School of Minerals and Energy Resources Engineering

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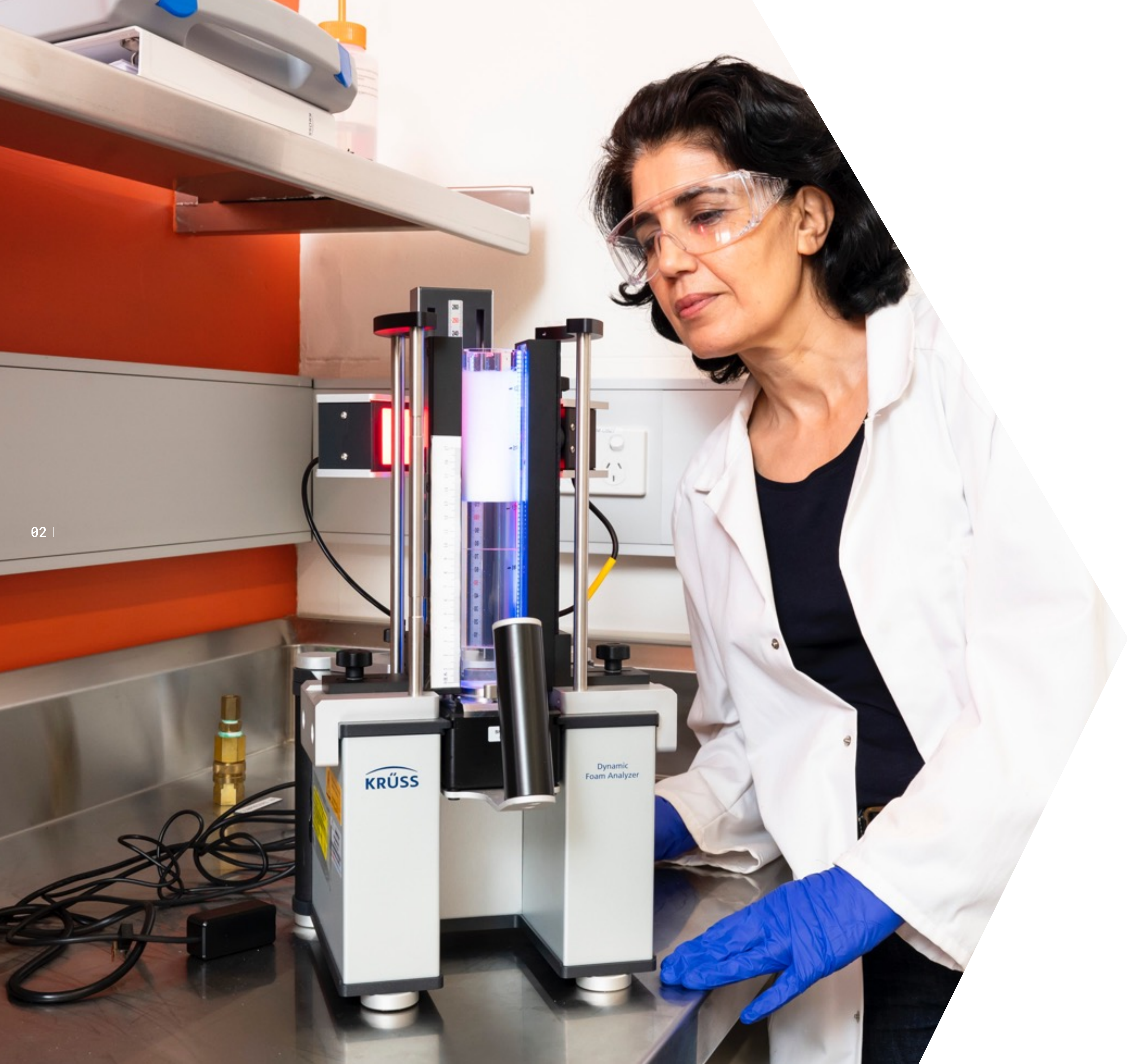
RESEARCH CAPABILITY AND FACILITIES

UNSW
SYDNEY



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About UNSW

Research Excellence

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> No. 1 in Australia for Research Quality and Impact
(Excellence in Research for Australia and Engagement & Impact 2018 outcomes)

> $3.3B research income over the last five years

> 12,831 research publications in 2021

> 4,358 higher degree research candidates in 2021

> 777 higher degree research completions in 2021

UNSW, Australia's Global University

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Vision

Improving lives through excellence in research and education, and a commitment to advancing a just society.

Values

In pursuing the University's vision to make a real difference, members of the UNSW community will demonstrate:

- Partnership: working in teams to best serve our communities.
- Integrity: transparency and ethical decision-making, inspiring openness, courage, and trust.
- Respect: listening and engaging with each other and our communities.

An international influencer in education

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UNSW is a leading education and research-intensive university, delivering outstanding teaching alongside cutting-edge research. Established in 1949, UNSW has a unique focus on the scientific and professional disciplines.

UNSW is one of the world's top 100 universities and has a proud tradition of sustained innovation, focussing on areas critical to its future, from climate change and renewable energies to lifesaving medical treatments and breakthrough technologies. The University aims to make an impact on people's lives globally through excellence in research and education, and a commitment to advancing society. Its research informs policy and expert commentary on key issues facing society.

UNSW is a founding member of both the Group of Eight, a coalition of Australia's leading research intensive universities, and the prestigious Universitas 21 international network. Working in partnership with leading businesses, community organisations and governments and major universities across the world, the University amplifies its expertise to help solve the world's biggest issues, whilst developing innovative solutions and emerging cutting-edge technologies.

Fast Facts

> 7 Faculties
Faculty of Arts, Design & Architecture
UNSW Business School
Faculty of Engineering
Faculty of Law
Faculty of Medicine
Faculty of Science
UNSW Canberra (college) at the Australian Defence Force Academy (ADFA)

> 47 Schools

> 54 Centres and institutes

> 17 Residential colleges and apartments

> 38ha Kensington campus size

UNSW at a glance

Australia's Global University

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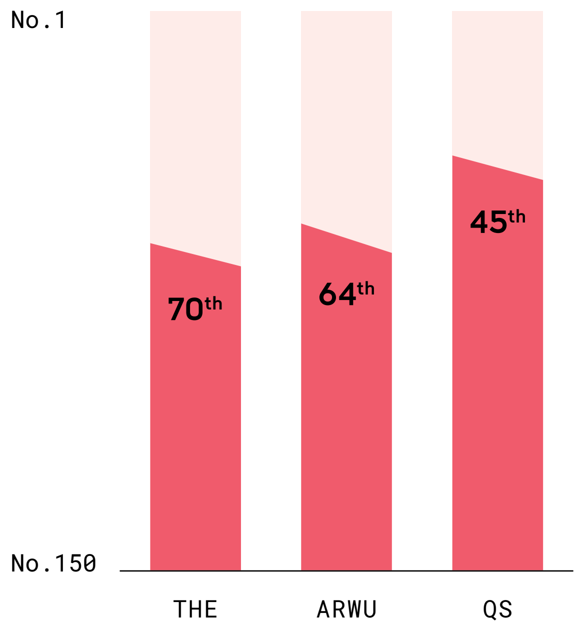
- 65,600 Total students
- 23,052 Students commencing 2019
- 42,654 Local students
- 22,946 International students
- 4,358 Higher degree research candidates
- 353,612 Alumni



> THE – Times Higher Education World University Rankings
> ARWU – Academic Ranking of World Universities*
> QS – Quacquarelli Symonds World University Rankings

*UNSW was one of only two universities to make the leap into the top 100 in 2019 – our highest position since the ARWU rankings were first published in 2003.

UNSW Engineering

UNSW Engineering is Australia's largest engineering faculty, producing the most graduates and having the greatest breadth of research and education opportunities. The Faculty is a powerhouse of innovation in Australia and the region, housing more than 800 researchers and educators, and expertise across eight schools of engineering, 36 research centres and three institutes. It is home to state-of-the-art facilities valued by industry and our world-leading academics.

Since its inception in 1949, UNSW Engineering has a proud history of developing technologies that have a world-changing impact including membranes for water filtration, bionic eyes, soft contact lenses, quantum computing, and silicon solar photovoltaics. UNSW Engineering achieves the level of impact in translating research into real-world solutions by working closely with industry.

UNSW Engineering ranks 1st for Engineering Faculty in Australia and 23rd for Engineering Faculty in the World in 2022 QS World University Rankings. Under QS Rankings, Times Higher Education World University Rankings and Academic Ranking of World Universities, the disciplines within the Faculty of Engineering are consistently ranked in top place in subject rankings in Australia.

UNSW Engineering offers industry innovative solutions by drawing upon extensive expertise from leading experts and specialists across the eight schools of engineering:

- **School of Minerals and Energy Resources Engineering**
- School of Chemical Engineering
- School of Civil and Environmental Engineering
- School of Computer Science and Engineering
- School of Electrical Engineering and Telecommunications
- School of Mechanical and Manufacturing Engineering
- School of Photovoltaic and Renewable Energy Engineering
- Graduate School of Biomedical Engineering

School of Minerals and Energy Resources Engineering

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The School of Minerals and Energy Resources Engineering is a leading provider of innovative world class engineering education and research for more than 70 years. The School continues to thrive with highly sought-after undergraduate and postgraduate programs, along with an increase in our internationally acclaimed research output.

In the latest global rankings, the School of Minerals and Energy Resources Engineering was ranked 3rd in the world (QS World University Rankings, 2022), and 10th in the world (Academic Ranking of World Universities, 2022).

From the bronze age to the digital age, minerals and energy resources have always played a critical role in the evolution of humankind – from farming to space technology. As we transition to a more sustainable way of life, minerals and energy resources have taken on a new, innovative role in shaping our future.

At the School of Minerals and Energy Resources Engineering, we cultivate change makers and immerse them in a world that few people get to experience. Whether it's finding the lithium that powers electric cars, spearheading the sustainable exploration and development of subsurface energy resources, investigating ways to decarbonise industry, or developing the technology to extract water and minerals from the Moon and Mars.

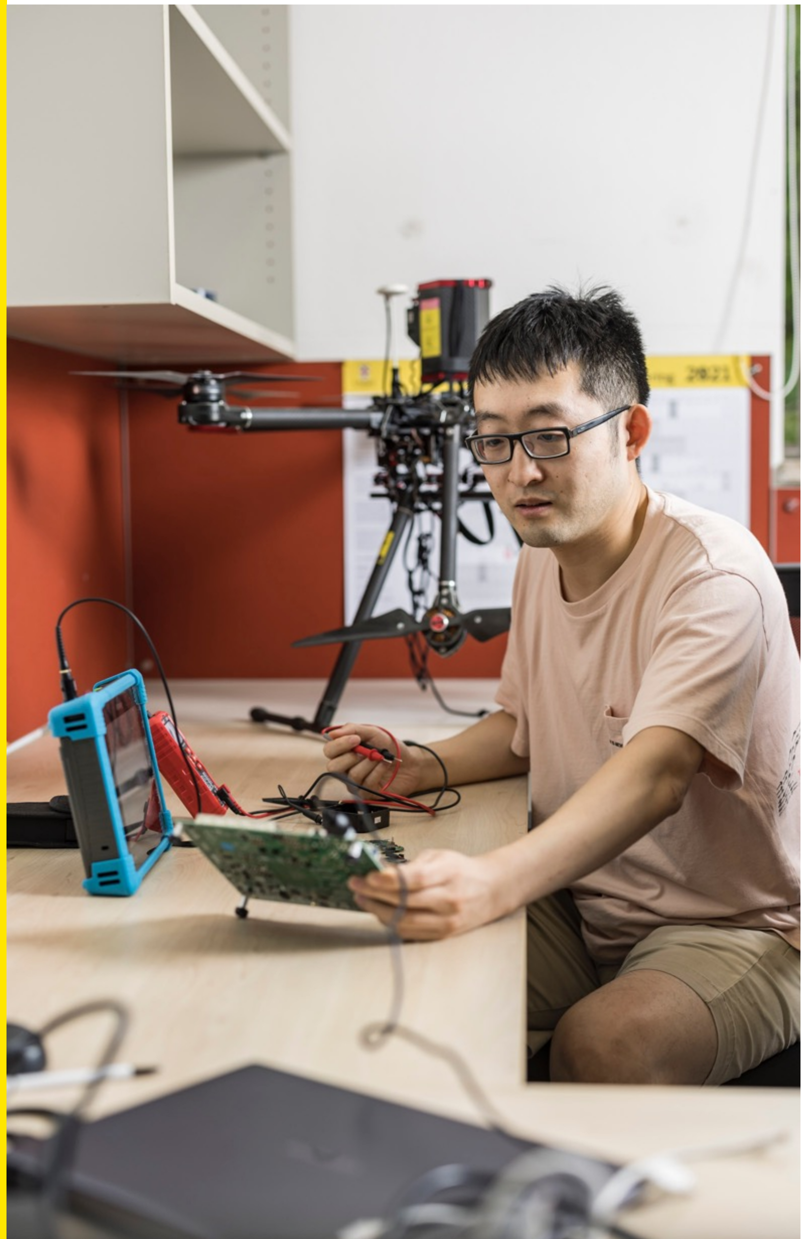
Where others see a limited resource, we have the imagination to see further and bring new life to those essential things you cannot grow. We generate ideas and technologies that will continue to inform how society uses and thinks of energy, minerals, and resources into the future.

About the School

The School of Minerals and Energy Resources Engineering was established in 2018 when the Schools of Mining Engineering and Petroleum Engineering were merged. Both schools had a rich history of technological developments and fundamental insights in collaboration with the Australian Petroleum and Mining Industries. Union of the schools now brings together two of the largest economic drivers in Australia. Our new school is poised to address grand challenges for the 21st Century involving the integration of new technologies and innovations that provide safety, protect the environment, and meet our energy and minerals demands.

We continue to drive the national agenda across the breadth of Minerals and Energy Resources Engineering, and in doing so enhance the quality of life for humanity sustainably.

In this document, we look to identify the challenges relevant to mineral and energy resources engineering and the future role of research in these areas.



Research Facilities

> Advanced Visualisation Lab
Virtual reality and augmented reality technologies for site operations.

> Tyree X-ray
X-ray computed microtomography for rock/materials characterisation and quantification.

> Space Resources Environmental Analogue Facility
Extreme environment testing facilities, including Dirty Thermal Vacuum Chamber, an indoor Moon Yard.

> MIoT & IPIN Lab
Integrated technologies for Mine Internet of Things and Indoor Positioning Indoor Navigation.

> Low-Field NMR Laboratory
Nuclear Magnetic Resonance (NMR) characterisation of fluids and transport in porous media.

> Multiphysics Geomechanics Laboratory
Analysis of mechanical, thermal, hydraulic, and chemical processes affecting rock deformation.

> Petrophysics Laboratory
Core flooding equipment for the study of flow and transport in rocks.

> Mine Geomechanics Laboratory
Equipment to study the mechanics of rocks and materials at mining conditions.

> Mineral Processing Laboratory
Optimisation of chemical processes for the extraction of minerals from ore bodies.

> Advanced Geochemistry Laboratory
Electrochemistry and hydrometallurgy related to extraction of minerals from ore bodies.

> Underground Ventilation and Environment Laboratory
Optimisation of air movement and underground work environment for mine sites.

Our Vision & Commitment

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The School of Minerals and Energy Resources Engineering (MERE) has the vision to develop fundamental insights that lead to technological advancements, facilitating the discovery and extraction of future minerals and energy resources with minimal environmental impact, increased safety, and improved productivity.

MERE Fast Facts

> 18 Academic Staff

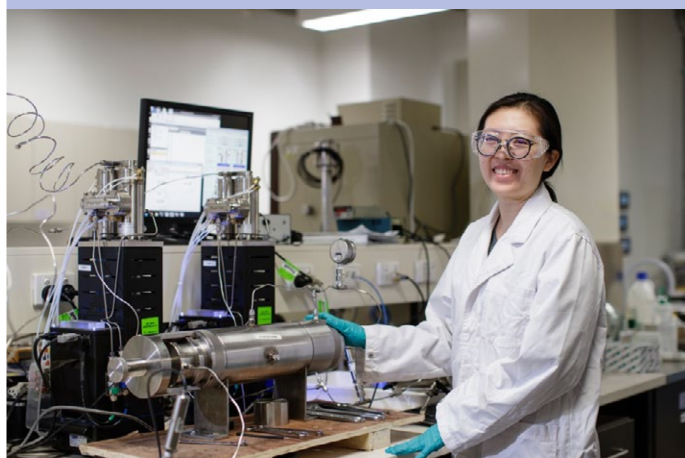
> 17 Research Staff

> 8 Visiting, Adjunct, and Conjoint Staff

> 58+ Higher Degree Research Students

> Past 5 years

$14M+ Research Income
62 PhD Completions
536 1st Quartile Research Publications
18 Book Chapters



We are committed to:

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Technology Development & Integration
Advance the uptake of state-of-the-art technologies for minerals and energy resources industry to achieve sustainable technology-integrated operations.

Advance the knowledge of extractive industries
Develop novel mining systems and sustainable practices for waste disposal, mine tailings, ground and surface water interactions, and *in situ* mining approaches.

Reduce the energy footprint of extractive industries
Deploy hybrid renewable energy technologies by co-developing and designing effective solutions for energy transition including deep subsurface storage of CO_2.

Development of energy storage solutions
Expand the effective recovery of essential minerals for the onset of renewable technologies and storage of heat and pressure in underground reservoirs.

"An enduring source of energy, minerals and resources for future generations."

Professor Ismet Canbulat, FIEAust, FAusIMM, RPEQ
Head of School

Australia's past and future economic success is undeniably linked to the resources industry. Producing minerals and energy resources is crucial for global socio-economic development and is linked to almost every industry value chain.

As an enabler of technological innovations and knowledge, the School of Minerals and Energy Resources Engineering aims to engage with industries to develop current and future extraction technologies that improve upon current techniques and drive forward future energy and minerals supplies.

Our primary focus is to drive forward technologies required to meet the increased demand for minerals required for renewable energy sources, improve the sustainable extraction of resources, and reduce the carbon footprint of the extraction industry.

Our unique approach will bring together expertise from both academia and industry, to address the grand challenges around future energy and minerals supplies and drive sustained economic development.

Our Research Strengths

Geoenergy

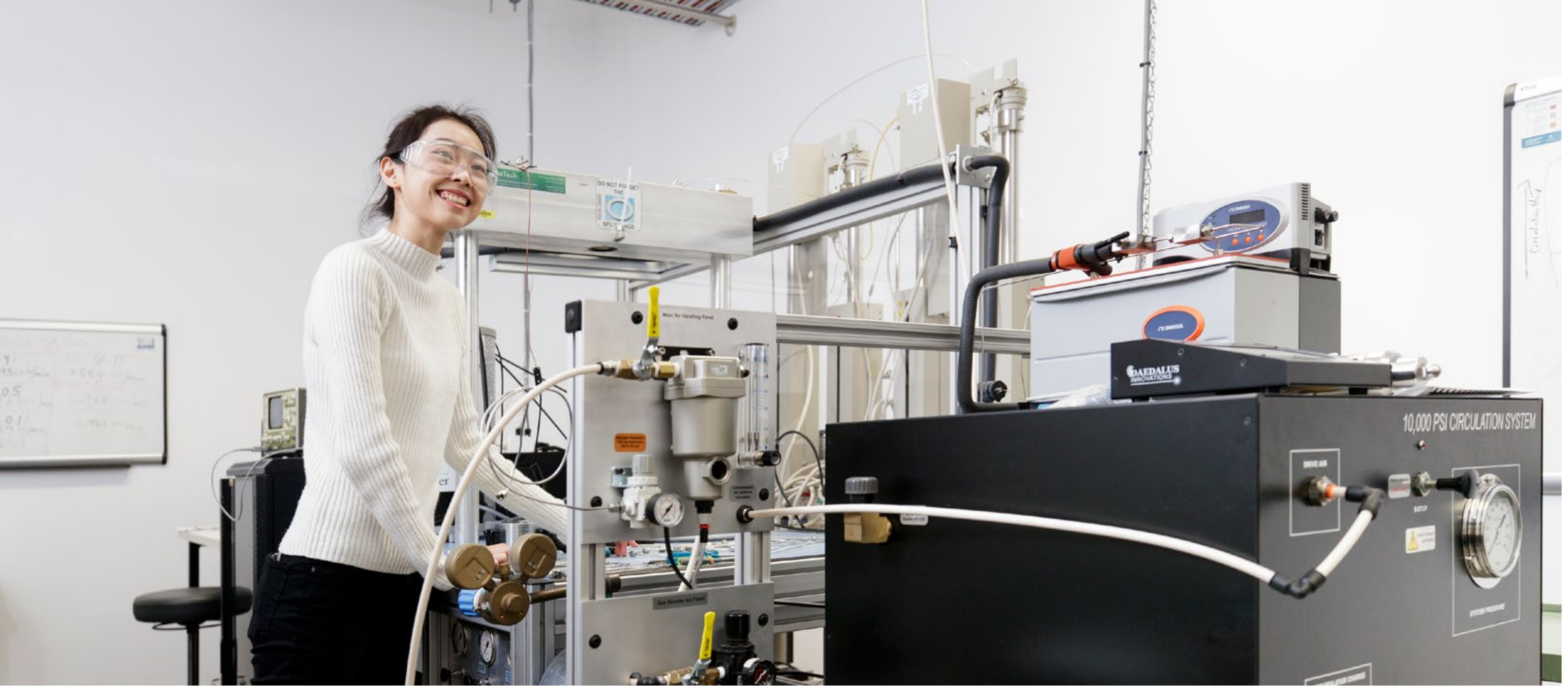
This theme focuses on fundamental and applied research related to minerals, energy extraction and storage. Of particular interest are technologies that improve recovery and provide new insights into the production of transition fuels and critical minerals. Traditional knowledge and expertise in petroleum and mining engineering will drive new technologies related to the geological storage of CO_2 and hydrogen, recovery of critical minerals, production of transition fuels, and extraction of geothermal energy.

Geomechanics

This theme focuses on fundamental and applied geomechanics related to the mining industry. Our interests are oriented towards improving safety performance related to current and emerging technologies. Our experts closely collaborate with industry partners to find innovative ways to ensure environmentally safe and sustainable practices are incorporated in all aspects of design and operation. With future energy technologies new practices and approaches are ever evolving that require geomechanical expertise.

Transformative Technologies

This theme focuses on innovating new technologies for operational excellence to accelerate the transformation of the minerals and energy resources sectors. Of particular interest is to adopt scientific knowledge and emerging technologies from other disciplines tailored for the minerals and energy resources sectors. This includes monitoring and communication technologies to improve operational safety, evaluate environmental impact and expand efficiencies, and artificial intelligence for automation and data analytics.



Geoenergy

Our team working in the field of Geoenergy focus on fundamental and applied research related to subsurface energy extraction, energy storage, and critical minerals recovery. Of particular interest are technologies that improve recovery, provide new insights into the production of transition fuels, and facilitate the future energy landscape.

Traditional knowledge and expertise in petroleum and mining engineering will drive new technologies related to subsurface energy extraction, geological storage of CO_2 and hydrogen, and extraction of critical minerals for future energy technologies. These new technologies will redefine the traditional petroleum and mining engineering disciplines and provide new opportunities for novel research, fundamental insights, and ground-breaking technological innovations. We have three main themes within our Geoenergy flagship.

Research Spotlight

Professor Ryan T. Armstrong is leading research on the development of pore-to-core scale models for subsurface engineering applications with a focus on 'Digital Materials Characterisation' and thermodynamics of multiphase systems.

Professor Christoph Arns is a pioneer in the area of Digital Rock Physics and specialises in the area of computational pore-scale physics based on tomographic images including the integration of digital and conventional core analysis.

Multiscale Reservoir Engineering

Heterogeneity of structure and mineralogy affects reservoir performance at multiple scales. We provide fundamental insights into the physics of flow and transport in multiscale heterogeneous environments and practical approaches to provide predictive models. Our approach considers flow and transport from the micrometre length scale to field scale operations in integrated workflows to provide high-fidelity models for the management of subsurface resources. A key to the approach is the combination of multiscale experiments and numerical simulation for the development of integrated subsurface modelling and characterisation.

Applications include unconventional reservoirs, geothermal energy, CO_2 sequestration, natural gas recovery, colloid and contaminant transport, digital rock physics, geological hydrogen energy storage, and waste storage related to extractive industries.

Integrated Storage and Recovery Systems

Emerging energy technologies require innovative storage and recovery systems. CO_2 geo-sequestration in deep aquifers and hydrocarbon reservoirs is a promising carbon capture utilisation and storage (CCUS) method. The emerging hydrogen economy also provides an opportunity for large-scale hydrogen energy storage in geological formations. Other storage and recovery technologies associated with energy include the safe disposal of waste related to extractive industries.

Applications include CO_2 chemical modification to enhance storage, co-optimisation of hydrocarbon recovery and CO_2 sequestration, assessment of long-term subsurface storage, subsurface hydrogen gas storage, and waste storage.

Research Spotlight

Associate Professor Furqan Le-Hussain's research enhances the feasibility of CO_2 geosequestration in heterogeneous and low-pressure formations to maximise storage capacity.

Professor Peyman Mostaghimi is leading collaborative research with the Commonwealth Scientific and Industry Research Organisation on underground hydrogen storage for long-term energy storage.

Critical Minerals

Renewable energies will place an increasing demand on mineral resources. These demands will change the way minerals are recovered and processed, placing new challenges on sustainability and environmental impact, and drive new innovative technologies. We carry out both fundamental and practical studies on mineral separation, and environmental impacts related to mineral recovery.

Our research is aimed at smart methods for exploring minerals and delivering sustainable recovery technologies and separations to minimise losses of high value minerals, environmental impact, and energy/water consumption.

Applications include characterisation of flotation reagents and froths, processing of low grade and complex ores, utilization of mine tailings, sustainable mine waste management, mineral exploration and characterisation, and *in situ* recovery technologies.

Research Spotlight

Associate Professor Seher Ata's research focuses on froth flotation, a separation technique used as the first step in separating minerals from rock, including critical minerals and solid-liquid separation.

Our researchers are leading research on the in-situ recovery of minerals from orebodies, ore characterisation using deep learning, and mineral recovery from metallic/non-metallic ores and mine tailings.

Geomechanics

`Our team working in the field of Geomechanics focus on fundamental and applied research related to the design of mining systems, underground environments, and geological systems. Of particular interest is the safety of current technologies and new challenges driven by emerging technologies related to future energy.`

Geomechanics provide a means to design safe, sustainable, and effective minerals and energy resources operations. The systems considered often involve coupled processes and complex multi-physics that require an interdisciplinary skill set. We work collaboratively with industry partners on mine safety and design, coupled geomechanical systems, and exploration/production systems. We have three main themes within our geomechanics flagship.

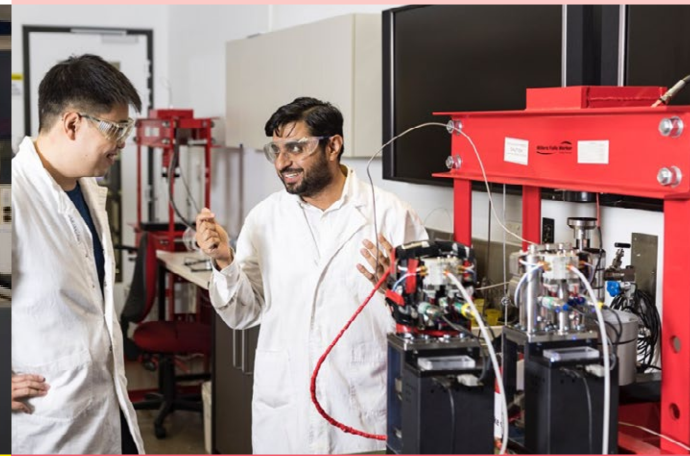
Coupled Geotechnical Systems

Geomechanics plays a central role in minerals and energy resources engineering. Our works focus on laboratory tests, numerical models, and field measurements to understand rock mass behaviour and ground support to optimise the design and safety during resource extraction. Geomechanics required in recovering various resources drives the need for coupled thermal, hydro, chemical, and mechanical modelling of multiscale systems. Our experts are working on unique physics-based approaches with the integration of data-driven algorithms to guide industry decisions, optimise recovery, ensure safety, and drive innovative approaches for asset management. Applications include gas drainage, CO_2 sequestration, mining impact on groundwater, basin dynamics and exploration studies, in-situ stress estimation, fracture propagation and activation, ground subsidence, and recovery of unconventional resources.

Research Spotlight

Our mining geomechanics team is dedicated to understanding the coupled behaviour of fluid flow and rock mechanics using theoretical analysis, laboratory testing, and numerical simulation, from lab-scale to field-scale challenges.

Associate Professor Hamid Roshan's advanced multiphysics laboratory hosts the next generation of equipment for coupled geomechanics - offering state-of-the-art academic and technical services.



Underground Mining and Safety

Underground operations require high-precision geotechnical knowledge and advanced numerical techniques to ensure safety. Australia has unique mineral resources that require novel approaches. We focus on suitable mining methods that are capable of safe, efficient, and productive resource recovery.

Our research maintains Australia in its leading role in operating best practice mines and applying state of the art technologies, which leads to improved safety and increased productivity in underground mines resulting in better viability.

Applications include rockburst and gas outburst projects, triggering mechanism for floor heave, ground support and ground control, mine subsidence, corrosion failure, seismic monitoring, numerical modelling of rock mass behaviour, and novel geotechnical methods for Australian resources.

Research Spotlight

Associate Professor Joung Oh's research advances tunnelling and underground space development, coupled behaviour of rock discontinuities, ground-structure interaction, and rock mechanics for caving.

Professor Ismet Canbulat has over 30 years of experience in research, consultancy, management, on-site and academia related rock mechanics theory and implementation under industry practice.

Resource Extraction and Production

Extraction and production systems are central operations for the recovery of underground resources. We focus on developing numerical simulations and conducting experimental studies for drilling and production systems in complex and high-stress conditions. Developing reliable methods for estimating and modelling the *in situ* stress magnitudes and technologies for real time monitoring requires an integrated systems approach. We also work on operations safety and hazard management, operational optimisation, emerging effective planning techniques, extraction methods and systems for deep and unconventional deposits. We are proud to work with partners in industry to improve current techniques and drive innovations.

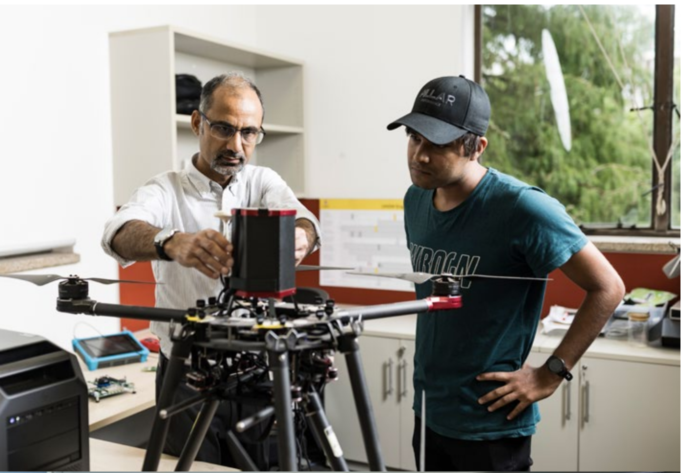
Applications include drilling and extraction method simulators, borehole breakout modelling, log interpretation methods, automated techniques for *in situ* stress monitoring, fracture stimulation, drilling mechanics, disaster elimination, gas management & monitoring, and ventilation on demand.

Research Spotlight

Associate Professor Stuart Clark is leading research on resource exploration in frontier environments including the automation of geophysical interoperation, optimisation of infrastructure placement, and numerical simulations of Earth processes.

Lecturer Zhixi Chen is leading research on well stability, drilling fluids, and cementing with a focus on geo-storage of CO_2 and future energy storage of hydrogen gas.

Transformative Technologies



Our team working in the field of Transformative Technologies focuses on innovations with game changing potential for industry. Of particular interest is to adopt scientific knowledge and emerging technologies from other disciplines tailored for the minerals and energy resources sectors.

Our innovations draw upon advances in artificial intelligence, computer sciences, and electrical engineering. This includes data analytics for resources engineering, Mine Internet of Things, exploring & engineering extreme environments, and low emission technologies. We work collaboratively with our domestic and international partners to find innovative and efficient ways to ensure sustainability and redefine industry practices. We have three main themes within our Transformative Technologies flagship.

Data Analytics and Digital Integration for Resources Engineering

Artificial intelligence (AI) and digital integration have provided step changes for various industries. Minerals and energy resources industries are rapidly developing these technologies as the industry becomes more digitally connected. The Internet of Things (IoT) is about the digital integration of the physical workplace with sensors, processing ability, software and other technologies that connect and exchange data. These technologies are critical for safe, efficient, and automated operations in isolated environments common to minerals and energy resources engineering. Our machine learning work focuses on the integration of AI technologies to industry workflows and discovering opportunities to surpass current hardware limitations.

Applications include digital core imaging and characterisation, automated seismic and core interpretation, subsurface characterisation, automation, computer vision of materials, data analytics, site monitoring & assessment, inertial measurement units, global navigation satellite systems, wireless communication technologies, and LIDAR 3D laser scanning.

Research Spotlight

Associate Professor Binghao Li works with industry partners through CRC Projects and ARC Industrial Transformation Research Hubs to develop world-class MIoT solutions for improving the productivity and safety of mines.

Associate Professor Simit Raval leads the development of drone-based smart sensing, underground mobile laser scanning, image-based automated material characterisation, and mine rehabilitation/closure.

Low Emission Technologies

The resource and energy sectors are making a step change to embrace the zero-carbon or carbon-neutral future. The extraction of minerals and energy resources results in significant greenhouse gas emissions. This requires Australian industries to adopt innovative approaches to manage their carbon emissions. We focus on developing analytical, modelling, and laboratory solutions to enable companies to reduce their environmental footprint, by reducing carbon emissions during extraction and processing of raw earth materials.

Applications include coal mine gas capture and utilisation, ventilation air methane abatement, ventilation strategies, battery electric vehicles (BEVs), clean coal technologies, and CO_2 storage in abandoned mines and unconventional deposits.

Research Spotlight

Senior Lecturer Guangyao Si is dedicated to reducing greenhouse gas emissions from the mining industry and decarbonising high-production mines, using technologies such as mine methane capture, ventilation methane abatement, ventilation on demand, and diesel fleet electrification.

Lecturer Yu Jing is leading research on characterising fractured formations to gain insights into gas transport through fracture networks for the purpose of optimising CO_2 geological storage.

Exploring and Engineering Extreme Environments

Minerals and energy resources engineering has expanded to operations in remote and extreme environments. These new operations bring numerous challenges regarding exploration, utilisation, economics and management. We aim to analyse technologies specific to off-Earth resource exploration, extraction and new resource extraction systems, and processing in remote environments. In particular, our capability and proven expertise in Space Resource Utilisation research has connected us with the mining and space industries. We closely collaborate with National Aeronautics and Space Administration, European Space Agency, European Space Resources Innovation Centre, and other industry partners.

Exploration in remote environments requires specific instruments engineered for restricted payload weights and operating in extreme environments. We work with our partners to design such devices and interpret the geological environments they will be deployed into.

Applications include environmental impact of space mining, mine optimisation and resource processing, integrated economics modelling, extraction technologies for extra-terrestrial operations, geophysics-based exploration, and resources assessment.

Research Spotlight

Professor Serkan Saydam's research addresses the current needs and future challenges faced by the minerals industry, and he leads projects on space resources engineering, ground control, mine systems design, and technology integration and management.

Senior Lecturer Dr. Chengguo Zhang focuses on integrating data analysis, numerical modelling, and visualisation technologies into the assessment of rock mass behaviour and management of geotechnical risks in deep hard rock mines, dynamic rock failures, and mine subsidence.

Future ahead...

Our role in Future Energy

The need for reliable and affordable energy is vital in today's world. To meet the increasing future demand while cutting the harmful by-products and emissions from our current energy sources, alternatives need to be found. These can be a mix of primary energy sources such as wind electricity, hydropower and solar, and secondary energy carriers, of which hydrogen can contribute as a low or zero-emissions fuel.

Our excellent renewable energy, mining and subsurface engineering research capabilities give UNSW a natural advantage and the potential to conduct research on implementing these technologies into the energy and resources sector.

The conflict between global energy demand and the conservation of natural resources provides an opportunity for novel engineering solutions.

Our experience with extraction technologies, geomechanics, flow and transport processes, and industry engagement provides a prime platform to address the challenge of future energy.

We are focusing our research efforts on new extraction technologies for resources related to alternative energy sources and investigating approaches to reduce the environmental impact associated with the extraction of raw materials.

As energy demand is ever growing, a diverse collection of technologies will be required to address the need since the utility of each technology is not equivalent. We are therefore focusing on natural gas as a transition fuel, geological storage of CO_2 to mitigate current technologies, and geothermal energy as an alternative energy source. What we are doing today in our discipline will change; however, the conflict between energy and the environment will remain a pressing question needing new insights, novel research, and technological innovations all of which are driven by our school.

It is our aim to be at the forefront of the energy transition with novel technological innovations.

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