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The University of Adelaide

Institute for Mineral and Energy Resources

Annual Report 2016

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seekLIGHT

IMER

Building teams of specialist problem solvers - with experts across disciplines and partner companies from around the globe.

The Institute for Mineral and Energy Resources (IMER) is part of the University of Adelaide and is the principal point of contact for mineral and energy resources research, including industry and government partnerships.

We believe that industry-led, challenge-based research is key to the sustainable use and development of the world's resources. Our research addresses scientific, technological, environmental and social challenges.

IMER's key role is to assemble interdisciplinary teams from the University of Adelaide and research partners to address global challenges in:

- **Deep resources**
- **Deep mining**
- **Complex processing**
- **Tight energy resources**
- **Low cost, low emissions energy**

As a member of the *Group of 8*, Australia's eight leading research universities, the University of Adelaide attracts some of the world's top researchers. Our strengths are in geology, geophysics, petroleum engineering, mining engineering and energy technology.

These centres are at IMER's core:

Centre for Tectonics, Resources and Exploration

Centre for Energy Technology

South Australian Centre for Geothermal Energy Research

Some of the University of Adelaide's faculties and schools involved with IMER include: from the Faculty of Engineering, Computer and Mathematical Sciences: School of Mechanical Engineering, School of Chemical Engineering, Australian School of Petroleum, School of Electrical and Electronic Engineering, School of Civil, Environmental and Mining Engineering, and School of Mathematical Sciences; from the Faculty of Sciences: School of Physical Sciences; and from Faculty of the Professions: Adelaide Business School and the Entrepreneurship, Commercialisation and Innovation Centre.

The University of Adelaide is also a leading research and postgraduate training facility for the mining and energy sectors in the Asia-Pacific region.

146 STAFF

16 BOOK CHAPTERS

533 JOURNAL ARTICLES

189 CONFERENCE PAPERS

149 STUDENTS

70 PHDs COMPLETED

10 MASTERS DEGREES COMPLETED

Contents

Acting Deputy Vice-Chancellor and Vice-President (Research) report

Professor Julie Owens

In 2016 the University launched *Adelaide Research for Impact*, our research strategic plan to generate local, national and global impact. IMER is already delivering outcomes in line with this strategy through its work to ensure the growth and sustainability of our mineral and energy resource industries.

There is no doubt that the interdisciplinary teams that IMER brings together are having an impact on the world stage across the four key themes of Adelaide Research for Impact:

- **Adelaide Excellence – Research excellence, delivering world-class research**

  IMER is a leader in internationally significant projects like the Australian Solar Thermal Research Initiative, ARENA Solar Thermal for Alumina, and the Iron Oxide (FOX) Research Program.

- **Adelaide Innovation – Industry engagement and innovation**

  IMER regularly partners with industry to bring innovation to the mineral and energy resource sectors. The ARC Research Hub for Australian Copper-Uranium with industry partners BHP and OZ Minerals is a great example of this in action, and directly feeds into South Australia's Copper Strategy.

- **Adelaide Global – Global partnering, engagement**

  IMER has relationships with global companies including BHP and Chevron, and with universities like ETH Zurich, one of the top five engineering universities in the world. Professor Stephen Grano's important work engaging with industry, including members of the Canadian Ultradeep Mining Network, promotes our capabilities on the world stage.

- **Adelaide Enabled – High-performance culture and capacity**

  Although in a traditionally male-dominated field, IMER works towards gender equity by incorporating funding for women in STEM within research proposals. Programs like NExUS (see the IMER Engagement section) also help ensure that IMER's legacy continues, by training the next generation of outstanding industry professionals.

I congratulate IMER for its many achievements this year, and I am pleased to present this report which offers a glimpse of their expertise.

Executive Director's report

Professor Stephen Grano

In 2016, we made significant achievements in addressing the five global challenges that form our priority research areas: deep resources, deep mining, complex processing, tight energy resources and low cost, low emissions energy. Our strategy to deliver large-scale projects within these areas is on track, with 45 significant projects under way.

We made a strategic move into the research areas of sensors, data analytics and process optimisation for the mining sector and commenced a major project in locating subsurface permeability for the hydrocarbon and geothermal sectors.

We have consolidated a number of projects with new funding to extend their lives and increase value and impact. One of these is the nationally significant AusLAMP, aimed at mapping the geological architecture of our continent, and assessing where new large-scale mineral systems might exist. Another injection of funds was contributed by industry for a new laboratory that will service the already established ARC Research Hub for Australian Copper-Uranium (see Case Study #5).

We've continued to engage with ARENA, Australia's peak government organisation on clean energy technology, the METS Ignited Industry Growth Centre and the National Energy Resources Australia (NERA) Industry Growth Centre.

This year we developed two highly-rated applications for the Premier's Research and Industry Fund (PRIF), Research Consortia Program:

- *Sustainable and secure energy systems to power the new economy*
- *Unlocking complex resources through lean processing*.

Each bid involved as many as 25 different parties. Their development is a testament to IMER's research expertise, engagement skills, and ability to assemble interdisciplinary teams after many years of relationship building with colleagues and industry. I'd like to thank the IMER team for their incredible work on these applications.

This is our strength – bringing together interdisciplinary teams to solve problems for industry – and I am confident IMER members will continue to connect and innovate in the years to come.

IMER Advisory Board Chair's report

Mr Andrew Stock

The dire need for solutions to what Australia's Chief Scientist Dr Alan Finkel called the 'Energy Trilemma' – secure, affordable and sustainable energy for the long term – created a paradigm shift in 2016.

We've seen a convergence of gas, fuel and electricity markets, with coal power stations closing due to their inability to compete and the cost of wind and solar power continuing to fall. IMER, and in particular the Centre for Energy Technology (CET), was well-prepared for these shifts, having already begun responding to these global challenges.

Research within the Australian Energy Storage Knowledge Bank program is helping us to understand the use of battery energy storage under Australian conditions, which has major implications for the future use of renewable energy within our electricity mix. Solar thermal technologies, particularly our solar thermal hybrid projects, will help industry transition from black to clean energy, and IMER's new solar simulator laboratory is unique in the world. Our research on next generation solar thermal technology will help reduce our reliance on coal and natural gas, as exemplified by the Solar Thermal for Alumina $15 million project with Alcoa. We are also working to develop new fuels, and even carbon negative fuels, to reduce carbon emissions.

Efficiency and optimisation within the mining and energy sectors will most likely come via automation, machine learning, sensor development and large-scale data analytics. IMER's research teams, drawing on computer scientists, engineers and artificial intelligence experts are helping to:

- develop cost-competitive and safer mines, by working towards the integration of new sensing and data analytics technologies
- secure energy delivery, through battery storage and grid testing facilities
- develop more competitive mining equipment and technology services (METS) through our involvement in the METS Ignited Industry Growth Centre.

This year, more than ever, we've seen the value of IMER's Advisory Board as rapid changes in the energy and technology sectors have signalled major research shifts. I'd like to thank the Board members for their support and commend IMER members for their foresight and research contribution throughout the year.

Research Funding

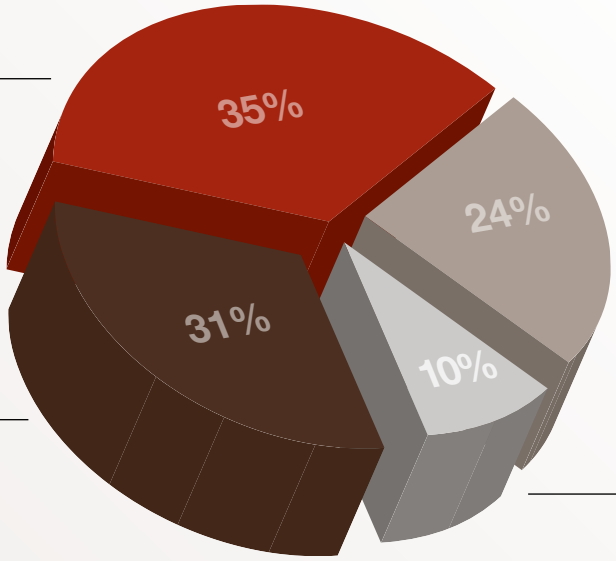
In 2016 IMER received over $13.7 million of external funding from new and continuing multi-year grants. Although IMER is successful in obtaining nationally competitive research grants, it is also telling that more than 20% of external funding comes from industry.

Category 1

Nationally competitive research grants
$4,920,889

Category 2

Other public sector funding
$4,238,015



Category 3

Australian industry, donations and international grants
$3,226,254

Category 4

Cooperative research centres
$1,323,586

Industry Trends

Deep resources

The global demand for mineral resources is increasing. This is due in part to the growth in world population, currently at 7.5 billion and growing at 1.1% or 80 million per year[1]. It is also due to middle class cohort expansion in the 85% of the world's population living in developing countries, particularly in China and India[2].

RENEWABLE ENERGY SOURCES[4]

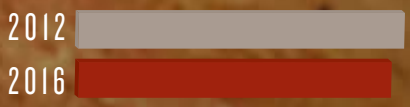
4-12x MORE COPPER REQUIRED THAN FOSSIL FUEL BASED POWER GENERATION

UP TO 4x MORE COPPER REQUIRED FOR ELECTRIC CARS THAN TRADITIONAL CARS

7-10 MILLION TONNES OF COPPER FOR SOLAR POWER GENERATION IS PREDICTED TO BE REQUIRED BY 2030

DECLINES IN MINERAL EXPLORATION AND PRODUCTION

GLOBAL PRODUCTION OF REFINED LEAD (MILLION TONNES)[6]



GLOBAL MINE PRODUCTION OF REFINED ZINC DECLINED SLIGHTLY IN 2016 TO 12.8 MILLION TONNES[6]

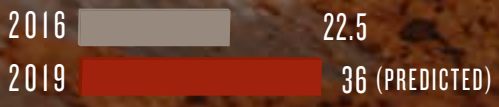
AUSTRALIAN COPPER EXPLORATION FELL BY 26% TO $121 MILLION IN 2015[7]

One mineral resource in particular demand is copper, driven by its use in building construction, infrastructure and technology[3]. The global move towards renewable energy is also a major driver of copper demand due to its role in the energy and transport sectors[4]. Even taking into account the expected growth in global copper production, global supply is not expected to be able to keep up with demand, and deficits are predicted.

These trends of growing demand while supply becomes more difficult and costly mean that prices are predicted to increase over the medium to long term. With its rich mineral resources, Australia will remain an important global player, with minerals continuing to be an important part of our economy.

GLOBAL COPPER PRODUCTION[5]

MILLION METRIC TONNES

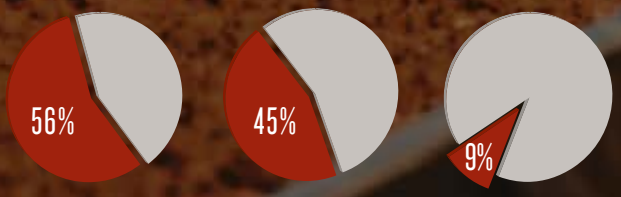


DEFICITS OF 150,000 METRIC TONNES IN 2017 & 170,000 TONNES IN 2018 (PREDICTED)

While global demand for minerals continues to grow, supply has remained relatively stagnant. Mineral resources are getting harder to find as shallow bodies are exploited, requiring deeper mines that are more complex and costly, and come with greater risk.

IMPORTANCE OF AUSTRALIA'S MINERAL EXPORTS TO THE ECONOMY

AUSTRALIA'S MINERAL EXPORTS APPROXIMATELY $141 BILLION IN 2015 (EXCLUDING PETROLEUM PRODUCTS)



EXPORT MERCHANDISE

EXPORTED GOODS & SERVICES

GROSS DOMESTIC PRODUCT

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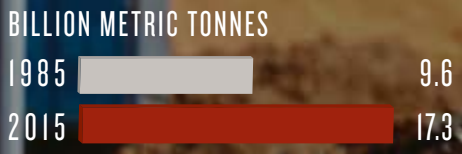
Industry Trends

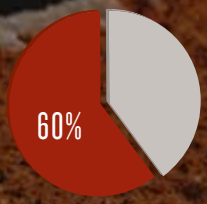
Deep mining and complex processing

Global mine production rates have increased over the past 30 years[1]. However, growth has not been in steady increments, with plateaus in the 1990s, and a more recent slowing in production.

GLOBAL MINE PRODUCTION RATES[1]



AUSTRALIA IS A GLOBAL LEADER IN MINING INNOVATION



PRODUCED MORE THAN 60% OF THE WORLD'S MINING SOFTWARE[6]

MORE THAN 6500 INVENTIONS IN THE MINING SECTOR FROM 1994 TO 2011[6]

RECENT SLOWING IN GLOBAL MINE PRODUCTION[1]

GROWTH FROM 2013 TO 2015

AVG. ANNUAL GROWTH OVER THE PREVIOUS 28 YEARS

The recent slowing of mine production reflects many factors. Mining is becoming logistically and technically more complex. As the resources closer to the surface are exploited, deeper resources must be sought requiring more challenging and expensive processes. Production is also being affected by decreasing ore grades, increasingly complex mineral systems and a shortage of suitably qualified people.

As mining becomes more complex and worker safety becomes paramount, mines are becoming more automated. One of the key trends making this possible is the Fourth Industrial Revolution, where networks of computers, devices and objects are able to collect, share and analyse large amounts of data more efficiently and at greater speeds[2]. The benefits of Industrie 4.0 for the mining industry promise to be improved safety and accuracy rates, predictive maintenance and cost and time and energy savings[3]. Another feature of Industrie 4.0 is the use of sensors to generate large amounts of data that can be analysed in real time and translated into actions for equipment operators[4]. Benefits include improved performance and productivity and the elimination of unnecessary costs, waste and machinery failures[4].

These trends have the potential to create mines of the future that operate very differently from today. Mines may become so technically advanced that they operate deep underground, yet are controlled remotely by highly skilled people[5]. The Australian mining sector is well placed to benefit from these trends as a global leader in new mining innovations[6].

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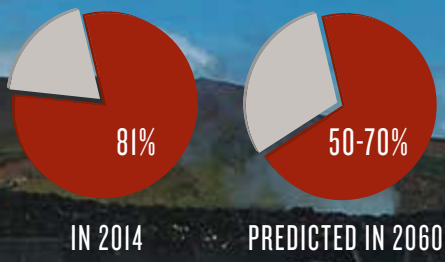
Industry Trends

Tight energy resources

The world remains dependent on petroleum and petroleum derived products. Driven by industrialisation and petrochemical production, resulting in massive global demand, oil and gas production continues to grow. Despite predicted growth in non-fossil energy sources, fossil fuels are expected to contribute a significant portion of global energy in 2060[1].

PETROLEUM AS SOURCE OF GLOBAL ENERGY[1]



OIL PRODUCTION

ENHANCED OIL RECOVERY (EOR)

PLASTICS PRODUCTION

Global demand for petroleum and petroleum based plastics will continue to increase, due to the world population of 7.5 billion growing at a rate of 1.1% or 80 million per year[5], and as the 85% of the world's population who live in developing countries increase energy demand through class advancement.[6]

While the demand for petroleum grows, petroleum resources are becoming more costly to find and efficiently extract. As with minerals, the most accessible resources have been exploited, requiring deeper and more complex resources to be extracted. As a result, the focus is now on maximising extraction from existing fields as a way of reducing costs and risks.

To improve recovery, there is a need for advanced data analytics to enable better insight into the resources and how to maximise their extraction. There is also a focus on Enhanced Oil Recovery techniques that increase the amount of crude oil extracted from an existing oil field[7]. Current techniques include thermal recovery, gas injection and chemical injection that allow increased extraction of oil compared to traditional methods.[8,9]

Facing similar challenges of economically and sustainably developing deep underground resources, geothermal energy offers the potential for clean, renewable energy by harvesting the earth's heat. This heat can be used in many ways including generating electricity, direct use to desalinate seawater, and heating and cooling of buildings[10]. Successful and sustainable exploitation of geothermal energy is a global challenge.

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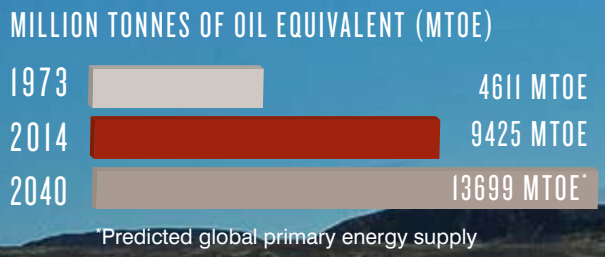
Industry Trends

Low cost, low emissions energy

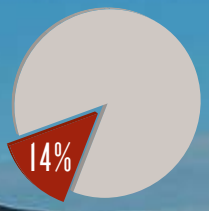
Countries around the world are moving towards a more sustainable, low emissions future[1]. As the largest end-use consumer of delivered energy globally, the industrial sector has both the opportunity and responsibility to maximise the environmental and economic benefits of this shift.

GLOBAL CONSUMPTION OF ENERGY[2]



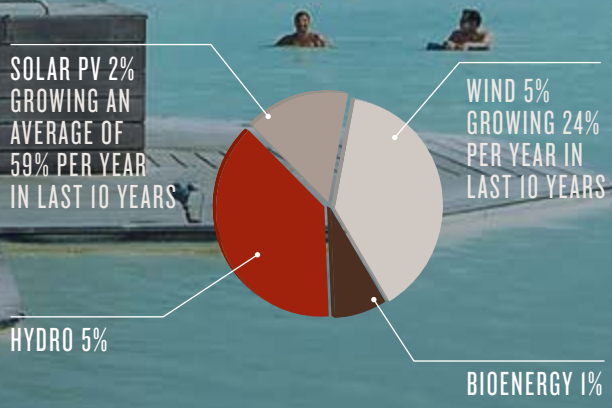
*Predicted global primary energy supply

AUSTRALIAN RENEWABLE ENERGY[4]



OF TOTAL GENERATION IN 2014-15
GROWING AN AVERAGE
OF 5% PER YEAR IN 10 YEARS

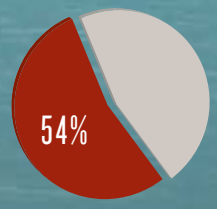
AUSTRALIAN RENEWABLE ENERGY SOURCES[4]



Other emerging energy sources include:

- biofuels, which are predicted to reach US$57.8 billion gallons by 2020[7]
- concentrated solar thermal (CST) energy, which was a relatively new technology 10 years ago, is now reliable and could meet up to 12 per cent of the global projected power needs in 2050[8]
- hydrogen and derivatives, which are able to be stored and transported in liquid or gas form, and could offer supply security for renewable energy networks enable energy to be redistributed effectively[9].

GLOBAL ENERGY CONSUMPTION OF THE INDUSTRIAL SECTOR[3]



OF GLOBAL DELIVERED
ENERGY USED IN 2012
AVERAGE GROWTH OF
1.2% PER YEAR PREDICTED

Fossil fuels provide the majority of global energy, representing 81.1 per cent of global supply in 2014[2]. Petroleum and other liquid fuels are predicted to remain the largest source of energy, 30 per cent in 2040[3]. Coal is predicted to have the largest decline, from 40 per cent of total generation in 2012 to a still-significant 29 per cent in 2040[3].

There is potential for renewables to play a much larger role in global energy supply compared to the 14.1 per cent supplied in 2014[2]. Under the 450 Scenario, based on policies needed to limit global atmosphere CO_2 levels to 450 parts per million and to limit the average temperature increase to 2 degrees Celsius to meet the low carbon future envisioned in the Paris Agreement[1], renewables could contribute nearly 60 per cent of power generated in 2040[2]. Almost half of this could come from wind and solar PV[2].

With global expenditure on energy at 6 trillion USD (10 per cent of world GDP) in 2011 and increasing[5], reaching the 450 Scenario would mean that the global renewable energy market's revenue of $476.3 billion in 2014 will need to increase exponentially[6]. New technologies are required for efficient batteries, for energy storage and to manage networks and grids with increasing levels of intermittent renewable energy.

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IMER's research

IMER facilitates interdisciplinary initiatives aligned to global challenges by:

- assembling **interdisciplinary teams** from across the University of Adelaide and external partners
- forging **strategic relationships** between researchers and industry, including international research institutions and industry
- supporting research leadership by investing in **strategic research initiatives** that leverage new funding and build capability for high quality research outputs
- increasing the number, scale and success rate of national competitive **grant applications** to build research capability and capacity.

Key principles

IMER's mission encompasses the key principles:

- **Interdisciplinary research** – brings together the disciplines of science, engineering, professions and humanities to address globally significant challenges
- **Global recognition** – positions the University of Adelaide to be a leading research university by world standards
- **Fundamental and applied research** – recognises the critical importance of fundamental research to underpin applied research which will directly address State and global challenges
- **Innovation** – recognises the importance of step-change research and the breakthroughs required to make a positive and lasting impact on State, National and Global communities
- **Outreach** – recognises the importance of communication in all its forms to maintain mutually beneficial relationships between the University of Adelaide, industry and society.

Our principles in action

Here you can see IMER's principles in action, with a sample of our interdisciplinary projects presented across the five global challenges. The teams have been built by IMER in concert with industry, in direct response to their needs.

Hover your mouse over each **case study** below to highlight in the table opposite research fields involved. Note that some case studies address more than one challenge.

Click on an icon to read more.

Case studies

Deep resources

Case Study #1:
MT for mineral discovery

Case Study #2:
Gold sensing at ppb level using optical methods

Deep mining

Case Study #3:
Choosing the right injection fluids just got easier

Case Study #4:
Shaping South Australia's copper future

Complex processing

Case Study #5:
New radiation sensitive research for the Prescott Laboratory

Case Study #6:
New partnerships in IIoT and sensors for minerals processing

Tight energy resources

Case Study #7:
De-risking geothermal exploration ahead of drilling

Case Study #8:
Gas production from deep coal seams

Low cost, low emissions energy

Case Study #9:
Hybrid Solar Receiver Combustor (HSRC)

Case Study #10:
Photocatalysis moved along the TRL scale

Challenges

	Deep resources	Deep mining	Complex processing	Tight energy resources	Low cost, low emissions energy
Chemical engineering	■	■	■	■	■
Chemical sciences	■	■	■	■	■
Community engagement	■	■	■	■	■
Computer science	■	■	■		
Data analytics	■	■	■	■	■
Earth science	■	■	■	■	■
Economics	■	■	■		
Electrical / electronic engineering	■	■	■		■
Energy systems	■	■	■	■	■
Environmental science and management	■	■	■	■	■
Fuel technology		■	■	■	■
Functional materials	■	■	■	■	■
Geochemistry	■	■	■	■	■
Geology	■	■	■	■	■
Geomechanics	■	■	■	■	■
Geophysics	■	■	■	■	■
Geostatistics	■	■	■	■	■
Hydrogeology	■	■	■	■	■
Machine Learning	■	■	■		
Materials engineering	■	■	■	■	
Mathematical sciences	■	■	■	■	
Mechanical engineering	■	■	■		■
Microscopy	■	■	■	■	■
Mineralogy	■	■	■	■	■
Mining engineering	■	■	■	■	■
Nanotechnology	■	■	■	■	■
Optics and photonics	■	■	■		
Petroleum engineering	■	■	■	■	■
Physics	■	■	■	■	■
Sensors	■	■	■		

Deep resources

Shallow resources are now harder to find. Explorers must look deeper for mineral systems hidden beneath extensive rock cover.

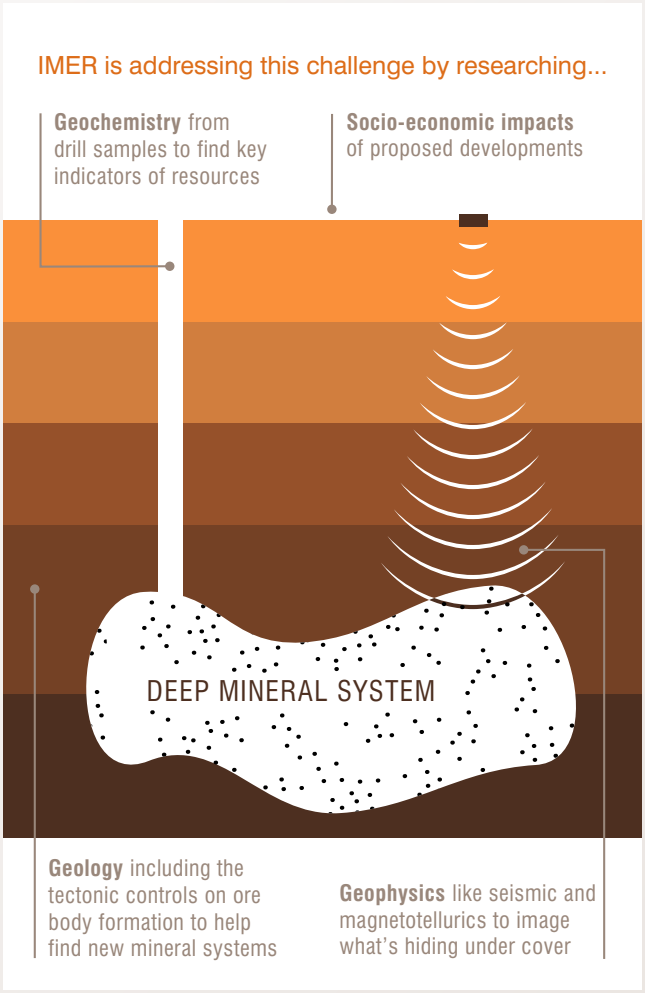
Global demand for minerals resources such as copper has never been higher and continues to increase. The problem is, if we can't easily 'see' through the rock cover, how will we find new deposits?

It's not economically viable or socially acceptable to extensively drill for exploration. New low cost, low impact techniques for exploration are needed, and this is where IMER's research comes in.

IMER hosts the National Facility for Magnetotellurics (MT) and is using MT to investigate new ways to explore for mineral systems under cover (see Case Study #1).

Also, IMER researchers were recently awarded a prize for their paper on an optical detection method, in which they demonstrated that a portable sensor can be used on-site to estimate the presence of gold (see Case Study #2).

For all other IMER projects addressing this challenge, see page 19.



How can we image what lies under cover rocks before we drill?

Case Study #1
MT for mineral discovery

New magnetotellurics (MT) research reveals the source of known mineral systems in the Olympic Domain, showing great promise for the use of MT for exploration under cover.

Over the past few years, Professor Graham Heinson and his team have collected MT data at various scales, including at continent-level in AusLAMP, which has sites every 50 km and is aiming for 3,000 sites over ten years.

"From MT data, we reconstruct an image of the deep Earth in 3D. This tells us something about the geology of the Earth that we can't otherwise access," says Professor Heinson.

After following up the AusLAMP surveys by in-filling data at the 1-2 km scale in the Olympic Domain, the team was amazed to see a clear link between deep 'source' rocks – seen as 'footprints' of past events, where minerals are thought to have originated sometimes a billion or more years ago – and known, world-class mineral deposits.

"When we reconstructed the deep region below the Olympic Domain, we saw remarkable narrow

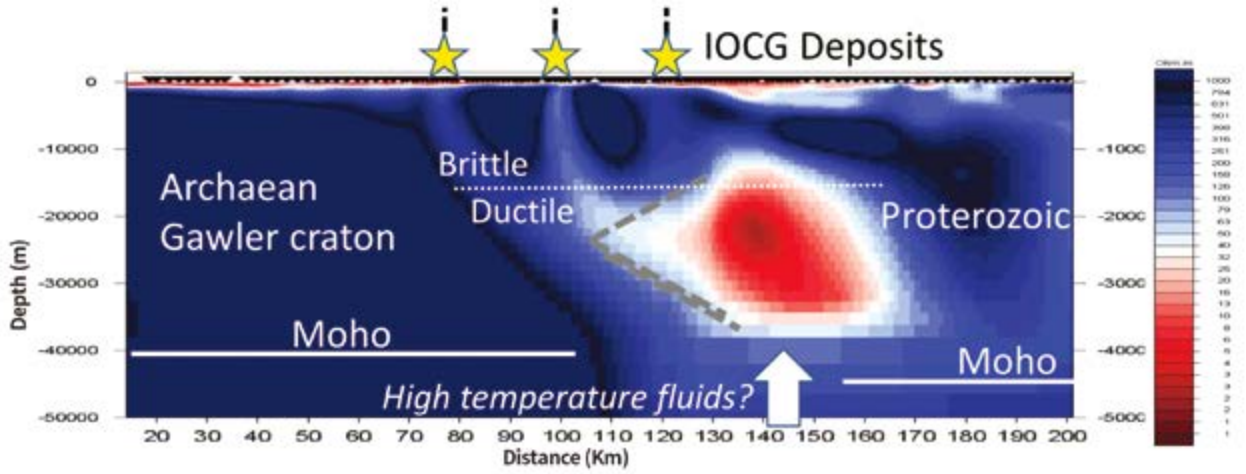
Professor Graham Heinson
Electrical Earth Imaging Group
School of Physical Sciences

structures that seem to show where fluids containing minerals moved from the source region to the surface in the past," says Professor Heinson. "The fluid paths are at least partly supported by observations in the seismic data."

One of the narrow structures leads directly to Olympic Dam, one of the world's largest and most significant copper deposits.

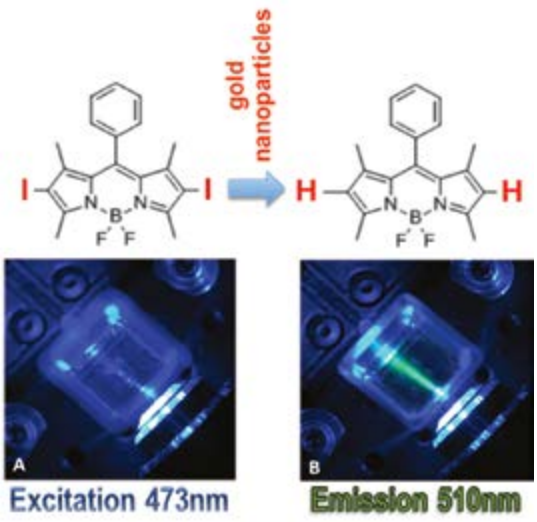
"We could apply this approach in different places to try to discover new mineral deposits," says Professor Heinson. "We could look for fluid paths from very deep structures, which could be new areas of high prospectivity."

Read more about the project: www.adelaide.edu.au/eei/



Case Study #2
Gold sensing at ppb level using optical methods

Gold is one of the most desired precious metals, however as near-surface high-grade ore bodies are being depleted, finding new ores is becoming more and more difficult. Currently, the most popular portable device for detection of elements present in the minerals is x-ray fluorescence (XRF). Its detection limit is in the parts per million (ppm) range. The economically relevant amount of gold, which encourages exploration, is between 0.5 and 8 ppm. Increased sensitivity of the analysis would help to find new threads of the ore. To facilitate gold exploration, the sensor should be portable and enable fast analysis at the drilling site.



Professor Heike Ebendorff-Heidepriem Senior Research Fellow, Department of Physics, School of Physical Sciences

Professor Heike Ebendorff-Heidepriem and her team were recently awarded the 2016 Deep Exploration Technologies CRC Best Paper Prize, (Zuber et al., Sensors and Actuators B: Chemical 2016) for their work on developing an optical detection method and their successful demonstration that a portable set-up can be used for on-site estimation of the presence of gold nanoparticles below 200 parts per billion (ppb). It was shown that, depending on the size of the nanoparticles to be detected, different optical methods should be used: fluorescence analysis for small nanoparticles (5 nm), absorption for larger ones (50 nm).

Follow-on work focussed on pre-concentration of gold from rock samples on a surface to facilitate gold detection at low levels and directly from rock at the drilling site. The team compared the efficiency of a range of surface coating methods in retention of functional groups and binding gold ions versus nanoparticles on the surface. Early results indicate that pre-concentration of gold on the surface may decrease the detection limit of the currently available portable techniques.

Reference: Zuber, A, Purdey, M, Schartner, E, Forbes, C, van der Hoek, B, Giles, D, Abell, A, Monro, T, Ebendorff-Heidepriem, H, 2016, 'Detection of gold nanoparticles with different sizes using absorption and fluorescence based method', Sensors and Actuators B: Chemical, vol. 227, pp. 117–127.

Key projects
active in 2016

Building Central Asia: Linking the growth of Asia to its exhumation
Sponsor: Australian Research Council
Chief Investigators: Dr Stijn Glorie, Prof Alan Collins
Collaborators: Curtin University, Institute of Geology and Geophysics (China) Partnership

Chair of Geostatistics and Quantitative Geology II
Sponsor: Department of State Development – Mining and Petroleum Services Centre of Excellence, Government of South Australia
Chief Investigator: Prof Peter Dowd

Embedded research for Geological Survey of South Australia
Sponsor: Department of State Development – Geological Survey of South Australia
Chief Investigators: Prof David Giles, Dr Simon van der Wielen

Enhanced imaging of South Australia's Tier-1 mineral resource system
Sponsor: BHP
Chief Investigator: Prof Graham Heinson

Imaging capital and operations NCRIS 2016
Sponsor: Department of Industry, Science and Resources, Australian Government
Chief Investigator: Prof Graham Heinson

The origin of Australian Gondwana – using isotopic proxies for subduction to reconstruct ancient oceans
Sponsor: Australian Research Council
Chief Investigator: Prof Alan Collins

Calibrating electrical responses to natural fracture networks to support permeability mapping
Sponsor: Australian Geophysical Observing System
Chief Investigator: Prof Graham Heinson

Monitoring of shale gas exploration and exploitation
Sponsor: Australian Geophysical Observing System
Chief Investigator: Prof Graham Heinson

AusLAMP deep MT imaging of the South Australian crust
Sponsors: Geological Survey of South Australia (Department of the Premier and Cabinet, Government of South Australia), AuScope (NCRIS) and AusLAMP
Chief Investigator: Prof Graham Heinson

Deep Exploration Technologies Cooperative Research Centre

Project 3.4 Regional mineral system drilling for targeting and testing
Sponsor: Deep Exploration Technologies Cooperative Research Centre
Chief Investigator: Prof David Giles

Impact of melt loss on crustal heat production and Earth geodynamics
Sponsor: Australian Research Council
Chief Investigator: Dr David Kelsey
Collaborators: University of Bern, Rensselaer Polytechnic Institute

Rehydration of the lower crust, fluid sources and geophysical expression
Sponsor: Australian Research Council
Chief Investigator: Prof Martin Hand
Collaborators: Curtin University, Macquarie University, University of California

Deep mining

As exploration efforts move deeper, so does mining. This means we need to better understand stressed rock behaviour and to optimise mine operations.

Global production has increased steadily over the last 30 years as demand for minerals continues to rise. But supply is becoming more difficult and costly. The deeper we go, the more rock cover there is, and the more complicated the mining challenges become.

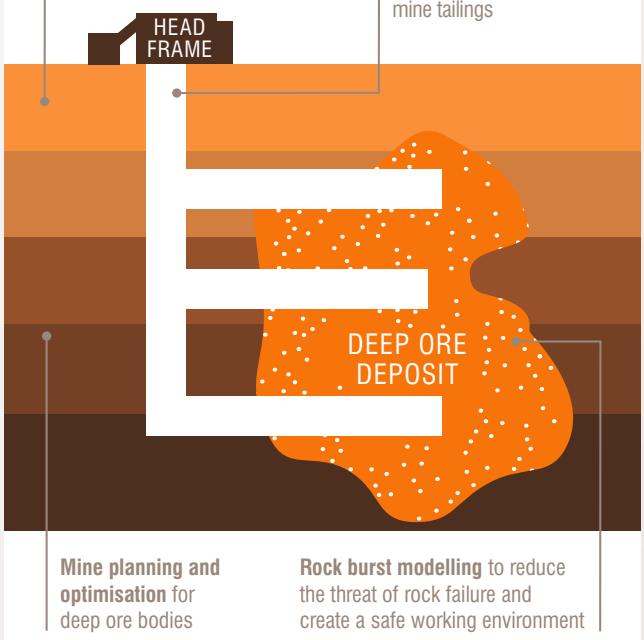
Underground mining requires more challenging and expensive processes. Stresses (the forces that stretch, squeeze and twist rocks) can be high enough to cause rock "failure" of development openings, tunnels, walls and faces in slopes. There are issues around construction, safety, energy, ventilation and water. Mine planning and design become critical.

IMER has developed techniques to help companies maximise and sustain recovery of materials by *in situ* leach by choosing the optimal injected fluid composition for their settings (see Case Study #3).

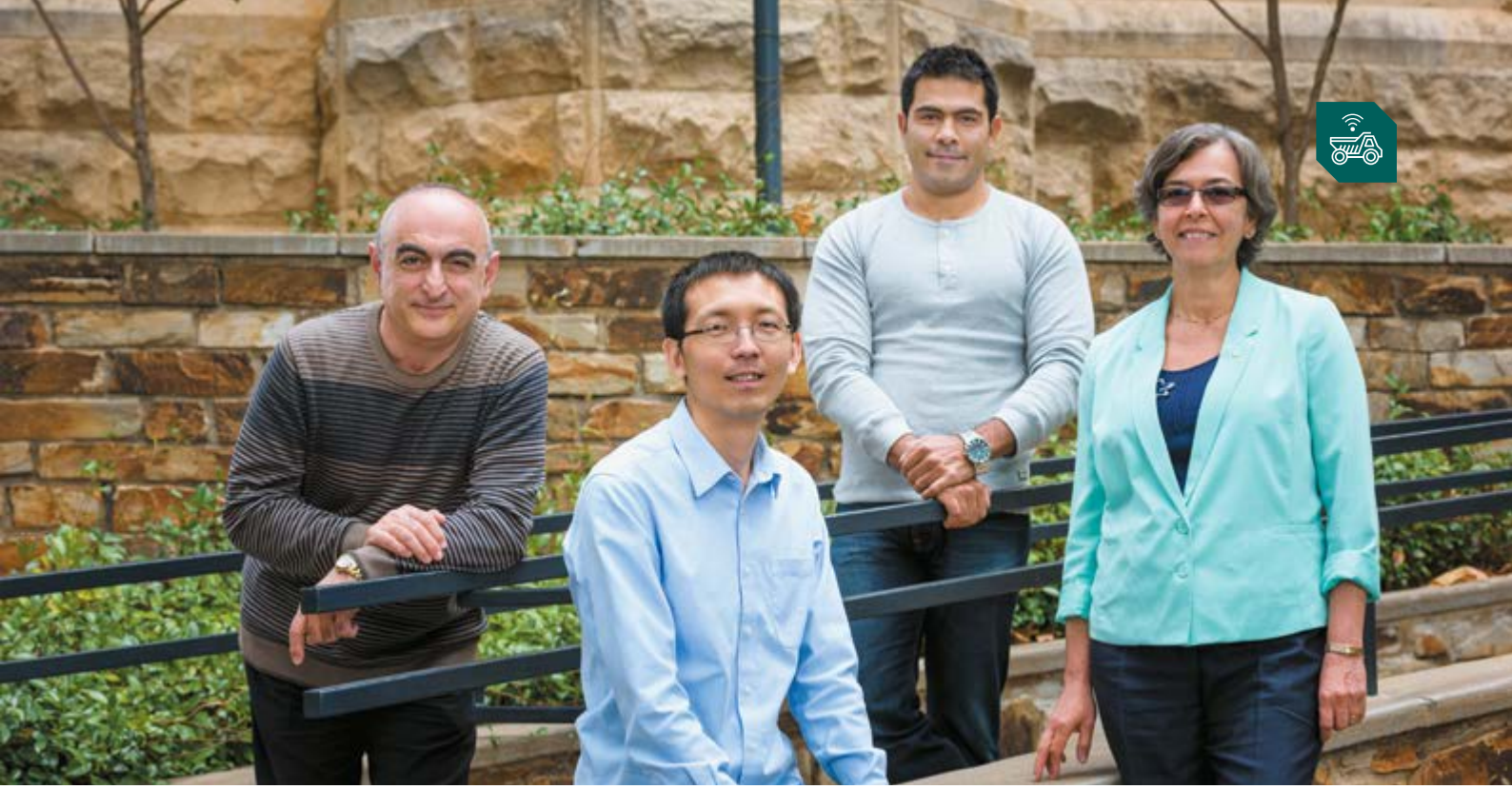
IMER is also seen as a thought leader and valuable strategic adviser in matters relating to the South Australian Government's Copper Strategy (an example is given in Case Study #4).

For all other IMER projects addressing this challenge, see page 23.

IMER is addressing this challenge by researching...



This shaft mine is just one type of deep mine. IMER assists industry to choose the optimal mine type for each individual ore body.



Case Study #3
Choosing the right injection fluids just got easier

Well injectivity and productivity (how easy it is to pump water in or out of a drillhole) can be highly impaired by fine particles being mobilised in the underground aquifer.

Despite 70 years of intensive research on so-called "fines" migration, mathematical models and laboratory methods to determine optimal injected fluid composition have only recently been developed by the team at IMER.

At Heathgate Resources' Beverly Uranium Mine, IMER set out to define the mathematical and laboratory modelling needed to determine "fines" migration at the mine site for *in situ* leaching.

Professor Pavel Bedrikovetsky's team wanted to find out whether fines migrate through the underground aquifer during *in situ* leaching, which would affect rock permeability and, consequently, well productivity. They wanted to determine the conditions under which a minimum number of particles are mobilised during solvent injection in a specific reservoir.

"Our main finding is that there is no fines detachment occurring at the Beverly Mine due to the high acidity of the injected solvents. Also, no fines will be released due to chemical reactions," Professor Bedrikovetsky says, adding that "no formation damage is expected."

Professor Pavel Bedrikovetsky
Chair in Petroleum Engineering
Australian School of Petroleum

"To determine the optimal composition of the injected solvent," Professor Bedrikovetsky continued, "we looked at how fines migration damages permeability, and subsequently how this affects production and injection rates".

A complete service on injected fluid optimisation is currently only available at IMER via the Australian School of Petroleum. The complete works include:

- an assessment of fines migration in natural reservoir conditions and a recommendation of the injected fluid composition
- one dimensional modelling
- fines migration testing with three-point pressure measurements and particle counting
- inverse solver for model adjustment from laboratory data
- 3D modelling for field reservoir simulation.

Partner: Heathgate Resources

Case Study #4
Shaping South Australia's copper future

IMER provided many innovation and research ideas to help frame South Australia's Copper Strategy as it was developed.

Mr Charles Moore, Director of Resources and Strategy at the Department of the Premier and Cabinet (DPC), who led the development of the strategy, explains why IMER's involvement was important as part of DPC's collaboration across industry, academia and the community.

"IMER is a major player in South Australia for minerals and energy research, so we really value their input into the strategy," says Mr Moore. "IMER was one of the early parties to get involved."

The objective of the strategy is to more than triple the state's copper production to 1 million tonnes per annum by 2030. To achieve this, the strategy outlines three action themes, one of which focuses on innovation and research.

"IMER's Professor Stephen Grano, Professor Nigel Cook and Dr Chris Matthews were active in providing ideas to determine what the innovative research might be, and identifying some of the inclusions in the strategy as a whole," explains Mr Moore.

IMER participated in the engagement workshops and is now on the Steering Committee for the International Copper Technology and Research Hub.

Mr Charles Moore
Director, Resources and Strategy
Resources Infrastructure and Investment Task Force
Department of the Premier and Cabinet

"The great thing about IMER is the conversations and thinking that happens between us, enabling us to pursue ideas in different ways," observes Mr Moore.

The Copper Strategy is an excellent example of industry, METS companies, research groups and government working together. Feedback from international groups has acknowledged that South Australia is the first jurisdiction to do something that encompasses the whole copper value chain.

IMER will contribute to the strategy delivery through:

- the ARC Research Hub for Copper-Uranium, to research how to unlock copper potential and manage other parts of the IOCG mineral system
- their excellent links with other parts of the University of Adelaide, which cover the spectrum of innovative research required by the strategy.

Access the Copper Strategy:
www.minerals.statedevelopment.sa.gov.au/about_us/initiatives/south_australias_copper_strategy

Key projects active in 2016

A new damage model for rock burst in hard rocks during deep mining
Sponsors: Australian Research Council, OZ Minerals
Chief Investigators: A/Prof Murat Karakus, Dr Abbas Taheri, A/Prof Giang Nguyen

Modelling rolling dynamic compaction
Sponsors: Australian Research Council, Trustee for the Bowes & Co Machinery Unit Trust Partnership
Chief Investigator: Prof Mark Jaksa
Collaborator: University of Sydney

Optimisation of cemented paste backfill (CPB) using various fly ash additives to reduce CPB cost
Sponsors: Mining Education Australia, OZ Minerals
Chief Investigators: Dr Abbas Taheri, A/Prof Murat Karakus
Collaborator: University of Queensland

Particle mobilisation during solvent injection
Sponsors: Department of Industry, Innovation and Science, Australian Government, Heathgate Resources
Chief Investigators: Prof Pavel Bedrikovetsky, Dr Zhenjiang You, Dr Abbas Zeinijahromi, Dr Themis Carageorgos, Dr Alex Badalyan

Visual sensing for localisation and mapping in mining
Sponsor: Australian Research Council, Maptek
Chief Investigators: Prof Ian Reid, A/Prof Tat-Jun Chin

Cooperative Research Centre for Optimising Resource Extraction

University of Adelaide Essential Participant membership
Sponsor: BHP
Chief Investigators: Prof Stephen Grano, Prof Peter Dowd, A/Prof David Ottaway, Adjunct Prof Nigel Spooner

Upconversion fluorescence for real-time mineral identification
Sponsor: Cooperative Research Centre for Optimising Resource Extraction
Chief Investigators: Adjunct Prof Nigel Spooner, A/Prof David Ottaway, Dr Georgios Tsiminis

Photo courtesy of OZ Minerals Ltd.

Complex processing

The problems faced by complex ore processors include decreasing ore grades, increasingly complex mineral systems, and a shortage of qualified people.

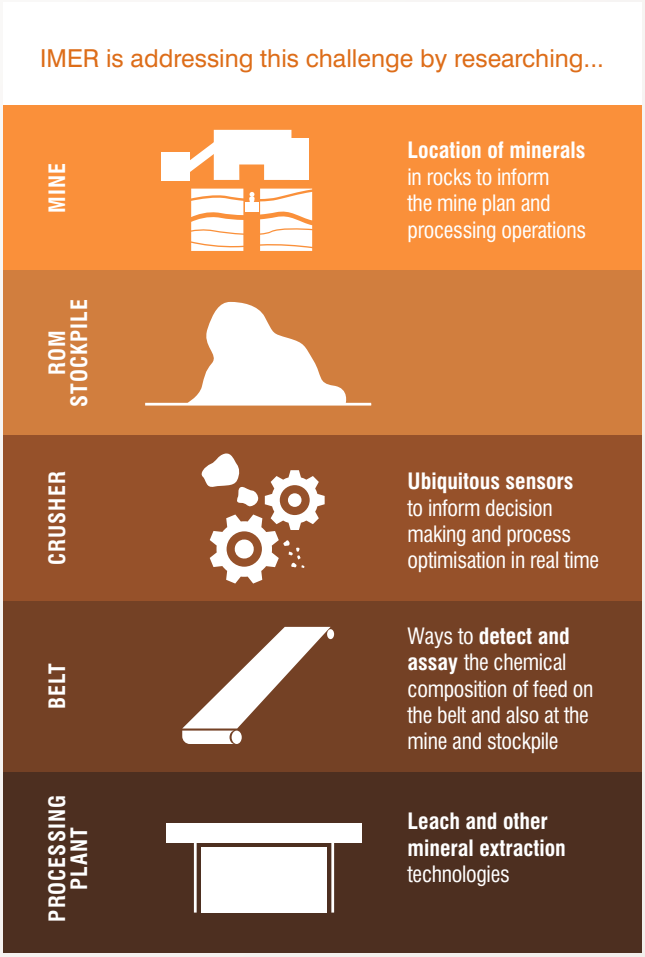
Complex ores are those that contain more than one economic mineral, such as iron oxide copper gold (IOCG) deposits. Each mineral deposit has distinct chemical properties that require tailored processing to extract the metals.

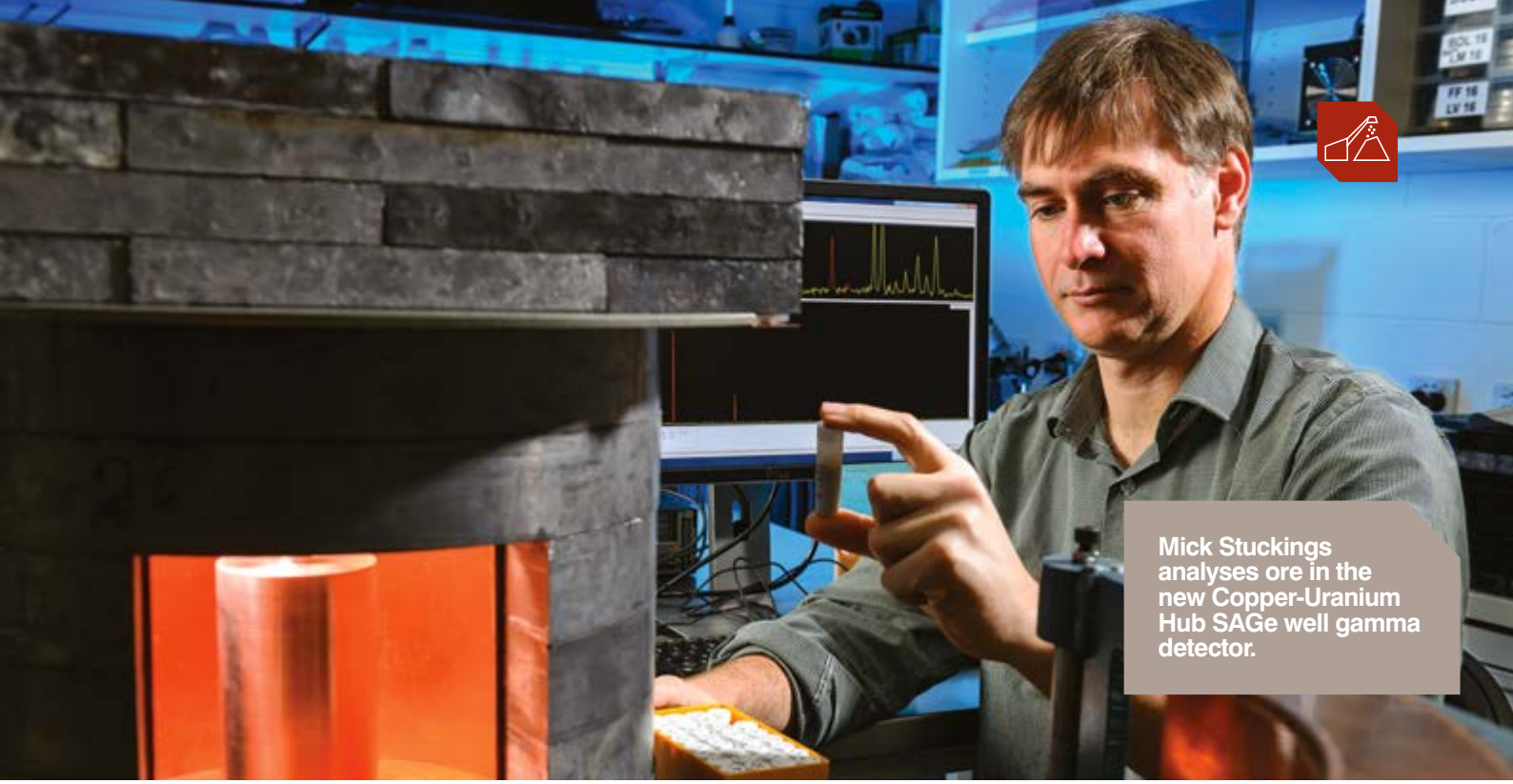
At IMER, we understand that Industrie 4.0 principles will dictate the future of mineral processing. That means automation and the Industrial Internet of Things (IIot) will see information flow in real time along the entire mining chain. For this to happen, mines will need ubiquitous sensors, the ability to process large amounts of data, and the ability to make decisions in real time.

The ARC Research Hub for Copper Uranium, which is well into its second year of research, is finding new ways to make copper production from IOCG ores more economically and environmentally sustainable (see Case Study #5).

IMER has been building relationships with industry, research and government partners to focus on automation and IIoT in mining (see Case Study #6).

For all other IMER projects addressing this challenge, see page 27.





Mick Stuckings analyses ore in the new Copper-Uranium Hub SAGe well gamma detector.

Case Study #5
New radiation sensitive research for the Prescott Laboratory

IMER researchers can now monitor radiation fields in real time using radiation-sensitive optical fibres in a new, industry-funded laboratory.

The Prescott Environmental Luminescence Laboratory, and the appointment of its technical analyst Mr Mick Stuckings, are funded by BHP and OZ Minerals to the tune of around $1 million.

"The lab is the first of its kind in South Australia," Mr Stuckings says. "Our industry partners saw the cutting edge research of the expert team at the ARC Research Hub for Copper-Uranium, and saw IMER as the natural place to build the lab."

The lab is set up for two main fields of research:

- Luminescence research, with equipment that includes the world's most sensitive thermoluminescence spectrometer and a photon-counting imaging system
- Radiation research with equipment that includes a state-of-the-art SAGe well gamma detector for small sample measurements and an alpha-counting facility for monitoring total alpha radiation and estimating the proportion of primordial thorium and uranium in samples.

Measurement techniques are important for the evaluation of mineral processing ore containing Naturally Occurring Radioactive Material (NORM) nuclides.

Mr Mick Stuckings
Technical Analyst
ARC Research Hub for Copper-Uranium

The new analysis support is great news for the Hub.

"We're trying to combine all our measurements in one spot so that we can provide cross-disciplinary analysis and interpretation," Mr Stuckings explains.

"The focus of my role is to understand the needs of industry and the researchers, and the materials and processes they are working with. I can then suggest analyses to get the best results as efficiently as possible" Mr Stuckings says.

His role also involves managing and analysing many BHP and OZ Minerals samples between research partner laboratories across locations at the University of Adelaide, University of Queensland, Monash University and Flinders University.

Partners: BHP, OZ Minerals

For more information:
www.adelaide.edu.au/copper-uranium-research/

Mineral processing is an expensive and energy intensive operation.

Case Study #6

New partnerships in IIoT and sensors for minerals processing

New partnerships aim to maximise value and reduce costs for mineral production using sensors, data analytics and optimisation in the Industrial Internet of Things (IIoT).

Supporting partners include end user mining companies, mining equipment technology services (METS) companies, the University of South Australia, South Australian Government departments, plus enabling research providers and commercialisation service providers.

Lead investigator, Professor Stephen Grano, explains that the establishment of the initiative is the result of years of relationship building and discussing ideas with industry.

“Large scale partnerships don’t happen overnight,” says Professor Grano. “IMER has a solid research relationship with many companies in the exploration, mining and METS sectors. Garnering support started with that firm base.”

The technologies to be investigated – and, where possible, commercialised – include integrated operations, sensors, machine learning, big data and automated data handling.

“The problem with complex ore is its heterogeneity,” explains Professor Grano. “It erodes value. The resultant feed variability makes mining and mineral processing costly.”

Professor Stephen Grano
Executive Director
Institute for Mineral and Energy Resources

Resource challenges are exacerbated by rising energy costs and a shortage of technical skills in computer science, and mining and processing.

Professor Grano adds that “Conventional processing strategies treat the resource in an ‘in-line’ manner to deliver the mine plan. Sometimes, we see high cost and energy intensive processing applied unnecessarily to the entire Run of Mine ore.”

Operations with complex, poly-metallic and variable mineralogy that require high cost downstream processing will benefit from this initiative.

Initiative supporting partners: University of Adelaide, BHP, OZ Minerals, University of South Australia, AMIRA International, AIIA, ASTC, Boart Longyear, Consilium Technology, CRC ORE: Optimising Resource Extraction, Datanet, Data to Decisions CRC, Eka, HiSeis, Innovyz, Magotteaux, Manta Controls, Maptek, METS Ignited, Mine Vision Systems, Rockwell Automation, SA Department of State Development, SAGE Automation, Scantech, South Australian Chamber of Mines, SRA Information Technology, ThermoFisher Scientific

Key projects
active in 2016

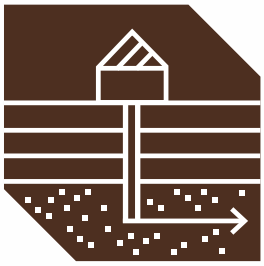
ARC Research Hub for Australian Copper-Uranium
Sponsors: Australian Research Council, BHP, OZ Minerals, Department of State Development, Government of South Australia
Chief Investigators: Prof Stephen Grano, Prof Nigel Cook, A/Prof David Ottaway, Adjunct Prof Nigel Spooner
Collaborators: Environmental Protection Agency SA, Flinders University, University of Queensland, Monash University, UCL Australia, Defence, Science and Technology Organisation

ARC Research Hub on Graphene for Advanced Manufacturing
Sponsor: Australian Research Council
Chief Investigators: Prof Dusan Losic, Prof Christopher Fumeaux, Prof Michael McLaughlin, A/Prof Reza Ghomashchi
Collaborators: University of South Australia, Monash University, Tsinghua University, University of Cambridge, Catalan Institution for Research and Advanced Studies, Case Western Reserve University, Qingdao University, Ziltek, Tata Steel

FOX Project - Trace elements in iron oxides: deportment, distribution and application in ore genesis, geochronology, exploration and mineral processing
Sponsors: BHP, Department of State Development – Mining and Petroleum Services Centre of Excellence, Government of South Australia
Chief Investigators: Dr Cristiana Ciobanu, Prof Nigel Cook
Collaborators: Curtin University, University of Tasmania, British Geological Survey

Geobiological gold cycling: golden opportunities for the minerals industry
Sponsor: Australian Research Council
Chief Investigator: Dr Frank Reith

Extreme temperature monitoring in minerals and metals processing facility
Sponsor: Australian Research Council
Chief Investigator: Prof Heike Ebendorff-Heidepriem
Collaborator: University of South Australia



Tight energy resources

Accessing tight petroleum, gas and geothermal resources efficiently is a massive technical challenge.

Tight energy resources are 'unconventional' deposits of oil, gas and geothermal energy. In conventional settings, the resources can be pumped from the ground with minimal or no engineering. In tight settings, the resources are often trapped in rock pores and the rocks must be engineered in some way for the resources to flow.

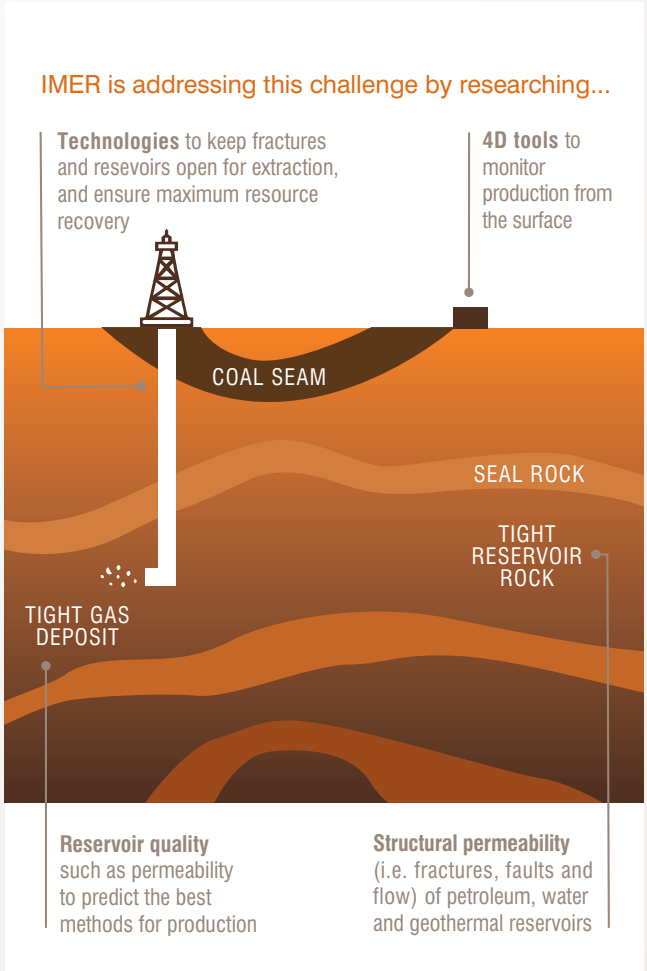
Conventional resources are more accessible and for that reason most have already been exploited. As they dry up, industry is turning its attention to deeper, tighter, resources.

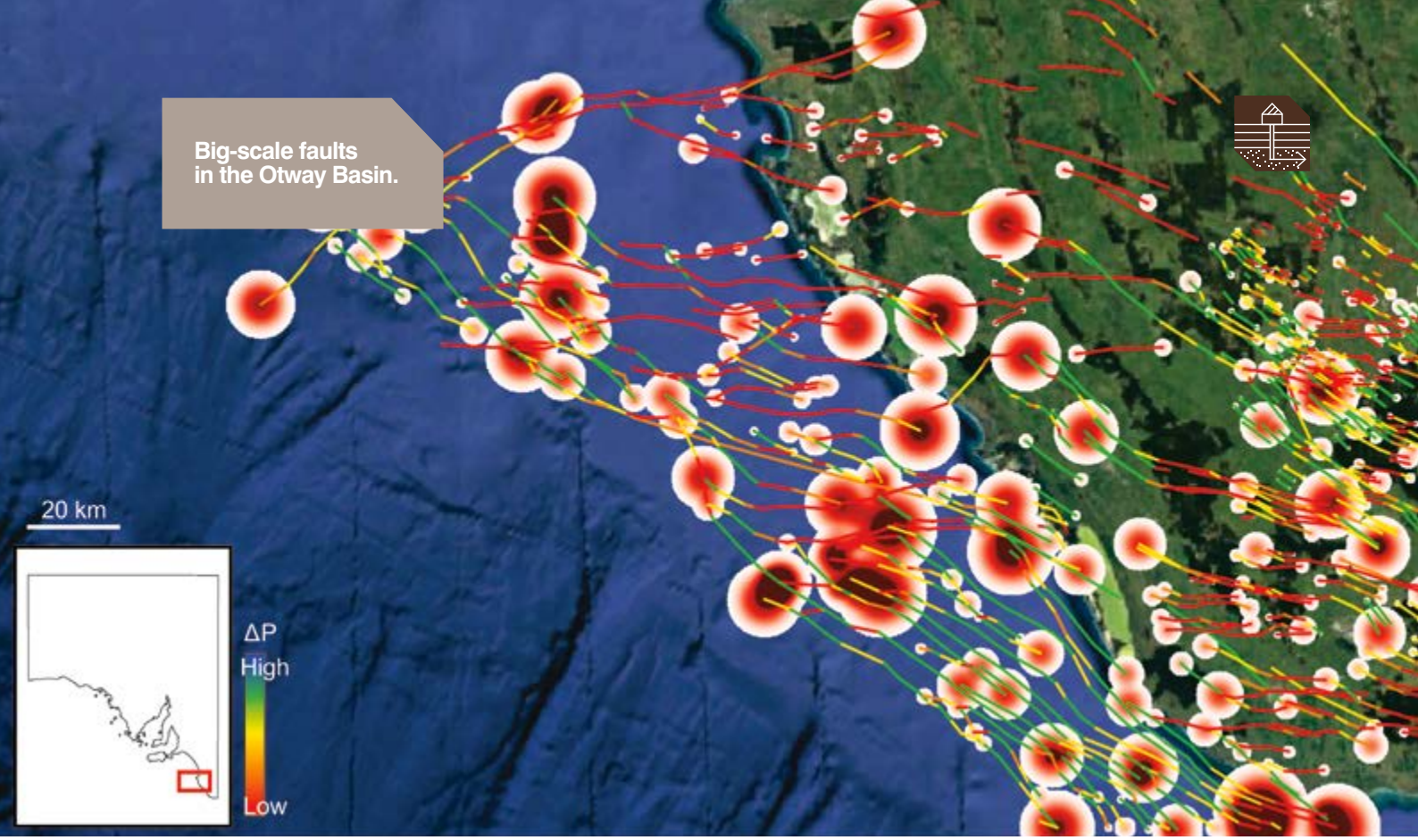
Australia's geothermal industry faces particularly difficult challenges. In 2014, ARENA's International Geothermal Experts Group found that geothermal explorers needed to take a step back to better understand permeability and fluid flow at depth.

At IMER's South Australian Centre for Geothermal Energy Resources, the Australian Structural Permeability Map project seeks to provide industry with a toolkit for locating and developing underground energy resources (see Case Study #7).

IMER has also completed a project with Santos which found that, at their pilot well in the Cooper Basin, permeability doubled during monitoring (see Case Study #8).

For all other IMER projects addressing this challenge, see page 31.





Case Study #7
De-risking geothermal exploration ahead of drilling

IMER rises to the challenge of mapping structural permeability at depths of 2 to 4 kilometres.

Structural permeability refers to naturally occurring faults and fractures that act as pathways for fluids. In the unconventional gas industry, such areas are the primary target for developers. In recent years, Engineered Geothermal Systems developers have recognised the importance of targeting structural permeability as well as other factors such as heat flow and rock types.

Dr Rowan Hansberry and his team researched natural fractures at depth with the aim of seeking and defining proxies for geothermal potential to provide a toolkit for locating permeability ahead of drilling.

"We analysed four Australian basins," says Dr Hansberry. "We wanted to know how well we could identify fracture network properties, and how well those fractures might conduct fluids."

Using data from industry such as borehole image logs, 3D seismic data, and even MT data, Dr Hansberry says they "analysed image logs that overlapped with available seismic data. This provided a dataset of natural fractures to cross-reference with fractures and faults identified with remote-sensing data, like 3D seismic."

Dr Rowan Hansberry
Research Associate and Leader,
Structural Permeability Project,
Department of Earth Sciences,
School of Physical Sciences

The data were integrated with data from the World Stress Map to understand permeability within the context of the present-day stress regime of the study basins.

The team is putting their new maps, data and 'toolkit' information on a new website, due to be launched in 2017. The map will serve as a first port of call to give explorers an idea of where they should be looking.

"The evidence we've seen is that the image log data strongly reflects what we see in seismic," concludes Dr Hansberry. "We're confident that we can use a mixture of technologies at a range of scales to identify fault and fracture orientation, as well as other proxies for geothermal potential".

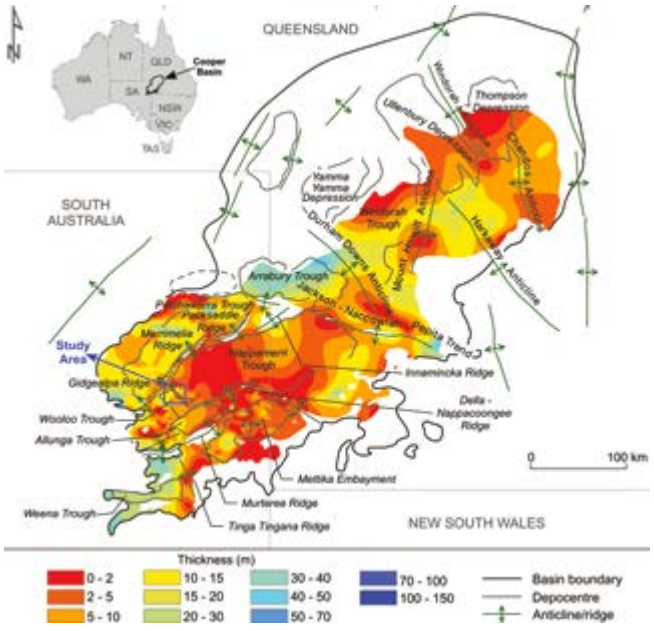
Partners: ARENA, University of Aberdeen

Case Study #8
Gas production from deep coal seams

IMER is investigating ways to economically produce gas from Santos's huge resource in the ultra deep coals of the Cooper Basin.

The coals of the Cooper Basin are 2500+ metres below the surface, far deeper than the coal seams gas 'plays' of Queensland. Fractures are typically tiny and fluids move very slowly through them, hence the description 'tight'. As a result, permeability – a measure of how well fluid flows through rock – is very low.

The project study area in the Otway Basin showing net coal thickness in the Patchawarra Formation.



Dr Alireza Salmachi
Lecturer, Australian School of Petroleum

Dr Alireza Salmachi and his team (Erik Dunlop, Zara Tooski and Mojtaba Rajabi) carried out research on a Santos pilot well to answer questions typically asked by companies with this type of resource:

- Does permeability evolve (or increase) over time in a hydraulically fractured deep well?
- If it does evolve, does this help to produce gas?

"Once production from a tight well commences, gas is 'squeezed' out of the rocks, making the rocks shrink as a sponge would, and opening up the fractures," Dr Salmachi explains. Industry calls this 'matrix shrinkage' and it explains why permeability improves over time.

The Santos pilot well, which was drilled several years ago, provides very accurate pressure data measured at surface, so the team had excellent data to analyse to get answers to the above questions.

"At this well, we found that permeability increases over time. In fact, permeability doubled in the time that we monitored the well," says Dr Salmachi. "We also found that the gas drainage area did not extend deep into the coal formation."

The researchers found that gas drained from only a very short distance from the fracture face, and concluded that other techniques are needed to achieve commercial rates of production. At this stage, this particular well is not commercially viable.

Partners: Santos, Origin Energy, Delhi Petroleum

Key projects
active in 2016

Structural permeability mapping in Australia: De-risking geothermal exploration ahead of drilling
Sponsor: Australian Renewable Energy Agency
Chief Investigators: Prof Martin Hand, Dr Rosalind King, Dr Simon Holford, Dr Khalid Amrouch, Prof Graham Heinson
Collaborator: University of Aberdeen

Carbon capture and storage, seals, and unconventional resources
Sponsor: Department of State Development, Government of South Australia
Chief Investigator: Prof John Kaldi

Cenozoic igneous activity in the Ceduna sub-basin: origin, distribution and impacts on petroleum systems
Sponsors: CSIRO Deepwater Great Australian Bight Program, Chevron
Chief Investigator: Dr Simon Holford

Combining transient micro-reflections and multi-sensor arrays for condition assessment of buried pipes
Sponsors: Australian Research Council, Detective Services Partnership
Chief Investigators: Prof Martin Lambert, Prof Angus Simpson, Dr Aaron Zecchin

Cost-effective pipeline condition assessment using paired pressure sensor arrays
Sponsor: Australian Research Council
Chief Investigators: Prof Martin Lambert, Prof Angus Simpson, Dr Aaron Zecchin
Collaborator: CSIRO Materials Science & Engineering

Subsurface fluid flow through fractures in sedimentary basins
Sponsor: Australian Research Council
Chief Investigators: Dr Rosalind King, Dr Simon Holford, Dr Khalid Amrouch
Collaborators: University of Aberdeen, Deep Exploration Technologies Cooperative Research Centre

New nano technologies in shale and tight gas reservoirs
Sponsors: Australian Research Council, Santos
Chief Investigators: Prof Pavel Bedrikovetsky, Dr Zhenjiang You, Dr Abbas Zeinijahromi
Collaborator: University of South Australia

Low cost, low emissions energy

Society's energy needs can be summed up in three main forms of supply: power, heat and fuel.

As energy demand increases globally, there is a pressing need to find energy sources that are reliable, affordable and produce low or no emissions. IMER's goal, through its Centre for Energy Technology, is to accelerate society's transition to carbon neutrality through collaboration with leading organisations.

Energy-intensive industries, in particular, are looking to renewables to at least partially meet their energy needs. They need stable and secure electricity supply that addresses the intermittent nature of renewables, and reliable technologies to provide transport fuels and heat for industrial processes.

IMER specialises in hybrid energy systems, which give the ability to produce energy from a combination of renewable sources with fossil fuels in a single, combined unit (see Case Study #9).

In Australia, an area of 50 x 50 km receives enough solar energy to meet the energy demand of the whole country. In the field of solar energy research, the conversion of carbon dioxide into hydrocarbon fuels is one of the many promising technologies IMER is developing (see Case Study #10).

For all other IMER projects addressing this challenge, see page 35.

IMER is addressing this challenge by researching...

Sustainable fuels, including solar gasification, liquefaction, liquid fuel synthesis and CO_2 to fuel conversion

Secure power, including solar thermal, advanced combustion and hybrids

Sustainable process heat, including concentrating solar thermal in the primary production of materials such as alumina, copper and iron/steel

Sustainable networks, including integrating renewable energy into conventional and micro grids, power networks and markets

Energy storage, including building a mobile energy storage test platform and establishing an online knowledge bank

Case Study #9
The Hybrid Solar Receiver Combustor (HSRC)

This year saw us build a world-first experimental system of the patented HSRC, which could help energy-intensive industries transition to renewables.

After being awarded an ARC Linkage grant in 2012, Professor Bassam Dally and his team have:

- solved the problem of integrating two sources of energy into a single device
- conducted techno-economic analysis and identified markets in which the technology is competitive
- completed computational fluid dynamics analysis to optimise the design so that it can operate in three modes – solar only, combustion only, and a combination of both
- continued to engage industrial partners to garner interest for large-scale on-sun demonstration.

Explains Professor Dally: "We expect a 24 per cent reduction in the levelised cost of electricity, 45 per cent reduction in net fuel consumption, and 51 per cent reduction in overall power plant capital cost compared to a system with standalone solar and combustion systems."

The HSRC has the flexibility to heat fluids to a wide range of temperatures, and it can supply industrial process heat or drive a power cycle to generate electricity.

"When the sun isn't shining, the HSRC, which has an in-built combustor, switches the burners on to use gas," says Professor Dally. "It ensures continuous energy supply regardless of weather conditions or seasonal variation."

Professor Bassam Dally
Deputy Director, CET
School of Mechanical Engineering

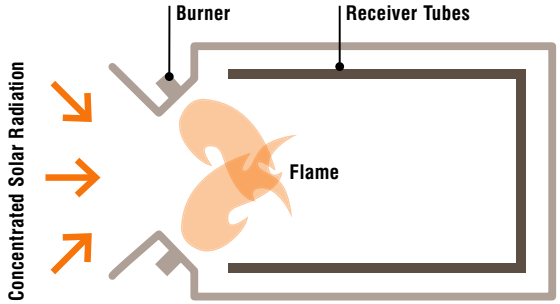
The technology will be able to supply baseload combined heat and power from a single unit, unlike solar systems that have back-up gas generators. It will help accelerate the penetration of renewables and minimise dependence on natural gas in industrial processes that require 24/7 energy supply and constant temperature.

Hybrid solutions could eventually be fully renewable because flames, which are traditionally run with fossil fuels, can also be run on renewable fuels such as hydrogen, syngas or ammonia.

The next steps are to carry out on-sun testing and to build a 250 kW pilot system.

Partners: Vast Solar, FCT Combustion, Heliostat SA.

For more information:
www.adelaide.edu.au/cet/technologies/hybrid-solar/



Methane gas can be made from CO_2 and water using photocatalysis.

Case Study #10
Photocatalysis moved along the TRL scale

It's been a big year for CO_2 to fuel research, as the IMER team completed a large project and attracted new industry partners.

Photocatalysis is a mechanism by which light energy is put into chemical bonds, for example turning CO_2 into a hydrocarbon fuel such as methanol using solar energy.

"The storage of intermittent solar energy with 24/7 reliability will be valuable, even necessary, in a low carbon future," says Professor Greg Metha, the project's leader. "It will also help Australia and the world to meet carbon reduction targets because CO_2 is one of the raw materials in this process."

Professor Metha and the project partners have developed a system in which their innovative photocatalyst is now internationally patented. The system comprises metal clusters deposited on titanium that convert CO_2 and water into a renewable and storable hydrocarbon fuel. "The metal clusters act as active catalytic sites to facilitate the reduction chemistry," explains Professor Metha.

As part of the work completed in 2016, the team demonstrated single atom selectivity, showing that the photocatalytic reaction is dependent upon the exact number of atoms in the cluster catalyst.

Professor Greg Metha
Head of Chemistry,
School of Physical Sciences

"In 2016, we completed our Premier Research and Industry Fund grant project," Professor Metha says, "and we successfully secured a grant from the US Army to explore other aspects of photocatalysis."

The new technology is steadily moving up the Technology Readiness Level (TRL) scale.

"Our next step is to develop the technology across the middle TRL stages," says Professor Metha. "It has advanced to a point where we can no longer apply for funds for fundamental research, but it is not ready for commercialisation either."

Partners: Flinders University, University of Canterbury (NZ), Victoria University of Wellington (NZ), US Army, University of Utah, Latrobe Fertilisers

For more information:
www.adelaide.edu.au/cet/technologies/photocatalysis/

Key projects active in 2016

Commercial scale production of bio-crude by hydrothermal liquefaction
Sponsors: Australian Research Council, Muradel Partnership
Chief Investigators: Prof Gus Nathan, Prof Peter Ashman, A/Prof Zeyad Alwahabi, Dr Zhao Feng Tian, Prof David Lewis, Prof John Abraham

Establishing the Australian energy storage knowledge bank
Sponsors: Australian Renewal Energy Agency, Department of State Development – Government of South Australia, Energy Networks Association, Power and Drive Solutions, SA Power Networks, Zen Energy
Chief Investigators: A/Prof Nesimi Ertugrul, Prof Gus Nathan, Prof Bassam Dally, A/Prof Wen Soong, Prof Shizhang Qiao

Fabrication of solar fuel through photocatalytic reduction of CO_2 and H_20 to hydrocarbons
Sponsor: Department of Further Education, Employment, Science and Technology, Government of South Australia
Chief Investigator: Prof Greg Metha
Collaborator: Flinders University

Integrating concentrating solar thermal energy into the Bayer alumina process
Sponsors: Australian Renewable Energy Agency
Chief Investigators: Prof Gus Nathan, Dr Saw Woei, A/Prof Zeyad Alwahabi, Dr Maziar Arjomandi, Prof Peter Ashman, Prof Bassam Dally, Dr Zhao Feng Tian, Dr Philip van Eyk
Collaborators: University of New South Wales, University of Newcastle, Swiss Federal Institute of Technology, Australian Nuclear Science and Technology Organisation, Alcoa World Alumina, IT Power Australia, Commonwealth Scientific & Industrial Research Organisation

Nanostructured Electrocatalysts for Clean Fuels Production
Sponsor: Australian Research Council
Chief Investigator: Prof Shizhang Qiao
Collaborator: Kent State University

New understanding and models for two-phase solar thermal hybrid reactors
Sponsor: Australian Research Council
Chief Investigators: Prof Gus Nathan, A/Prof Zeyad Alwahabi, Dr Maziar Arjomandi, Dr Zhao Feng Tian
Collaborators: Purdue University, Swiss Federal Institute of Technology

Oscillating water column efficiency improvement through impedance matching and active latching control techniques
Sponsor: Australian Research Council
Chief Investigators: Prof Ben Cazzolato, Prof Gus Nathan, Dr Maziar Arjomandi
Collaborator: Carnegie Wave Energy

Solving the energy waste roadblock
Sponsor: Science & Industry Endowment Fund
Chief Investigator: Prof Christopher Sumby, Prof Christian Doonan
Collaborators: CSIRO, University of Sydney

Tools for design and scale-up of solar thermochemical reactors
Sponsor: Australian Renewable Energy Agency
Chief Investigators: Prof Gus Nathan, Prof Bassam Dally, A/Prof Zeyad Alwahabi, A/Prof Paul Medwell

Towards the application of MILD combustion to gas turbines
Sponsor: Asian Office of Aerospace Research & Development - United States Airforce
Chief Investigator: A/Prof Paul Medwell

X-ray snapshots of chemical transformations in open framework materials
Sponsor: Australian Research Council
Chief Investigators: Prof Christian Doonan, Prof Christopher Sumby, Dr David Huang
Collaborator: University of Nottingham

Energy Pipeline Cooperative Research Centre

Emerging energy sources and their transportation
Sponsor: Energy Pipelines Cooperative Research Centre
Chief Investigators: Prof Peter Ashman, Prof Gus Nathan, Dr Neil Smith

Gas pipeline blowdown – Project 1: Characteristics of natural gas pipeline blowdown in remote areas

Sponsor: Energy Pipelines Cooperative Research Centre
Chief Investigators: Dr Neil Smith, Dr Akhilesh Mimani, Prof Anthony Zander, Prof Peter Ashman, Dr Cristian Birzer, A/Prof Paul Medwell, Dr Timothy Lau, Prof Ben Cazzolato

IMER engagement

Success in building teams to address industry challenges comes through engagement – building networks and relationships with industry, other research organisations and the community.

National Energy Resources Australia (NERA) workshop

The NERA Workshop was held in April 2016 at the National Wine Centre in Adelaide, and focused on future oil and gas resources for Australia. Attended by over 50 representatives from government, industry and research, presentations and discussions centred on where Australia's future resources are, what is needed to make these resources economic, and how to make it happen in terms of funding mechanisms and industry led research.

Australian Energy Storage Knowledge Bank and Test Facility launch

The Australian Energy Storage Knowledge Bank project was launched in November 2016 at the Art Gallery of South Australia. The Knowledge Bank is an Australian Renewable Energy Agency supported project and is the result of significant work from a range of companies and partners, including the University of Adelaide, Renewables SA, Energy Networks Australia, ZEN Energy and Power and Drive Renewable Solutions.

The project will build and deploy a mobile energy storage test platform and establish an online knowledge bank to host Australian energy storage expertise. This will provide industry and researchers with the resources to independently test entire energy storage systems both under laboratory conditions and in the field. It will also provide a central source for data and information about energy storage performance in a range of applications and conditions.

Climate-KIC launch

The Australian Climate Knowledge and Innovation Community (Climate-KIC Australia) was launched at the University of Adelaide, with the University announced as a founding partner of the national initiative. Climate-KIC is a public-private-research innovation partnership aimed at better positioning entrepreneurs, developers and low carbon technology start-ups to bring their innovative climate solutions to market.

Climate-KIC Australia will work in close collaboration with EIT-Climate KIC (Europe) to help Australia transition to a low-carbon economy. EIT-Climate-KIC is Europe's largest climate public-private partnership, comprising more than 250 partners across large corporates, small medium enterprises, government and academic institutions, and has delivered more than €1.8bn in climate innovation investment capital.

PDAC Conference and Sudbury visit

Executive Director of IMER Professor Stephen Grano was part of a mining equipment and technology delegation to Ontario, Canada in March 2016. The Department of State Development led delegation had the opportunity to witness latest service trends and technologies as well as meet with global industry representatives. The visit included the 2016 Prospectors and Developers Association of Canada (PDAC) conference, one of the largest mining conferences in the world, as well as a guided tour of the world-renowned Sudbury mining services cluster of more than 500 companies.

South Australian Energy Symposium

The South Australian Energy Symposium was held at the University of Adelaide in December 2016. Premier Jay Weatherill set the scene with South Australian Government commitments and future directions, followed by presentations on South Australia's energy market, national policies and progress, integrating new energy to manage secure supply to customers and the pathway to clean energy development. Discussion by the seventy attendees, including industry, researchers and policy-makers, highlighted that a greater understanding of renewable energy technology in South Australia is needed, particularly determining which technologies should be focused on and invested in, how we ensure that they will meet our needs, and the important future roles of solar thermal and energy storage technologies.

The event followed the severe storm event in September during which transmission and distribution electricity assets were damaged, leading to a statewide blackout.

Clean Energy Regulator visit

Members and senior executives from the Australian Government Clean Energy Regulator visited South Australia in August 2016 to gain an overview of the activities being conducted in the state by industry, government and academia in the pursuit of carbon neutrality and the renewable energy target. As part of the visit, the Centre for Energy Technology had the opportunity to meet with the members and give a presentation on the Centre's role, research priorities, facilities and research programs. This was followed by discussions on collaboration and innovation for carbon abatement, particularly the alignment of economic and environmental policies, technologies to support transformation of the electricity grid and sustainable fuels and minerals processing. The members were then taken on a tour of the laboratories at Thebarton.

Energy Innovation in the Built Environment Australia-Germany Seminar

German and Australian researchers shared innovations and ideas to find smarter ways of saving energy in the built environment as part of the Energy Efficiency Innovation Seminar 2016 held at the University of Adelaide. Energy consumption in buildings is a common challenge: it accounts for over 40 per cent of all energy consumed in Europe, while heating and cooling account for 40 per cent of household energy use in Australia. The seminar was part of the German-Australian Chamber of Industry and Commerce's Energy Efficiency – Made in Germany Initiative, and was moderated by Dr Chris Matthews, Manager of IMER.

Premier Jay Weatherill addresses the South Australian Energy Symposium.

The seminar created an interactive platform to facilitate the formation of lasting and sustainable relationships between German companies that are technology innovators and Australian academic institutions. German researchers and industry leaders in energy efficiency in buildings presented their Smart Grids, Smart Buildings and Sensors and Data Enabling Human Centric Buildings innovations to members of leading Australian universities. University of Adelaide researchers presented on designing for Australian cities, innovative cooling technology and Smart Cities.

ARPS Conference sponsorship

The Australasian Radiation Protection Society's 2016 Conference was held in September 2016 at the Adelaide Convention Centre. The conference was focused on perceptions, risks and opportunities. The University of Adelaide and IMER were a sponsor, and participated with a booth manned by Copper-Uranium Hub members.

National Exploration Undercover School (NExUS)

The first NExUS in November/December 2016 attracted applicants from all over Australia. Three-weeks of intensive industry-focused training exposed 30 students and recent graduates to the opportunities and challenges facing the exploration and mining industry as research areas move under cover.

The course kicked off with a visit to the South Australian Drill Core Reference Library, with workshops in regolith characterisation, mapping interpretations and more. Participants were treated to talks by the Minerals Council of Australia, UNCOVER, the Geological Survey of South Australia and many others.

Next came field trips to the:

- Adelaide Hills where Hillgrove Resources provided ground access to, and data resources from, one of their exploration tenures
- prototype coiled tube drill rig at Deep Exploration Technologies Collaborative Research Centre's Brukunga facility
- Yorke Peninsula, where students identified minerals and logged and interpreted the mineral contents of exploration drill core at Rex Minerals Hillside's copper deposit.

NExUS is preparing for a 2017 course and the number of placements is increasing to 35, reflecting the high demand from students.

Partners include the Minerals Council of Australia's Minerals Tertiary Education Council, Hillgrove Resources, DET CRC and Rex Minerals.

More information: www.nexus.org.au

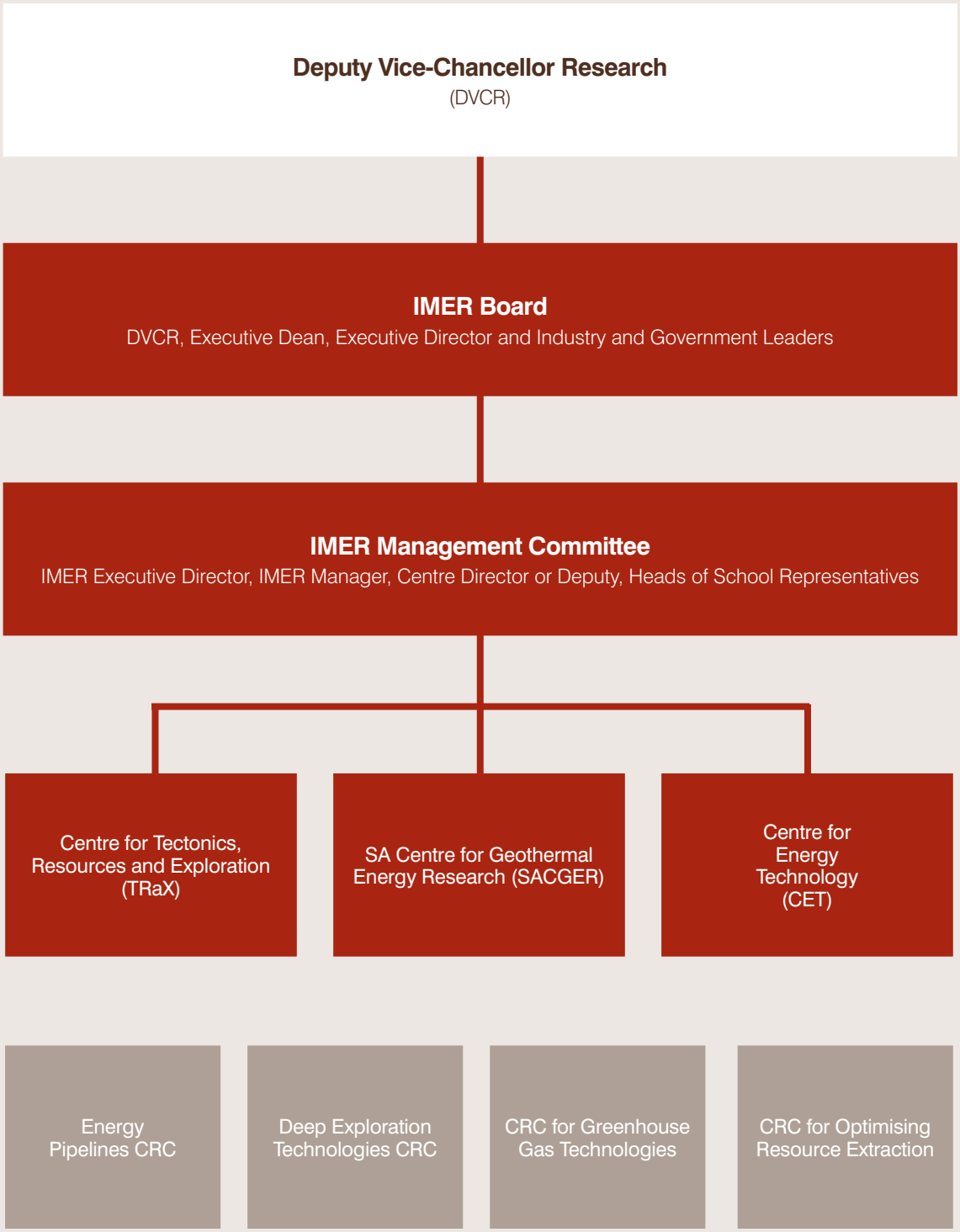
Prominent Hill and Olympic Dam field trips

Field trips were undertaken in 2016 to Prominent Hill and Olympic Dam as part of the ARC Research Hub for Australian Copper-Uranium. Seven Hub participants visited Prominent Hill to see firsthand the current flotation process for targeting the separation of fine liberated lead sulphide from copper sulphide minerals. Flotation tests were conducted by Hub researchers within the Prominent Hill plant, with the results determining future research directions.

The Olympic Dam Field Trip provided 23 Hub participants with an overview of the mineral mining process, and gave the researchers a better understanding of the technology currently being used and the scale and robustness required of new technologies.

23 Hub participants at Olympic Dam.

Organisational structure



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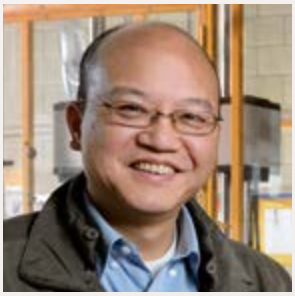

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Energy Pipelines Cooperative Research Centre (EPCRC)

Professor Peter Ashman
Program Leader

Deep Exploration Technologies Cooperative Research Centre (DET CRC)

Professor David Giles
Research Leader

Cooperative Research Centre for Optimising Resource Extraction (CRC ORE)

Adjunct Professor
Nigel Spooner
Chief Investigator

Strategic framework

IMER was formed by the University of Adelaide to focus interdisciplinary research in mineral and energy resources, address globally significant challenges and enhance the impact of research.

IMER's mission is to be a globally recognised centre of excellence for interdisciplinary research, innovation and technology transfer in mineral and energy resources.

Centre for Tectonics, Resources and Exploration (TRaX)

Understanding the evolving Earth and its resource potential.

TRaX provides a link between continental and regional-scale geology and deposits of minerals and petroleum to improve our understanding of deposit formation and develop predictive methods for the discovery of new deposits.

Our goal is to be the leading provider of research and teaching in tectonics, resources and exploration in Australia and conduct focused research into South Australia's unique geological characteristics.

TRaX research areas

- Basins
- Tectonics
- Geophysics
- Minerals

Professor Allan Collins
TRaX Director

South Australian Centre for Geothermal Energy Research (SACGER)

Working towards efficiently and sustainably managing the world's unconventional energy resources.

SACGER's research is focussed on understanding the thermal structure and evolution of the Australian crust and the continental regions that are connected to it. We carry out practical, high-priority research on geothermal systems and tight unconventional energy resources such as shale gas.

SACGER research areas

- Heat flow
- Structural permeability
- Reservoir quality
- 4D magnetotellurics
- Rock thermal properties

Professor Martin Hand
SACGER Director, IMER Deputy Director

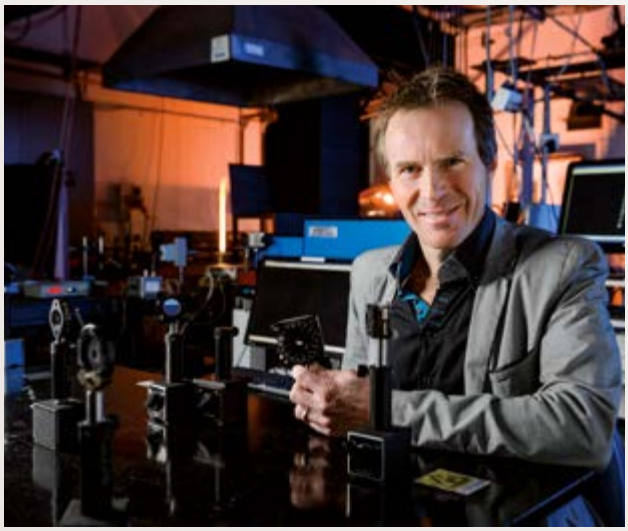
Centre for Energy Technology (CET)

Developing clean, reliable, affordable energy technologies.

CET works with industry partners and builds research teams to develop innovative, low emissions solutions for sustainable fuels, minerals processing and power. We do this by retro-fitting innovative technologies to existing systems, and by developing new carbon neutral and carbon negative technologies to replace existing heat, power and fuel production systems, especially through hybridisation.

CET research areas

- Biomass/waste to energy
- Chemistry
- Combustion
- Electrical technologies
- Energy analysis and optimisation
- Energy efficiency
- Energy materials
- Energy storage
- Hybrid solar technologies
- Mathematical modelling
- Solar energy, including solar thermal and concentrating solar power
- System integration
- Transmission and storage
- Wind, wave and tidal power



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