle tracks from mineral processing products, and tracing the tracks back to the tiny radioactive mineral grains emitting them. This opens the door to new ways of processing low-grade ore deposits that are radioactive, notably the difficult but high-value iron ore-copper-gold-uranium (IOCG-U).”

This was a powerful discovery that will have a major impact on the mining sector of the future, with vastly improved productivity and profitability.

“All this exciting work and our discoveries promote the University’s reputation as a centre of advanced mineral research, together with IPAS.

“IMER are the essential instigators and the motivators for all the players involved, by providing the real-world application problems to tackle, and IPAS brings the technology – I like to think of it as IMER providing the playground and IPAS bringing the toys,” says Professor Spooner.

A major 2019 spin-off from the PELL and the Australian Copper-Uranium Hub has also been the creation of the University of Adelaide’s Centre for Radiation Research, Education and Innovation (CRREI).

“BHP funded us to create a radionuclide analysis capability in Adelaide because of its vital significance to the future of useful minerals here,” explains Professor Spooner.

“Through the Copper-Uranium Hub’s use of BHP-targeted funding of just over \$1m, we now have leading-edge capability and state-of-the-art radiation measurement technology for research and commercial services.”

For further information see <https://www.adelaide.edu.au/copper-uranium-research/> and <https://crrei.com.au/>.

EVENTS IN 2019

IMER participated in or hosted the following events in 2019

Global Mining Guidelines Group (GMG) Adelaide Forum, 20-21 March 2019

Bringing the mining and energy industries together to achieve secure integration across the sector. Sponsored by IMER, Austmine, Department for Energy and Mining (Government of South Australia) and Dassault Systemes

Meeting Australian's Climate Change Targets: Price, Opportunity and Pathways, 29 April 2019

A public lecture hosted jointly by the Centre for Energy Technology (CET) and the Environment Institute

International Forum on Hydrogen Production Technologies (HyPT) 2019, 23 September 2019.

An international forum attended by 100 delegates including international and interstate visitors

International Mining and Resources Conference (IMARC), Melbourne, 28 October-1 November

IMER hosted a booth at Australia's largest mining event where global mining leaders connect with technology, finance and the future.

Attended by: Professor Peter Dowd, Dr Ley Chen, Dr Ruth Shaw, Dr Tatiana Khmeleva, Dr Amir Adeli, Dr Chris Matthews

Professor Peter Dowd presented 'Maximising productivity and reducing risk in the mining value chain: The South Australian response to these challenges'.

ARC Copper Uranium Transformation Research Hub 18 November 2019

Presented highlights and capabilities of the research hub, with 61 delegates. Companies such as BHP Olympic Dam, OZ Minerals, Worsley Chemapps, SIMEC Mining, InnovEco, Environmental Copper Recovery, JHRC Enterprises, MZ Minerals, Proxa Australia and SIMEC Mining were represented. Government representatives included the Hon David Fawcett, Senator for South Australia and SA Department of Energy and Mining, Department for Innovation and Skills, Environmental Protection Agency, and Victorian Government Department of Health and Human Services.

Attendees from research Institutions included Hiroshima University, Australia's Nuclear Science and Technology Organisation, University of Adelaide, University of South Australia, Flinders University, University of Queensland, Monash University, and National Nuclear Safety Administration of China.

2019 Memorial Luxton lecture, 21 November 2019

Theme of 'Avoiding the winners curse: How to manage Australia's energy transition', presented by Dr Alex Wonhas, Chief System Design and Engineering Officer with the Australian Energy Market Operator (AEMO).

Australian industry organisation memberships

- South Australian Chamber of Minerals and Energy (SACOME)
- AUSTMINE
- Coalition for Energy Efficient Commination (CEEC).

Australian board memberships

- Professor Michael Goodsite is a member of SACOME's Minerals Extractive, Energy and Petroleum Committees
- Professor Michael Goodsite is a Fellow of Engineers Australia and member of AusIMM
- Professor Gus Nathan is a member of the Energy Research Institutes Council for Australia (ERICA).

International board memberships

Professor Nigel Cook is section editor of Mineral Chemistry and Geochronology in the Minerals journal.

Professor Michael Goodsite is a Danish Minister-appointed member of the Danish National Energy Technology Development and Demonstration Program (EUDP).

THE DIGITAL REVOLUTION HAS ADVANCED THE TREND:

- towards harder-to-find and extract mineral deposits
- away from mining education and training in the traditional way
- towards shareholders' desires for lower company carbon footprints.

The University of Adelaide supports these trends through the PRIF Consortium, the ARC Training Centre, Heavy Industry Low-Carbon Transmission (HILT) CRC proposal, NEXUS annual summer school and uncover

HOW IMER PROVIDES VALUE TO THE UNIVERSITY

As one of seven research and innovation focused institutes, IMER exists both to advance knowledge and research to benefit the sectors of energy, minerals and resources, and to achieve the desired return on investment made by the University of Adelaide.

Interim Director, Professor Michael Goodsite has spent a good deal of time in 2019 engaging with stakeholders across the University of Adelaide to create a sense of "co-ownership" across the institutes, schools and faculties.

"We seek feedback and transparency as an investment in IMER's success as part of the University's Future Making strategy," he says.

"Research is essential but expensive. Industry funding is fundamental to the University's ability to explore cutting edge solutions, and because the large corporations no longer have internal research and development arms, IMER is in a strong position to deliver wins for everyone.

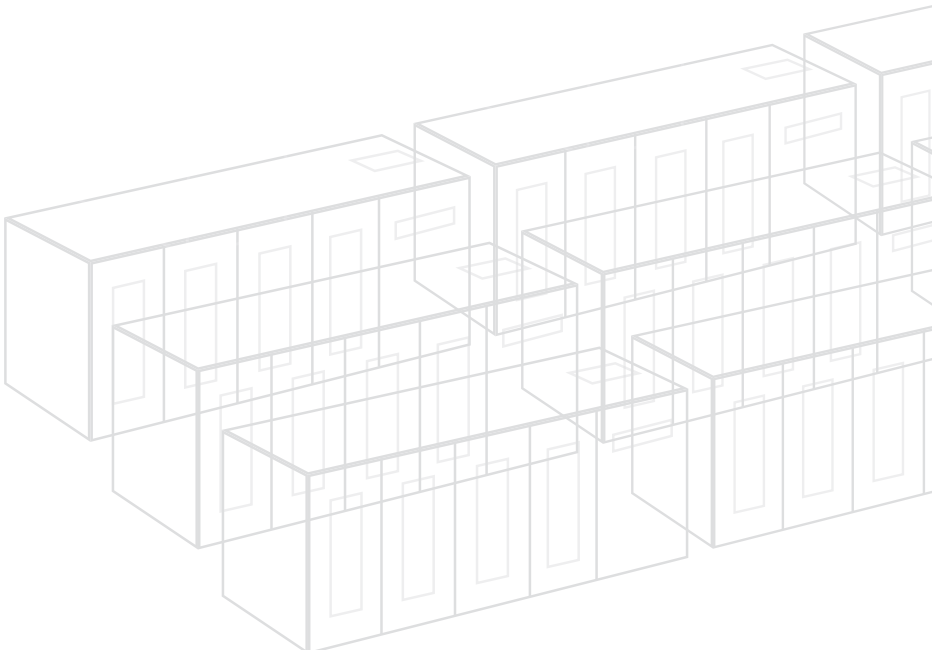
"Research and development are drivers for prosperity and growth, and is now more essential than ever before. Australia, like the rest of the world, is working towards an orderly, affordable and reliable transition to more sustainable energy resources.

"The best-prepared graduates to address global challenges are generally from universities with top research environments," says Professor Goodsite.

"The University of Adelaide has a solid reputation as a research leader, and IMER helps bring it all together – industry contacts and intelligence, research and project funding expertise, marketing and bid submission skills – plus our time and efforts to genuinely collaborate for the greater good."

IMER's projects and outcomes feed into the University's teaching and research capabilities, fuelling interdisciplinary synergies and strengthening the University's ability to achieve its strategic plan and budgeting.

"The institutes are about championing people and their research," says Professor Goodsite. "In this 2019 report, we've taken the opportunity to speak with researchers in each sector about the successes that have contributed to IMER's outcomes this year."



ENERGY DASHBOARD

Note: Figures relate to Future Fuels CRC



CASE STUDY #3

Research with impact: Energy

The Future Fuels Cooperative Research Centre (FF-CRC), in partnership with Australia’s multi-billion-dollar energy, gas and pipelines sector, works towards a low-carbon future through exciting developments with hydrogen and bio-derived gas.

Both ‘green hydrogen’ and ‘biogas’ are expected to play a growing role in transforming Australia’s natural gas pipeline for a new low-carbon economy. The FF-CRC, as the leading national research and development entity of the pipelines industry, is guiding this transition while also contributing to the National Hydrogen Strategy.

Through Professor Mike Young’s team in the Centre for Global Food and Resources, Faculty of the Professions, in 2019 the FF CRC completed the first meta-study of all national hydrogen ‘road maps’.

Similarly, Dr Neil Smith in our Engineering team, is undertaking testing of domestic appliances, while

Prof Bassam Dally is leading a similar program for industrial hydrogen burners. Both of these initiatives will help to remove the risk of introducing hydrogen into domestic and industrial applications.

Together these activities support the CRC’s goal to ‘de-risk’ the introduction of hydrogen into the existing 120,000-km pipeline network throughout Australia.

“Producing green methane from biogas – rather than fossil fuels – will also play an important role in meeting international greenhouse targets, through providing a competitive, low-carbon energy alternative for residential, commercial, industrial and/or transport sectors,” says University of Adelaide’s Professor Gus Nathan, director of the Centre for Energy Technology (CET).

Professor Holger Maier from the School of Civil, Environmental and Mining Engineering is leading an investigation seeking to identify cost-effective investments into the supply chain for these systems.

“Bio-derived methane has the advantage of requiring no change to either the pipeline or end-use appliances. It can also use commercially available digesters and purification technology,” says Professor Nathan.

“There are also challenges though, associated with the way resources are distributed and the investment needed to harness them, so new analysis aims to unlock the potential.”

Using matter commonly either dumped or underutilised, the CRC partners with multiple investors to replace up to 30% of Australia’s gas pipeline network with biomethane.

“Another option to ‘decarbonise’ is to convert hydrogen to methane – using ‘power to gas’ technology that uses ‘surplus’ renewable electricity,” he says.

“The CRC is evaluating which combination of the available options for ‘green’ pipeline fuels makes the most sense and is the most viable.”

The FF-CRC also leverages a core focus of the University’s Centre for Energy Technology, by addressing pathways to decarbonise ‘heavy industry’ – producers of alumina, iron and cement.

“Since these users are large consumers of natural gas, the FF-CRC is offering new opportunities for them. IMER also plays an important role in bringing together some of these major players,” says Professor Nathan.

“There’s a strong synergy between green hydrogen and decarbonising the heavy industry sector. So this field of work aligns strongly with IMER’s wider focus of driving the transition to sustainable, high-value mineral products.”

By establishing major new initiatives in the application of hydrogen to minerals processing, in addition to hosting forums and think-tanks, and seeding new ideas, IMER provides critical support. This includes engaging partners and using advisory boards to drive challenges and opportunities.

During 2019, IMER supported both the hosting of the novel Hydrogen Production Technologies (HyPT) forum and the preparation for the second HiTeMP.

The HyPT forum, attracting more than 100 delegates from around world, was held as a joint initiative with the international HySafe conference, also sponsored by IMER.

HyPT engaged multiple stakeholders to consider the complementary role that different types of hydrogen production technology are expected to play in lowering the cost of green hydrogen.

A major deliverable in 2019 for the HiTeMP forum was publishing the Outlook Report, which synthesises key perspectives on the pathway to carbon-neutral metals and other energy-intensive industrial products such as cement.

IMER also assisted with the 2020 forum, set to examine how key technologies such as green hydrogen, green electricity, solar thermal and refuse-derived fuels can be further developed and commercially implemented on an industrial scale.

“We’re excited to see two new patented technologies developed by the University of Adelaide,” says Professor Nathan. “One patent from the Department of Chemistry has demonstrated successful hydrogen production through a lab-scale reactor. The second patent from our School of Mechanical Engineering has demonstrated a ‘bubbling molten metal’ patent for low-cost hydrogen production.”

The CRC’s work has fed into University of Adelaide postgraduate programs, growing research programs and training in working with hydrogen.

Collaborating with over 60 companies, six universities, the energy market operator and two regulators, low-carbon fuels offer increasing potential to store and deliver reliable, clean, secure, and affordable energy to Australian consumers.

The Future Fuels CRC is supported by \$26m in funding from the Australian Government and some \$65m of cash and in-kind funding from industry and universities over its seven-year life.

Using matter commonly either dumped or underutilised, the CRC partners with multiple investors to replace up to 30% of Australia’s gas pipeline network with biomethane.

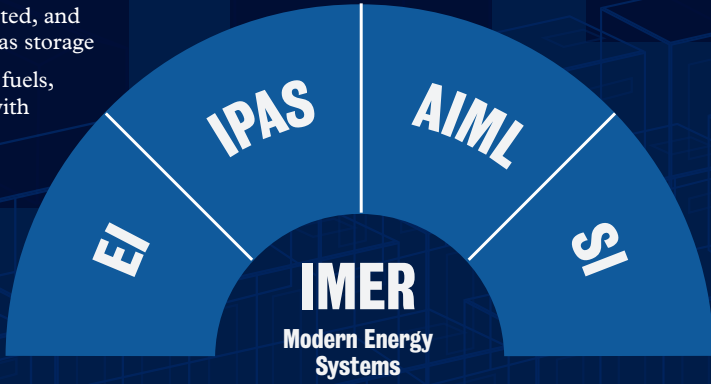
For further information see <https://www.futurefuelscrc.com/> about partners at <https://www.futurefuelscrc.com/about/participants-and-partners/> and about the HiTeMP Forum 2 <https://www.adelaide.edu.au/imer/news/list/2020/01/30/hitemp-2-forum-be-part-of-the-conversation-to-transition-high-temperature>

IMER OF THE FUTURE

We use the phrase ‘Modern Energy Systems’ to encompass the energy systems required for decarbonisation and the transition to a net-zero emissions energy future, including:

- the raw materials needed to generate and transmit renewable electricity
- renewable energy generated, and grid requirements, such as storage
- decarbonising transition fuels, such as gas (compared with coal) and carbon sequestration.

The relationship between five of the University of Adelaide’s research institutes, showing IMER’s core business of ‘modern energy systems’.



- EI: Environment Institute
- IPAS: Institute for Photonics and Advanced Sensing
- AIML: Australian Institute for Machine Learning
- SI: Stretton Institute
- IMER: Institute for Minerals and Energy Resources
- ECMS: Faculty of Engineering, Computer & Mathematical Sciences

IMER is strongly positioned for the next chapter in South Australia’s future



Critical Minerals Initiative (Spandler et al.)	Energy & Climate Change Policy (Khurana et al.)	Low Carbon Heavy Industry Including H ₂ (Nathan et al.)
Gas (CH ₄) in the Transition & CO ₂ Sequestration (ASPER)	Mining Chain Energy and Optimisation (Dowd et al.)	Power, Storage, Transmission & Renewable Energy (ECMS)
Advisory Board energy/mining nexus	SA 2030 Target Emissions 50% 2005	SA Hydrogen Action Plan
SA Mining & Energy State GSP*	Draft Commonwealth Technology Innovation Roadmap	Department of Foreign Affairs & Trade Mission Innovation

ECMS CAPABILITY

- power engineering
- energy supply
- energy vectors
- energy storage
- modelling energy systems
- sustainable energy systems
- energy cybersecurity

There are six core focus areas (activities) for 2020 and beyond. IMER will continue to be a catalyst for research into sustainable energy and resource extraction/maximisation through research and development as drivers for growth and change.

* South Australian Government Sector Growth Plan for Energy and Mining

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UNIVERSITY OF ADELAIDE IMER MEMBERS

28	School of Physical Sciences	8	School of Biological Sciences
27	School of Mechanical Engineering	4	School of Economics
25	School of Computer Science	3	School of Mathematical Sciences
21	School of Chemical Engineering & Advanced Materials	2	Centre for Global Food and Resources
21	School of Civil, Environmental and Mining Engineering	2	Adelaide Business School
20	Australian School of Petroleum and Energy Resources	2	School of Agriculture, Food & Wine
17	Professional Staff	2	Adelaide Law School
10	School of Electrical and Electronic Engineering		

CENTRES THAT OPERATE WITH IMER

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

AWARDS IN 2019

South Australian Government Premier's Awards – 2019 Finalist Young Achiever Award

Recognising excellence demonstrated by leading resources and energy sector organisations to improve the economic, environmental, health and social wellbeing of South Australian communities.

Recipient: Thomas Bruning, PhD Candidate, School of Civil, Environmental and Mining Engineering, University of Adelaide for his work on rockburst processes and mechanisms in hard rock mining, focusing on better calibration and validation processes in constitutive modelling.

OZ Minerals Explorer Challenge

Modern mining company OZ Minerals partnered with energy and resources open innovation platform Uearthed to deliver this unique, online crowdsourcing competition. It involved the challenge and accompanying data being made available digitally to geologists, geoscientists and data scientists from around the world, who then competed to deliver the best solution.

Recipient: University of Adelaide Team 'DeepSightX' was placed second, winning \$200,000

Team members: Dong Gong, Javen Qinfeng Shi, Zifeng Wu, Hao Zhang, Ehsan Abbasnejad, Lingqiao Liu, Anton van den Hengel, Karl Hornlund, John Anderson and Chris Matthews..

The DeepSightX team exploited multi-disciplinary skills at the intersection of artificial intelligence and geoscience. Researchers from the Australian Institute for Machine Learning (AIML) and IMER collaborated with industry experts in minerals exploration (Austrike Resources) and geoscientific modelling (Gondwana Geoscience).

DeepSightX used a multidisciplinary approach to generate an AI model, DeepSight, which provides promising exploration targets in the Prominent Hill Region (PHR) supported by best practice geoscience.

Inaugural Vice-Chancellor's Award for Excellence in Research, University of Adelaide

Recipient: Professor Shizhang Qiao, School of Chemical Engineering and Advanced Materials

Professor Qiao is the Director of the Centre for Materials in Energy and Catalysis. His research expertise is in nanomaterials and nanoporous materials for new energy technologies (electrocatalysis, photocatalysis, batteries, fuel cell, supercapacitors).

Australian Star of Research (Lifetime Achievers Leaderboard), 2019

Awarded by The Australian newspaper

Recipient: Professor Shizhang Qiao, School of Chemical Engineering and Advanced Materials. Professor Qiao was awarded this prize for his research interests in synthesis and characterisation of nanomaterials.

University of Adelaide Institute for Photonics and Advanced Sensing 2019 Scientific Outreach Award

Recipient: Dr Ruth Shaw for her work on the highlights and capabilities of the Research Hub for Australian Copper Uranium event (see page 11, 15).

Australian X-ray Analytical Association Student Seminar Prize

Recipient: ARC Industry Transformation Research Hub for Australian Copper-Uranium Postgraduate student Alok Chaudhari from Monash University. (Alok is a PhD student from the ARC Industry Transformation Research Hub for Australian Copper-Uranium).

University of Adelaide Dean's Commendation for a PhD thesis

Recipients: Danielle Schmandt and Mark Rollog, two students from the ARC Industry Transformation Research Hub for Australian Copper-Uranium higher-degree research students

University of Adelaide Medal

Recipient: William Keyser (higher-degree research student, FOX project) for his PhD thesis, 'Mineralogy and geochemistry of Precambrian banded iron formations of the Middleback Ranges, South Australia'

Highly cited researchers connected to IMER in 2019

Professor Shizhang Qiao and Dr Yan Jiao from the Centre for Materials in Energy & Catalysis

Recognising the world's most influential researchers of the past decade, demonstrated by the production of multiple highly-cited papers that rank in the top 1% by citations for field and year in Web of Science:

'Design of electrocatalysts for oxygen and hydrogen-involving energy conversion reactions'

Published in Chemical Society Reviews, Volume: 44, Issue: 8, Pages: 2060-2086, DOI: 10.1039/c4cs00470a, times cited 1752

'Sulphur and nitrogen dual-doped mesoporous graphene electrocatalyst for oxygen reduction with synergistically enhanced performance'

Published in Angewandte Chemie-International Edition, Volume: 51, Issue: 46, Pages: 11496-11500, DOI: 10.1002/anie.201206720, times cited 1374

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Published June 2020 IL
CRICOS 00123M

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