IMPACT

THE MAGAZINE OF THE AUSTRALIAN ACADEMY OF TECHNOLOGY AND ENGINEERING
ATSE.ORG.AU
NUMBER 210 | 2020

Earth, wind and fire

Climate change and human adaptation

ATSE

ATSE Awards 2020

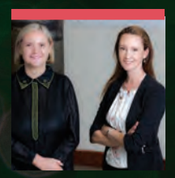
Innovation & Excellence Awards

See full story on page 18

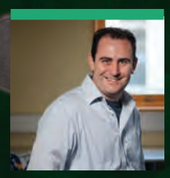
Our congratulations to the winners of the 2020 ATSE Awards.

Mark Sullivan
CLUNIES ROSS AWARD
ENTREPRENEUR OF THE YEAR

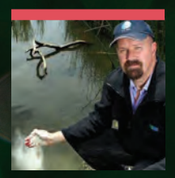
Professor Michelle Colgrave
ICM AGRIFOOD AWARD



Dr Alison Todd FTSE & Dr Elisa Mokany
CLUNIES ROSS AWARD
INNOVATION



Dr Greg Falzon
ICM AGRIFOOD AWARD



Dr Grant Douglas
CLUNIES ROSS AWARD
KNOWLEDGE COMMERCIALISATION

Charmaine Hee
EZIO RIZZARDO POLYMER SCHOLARSHIP

Associate Professor Pauline Pounds
BATTERHAM MEDAL
FOR ENGINEERING EXCELLENCE

Dr Gang Li
DAVID & VALERIE SOLOMON AWARD

Cover photo by Jack Bassingthwaighte / Unsplash

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The Academy acknowledges the Traditional Owners of the land on which we meet and work. We pay our respects to Elders, past, present and emerging.

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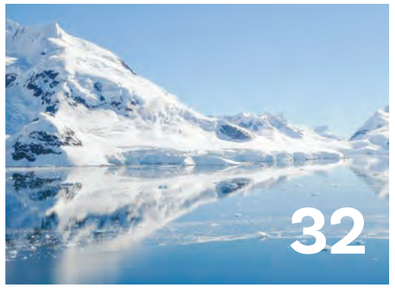
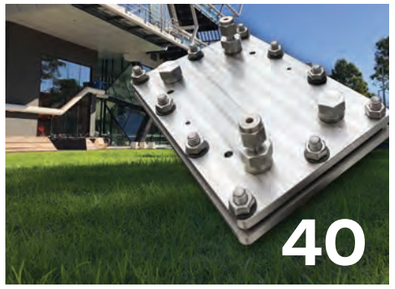
Contents





FEATURES

REGULARS

The best of times and the worst of times.

How technology can lead us through crisis into an age of wisdom

From a technologist's perspective it is "the best of times and the worst of times". As at the time of the French revolution Dickens was referencing, the past six months have seen our world turned upside down.

Climate change and devastating pandemics are no longer theoretical future possibilities but active realities, witnessed by Australia's bushfires this summer and the COVID-19 pandemic.

Responsible leaders around the globe are recognising science and technology as essential to enabling a modern society to function. Technologists are in unprecedented demand as the world comprehends that technology solutions are vital to our future wellbeing, both in terms of climate change and managing our health system — as well as maintaining economic, educational and social activity.

At the same time, there is a cohort of people who find science and technology frightening and threatening. These people are unable to adjust to the new reality and so choose to ignore it. They are being left behind, but that does not stop them from trying to drag the rest of us back with them. One example is protests about 5G mobile technology based on the false claims it is dangerous and causes COVID-19.

As an Academy of technological scientists and engineers, we are boldly indicating the way forward with pandemic-specific pointers for Australia's technology economy, state-of-play assessments of the STEM workforce, and longer-term roadmaps to lead the way beyond the pandemic. Our recent report on technology readiness in the health system came out just as the COVID-19 pandemic took hold.

The ATSE report pointed out that we have the technological solutions (health data technologies, diagnostic technologies including wearables, and 'omic' technologies) to address many of the challenges of COVID-19. However, our state of adoption was behind the technology available and there has been much scrambling to catch up. For example, something as routine and simple as telehealth consultations were not widely available until the pandemic hit us.

In some sense, climate change is similar. We have technology solutions to mitigate the impact of climate change, yet we have not created the conditions to adopt them. Hopefully, the apocalyptic summer we experienced may act as a trigger in the same way as the pandemic did for the health system. The Academy has again been leading the way in identifying these technological solutions.

For example, ATSE's 2018 position statement on climate change identified many opportunities. We are preparing to update this position statement as the pace of climate change quickens. We have also sought to declutter the political narrative by writing an 'explainer' to enable people to form their own judgement on whether Australia is meeting its responsibilities in terms of emissions reduction.

Returning to Dickens, I remain optimistic that we are entering "the age of wisdom" — Australia's response to COVID-19 has proven we are a rational, ordered society that accepts the rule of law and the wisdom of science. It is time for us to move beyond the climate change deniers (or flat earthers or anti-vaxxers or whatever guise they come in) and embrace and apply science and technology to create a more sustainable future. ▶

Professor Hugh Bradlow
FTSE

Hugh Bradlow is the President of the Australian Academy of Technology and Engineering. You can read his reflections on the big issues facing Australia on our website.

atse.org.au

Kylie Walker
Chief Executive Officer

This year has so far been one of change and challenge: environmental, social, and economic upheaval have prompted many to think about what's worth keeping, and what needs to evolve.

It's a privilege to step in as CEO of the Academy of Technology and Engineering at a time when the expertise and experience of our Fellows has so much to offer through supporting evidence-informed decision and policy making to strengthen Australia's economic, social and environmental resilience and build the potential for our nation to flourish into the future.

COVID-19 has presented challenges as well as opportunities: ATSE and many of our Fellows have been and continue to contribute materially to the crisis response, as well as to planning for a post-pandemic recovery. We've been informing decisions and thinking around the STEM workforce, advanced manufacturing, technology-supported healthcare delivery, access to education, and more.

Meanwhile, secretariat staff have proved incredibly resilient through times of multi-faceted change, as we transition to being located across two cities (Melbourne and Canberra); work to stage important events like our annual Awards celebration online; recruit for greater capacity to research, report, inform and influence national leaders on issues of technology, applied science and engineering; and introduce new systems to improve transparency, engagement and risk management.

Despite the restrictions of lock-down I've had the pleasure of meeting and hearing from a great many Fellows over the last few months. As well as representing a Fellowship of esteemed and accomplished applied scientists, technologists and engineers, it's clear to me that ATSE also represents a strong community of engaged and proactive individuals who are committed to building a strong and lasting legacy for the Academy and for Australia.

Those discussions have informed updates to ATSE's operations and governance, and been directed at informing ATSE's strategic goals through until 2025. While the strategy is still in formation, there's already emerging a strong will to continue to recognise and celebrate excellence, to lend expertise to leading bold discussions on issues of importance to Australia, and to nurture the nation's future great engineers, applied scientists, and technology experts.

I'm looking forward to meeting many more Fellows and partners in person when restrictions permit, and to working with Fellows, forums, the Board, Assembly, divisions and staff, to build our capacity to provide timely expert advice to national leadership, to nurture an outstanding and diverse engineering, applied science, and technology workforce of the future, and to celebrate outstanding achievement in applied science, technology and engineering. ▶

Kylie Walker
CEO

Kylie Walker is the CEO of the Australian Academy of Technology and Engineering. Formerly CEO of peak body Science & Technology Australia, she is Chair of the Australian National Commission for UNESCO, a visiting Fellow at the Australian National Centre for the Public Awareness of Science and was included the Australian Financial Review's 100 Women of Influence list for 2019 for her work to improve equity, diversity and inclusion in STEM.

Photo by Ivan Bandura / Unsplash

A new prescription

PREPARING FOR A HEALTHCARE TRANSFORMATION

Sue MacLeman
FTSE

Sue MacLeman is a pharmaceutical, biotechnology and medical technology executive who has held senior roles in corporate, medical, commercial and business development. She is the Chair and Non-Executive Director of MTP Connect, a not-for-profit that aims to accelerate the growth of the health sector in Australia. She co-chaired the steering committee for this project.

Professor Simon Foote
FTSE FAA

Simon Foote is a leading geneticist and the Director of the John Curtin School of Medical Research at ANU. He works widely within the medical research community on scientific advisory boards of charitable organisations and research institutes. He co-chaired the steering committee for this project.

Australia needs a new prescription for healthcare; specifically, a focus on prevention and wellness, enabled by technology. While the healthcare system has delivered increased life expectancies and improved quality of life for several decades, these successes have also thrown up new challenges.

ATSE completed a major project on technology readiness in the healthcare system in 2019/20, before the onset of the COVID-19 pandemic. It's a testament to the work of ATSE's Fellows and project team that the recommendations are as valid, if not more so, today, as we tackle the issues thrown up by the pandemic at the front line of healthcare, in industry and at home.

Healthcare in Australia is under strain, and nowhere is this more obvious than in the poor outcomes associated with chronic illnesses such as obesity, mental illness and cardiovascular disease. The rising burden of chronic conditions is one of several critical challenges the healthcare sector will face in the coming decade.

Other challenges include changes in consumer behaviour and expectations, incompatible record-keeping systems, poor communication between healthcare professionals, inequity in access to care and unsustainable funding models.

To effectively tackle these challenges the sector must undergo a step change, embrace technology, and shift its focus to prevention and wellness, radically moving from reactive to preventative strategies.

Are we technology ready?

Drawing on its experience as a Learned Academy of independent, non-political experts dedicated to helping Australians understand and use technology to solve complex problems, ATSE has examined the healthcare sector's readiness to develop, adapt and adopt technologies that will underpin this shift over the next ten years.

In developing a report ***A New Prescription: preparing for a healthcare transformation*** — we drew on the expertise of key stakeholders from the nation's healthcare sector.

Discussions with experts in healthcare research and delivery reveal a consistent and common theme: we must use technology to support a shift in focus to a patient-centred, outcomes-focused, value-based system.

A roadmap for essential change emerged. In the decade to 2030, data and digital technologies will enable a transition from paper files to secure electronic health records; from fax machines to universally accessible health information platforms; and from fragmented information to big data that can be mined and analysed to accurately map, monitor and predict population health trends.

Technology will integrate patient histories, with an individual's electronic health records functioning as a shared resource between themselves and their general practitioner, hospital, specialist, pharmacist and other healthcare professionals.

Precision medicine will become more common, with prevention and treatment strategies targeted to individuals. Genetic testing and screening for preventable disease will also become an affordable option. Healthcare will become integrated through technology, with smart devices, mobile health and telehealth — all linked through a digital health record — enabling a holistic picture of a person's health.

Technological solutions to the problems of distance and mobility will enable affordable healthcare access for more Australians, when and where we need it.

A roadmap for the future

ATSE's analysis shows this vision is achievable by 2030 through increased support for work that's already underway, and by accelerating work in critical, foundational technology. Governments and industry are already working on these complex and sensitive issues, and through targeted action can maximise health outcomes and economic opportunities for Australia.

As individuals, Australians are prepared for a technology-supported transition. In fact, we expect it, although we have concerns about cybersecurity and ethics. There's still debate over the appropriate regulatory structures for this transition, but our technology is world-class and heading in the right direction.

Some new technologies will need fit for purpose regulation and market access pathways. Greater preparation is required in our infrastructure, workforce skills, and economic and commercial environment, while continuing to ensure equity in our health system.

The most critical priority is the digitisation of health records;an issue that was highlighted by the majority of stakeholders and underpins the technology solutions identified by ATSE. Without a shift to electronic records, the fragmented healthcare system will not cope with increased volumes of data and the emergence of digital technologies, nor with the increasing personalisation of healthcare.

Integrated care will be unachievable without electronic health records, which are essential for efficient, accurate, timely and patient-centred care.

Embracing new technologies will also be vital in ensuring that the benefits of a wellness system are available in regional areas, in Aboriginal and Torres Strait Islander communities, and to disadvantaged people in urban communities.

Barriers to equitable outcomes include distance, communication difficulties, financial resources, education levels, accessibility, and shortages of healthcare workers. Mobile and telehealth services can easily and inexpensively help Australians overcome these obstacles and access the best available care in a timely way.

Empowering the workforce to maximise the benefits from new healthcare, data and communications technologies will result in increased efficiency, better clinical decision-making and improved outcomes. The workforce must be supported in its transition to a focus on prevention and wellness, particularly developing skills to adapt to a technology-driven workplace.

Finally, the research sector needs a boost to provide the healthcare system with the tools it needs and to ensure a robust return on investment. Despite generous government support, Australia's position as a world leader in health technology research is at odds with its poorer translation and commercialisation record, indicating a system failure.

Government has a responsibility to ensure that there is support for, and a clear path to develop, timely, cost-effective and commercially successful products from initial research outcomes.

Our recommendations

ATSE made the following pragmatic recommendations, grouped under four key issues to help policy-makers, industry and researchers accelerate positive change and use technology to revolutionise Australian healthcare over the coming decade.

We encourage government, funding agencies, the healthcare sector, and the research community to use these recommendations to plan for the needs and expectations of diverse Australian communities, and to work towards an effective and equitable, prevention-focused future healthcare system.

1. Transition to interoperable electronic health records

All healthcare providers must switch to electronic records as soon as possible. Social licence for this move will fundamentally depend on well-communicated privacy and cybersecurity frameworks.

2. Improve equity of access to healthcare through technology

Use of telehealth and AI-enabled devices must increase to support equitable outcomes for people living with disadvantage, to improve access and reduce financial burden.

3. Support the existing and future healthcare workforce in the transition

Existing and new members of the national healthcare workforce must be supported and empowered to retrain, adapt and develop skills to use new digital technologies.

4. Provide targeted support for a thriving health technology sector

Government must support investment in improving pathways to commercialisation for Australian-developed medical technology.

These recommendations are intended as guidelines for government, funding agencies, the healthcare sector and the research community to meet the needs and expectations of diverse Australian communities, and to build practical research agendas to address questions about our future healthcare system.

This report provides an opportunity to plan for the future of healthcare in Australia, using technology to support our health and wellness.

Australia is a global leader in health, but it is critical that we continue to identify what we want for our society, what action government and the healthcare sector need to take, and how this will translate to a healthcare sector of the future. ▶

A New Prescription — preparing for a healthcare transformation *was published in April 2020.*

MORE

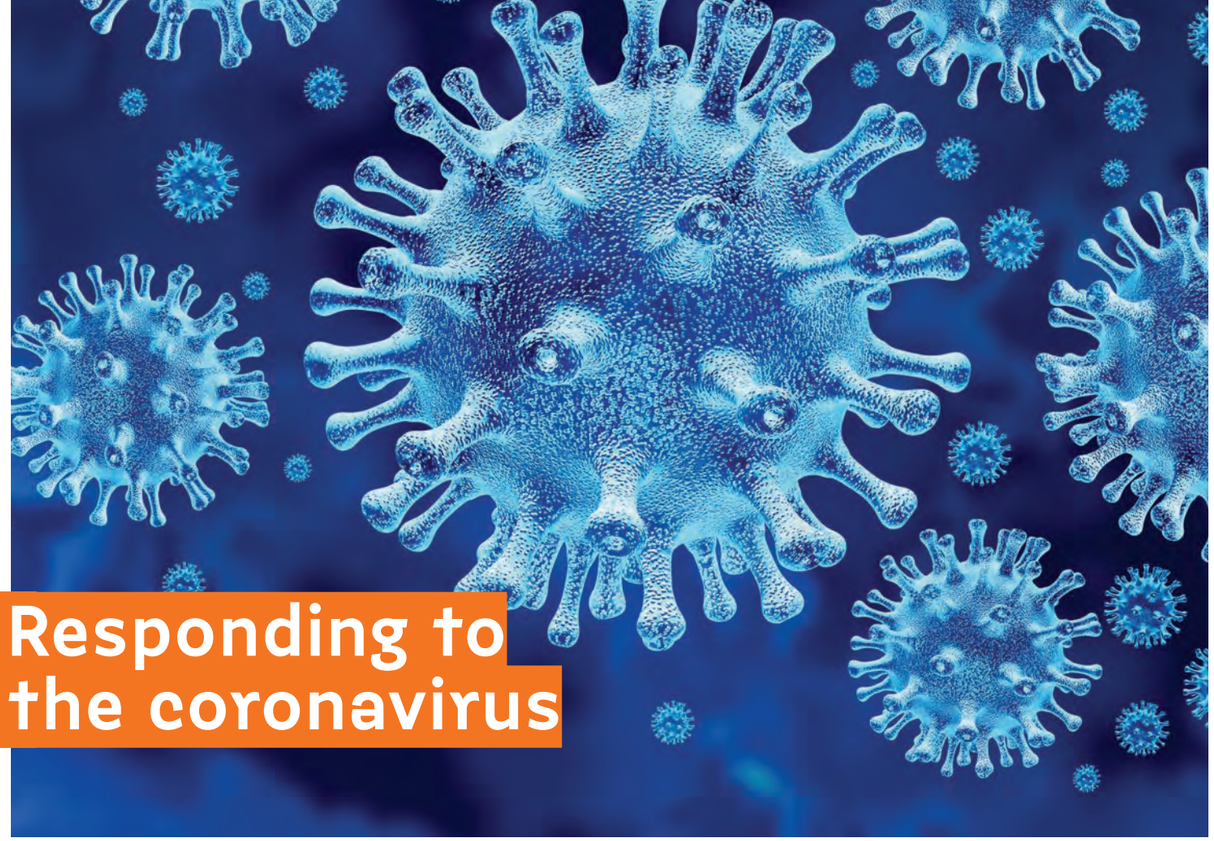
IMPACT
The report gained considerable media coverage

WEBINAR
Held with attendees from around the world.A recording is available online

WATCH
A video accompanying the report can be viewed online

READ
Read the full report online

atse.org.au/healthtech



Responding to the coronavirus

In tumultuous times when uncertainty is rife, independent expertise is more important than ever. COVID-19 poses unprecedented economic and societal challenges that call for innovative, evidence-based solutions.

The Australian Academy of Technology and Engineering is spearheading a range of initiatives to respond to the immediate impacts of the crisis and identify longer-term opportunities.

We're also collaborating with other experts and decision-makers in Australia and around the world to help ensure a healthier, more prosperous, sustainable future for all — whatever the pandemic may bring.

MORE

READ
We have a dedicated COVID-19 section on our website

atse.org.au/responding-to-COVID-19

Using tech to get through the pandemic

Technology has empowered humanity to track, identify and fight the coronavirus, and keep our communities, businesses and educational facilities operating despite new constraints.

The Academy published a fact-sheet explaining technologies that are helping society:

- identify outbreaks, track the disease and minimise transmission
- get the facts straight
- create a vaccine
- support businesses to function
- stay social and connected.

It also looked at lessons for the future, like the urgent need for interoperable health records, further workforce training and new infrastructure.

Investing in a post-pandemic tech boom

What will our post-COVID economy look like? This crisis could be an opportunity to lay the foundations of a future "tech boom" that could help Australia flourish.

We published a fact sheet recommending a number of technology investments critical to ensuring a more economically and environmentally sustainable future. Our particular focus was on advanced manufacturing and agribusiness, clean energy, integrated digital healthcare, and advanced data collection and analytics.

We recommended these investments include:

- mechanisms for retraining at a time of high unemployment
- gender equity targets to unlock our workforce's full potential
- measures to ensure vulnerable people are not further marginalised.

This will also create genuine employment opportunities for people with disability, those living in rural and remote areas, and others who traditionally have found it difficult to train for and gain meaningful work.

Academies join forces to launch COVID-19 expert database

Australia's learned academies came together to launch a searchable database of leading experts to help tackle COVID-19. The COVID-19 Expert Database allows governments, researchers, businesses and others to easily access the expertise they need across a wide range of fields.

"With events developing rapidly, it's vital that decision-makers have access to targeted, evidence-based advice" said our CEO Kylie Walker.

"We all need to pool our knowledge and skills to help humanity address and recover from this crisis. If you're an expert who can contribute, we urge you to register on this database."

The database aims to provide access to expert insights into the COVID-19 pandemic and its scientific, health, social, cultural and economic implications.

Australia's Chief Scientist and former ATSE President Dr Alan Finkel AO FTSE FAA championed the initiative. Users of the public database will be able to search for credible expertise in science, technology, engineering, mathematics, health, humanities, arts, and social science.

"This is a complex issue affecting all facets of society, so it's important that our response is an interdisciplinary one," Ms Walker said.

Informing the decision makers

The Rapid Research Information Forum (RRIF) is a group of 35 leading research sector organisations working to inform Australia's response COVID-19 with swift, evidence-based advice.

Convened by Dr Alan Finkel AO FTSE FAA, the Forum's operations, are led by the Australian Academy of Science.

RRIF provides governments with multidisciplinary expertise to address pressing questions as they emerge. It also informs the Chief Scientist's collaboration with other national chief scientific advisers, and demonstrates the critical value of research and innovation in driving societal and economic progress.

The Australian Academy of Technology and Engineering is a member organisation of RRIF, and has led several of its reports.

Pandemic to impact Australian research workforce

The Academy led a research report detailing how a dramatic drop in international student fees and business research spending will significantly impact the sector 2020 and beyond.

It projected university job losses of up to 21,000 full time equivalent positions over the next six months, of which an estimated 7,000 could be research-related academic staff.

Research interruptions along with travel and visa restrictions suggest that more than 9,000 international research students will not resume their research in 2020, according to the report's authors.

They are concerned that women, early-career researchers and recent graduates will disproportionately experience negative impacts.

ATSE CEO Kylie Walker said industry sectors may experience a reduced capacity to innovate given that universities perform approximately 43% of all applied research in Australia.

"A decline in innovation may limit economic growth by slowing the development of new technology, skills, and efficiency gains in service and production processes," Ms Walker said.

The report also found:

- Income to universities, medical research institutes, publicly funded research agencies, CRCs, and the industrial sector are suffering from the loss of foreign students and a sharp decline in business research spending and philanthropy
- These impacts are greater than during the 2008 global financial crisis and are being observed internationally
- To try and make ends meet as budgets contract, universities are reducing the number of casual teachers and increasing the teaching loads of permanent staff, further limiting their research capacity.

Pandemic threatens hard-won gains by women in STEM

A RRIF report ATSE co-led with Science & Technology Australia found that hard-won gains for women's advancement in the science, technology, engineering and maths (STEM) workforce are now at risk of a major setback due to the COVID-19 pandemic.

Even before the pandemic hit, women were under-represented in STEM. Early evidence from during the shutdown suggests women in the STEM sector have suffered even greater job losses than men.

It also points to women carrying a greater share of responsibilities for caring and distance learning duties during isolation.

The research report was requested by the Minister for Industry, Science and Technology, the Hon Karen Andrews MP.

Academy Fellow and lead author Professor Emma Johnston AO FTSE, Dean of Science at UNSW Sydney, said the peer-reviewed report confirms an urgent need for STEM employers to closely monitor and mitigate the gender impact of the pandemic on jobs and careers — or the hard work over many years to recruit and retain more women in STEM could be undone.

"The challenges are likely to be most acute for women in STEM with children under 12," Professor Johnston said.

"The combination of juggling working from home while supervising distance learning for children has made women's well documented 'double burden' even greater again."

ATSE CEO Kylie Walker said diversity in the workforce is integral to higher quality and more resilient STEM research and application.

"The diverse perspectives that women bring to the STEM sector enable and drive better outcomes for scientific and technology-based industries," Ms Walker said.

New Fellows Welcome & Annual Academy Oration

Friday 29 November 2019, Melbourne

We welcomed our newest cohort of Fellows at a dazzling gala event in Melbourne. Twelve of the 25 new Fellows are women — the highest proportion ever and almost matching the Academy's 2025 target of electing at least 50 per cent women. We also welcomed a Foreign Fellow, an Honorary Fellow and a Fellow elected directly by the Board. Meet these extraordinary leaders at atse.org.au/newfellows

1. **Professor Neena Mitter** FTSE
Ag nano innovator
Director, Centre for Horticultural Science, QAAFI, The University of Queensland, QLD

2. **Romilly Madew** AO FTSE
Sustainable infrastructure pioneer
Chief Executive Officer, Infrastructure Australia, NSW

3. **Professor Sandra Kentish** FTSE
Polymer research industry pioneer
Head, School of Chemical and Biomedical Engineering, The University of Melbourne

4. **Dr Douglas Bock** FTSE
Radio telescope engineer
Director, CSIRO Astronomy and Space Science, CSIRO

5. **Professor Emma Johnston** AO FTSE
Marine scientist
Dean, UNSW Sydney

6. **Dr Gunilla Burrowes** FTSE
Electrical engineer & gender equity advocate
Chair, Eighteen04 Inc

7. **Anthony Wood** AM FTSE
Energy policy advisor
Energy Program Director, Grattan Institute, VIC

8. **Professor Saeid Nahavandi** FTSE
Intelligent systems researcher
Pro Vice-Chancellor (Defence Technologies) Deakin University

9. **Dr Surinder Pal Singh** FTSE FAA
Plant oil researcher
Chief Research Scientist, Agriculture & Food, CSIRO

FOREIGN FELLOW

10. **Francesca Ferrazza** FTSE
Photovoltaics & renewables researcher
Senior Vice-President Decarbonization & Environmental R&D, Eni, Italy

11. **Dr Alison Todd** FTSE
Molecular inventor
Co-Founder & Chief Scientific Officer, SpeeDx Pty Ltd

12. **Professor Chien Ming Wang** FTSE
Structural mechanics engineer
Transport and Main Roads Chair in Civil Engineering, University of Queensland

13. **Zoe Yujnovich** FTSE
Energy sector executive
Chair/Executive Vice-President, Shell Australia

14. **Associate Professor Elaine Saunders** FTSE
Engineer, audiologist & inventor
Former Executive Chair, Blamey Saunders Hears

15. **Professor Ranjith Pathegama Gamage** FTSE
Resource recovery innovator
Professor in Geomechanics Engineering, Monash University

16. **Professor Huanting Wang** FTSE
Advanced membranes inventor
Professor in Chemical Engineering, Monash University

17. **Dr Helen Cleugh** FTSE
Atmospheric scientist
Director, Climate Science Centre, CSIRO

18. **Dr Andy Sheppard** FTSE
Invasive organisms scientist
Research Director, Managing Invasive Species and Diseases, CSIRO

19. **Professor Jan Tennent** FTSE
Biomedical research leader
CEO, Biomedical Research Victoria

20. **Distinguished Professor Adrian Mouritz** FTSE
Materials engineer
Executive Dean of Engineering, RMIT

21. **Professor David Lloyd** FTSE
Tertiary education champion
Vice-Chancellor and President, University of South Australia

22. **Professor Nicolas Voelcker** FTSE
Nano-materials scientist
Professor in Pharmaceutical Sciences, Monash University

23. **Associate Professor Matthew Hill**
2019 David and Valerie Solomon Award Winner
Principal Research Scientist, CSIRO Manufacturing

24. **Dr David Cook** AO FTSE
Chair of the Academy Membership Committee

ABSENT FROM PHOTO

Dr Lynn Booth FTSE
Defence technologist
Chief, Joint and Operations Analysis Division Defence Science and Technology Group

Dr Martin Cole FTSE
Agribusiness & food security leader
Deputy Director, Agriculture and Food, CSIRO

William Cox FTSE
Infrastructure engineer & business leader
Global CEO Aurecon

Professor Melinda Hodkiewicz FTSE
Asset management thought leader
Professor, The University of Western Australia

BOARD-ELECTED FELLOW

Dr Andrew Thomas AO FTSE
Former NASA astronaut

HONORARY FELLOW

The Hon John Anderson AO FTSE
Former Deputy Prime Minister
Chair of the Crawford Fund

2019 Annual Academy Oration
Delivered by Professor Margaret Sheil AO FTSE, Vice-Chancellor & President QUT

MORE

LISTEN
The 2019 Annual Academy Oration delivered by Professor Margaret Sheil AO FTSE is available via our website

atse.org.au

Main photo by Peter Casamento

Submissions from the Academy

Australian Government's Technology Investment Roadmap Discussion Paper

June 2020

Through the use of clean energy technologies ATSE's Energy Forum believes Australia's emissions could fall by two-thirds by 2035.

Renewable energy already comprises 20 per cent of Australia's total electricity generation and renewable energy is becoming cheaper.

Technology also now exists to scale up production and introduce mechanisms to ensure the reliability of supply.

The next step is to continue to develop and adopt storage solutions that increase our ability to rely on renewable energy.

To become a world-leader in renewable energy, ATSE has recommended six crucial actions:

- scaling up infrastructure to support greater use of solar and wind power
- a rapid transition to electric heating and transport
- developing a hydrogen energy economy
- further R&D and demonstration in technologies that will support industry to reduce emissions
- skills development
- scanning and, where appropriate, adopting new technologies developed overseas.

South Australian Productivity Commission — Research and Development Commission Issues Paper

June 2020

South Australian industries, institutions and government should focus their R&D spending on information and communications technology, space, renewable energy generation and storage, mining, agriculture and marine bio resources, and natural resource management.

The South Australian Government should also increase R&D investment in the state by encouraging the Federal Government to broaden and enhance its R&D Tax Incentive Scheme. Tax concessions for companies with high growth and/or a high level of R&D investment should be encouraged to set up in the state and provide financial and in-kind support for CRC bids that plan to base their headquarters in South Australia.

NSW Government — 20 Year Waste Strategy Issues Paper

May 2020

ATSE is currently investigating the readiness of the Australian waste management and resource recovery sector to adapt, adopt, or develop technologies to meet key challenges it will face in the decade to 2030.

This includes transition to waste as a resource, domestic capacity to process core waste, and emerging waste streams.

The Academy supports the application of innovation and 'waste-tech' to improve collection and sorting systems and the development of technology-supported waste infrastructure to ensure adaptability and sustainability of the sector.

We encouraged NSW to leverage the understanding of waste generation and movement, to identify opportunities for jobs, infrastructure and investment.

Federal Government — A New Prescription: Preparing for Healthcare Transformation

April 2020

In order to support Australia's healthcare sector through digital transformation, all healthcare providers should switch to electronic records as soon as possible. Social acceptance of electronic health records will depend on well-communicated privacy and cybersecurity frameworks.

Increased use of telehealth and AI-enabled devices will support equitable outcomes for people living with disadvantage, including home tele-monitoring and tele-rehabilitation and wearable, monitors, apps and secure prescription transmission.

The existing and future healthcare workforce needs support during the transition. Skills need to be adapted and developed in line with the requirements and benefits of new digital technologies.

The research translation sector needs a boost to provide the healthcare system with its future tools, and we need to look to the global market.

Inquiry into Australia's Waste Management and Recycling Industries

May 2020

Consumers, manufacturers and the waste sector need to work together to reduce waste through business models such as product as service, sharing platforms and product life extension.

We encourage the manufacture of products designed with disassembly in mind from the outset, enabling industry to repair, repurpose and remanufacture them and recover valuable materials from them as they r each end-of-life.

Smart waste management systems for collection, disassembly, material recovery and processing should be encouraged to reduce waste. Advanced technologies could assist in minimising the effects of contamination of waste streams and maximising the values of recovered goods.

ATSE recommends advanced resource recovery solutions that use technologies to recover valuable materials for manufacturing as well as energy to produce electricity, heat, gas and fuels from waste.

Submission to NSW Legislative Assembly Committee on Environment and Planning Inquiry into the Professional Engineers Registration Bill

January 2020

Building trust in professional engineering services is essential and therefore ATSE supported the Bill put forward by the Committee.

It is important that professions are regulated from outside of the industry.

The Academy believes that any new legislation should only cover professional engineers. ATSE argues that engineering technicians and technologists who are supervised by a professional engineer and other professions working in the building industry, such as architects and land surveyors, are already covered by their own state registration schemes.

ATSE is pleased to see that these recommendations were accepted by the Committee, and that the Act was passed on 3 June 2020, introducing a requirement for professional engineers to be registered to practice without supervision.

Submission to the NSW Department of Premier & Cabinet Accelerating R&D in NSW

December 2019

ATSE recommends further funding and coordinated support for the scale-up phase of the research translation ecosystem. This could include a Business Development Fund; a Catapult Program to provide seed funding and for NSW small and medium enterprises (SMEs) to get access to aspects of large government contracts. It could also include founders' fellowships for academics, small business and entrepreneurs.

The NSW Government could encourage start-up and scale-up companies to establish in regional areas by instigating an industry attraction fund, building ecosystems for growth and strengthening local infrastructure.

There should also be more coordination between the NSW Government, industry and universities and a science-based strategic initiative to address water R&D.

Submission to the NSW Education Standards Authority NSW Curriculum Review — Interim Report

December 2019

'Learning through doing' should be advocated in the school curriculum as exemplified in ATSE's well-established STELR in-school science support program. ATSE supports balancing knowledge and application (skills) throughout the curriculum.

The Academy supports the concept of a major project in secondary years (which is already compulsory in South Australia), and of undertaking a review of ATAR and alternative university entrance methods.

To reverse the downward trends in students' participation and performance in STEM subjects from primary school, the curriculum should mandate increased in-service professional development for teachers in science, mathematics, digital technologies and design and technology.

The NSW Government should recruit more bachelors graduates into teacher education programs for all STEM subjects, possibly though NSW government scholarships.

Submission to the NSW Productivity Commission — Kick-Starting the Productivity Conversation

November 2019

Reliable, sustainable and productive use of water and energy, accompanied by a public information and education campaign, is an integral part of increasing productivity.

This would also include reformation of market institutions to ensure an efficient transition to a system that accommodates a high penetration of renewable energy sources.

An independent body could be developed to ensure a systematic approach to integrated water management and planning. The role of water recycling could also be expanded to improve its efficiency.

Electricity asset utilisation and demand management would also improve efficiency and lead to lower electricity prices through investment certainty. Reliability standards for electricity supplies would also improve productivity.

Australia's 2020 Cyber Security Strategy — A Call for Views

November 2019

The Federal Government should seek to establish national cyber security standards developed by knowledgeable bodies and technical experts.

Regulations regarding the liability of providers of cyber goods and services for data security and privacy would also contribute to improved cyber security.

The 2020 Cybersecurity Strategy should have a more proactive rather than reactive approach, with a view for managing future and emerging vulnerabilities and threats associated with emerging technologies.

The number of high quality cyber professionals in Australia could be increased by ensuring education bodies include cyber security as a component in all science and technology courses.

Rural and Regional Affairs and Transport References Senate Committee Inquiry into the Importance of a Viable, Safe, Sustainable and Efficient Road Transport Industry

November 2019

A shift towards low emission transport options will ensure a viable, safe, sustainable and efficient road transport industry in rural and regional areas..

This can be achieved through a national target and regulatory mechanism to drive the uptake of low emission vehicles (LEV). Public and private corporations could also be incentivised to use LEVs as fleet vehicles and imported cars should meet stringent emissions standards.

A framework is needed to regulate new transport technologies. This can be done by introducing flexible legislative and regulatory frameworks to keep pace with global technology. The Council of Australian Governments should set nationally consistent standards and regulations to facilitate the uptake of productivity-enhancing technology.

Inquiry into Growing Australian Agriculture to $100 Billion by 2030

October 2019

The immediate development of national strategies covering climate change in agriculture, drought, water and energy and emissions are needed to grow Australian agriculture by $100 billion by 2030.

ATSE joined the National Committee for Agriculture, Fisheries and Food of the Australian Academy of Science in calling for the immediate development of funded policies.

Australia needs to ensure that the regulatory environment enables the use of within-species gene manipulation techniques capable of significantly accelerating genetic improvement of agricultural plants and animals.

Sustainable intensification of agricultural yields without the conversion of additional non-agricultural land and adverse impacts to the environment should also be considered.

MORE

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Read our recent submissions online under /research-and-policy/publications

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Deep concerns about maths and science decline

The Academy expressed concern about Australian students' record low results in reading, maths and science in the Programme for International Student Assessment (PISA) report released in December 2019. ATSE is particularly concerned that the results for maths and science skills are at their lowest level since the survey began.

"As we transition to an increasingly digital future, our children will need science, technology, engineering and maths (STEM) skills more than any previous generation," said Academy President Professor Hugh Bradlow FTSE. "If we don't take urgent action to support STEM in schools our kids will be left behind."

A 2013 report from the Australian Council of Learned Academies (ACOLA) studied PISA results and found that science, universal learning and economic prosperity are all linked in a single interdependent system. The Academy maintains that the more rigorously a teacher is trained specifically in STEM education, the more they can nurture and empower the STEM workforce of the future.

"We need to support schools to ensure that all science and maths teachers are experts in science and maths," said Academy Education Forum Chair Professor Peter Lee FTSE. "Out-of-field teaching isn't fair to our kids, and it's not fair to the teachers either."

Higher-ed reform will have longlasting impacts

The proposed Job-ready Graduates Package is the most significant change to Australia's tertiary education system in over a decade, and will impact current and future generations. ATSE CEO Kylie Walker said that ATSE has long advocated for incentives to encourage domestic students to choose fields of education that lead to jobs of national priority, such as in STEM.

"ATSE is committed to enhancing technology and engineering career paths, supporting a strong, diverse, and appropriately skilled STEM workforce, and strengthening engagement with industry" said Ms Walker.

"We therefore welcome the Australian Government's proposed incentive for work-integrated learning such as internships, extending the Industry 4.0 advanced apprenticeship pilot and fostering closer university-industry research collaboration."

While ATSE supports the policy objective of increasing Australia's pipeline of STEM-skilled workers, early analysis suggests that the proposed funding model accompanying the policy may actually have the opposite effect.

"A foreseeable outcome would see less STEM places being offered by universities, rather than more," said Ms Walker.

"ATSE is very concerned about this possible outcome – particularly at a time when the economy needs all the STEM innovation it can access to develop and manufacture a vaccine, and then drive Australia out of recession."

Focus on cyber resilience, Academy tells home affairs

Complete cyber security cannot be achieved and Australia must focus on achieving cyber resilience: the ability to continue operating in the face of a cyber attack.

That's part of the advice the Academy provided the Department of Home Affairs' "Australia's 2020 Cyber Security Strategy — A call for views".

ATSE Fellow Dr Jacqueline Craig FTSE, a former Chief of the Cyber Electronic Warfare Division of the Defence Science and Technology group, said the increased dependence on connected systems put Australia at higher risk of cyber threats.

"Australia must develop strong cyber security systems and measures by playing a leading role in the development of cyber technology and its application in business, industry, government and society. Cyber security must be positioned as an enabler for our digital future.

"The Academy believes that complete cyber security cannot be achieved, and Australia must focus on achieving cyber resilience, which is the ability to continue operating in the face of a cyber attack.

"That involves understanding critical dependencies and system vulnerabilities that are key to achieving cyber resilience," Dr Craig said.

Dr Craig said: "As a trusted global cyber nation Australia will need to maintain the highest of cyber security standards including the development of a top-class professional cyber security workforce and a comprehensive education program for its citizens.

"New technologies such as big data and autonomous and cognitive systems based on Artificial Intelligence will play a central part in this."

The National Cyber Security Strategy was released in August 2020.

www.homeaffairs.gov.au/about-us/our-portfolios/cyber-security/strategy

The Government has made a significant commitment to supporting more cybersecurity education. ▶

Australia will need to maintain the highest of cyber security standards including the development of a top-class professional workforce and a comprehensive education program for its citizens.

MORE

READ
Read the full report online.

atse.org.au

Academies speak on bushfires

The Australian Council of Learned Academies (ACOLA), of which ATSE is a member, expressed deep sympathy for those affected by the 2019/2020 Australian bushfires. The consensus statement called on government, industry, academia and the public to come together to respond to the unprecedented fires and the underlying issues that contributed to their intensity.

"Alongside efforts to address regionally relevant industries such as agriculture and tourism, recovery efforts must focus on addressing the breadth of economic, cultural, health and social impacts. This includes:

"Food and water security: Agricultural land and livestock have been compromised, including bees and insects which are crop pollinators. The full extent of the impact is still unknown. However, supplies for humans and animals will be impacted. Recent rainfall has contributed to run-off of sediment, nutrients and contaminants into rivers and water storage, presenting further risks to aquatic life and food supply.

"Social, cultural and health impacts: The devastation will elicit immediate and medium- to long-term effects on physical and mental health that will require action and research. There are also long term cultural and social impacts, including the loss of significant and sacred sites for Aboriginal and Torres Strait Islander communities.

"Recovery of our flora and fauna: The widespread devastation to established forests, biodiversity and wildlife populations has threatened and marginalised the existence of at least 250 threatened species, of which 25 are critically endangered. Assessing the scale of devastation and protecting endangered species requires urgent attention.

"Climate change is a major contributor to the risk, frequency and severity of bushfires and drought. Significant work is required to understand and develop robust, evidence-based strategies to mitigate and adapt to our changing climate. Waiting for other countries to take stronger action first is not a viable option."

Read the full statement on our website.

Call for swift energy action

The Academy supported Australia's Chief Scientist, Professor Alan Finkel AO FTSE FAA, in his call for an urgent transition to clean energy via existing low-emission power generation technologies.

"The need to transition our energy economy is a matter of urgency, and we should be prepared to seriously consider all safe, low-emissions technologies," Academy President Professor Hugh Bradlow FTSE said.

Professor Bradlow added that it was vital to ensure any potential energy solutions meet key safety, regulatory, and sustainability criteria.

"It's important that any new Australian systems of power generation and distribution meet regulatory requirements as well as low-emissions targets," he said.

"It's equally important to ensure power generation systems are stable and secure, that the energy is able to be distributed where and when it's needed, and that the technology used is safe and sustainable.

Australia is heavily reliant on fossil fuels for its domestic energy needs.

In 2018, about 39 per cent of Australia's energy consumption was sourced from oil, 30 per cent from coal, 25 per cent from fossil gas and 6 per cent from renewables.

"The Academy of Technology and Engineering has long advocated for technology-neutral policies that can address the electricity trilemma. No technology solution should be excluded providing it is able to meet reliability, stability and emissions targets. It is up to the market to decide which technologies are the most affordable, which in turn will ensure the lowest cost to the consumer." Professor Bradlow said.

"As carbon dioxide emissions continue to amass in the atmosphere, and as Australia faces the increasingly tangible effects of climate change, ATSE calls for an urgent transition plan."

Bottling Australian sunshine

A report ATSE released in conjunction with top South Korean applied scientists and engineers found that Australia could be a world-leading hydrogen exporter by 2030.

The report is the culmination of collaboration between the Australian Academy of Technology and Engineering (ATSE) and the prestigious National Academy of Engineering Korea (NAEK).

Leading experts from both Academies came together to explore real pathways to creating a hydrogen economy.

"Our Korean counterparts clearly view Australia as a source of clean hydrogen, essentially continuing Australia's role as a reliable supplier of fuels while contributing to the fight against climate change," said ATSE President Professor Hugh Bradlow FTSE.

"Just two or three years ago, international discussions around a possible hydrogen industry were focused on developing the tech, and the conversation has moved from is it possible? to 'when do we start?"

The global effort to reduce greenhouse gas emissions has prompted a resurgence of interest in the role hydrogen can play in creating cleaner energy, transport and industrial sectors.

The report emerged from a critical hydrogen workshop the two Academies held earlier in the year. Fifty experts in hydrogen and clean energy from Australian and Korean government, industry, research and academia participated in the event at the University of Melbourne's Woodward Centre on 3 March.

The Australian Academy of Technology and Engineering was delighted to welcome a senior delegation from the Republic of Korea, including the President of NAEK, Professor Oh-Kyong Kwon.

The Hydrogen Futures workshop was supported by the Australian Korea Foundation (part of the Department of Foreign Affairs and Trade), Woodside Energy and the Melbourne Energy Institute at the University of Melbourne.

Australia's emissions targets — are we on track?

The science and lived reality of human-made climate change are unequivocal. Australia's horrific 2019/2020 bushfire season made it clear that the world must take urgent action to stop emitting greenhouse gasses.

So is Australia meeting its international obligations to cut carbon emissions? The Academy published an "emissions targets explainer" to clarify where we stand.

Australia has signed up to three separate targets, measured from different baselines:

- The Kyoto Period 1 target: to limit annual emissions to no more than 108 per cent of 1990 levels by 2012 (592 million tonnes)
- The Kyoto Period 2 (Cancun) target: to reduce annual emissions to five per cent below 2000 levels by 2020 (509 million tonnes)
- The Paris Agreement target: to reduce annual emissions to 26-28 per cent below 2005 levels by 2030 (452 million tonnes).

Australia comfortably met its first Kyoto target of increasing emissions by no more than eight per cent (the average target for OECD countries was a five per cent emissions reduction.) We have also stayed within our Kyoto "carbon budget" for most of the measured period.

However, in recent years, Australia's emissions have actually risen. The Department of the Environment and Energy projected that emissions would reach 534 million tonnes in 2020 – barely below the level recorded in 2000. This means Australia is not expected to meet its emissions reduction target in 2020.

All signatories of the Paris agreement pledged to work together to keep global temperature rise no more than 2°C above pre-industrial levels. The Paris targets pose a significant challenge for Australia, as our emissions currently are, and are projected to remain, well above our Paris "carbon budget".

The Australian Government has argued that Australia's cumulative "overachievement" under the Kyoto Protocol should offset any "underachievement" on the 2030 target – these offset reductions are known as "carry-over credits".

Most countries oppose the use of carry-over credits because they do not contribute to real reductions in emissions in the Paris commitment period.

It is also important to note that none of these targets account for greenhouse gas emissions from Australia's fossil fuel exports, which are approximately triple our domestic emissions. ▶

MORE

READ
Read the full explainer online

atse.org.au/emissionsexplainer

2020 ATSE Awards

Thursday 30 July 2020

A new way to capture greenhouse gases, treating toxic algal blooms, and eradicating a cause of blindness were among the world-class innovations celebrated on Thursday 30 July by the Academy.

At a ceremony streamed out as an online event, the award winners came from a range of fields including biotech, agriculture and engineering — and from across small and large private, government and academic organisations. This year's award winners included innovations and practical solutions to a range of issues, including AI-guided pest and crop management, ultra-low gluten barley, and self-assembling polymers to deliver personalised precision medicine.

THANK YOU

OUR MC
- Professor Emma Johnston AO FTSE (Dean of Science UNSW)

GUEST PRESENTERS
- Dr Sarah Pearce (Deputy Director of Astronomy and Space Science, CSIRO)
- Dr Mitra Safavi-Naeini (Senior physicist and research lead, Human Health, ANSTO).

CO-HOSTS
- Kylie Walker (CEO, ATSE)
- Professor Hugh Bradlow FTSE (President, ATSE)

Mark Sullivan
CLUNIES ROSS AWARD
ENTREPRENEUR OF THE YEAR

Mark Sullivan is Founder and Managing Director of Medicines Development for Global Health, a biopharmaceutical company developing medicines based on need, not profit.

Mark recognised the importance of Moxidectin — an intestinal worm treatment for domesticated animals — for treating neglected infectious diseases in humans.

Mark found funding, re-established manufacturing, and won approval for human use. In 2019 he sold the priority review voucher received from the US FDA.

This year, final human trials with more than 13,500 people will commence to demonstrate Moxidectin's importance and win approval to use the drug to treat and eliminate onchocerciasis, or river blindness — the second most common cause of blindness due to infection.

Dr Alison Todd FTSE & Dr Elisa Mokany
CLUNIES ROSS AWARD
INNOVATION

Doctors Alison Todd FTSE and Elisa Mokany are dedicated to fostering entrepreneurship and innovation in Australia.

Together, Dr Todd and Dr Mokany created a new molecular 'lego' that is opening the door to personalised clinical diagnostics. They've founded a successful company — SpeeDx — to roll out the technology which helps doctors choose personally targeted treatments.

They combine a profound, deep knowledge of molecular DNA and RNA-based detection — with flair and entrepreneurship, to develop their own inventions into fully-fledged products made in Australia and sold nationally and around the world.

Their products are fundamentally changing the way in which doctors work and patients heal.

Dr Grant Douglas
CLUNIES ROSS AWARD
KNOWLEDGE COMMERCIALISATION

Phosphorus run-off from fertiliser can cause major algal blooms that deplete water oxygen levels, and can cause fish die-offs, threaten fish farms and compromise fresh drinking water supplies.

Dr Grant Douglas from CSIRO Land & Water has developed and patented a new phosphorus-absorbent clay, Phoslock™, which addresses the source of harmful algae.

Dr Douglas has proved Phoslock™ effectively removes phosphorus without any lasting effects or adverse impact on the environment.

Now, the product is used in more than 20 countries to control and prevent algal blooms. And Phoslock™ is the core product for a $750M ASX-listed company.

Associate Professor Pauline Pounds
BATTERHAM MEDAL
FOR ENGINEERING EXCELLENCE

Associate Professor Pauline Pounds is an engineering trailblazer whose groundbreaking contributions to designing unmanned aerial vehicles have been game changing for the last 15 years.

Her creative and innovative problem-solving approach has systematically eliminated many previously critical limitations on drone technology, paving the way for new generations of large multirotor drones capable of practical real-world applications ranging from package delivery to search-and-rescue operations.

Associate Professor Pounds' most recent innovation — aerodynamic motion sensors — offers unprecedented precision measurement and control. Her rotor velocimetry technology is the best in the world, and enables safer, more effective drone use in challenging conditions.

Professor Michelle Colgrave
ICM AGRIFOOD AWARD

Professor Michelle Colgrave leads the Food and Agricultural Proteomics teams at Edith Cowan University and CSIRO, using revolutionary technology to identify key proteins that will benefit Australia's food and agriculture industries and improve human health.

Professor Colgrave is recognised for major breakthroughs in the analysis of gluten, which causes a dangerous auto-immune response in people with coeliac disease.

Her research has supported the development of an ultra-low gluten barley, now known as Kebari® which is used in the production of gluten-free cereals, beers and food products with all the nutritional benefits of whole grains, and is also safe to be enjoyed by coeliac sufferers.

Dr Greg Falzon
ICM AGRIFOOD AWARD

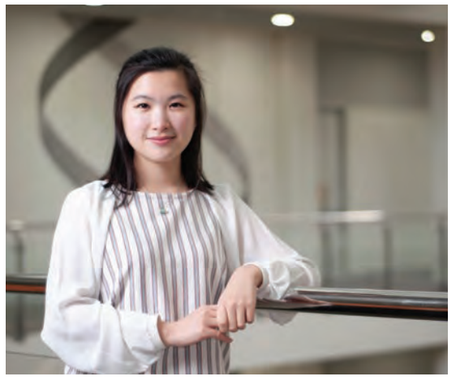
Dr Greg Falzon is recognised for advancing AI in Agriculture. He's researched, developed and applied artificial intelligence to create a multi-billion dollar growth industry in precision agriculture systems.

Dr Falzon has developed a surveillance alert camera system to detect feral animals, created sensor networks to manage soil moisture, and written algorithms and software to facilitate drone-based monitoring of livestock.

His work is transforming agriculture, from autonomous weed-spraying robots to sensor networks to monitor and respond to crop health.

Charmaine Hee

EZIO RIZZARDO POLYMER SCHOLARSHIP



In only her second year of a PhD at the University of Western Australia, Charmaine Hee is working on self-assembling polymers that can be programmed to create complex structures.

Ms Hee's work is aimed at developing precision and personalised medical solutions through improving understanding of molecular recognition within living cells. Holding a Bachelor of Philosophy with First Class Honours in Chemistry, Ms Hee is also a passionate science communicator who's been inspiring the next generation of STEM students since the beginning of her undergraduate studies.

Dr Gang Li

DAVID & VALERIE SOLOMON AWARD

Dr Gang (Kevin) Li has invented a new technique to capture greenhouse gas methane and reduce emissions from coal mines and natural gas production. His ionic liquid zeolites — or porous absorbent minerals — have advanced gas separation technologies.

Dr Li has earned three patent applications and a $1 million Global Innovation Linkage Grant, and he's worked with industry partners to establish a new company to commercialise this research, in collaboration with industry partners.

His company, Gas Capture Technologies Pty Ltd has scaled up the technology from grams to tonnes, placing Australia as a global leader in gas processing technology.

Academy President, Professor Hugh Bradlow congratulated all winners.

"One of the key roles of the Academy is to celebrate excellence and thus our annual Awards night is one of the highlights of ATSE's calendar" Professor Bradlow said.

"The 2020 ATSE Awards celebrate Australian success stories, where engineering, applied science and technology are improving existing Australian industries and creating new ones. My congratulations to the winners of this year's Innovation and Excellence Awards. I look forward to seeing their work transform Australia's agriculture, healthcare, and environmental management for years to come."

MORE

WATCH
A recording is available on our website

atse.org.au/2020ATSEAwards

Videos of all winners are on our website

We acknowledge the following people and organisations for their ongoing support of the ATSE Awards.

BATTERHAM MEDAL	ICM AGRIFOOD AWARD	EZIO RIZZARDO POLYMER SCHOLARSHIP	DAVID & VALERIE SOLOMON AWARD
Group of Eight Australia	ICM Agribusiness	Ezio Rizzardo Cooperative Research Centres Association	David and Valerie Solomon

Australian National University · Cochlear · University of Newcastle Australia · UNSW Sydney · QUT

Assessors

We are grateful to the following individuals who have volunteered their time to assess the Awards:

ProfessorMarilyn Anderson
Dr Mary Ann Augustin
Dr Julie Beeby
Professor Simon Biggs
Dr Amanda Caples
Professor Mark Cassidy
Dr Janis Cocking
Dr Peter Coldrey
Dr Ian Dagley
Dr Jacqueline Craig
Dr Eileen Doyle
Professor Emeritus Lindsay Falvey
Mr John Grace
Professor Bronwyn Harch
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Mr Wayne Osborn
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Dr Ezio Rizzardo
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Professor Emer Maree Smith
Professor Thomas Spurling
Dr Jenny Stauber
Professor Emeritus Elizabeth Taylor
Professor Emeritus Robert White
Dr Meryl Williams

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ATSE Awards 2021

CLUNIES ROSS AWARDS
BATTERHAM MEDAL
ICM AGRIFOOD AWARD
EZIO RIZZARDO POLYMER SCHOLARSHIP
DAVID & VALERIE SOLOMON AWARD

2021 Nominations close 5.00pm AEDT Monday 18 January 2021

By Professor John Church FTSE FAA

Rising sea levels

A threat to our coastal society

What the latest science and technology says about one of our greatest challenges.

Coastal populations have increased rapidly over the 20th and early 21st centuries. The most recent studies estimate that in 2010, there were:

- **230 million people living less than one metre below high tide level**
- **400 million people living less than two metres below tide level**
- **770 million people living less than five metres below tide level**
- **and over a billion living less than 10 metres below tide level.**

These people and the infrastructure that supports them are in the path of storm surges (which are already causing catastrophic conditions and loss of life) and rising sea levels.

For Australia, the equivalent numbers are 240,000; 750,000; 2.4 million and 3.9 million people respectively. And these population numbers are increasing in both the developed and the developing world as more people move towards the coast and coastal megacities.

At the end of the last glacial maximum, when Tasmania, New Guinea and mainland Australia were one landmass, global mean sea level rose by 130m. The oceans grew at an average rate of over 10mm a year for many millennia, at a peak rates of over four metres per century, dramatically transforming the face of the earth.

When humanity's global and coastal populations started to expand the mean sea level was relatively stable, changing just a few tenths of a millimetre each year. In some regions, like Australia, local sea level relative to the land actually slowly fell.

But starting in the 19th century and up to the present, coastal sea-level measurements show the rate of rise has accelerated. From 1900 to today, the earth's oceans have risen by 20cm.

The TOPEX/Poseidon satellite, launched in late 1992, has observed near global sea-level change. These measurements, along with tide-gauge observations, show that the rate of rise has accelerated further since 1993.

The sea is now rising more than 4mm per year – more than twice the average rate during the 20th century and ten times faster than before 1800.

Photo by Michael Glass / Unsplash

Technology on the rise

Better satellite and on-site observations, global analysis, and a new generation of climate models have improved our understanding of 20th century sea-level rise.

The two largest contributions were glaciers melting around the world – including in Alaska, the Himalayas and the periphery glaciers of Greenland – and the thermal expansion of the ocean as it warms.

Indeed, the ocean has by far the largest heat capacity of our climate system: it has stored over nine-tenths of the extra energy in the climate system since 1970. Ocean heat content is a fundamental measure of climate change.

That's why it's important to constantly measure sea temperatures across the globe. One way scientists and technologists do this is with the Argo program (a global array of over 4000 autonomous ocean profiling floats) and its extension into the deep ocean, marginal seas and ice-covered regions.

Thin ice

There have been smaller contributions to sea-level rise from the melting of Greenland's and Antarctica's ice sheets, and changes in terrestrial water storage (primarily a balance between extraction of ground water and the storage of water in reservoirs).

We now have a good understanding and improved simulation of global sea-level rise since 1970 and 1993. Although uncertainties remain about early 20th century contributions, our knowledge and modelling of sea-level rise since 1900 has also improved. All this indicates that human-made climate change was responsible for about 70 per cent of the observed rise from 1970 to 2005.

While the ice-sheets are thought to have made small contributions to sea level over the 20th century, this has been accelerating since the early 1990s. One important new tool for quantifying the impact of ice-sheets is the GRACE satellite mission, which observed changes to the Earth's gravity field.

The acceleration comes from increased flow of ice into the ocean from Greenland and Antarctica and increased surface melting in Greenland (currently Antarctica is too cold for significant surface melting). However, we still face challenges in simulating this rapidly changing flow of ice.

In deep water

Sea-level rise by 2100 will likely (two thirds probability) be limited to below about 60cm if the world manages to cut greenhouse gas emissions enough to limit global warming to well below 2°C – the targets of the Paris Agreement.

However, for high emissions, the likely range extends to 110cm. Comparing projected and observed global and regional sea levels over this short period of overlap (2007-2018) confirms this projected rate of rise.

The central values of the accelerations we've observed are larger than what we'd expect if the world was on track to meet the Paris Agreement, and are more consistent with the higher emissions scenario.

Sea-level rise will not stop in 2100 under any scenario. Present projections indicate that if high emissions continue, the rate of rise in 2100 will be over a metre per century and will continue for many centuries. Paleo sea-level data confirms that sea levels were metres higher in past warm periods.

In the last interglacial period, when global temperatures were only marginally warmer than present day values, sea level reached 5-10 metres above where it is today.

The biggest contribution on these longer time-scales will come from the potentially unstable ice sheets of Greenland and Antarctica. This could amount to many metres over coming centuries.

Turning the tide

Without urgent efforts to limit global warming, ongoing and even growing ice-sheet contributions may become essentially irreversible during the 21st century. This would commit the world to many metres of sea-level rise over coming centuries.

Sea-level rise is not globally uniform and nor is the local rate of rise constant over time. Climate variability and change will affect regional sea levels.

Changes in the distribution of water changes the Earth's gravitation, rotational and deformation fields, contributing to lower rates of sea-level rise near decaying ice sheets and larger rates in the far field (such as the Pacific islands).

Local factors can exacerbate anthropogenic sea-level rise. Sediment compaction in deltaic regions, particularly following ground water withdrawal, can lead to larger local rates of sea-level rise, as experienced in Jakarta and Bangkok over recent decades.

All of these factors change the frequency and intensity of coastal flooding and erosion events, impacting people, ecosystems and damaging infrastructure.

In many parts of the world and even with significant mitigation of our greenhouse gas emissions, what is currently a one-in-a-hundred-year flood could happen several times a year by 2100. Adaptation to rising sea levels will be essential.

To avoid worst case sea-level rise of many metres that would impact the lives of one billion people living in the low elevation coastal zone and damage ecosystems, urgent, significant and sustained global mitigation of our greenhouse gas emissions is required. ▶

> "What is currently a one in a hundred year flood could be happening several times a year by 2100."

Professor John Church
FTSE FAA

John Church is a Professor in the Climate Change Research Centre at the University of New South Wales and was co-convening lead author for the Chapter on Sea Level in the Third and Fifth IPCC Assessment Reports. Professor Church's numerous awards include the 2006 CSIRO Medal for Research Achievement, the 2007 Eureka Prize for Scientific Research and the 2019 BBVA Frontiers of Knowledge Climate Change Category Prize.

By Francesca Ferrazza FTSE

The road to decarbonisation

With greenhouse gas emissions raising global temperatures, today there is no doubt that we need a transition or even a radical change in the way we think about energy. Sadly, the consequences of a rapidly changing climate can already be seen in extremes which haven't spared Australia, recently hit by drought and dramatic fires.

The good news is that renewables are growing fast, and analysts are forecasting even stronger growth in the next years. According to the International Energy Agency, renewable energy sources make up 26 per cent of the global electricity demand today and the share could grow to 30 per cent by 2024. Only a decade ago the Agency was predicting numbers that showed renewables as totally marginal in the energy mix.

Solar, especially, is driving this change, due to ever lowering costs, new economic and financial schemes, and innovation. Australia has been an important actor here, especially through academia. Importantly, decarbonisation is growing as a compelling voice on the agenda world-wide.

After the ATSE New Fellows Induction and Oration event in November 2019, I travelled to the Northern Territory and visited its largest photovoltaic plant, which is under construction in Katherine. It was a beautiful experience, especially witnessing the commitment of the team and the technical solutions needed in fairly harsh conditions there — including termites!

I understand much larger projects, such as the Australia-Singapore Power Link, are planned in the near future to better exploit Australia's extraordinary renewable resources — from the sun to technological innovation itself.

A global challenge

However, as fast as renewables alongside other carbon-constraining measures may be growing, and other carbon-constraining measures, it will take time before a complete switch is possible. Energy demand is increasing and population is growing fast, especially in developing regions which largely lack access to modern types of energy.

It's true that according to analysts, access to electricity has steadily grown from about 71 per cent in 1990 to around 87 per cent in 2016. But we're still facing about one billion people without direct access to power, and even more without access to clean fuels for cooking.

Yes, progress has been made, but far too slowly to meet the UN Sustainable Development Goals. Goal number seven directly relates to energy, but many of the others are also strictly connected.

So how can we deal with meeting the Goals and keeping greenhouse gas emissions low enough to ensure global warming doesn't exceed 1.5°C: a limit considered essential by most specialists and agencies?

As has been endlessly pointed out, there is no silver bullet. We therefore need a coordinated effort between politics, finance, technology development and public awareness to pave the way to an energy transition. This means efforts should concentrate on education and development of science and engineering skills, coupled with economic, social and financial knowledge. Given we're already witnessing concerns about the future of our planet from younger generations, it's our duty to develop these skills. In my own experience this has been driven by passion, but we can and have to do better for future generations.

Here comes the sun

I've believed in renewables ever since I was studying physics in Rome in 1988, when I was lucky to join Eni, the parent company of Italy's largest oil and gas company. I have been working on solar and more broadly in the renewable energy field ever since.

I was also fascinated by advanced concepts such as fusion, a discipline which already had a tradition and strong competences at the University La Sapienza in Rome. Recently, my company invested in a US MIT spin-out targeting compact fusion reactors with a fast track approach, and entered various initiatives regarding fusion at a national level.

But this was my individual path. Now we need more focused approaches. At the time no one was thinking much, at least in schools or academia as far as I could see, about the global issue of energy. Yes, there was awareness of poverty, wars and pollution, but more on an idealistic basis rather than the main agenda (at least in Italy).

So where do we go from here? I would say we need to be steady on three points: vision, technology, passion. All of these require application, methodology and care. And people. From this point of view, it's essential to promote STEM in young generations, especially to girls.

A range of solutions

From a technological point of view, solar and wind are already showing their potential. This will grow as device performance continues to improve, but would also benefit from more attention on material availability, consumption, industrial cycles and end-of-life processes and regulations.

A key point for the further development of renewables for a true decarbonisation roadmap is storage: electrical or thermal. There again critical materials, and overall sustainability are crucial for true development. Technologies targeting metal-air batteries could have a chance when coupled with intermittent renewables.

Another area of interest looks at the various processes to transform waste into fuels and other products. There are already thermochemical processes for producing oil and water from urban waste, and others which turn agrowaste to oil through fermentation. All of these are under development in various research centres and companies, and my company has patented solutions at pilot and demonstration phases for both approaches.

Another important line of development is CCUS (Carbon Capture and Utilisation), as opposed to CCS (Carbon Capture and Sequestration). A number of processes are under study to transform carbon dioxide to useful products such as construction cements or fuels.

Provided processes are sustainable and cost effective, turning waste and carbon dioxide to products could be an effective decarbonisation strategy, and much better than incinerating waste.

One last point concerns magnetic fusion, potentially a true carbon-free option. It's been "30 years away" for a very long time. But now a number of new initiatives are underway.

These includes ITER, the giant multinational effort under construction in France; a Rome-based effort to develop a technological solution for heat management in a fusion reactor; a Japanese reactor; a Chinese roadmap; and multiple US projects. All of these could contribute to a potential breakthrough for fusion in the next decade.

In addition, supercomputing and artificial intelligence can have key roles in the overall management and design of energy systems. There again, education and skill will be crucial.

Overall, I am an optimist. When I started working in solar energy, it was a very small niche and now it's a reality. I think all forms of decarbonised energy have a chance to help in the global challenge we are facing. ▶

Francesca Ferrazza
FTSE

Francesca Ferrazza is the Academy's 2019 Foreign Fellow and Senior Vice President at Eni S.p.A., in charge of the Research Center for Decarbonization and Environment. Her work focuses on the company's research program on Renewable Energy Sources and Environmental Technologies, and Nuclear Fusion. With a background in semiconductor physics and 30 years of experience in applied research and R&D management, she has published many journal and conference articles, book chapters and papers, and has co-invented multiple photovoltaic patents.

Agriculture in a changing world when it's not business as usual.

Professor Neena Mitter FTSE and Dr Alice Haywood

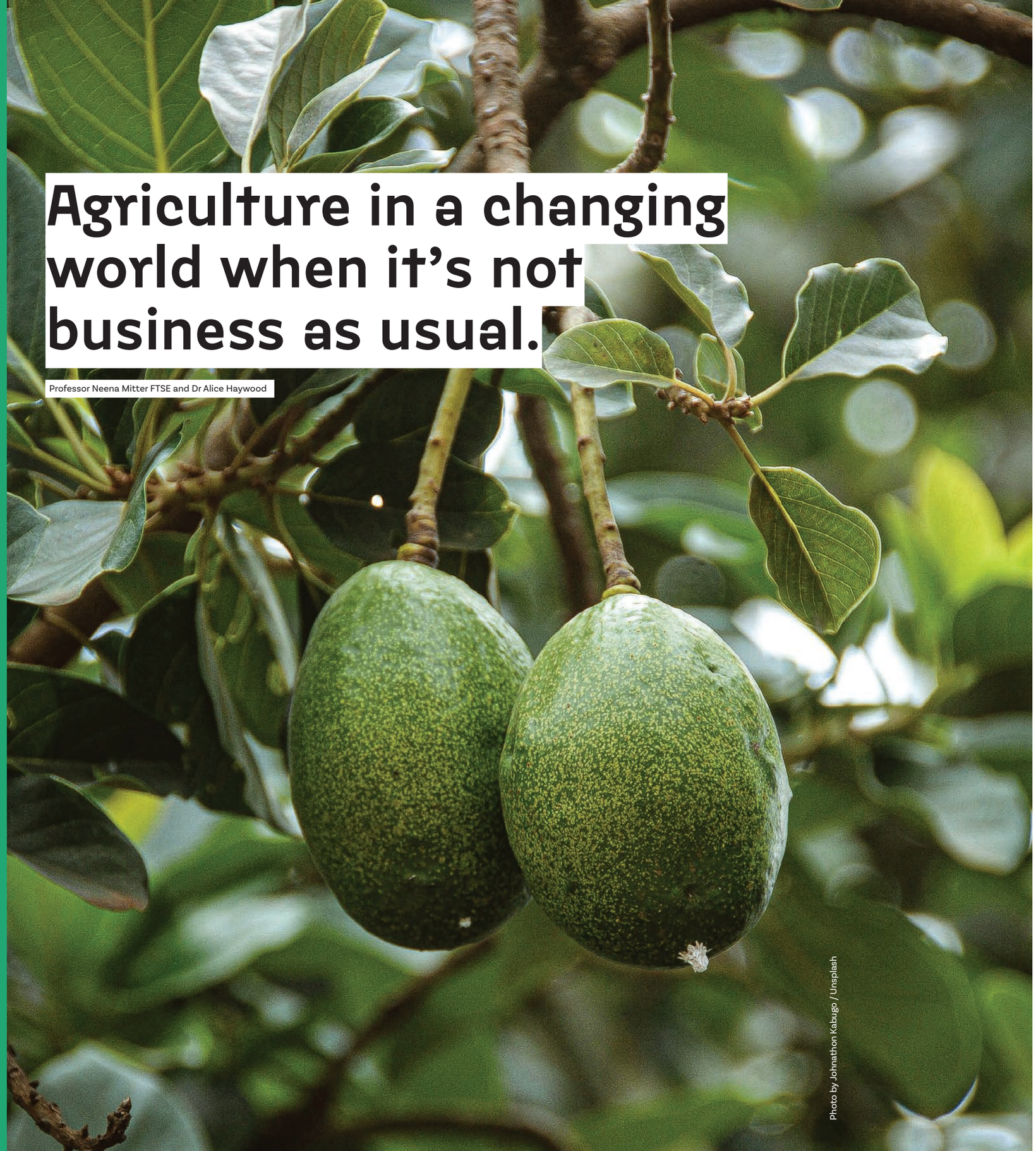


Photo by Johnathon Kabugo / Unsplash

Bushfires, floods, droughts, cyclones, new pests, new diseases and to top it all, COVID-19; there's no shortage of factors that threaten the three meals a day we sometimes take for granted.

Brutal scenes in supermarkets in the wake of COVID-19 gave us a glimpse of the consequences when food supply chains seemed uncertain. But human-made global warming is a far more serious and long-term threat to the future of human nutrition.

Climate change is impacting the production of many crops by influencing weather patterns and temperature ranges, and pests, weeds and diseases. It makes it clear that it is absolutely non-negotiable that we provide farmers with the support, tools and technologies to feed the world.

Food security is not just an issue for the 10 billion people who will walk on planet earth by 2050 with their daily need of two trillion calories. It's an issue for us today, next season, next year and every year after that.

We must not forget that even right now, almost 800 million people are chronically hungry and two billion suffer micronutrient deficiencies. We need transformative change in agriculture and food systems worldwide.

In March 2018, the National Farmers Federation presented its vision for 2030 of growing Australian agriculture into a $100 billion industry. To deliver that outcome, agriculture will need to grow by almost 60 per cent in the next 10 years.

Technology and innovation was identified as a key driver to benefit Australia's food and agribusiness sector. Here are a few key technologies that can shape the agricultural practices of tomorrow:

Gene technologies

Developing new genotypes of plants is a primary strategy for adaptation to climate change. Advances in genome sequencing and associated molecular and bioinformatics tools allow researchers and breeders to discover, predict and track the best climate-resilient genotypes at the DNA level.

Combined with speed-breeding programs being pioneered at the University of Queensland, this can allow us to breed climate resilient genotypes of a number of species up to six-times faster and cut years off traditional breeding practises.

Genetic modification (GM) provides a more direct way to integrate ideal genes into an existing commercial genetic background. GM cotton, corn, soybean, canola and sorghum contribute to the US$5 trillion global agribusiness industry.

In Australia, delays in adopting GM canola have resulted in an extra 6.5 million kg of herbicides, 8.7 million litres of diesel, 24.2 million kg of greenhouse gas and compound emissions, and economic loss of 1.1 million metric tonnes of canola.

However, a GM approach faces ongoing political, social and regulatory challenges. It also depends on technical amenability of the species to genetic modification. Gene editing is the new powerful entrant in this field to confer crops with a fitness advantage.

The biological scissors of CRISPR (clustered regulatory interspersed short palindromic repeats) can switch off an undesirable gene or insert desired sequences into the genome. What once looked like science fiction to precisely edit genes is now poised to change the landscape of breeding.

In many jurisdictions including Australia, some gene editing processes have been legislated as non-GM to support faster technology deployment.

The decision on how best to alter genotypes to maintain and improve productivity into the future is not just a technical one. It will depend on industry and public acceptance plus our ability to translate new genotypes to field conditions quickly.

And it's not just about adaptation; plants are in fact the ultimate technologies for climate change mitigation. The question of whether we can engineer or breed crop plants to be even more effective at turning carbon into food is being addressed with important outcomes for both climate and food security.

Protected cropping

While nature is almost boundless in its genetic potential to deliver improved genotypes, there are upper limits to the biological capacity of plants to survive extreme conditions. Protected

> “In a globally interconnected world, the threats posed by climate change, the intensification of natural disasters and upsurges in transboundary pests and diseases, and the need to adjust to major changes such as COVID-19 all point to the fact that we cannot operate under a business-as-usual scenario.

Professor Neena Mitter
FTSE

Neena Mitter is Director of the QAAFI Centre for Horticultural Science at The University of Queensland, and the ARC Research Hub for Sustainable Crop Protection. She is internationally recognised for developing and crop-protecting ag-nano “BioClay” spray and stem cell-based avocado propagation. Elected an Academy Fellow in 2019, Professor Mitter is an active deputy member of the Leadership Council of Cultural Diversity.

cropping systems are climate-controlled facilities that enable consistent, year-round crop production regardless of external conditions, thus safeguarding foods from climate change.

In addition, protected cropping has a much lower environmental footprint than field-grown crops. Reduced use of pesticides and fertilisers, recycling the majority of water and eliminating run-off are distinct advantages.

Currently, Australian growers use protected cropping primarily for cut flowers, tomatoes and leafy greens. However, less than a third of Australian vegetable growers use these facilities. The industry is expanding at four to six per cent each year, and the potential return on investment for high-tech, greenhouse vegetable enterprises is around 20-25 per cent each year.

Vertical framing adds another dimension to protected cropping. Investment in protected cropping for a greater diversity of crops will not only safeguard Australia’s food supply but bring new and desirable varieties of fruits and vegetables to consumers and niche markets.

Furthermore, these facilities can be built on non-arable land, such as disused mine sites, and can be made energy-neutral with water and nutrient recycling and solar energy.

Sustainable crop protection

Pests and diseases represent a major constraint for increased productivity. It’s estimated that $20.6B of the total value of crop production in Australia in 2015-2016 could be attributed to successful crop protection.

By controlling fungal plant diseases alone, farmers can save 125 million tonnes of food each year — enough to feed 600 million people.

Major issues with current crop protection practices include:

- growing resistance diseases
- not targeting specific pathogens
- persistence of residues
- run-off into our precious waterways
- potential harm to human health and the environment.

Indeed, harmful concentrations of pesticides have been detected up to 60 km inside the Great Barrier Reef World Heritage Area.

The general public is now seeking a transition to chemical pesticide-free agriculture. The key question is how innovation in ag-tech can deliver alternatives to reduce the use of chemical-based fungicides, while maintaining crop production, into the future.

One example of an RNA-based biopesticide is BioClay technology developed at the University of Queensland. This is a non-GM, safe, sustainable biological crop protection platform.

BioClay works almost like nature versus nature where a gene sequence from the pathogen is used to kill the pathogen itself without the need for any genetic modification.

As climate change creates variations in pest and pathogen populations, we need to develop a multi-pronged approach that combines traditional and innovative approaches to manage these threats.

Digital revolution

From GPS to remote sensing, UAVs (drones), AI and blockchain, digital and data-driven technology is transforming agriculture across the supply chain. From powerful crop forecasting models down to daily surveillance with UAVs and field-sensors, these technologies allow farmers to both plan ahead of time and respond instantly, to maximise productivity in a changing landscape.

The Aussie-developed Agricultural Production Systems sIMulator (APSIM) creates virtual fields to study how changing plant genetics, soil health, climate and farm practices influences socio-economic and ecological outcomes. GPS-guided UAVs and field sensors allow site-specific and even plant-specific data to be available to the farmer at the click of button on their laptop or smartphone.

This results in is being able to choose the best genotypes for their fields and also to plan when and where in the field to water, fertilise, apply growth regulators or disease control, harvest and prune — so called precision agriculture.

At the breeding level, AI platforms developed in Australia such as FastStack can track the flow of valuable genes in breeding programs to choose the best combinations for crop and livestock performance.

The digital revolution doesn’t just help us adapt to predicted change. It allows us to react and recover in the event of natural disaster. Digital Agricultural Services revealed that the unprecedented bushfires this year burned almost 2.5M Ha of agricultural land (29% of all land burned), with Queensland the hardest hit.

UAVs trained to detect imminent bushfire threats and AI models to predict burning behaviour are already being developed in order to help prioritise firefighting and relief efforts at key sites in future.

Innovative plant propagation

Adequate supply of superior, disease-free planting material are a key cog in the production supply chain. Tissue culture technology for mass production of plants (especially difficult-to-propagate crops, new improved varieties and selections, and gene-edited or modified crops) can be a valuable resource to sustainably and rapidly provide large numbers of adaptable genotypes.

As an example, the world’s first plant stem cell-based propagation of avocadoes developed at the University of Queensland can generate 500 plants from one small cutting from a mature tree. This technology could also support Australian native foods, working together with Indigenous Australians who have passed down the knowledge of their incredible properties. Many of these native foods are difficult to propagate but offer incredible nutritional diversity and are already highly adapted to harsh Australian conditions. Tissue culture tools can also conserve our precious biodiversity of flora that cannot be stored as seed.

This includes many of Australia’s rainforest trees at significant risk of extinction due to climate change and the threat of intensifying bushfires such as seen in the devastating 2019-2020 summer season. We can safeguard our crops as well as our biodiversity, which contains crops and medicines of the future and is essential to the health of our habitat.

Final thoughts

“World free from hunger and malnutrition, where food and agriculture contribute to improving the living standards of all, especially the poorest, in an economically, socially and environmentally sustainable manner”. The vision of the Food and Agriculture Organisation, captures the essence of what the future should look like. It embodies a vision that goes beyond the divide of “developed” and “developing” countries.

Sustainable development is a universal challenge and the collective responsibility of all countries. It requires fundamental changes in the way all societies produce and consume food. In a globally interconnected world, the threats posed by climate change, the intensification of natural disasters and upsurges in transboundary pests and diseases, and the need to adjust to major changes such as COVID-19 points to the fact that we cannot operate under a business-as-usual scenario.

We have a supreme opportunity and responsibility now as scientists, politicians, farmers, growers, consumers and human beings to affect real change that supports a climate-safe future and the future of food production for generations to come. Design of regulations and public acceptance for new technologies will be critical to achieving outcomes at a pace that has become a necessity.

Where possible our modern farming systems should also learn from the wisdom of Indigenous peoples, who have practised various forms of agriculture and sustainable land management in changing climates throughout the last few millennia.

It requires leadership and cohesion across the ecosystem to set strategic priorities and drive a more coordinated and cross-domain approach.

Recognising different pathways to success, guiding young minds to deliver for the future, and innovation that goes beyond discipline, organisations, governments, industries and geographies are all vital to creating more efficient, inclusive and resilient agriculture for us all. ▶

Dr Alice Haywood

Alice Hayward is a plant molecular biologist developing the world’s first high-multiplication tissue culture pipeline for avocado propagation. She is a Post-Doctoral Fellow with Advance Queensland and the Queensland Alliance for Agriculture and Food Innovation.

By Dr Marlene Kanga AM FTSE

Surviving bushfires and beyond will depend on our engineers

Dr Marlene Kanga
AM FTSE

Marlene Kanga is the former president of the World Federation of Engineering Organizations (WFEO), who led proposals for the first UNESCO World Engineering Day, which was celebrated on March 4. She was named the 2018 Professional Engineer of the Year by Engineers Australia, of which she was previously the National President. Dr Kanga has been listed among the Top 100 Women of Influence in Australia and the Top 100 Engineers in Australia.

For so many of us in Australia, the searing temperatures and devastating bushfires that shrouded our New Year in acrid smoke are at once the ghosts of Christmas past, present and future.

They are a traumatic reminder of the deadly Black Saturday fires that ravaged the state of Victoria a decade ago, and the inferno that reached my own back door and almost claimed my home in Sydney some 25 years ago.

But this year's punishing heat of 40°C or higher, prolonged drought and subsequent bushfires are also a harbinger of what we can expect from an increasingly hotter planet.

The result is that the world faces two simultaneous challenges: reacting to the more frequent extreme weather events we are now suffering while at the same time, building greater resilience against more frequent and intense disasters in the future.

Firefighters and other first responders have been critical in saving lives and property facing immediate threat. But the unsung heroes — those whose ingenuity and creativity will help both manage and prevent future climate events — are our engineers.

Australia has warmed by an average of 1.4°C in the past century, an increase likely to drive further changes and crises in our climate.

And Australia is not alone in experiencing the impact of climate change, with extreme temperatures, droughts, flooding and storms on the rise across the globe from India and Indonesia to Egypt and Ethiopia.

Since the Black Saturday fires in 2009, for example, Australian engineers have helped improve the forecasting and modelling of fires to allow authorities to better anticipate weather threats. They have also developed advanced, new technologies that better equip firefighters and first responders to manage fires.

Engineers have also led on revisions to building standards to help improve resistance to embers, which pose the greatest threat to homes during bushfires. Developing new construction codes that account for climate threats will help minimise damage to new buildings.

Similarly, in the US, where wildfires also raged across California last year, rebuilding efforts in fire-hit towns have included new measures to reduce fire hazards with fire-resistant materials and reduced landscaping.

And there is growing momentum to replace natural gas with electricity in new constructions to minimise building emissions and help mitigate carbon footprint.

In flood-prone countries such as Bangladesh, engineers have developed amphibious homes to help protect families from losing their homes during excessive rains and storms, while "smart roads" have been developed in Ethiopia to channel floodwater away from roads to agriculture.

As countries worldwide grapple with the aftermath of recent climate-related disasters, we see growing evidence of creative, innovative solutions to address climate change.

But the message is clear: we cannot afford to simply rebuild. If we are to reduce greenhouse gas emissions while also better anticipating future climate threats, we need to renew and reinvent, making use of smart engineering and new technology to solve climate-related problems now and for the years ahead.

From the threat posed to small island nations of rising sea levels to the economic vulnerabilities of countries dependent on rainfed agriculture, science and engineering can provide the solutions.

This is why it is so important that international bodies, governments and authorities first recognise the contribution of engineering to solving our global challenges, and then invest in developing engineering talent needed if we are to survive bushfires and beyond. ▶

This article was originally published by the Thomson Reuters Foundation

Since the Black Saturday fires in 2009, Australian engineers have helped improve the forecasting and modelling of fires to allow authorities to better anticipate weather threats.

Fire, floods and ice

How Antarctic science helps us understand Australian weather and climate.

Dr Katherine Woodthorpe
AO FTSE

Katherine Woodthorpe is Chair of the Antarctic Science Foundation and the Bushfires and Natural Hazards CRC. She has made substantial contributions to the Australian technology and science translation landscape over the past 25 years, and was elected a Fellow of the Academy in 2015.

Adjunct Professor Tony Press

Tony Press is an Adjunct Professor at the Antarctic Climate and Ecosystems CRC, Secretary of the Antarctic Science Foundation and Chair of the Advisory Board of the ARC Centre of Excellence for Climate Extremes.

Photo by Henrique Setim / Unsplash

The last Australian summer delivered hot weather and bushfires on scales not recorded before, followed closely by heavy rains and flooding. Why then, should we be thinking about science on the ice in Antarctica?

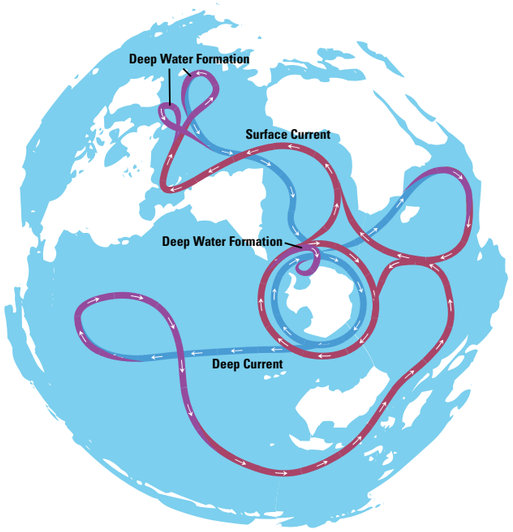
When Douglas Mawson set out from Hobart on 2 December 1911 to explore the Antarctic he was sure that Antarctica had an important influence on Australian weather. His early meteorological observations are part of our long engagement in Antarctic science.

With more than a century of Antarctic scientific observations and research enabled by ever-improving technology, we now know that Antarctica is the engine room of global climate. In its deep ice it holds a detailed record of past climate that could be more than one million years old.

The coldest, driest, windiest continent, surrounded by the Southern Ocean, has a profound impact on weather and climate in Australia, other southern hemisphere countries, and the world.

Antarctica's influence on Earth

The Antarctic Circumpolar Current (ACC) is the world's biggest current, linking the Indian, Pacific and Atlantic Oceans as it flows from west to east around Antarctica. This current forces deep ocean water to rise to the surface in the Antarctic, where heat and carbon dioxide are exchanged with the atmosphere.

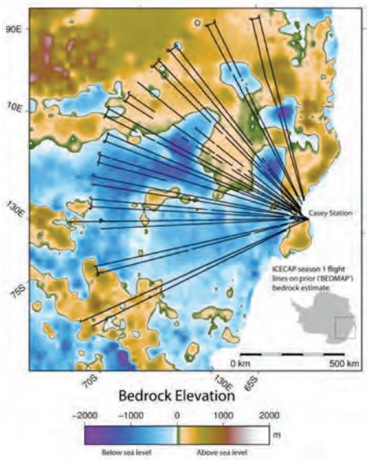


The Antarctic Circumpolar Current (ACC) is the world's biggest current, linking the Indian, Pacific and Atlantic Oceans as it flows from west to east around Antarctica. Source: Wikipedia, Creative Commons Licence

The Antarctic katabatic winds blow onto open patches of ocean water among the sea ice (polynyas), producing more sea ice and make the surface water saltier, colder and heavier. This water then sinks to the abyssal depths, producing Antarctic Bottom Water.

The upwelling deep ocean water and sinking Antarctic Bottom Water — linked to the rest of the world by the ACC — generate the global deep ocean overturning circulation. This is a great oceanic conveyor belt that moves ocean water, carbon, oxygen, and nutrients around the planet.

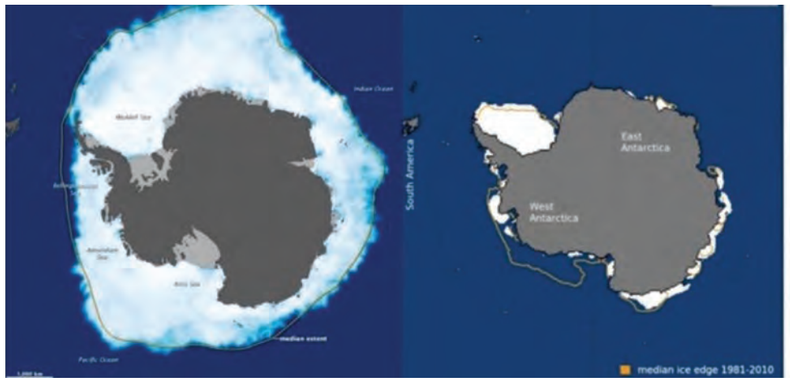
Research over the past three decades has shown that the Southern Ocean is warming and freshening and that the warming is having direct impacts on floating ice shelves fringing the continent. Even though the loss of floating ice doesn't directly affect sea level rise, it does reduce these ice shelves' ability to buffer the flow of ice from the inland. This contributes to the melting of glaciers at their grounding line on the ocean floor.



Antarctica's contribution to global sea level rise has increased significantly in the past two decades. Recent research has also revealed that much of the ice sheet in East Antarctica is grounded below sea level. This means its vast stores of ice are much more vulnerable to ocean warming than we assumed in the past.

The Southern Ocean also plays a major role in buffering the planet from climate change by storing a large proportion of the extra heat that human activity has added the additional atmospheric carbon dioxide.

Antarctica is also home to one of Earth's largest natural phenomena: the annual growth and decay of Antarctic sea-ice. The annual maximum area of Antarctic sea ice (in the austral spring) is around 19 million square kilometres, and the minimum (in the austral autumn) is around three million square kilometres. Sea ice is an important part of the climate system and a critical component of Southern Ocean marine ecosystems.



Left: Antarctic sea ice at its winter maximum in September 2012. Right: The ice at its minimum on March 3, 2017. New research found that the dramatic loss in late 2016 was due to unprecedented storm winds blowing warm air towards the South Pole.

The Antarctic sea ice zone is changing. There are estimates that the extent of sea ice has reduced by up to 40 per cent since the 1940s. Significant regional changes, some positive, some negative, have been recorded in recent decades.

Over the past five years or so, the maximum extent of Antarctic sea ice declined by around five per cent. It's vitally important that we better understand the physical and biological dynamics and trajectories of the Antarctic sea ice zone.

Secrets in the ice

In order to understand our current climate and project our future climate, we need to understand the climate of the past. The Antarctic ice sheet holds some of the world's most detailed climate records, stretching back over one million years. Air trapped in snow that is then transformed to ice is stored in the ice sheet, a precise record of Earth's past climate.

Along with these tiny samples of the Earth's past atmosphere, isotope analyses of ice cores drilled from Antarctica reveal past temperature records. Impurities in the ice can reveal additional information about past climate, volcanic activity and bushfires, and human activities such as lead smelting, industrialisation and nuclear explosions.

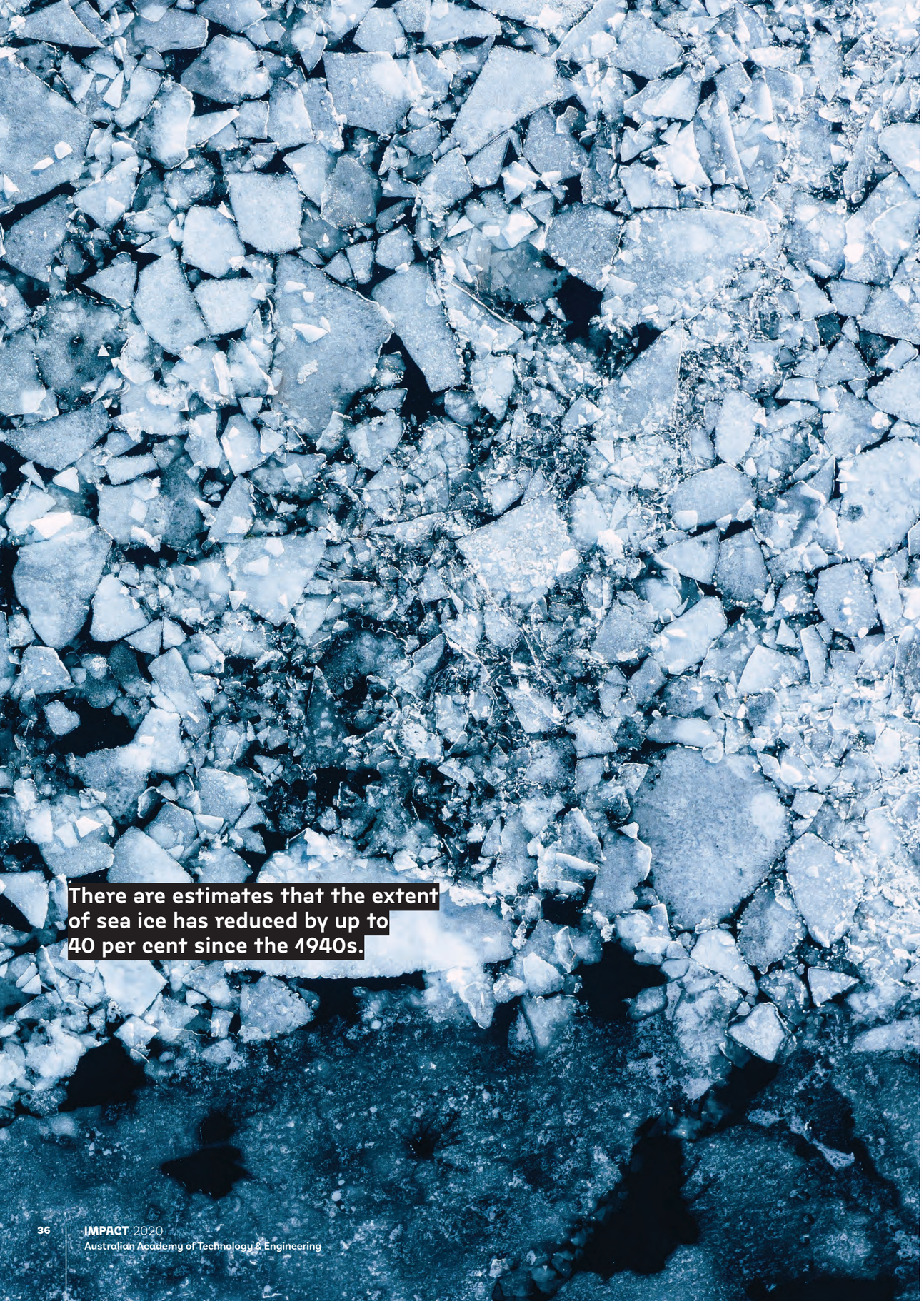
The longest ice core climate record to date comes from the EPICA project at Dome Concordia in Antarctica — a record stretching back 800,000 years. Reconstruction of climate from Antarctic ice cores show that atmospheric CO_2 and temperature are tightly coupled. This relationship clearly indicates that increasing CO_2 in the atmosphere will be associated directly with increased temperatures.

The current level of atmospheric CO_2 is around 414 parts per million (ppm) — a level not seen in the span covered by ice core records. Geological records indicate that current atmospheric CO_2 levels have not been present on Earth since between 5.2 and 2.6 million years ago.

During this period, CO_2 concentrations reached up to 400ppm and global temperatures were 2-3°C higher than present temperatures. Sea levels were tens of metres higher than they are today.

Very detailed climate records can be found in high-resolution ice cores from high precipitation areas such as from Australia's drilling at Law Dome on the coast of Antarctica near Casey station. The Law Dome ice core reveals a detailed history of the last 2000 years of the Earth's climate, including information on CO_2 and methane in the atmosphere, solar activity and volcanic eruptions.

ICE CONTENTS INDICATIONS	
Trapped air bubbles	Atmospheric composition, including greenhouse gases O_2 / H_2
Isotopes in water	Temperatures
Beryllium-10	Solar activity
Sulphate	Volcanic activity, biological activity
Methanesulphonic acid	Sea ice extent, biological activity
Sea salt and dust	Wind and atmospheric circulation



There are estimates that the extent of sea ice has reduced by up to 40 per cent since the 1940s.

“By taking knowledge from Antarctic science, we can build better tools to understand our Earth system, and the trajectory and impact of climate change.

Analyses of the Law Dome ice has also been used to reconstruct parts of Australia’s climate record. For example, snowfall at Law Dome is strongly inversely correlated with regional rainfall records from south-west Western Australia. The weather patterns that produce rain and drought in the Western Australian wheat belt also affect precipitation at Law Dome. Analyses of sea salts in the ice record can also be used to reconstruct rainfall in south east Australia. All of these high-resolution ice core analyses are significant contributions to understanding weather and climate in Australia and in the broader region.

Ecosystem services

The Southern Ocean is home to unique wildlife and ecosystems, including the greatest living animal, the blue whale. It is also home to one of the biggest underexploited fisheries on Earth — the krill fishery. Changes in sea ice distribution and extent, ocean temperatures and salinity, and ocean acidification due to uptake of CO_2, will all have impacts on ecosystems and the services they provide.

There are already species such as penguins on the move in Antarctica, and new species from the north, such as grasses and insects, making their way into the Antarctic.

A priority for Antarctic science?

Given Antarctica’s global role in the Earth’s climate system, its important influence on Australian weather and climate, and that of our near region, and the important carbon, climate and ecosystem services Antarctica and the Southern Ocean provide, Australia should remain actively involved in Antarctic science and play both a leadership and supporting role in international scientific collaboration.

By taking knowledge from Antarctic science, we can build better tools to understand our Earth system, and the trajectory and impact of climate change.

Antarctic science will help Australians better face our future. ▶

Image sources: agu.org; iStock; Unsplash; Dr Katherine Woodthorpe AO FTSE; Adjunct Professor Tony Press.

By Julian Cribb FRSA FTSE

Stopping the sixth mass extinction

Julian Cribb FTSE is a prominent science journalist and communicator. In this opinion piece he discusses the central ideas of his latest book, *Food or War*.

Image by Mathew MacQuarrie / Unsplash

The most destructive implement on the planet, without a doubt, is the human jawbone.

Every year, in the course of wolfing through 8.5 trillion meals, it dislodges more than 75 billion tonnes of topsoil, swallows 7 billion tonnes of fresh water, generates 30 per cent of our greenhouse gas emissions and distributes 5 million tonnes of concentrated biocides. It fells forests, empties oceans of life, destroys rivers and lakes, sterilises landscapes and blankets the planet in a toxic plastic shroud. It is the main driver of the present grotesque imbalance in terrestrial vertebrate biomass: 32 per cent human, 66 per cent domestic livestock, three per cent wildlife.

From these figures alone (and many others) it is clear that there can be no solution to the global ecological crisis or the sixth mass extinction without considering how humans produce and consume food. Bluntly, we are in the process of devouring a planet, and this is not a good outlook for the survival of our own species either.

Take heart as there is a solution. It is practical, affordable and the technology to implement it already exists. So do the people and skills. However, as you may imagine, it involves a food revolution an order of magnitude or so, greater even than the green energy revolution now sweeping the planet. But it is equally promising and feasible.

The first thing which everyone who eats needs to understand is that the present food system, perfectly adequate for the 20th Century and indeed the primary cause of the human population explosion, is not sustainable in the 21st Century. Apart from a growing vulnerability to climatic impacts, modern broadacre farming systems are destroying the very soils, waters and ecosystem services they depend on at such a rate that major food system failures will be unavoidable in coming decades, starting with water crises in the 2020s and beyond. Just because our bronze-age food system has served us well for 6000 years does not mean it will work for 10 billion people in the hot, resource-depleted, ecologically-impaired world of the latter 21st century.

Food failures, we know from history, nearly always lead to wars and mass refugee upheavals. Only this time they are liable to be global in impact. And war is almost as bad for ecology as food production. This process is already under way, with one third of a billion people — equal to the US population — leaving home each year in search of new lives in countries which appear to them more stable and food secure. Therefore, in developing a new food system, we also have to find a way to curb the human appetite for war.

In *Food or War*, I trace the nexus between food and conflict through human history, explore the food driver in recent and existing conflicts and identify nine regions of the world which are at high risk of conflict in the foreseeable future — conflicts which range on a scale from riots and government failures to thermonuclear war. My aim is to show that the link between food and war is inexorable, but that it can be broken. And that a sufficiency of food is the most under-rated, under-recognised weapon of peace in the world today.

So, how do we achieve sufficient food for all of humanity, to take us past the peak in human population later this century down to more sustainable levels, without laying waste to the entire planet either agriculturally or militarily?

There are basically three pillars to a sustainable global food supply, each supplying roughly one third of our food needs:

1. Regenerative farming and grazing, globally, to restore ecosystem function over an area of about half of the planet presently farmed or grazed, using minimal inputs of chemicals or fertiliser and locking up far more carbon.
2. Urban food production, in which all urban water and nutrients are recycled in a circular economy into climate-proof food, produced by a wide range of techniques from hydroponic, agritectural and aquaponic to cellular agriculture systems.
3. Redouble marine aquaculture, especially into deepwater ocean culture and algae farming or water-cropping. This will replace wild-harvest fisheries and substitute for some broadacre cropping on land.

There is a lot more to each of these than I can explain in this short article, so please bear with the argument. Suffice to say there are scientists, farmers, companies and innovative technologists all round the world already pioneering these techniques, hammering out the flaws and investing billions of dollars in new food ventures aimed at a safe, healthy, sustainable diet for all.

Furthermore, there is a dramatic opportunity to eat better. So narrow is our present industrial food base that we presently eat fewer than 300 (i.e. less than one per cent) of the 30,500 edible plants so far identified on Earth. We have yet to explore our planet in terms of what is good, safe and sustainable to eat.

In his book *Half Earth*, the great biologist E.O. Wilson argues that we need to set aside about half the planet for other life if we are to avoid mass extinction and an ecological collapse that will imperil our own future. In *Food or War*, I show how this may be achieved — by re-wilding half of the world's presently farmed and grazed lands, in all continents, under the stewardship of former farmers (whom the industrial food system is evicting anyway) and indigenous peoples — a scheme titled "Stewards of the Earth". On Wilson's calculus, this should spare around 86 per cent of the species presently destined for anthropogenic midnight.

Is this affordable? The funding to make it happen already exists. By diverting just 20 per cent of the global arms budget of $1.8 trillion (i.e. $340 billion a year) on the grounds that improved global food security is the most effective means of bringing peace to the planet since food scarcity is, nearly always, a fundamental propellant of the tensions that lead to war. An even larger cut happened between 1990 and 2005, so we know it is possible.

Such is the insatiable power of the human jawbone that rethinking food not only holds the key to peace and plenty for all, but also to ending the sixth extinction and regenerating a fairer, greener Earth. ▶

Julian Cribb
FTSE

Julian Cribb is an award-winning science writer whose work explores interlocking existential threats, including climate change, food insecurity, biodiversity loss and disease.

By Professor Douglas MacFarlane FTSE

Ammonia

Australia's next massive energy export

> "A 250km x 250km piece of land in the Australian outback receives enough solar energy annually to power the electricity demand of the entire world!

Australia's new coal?

Australia has been exporting coal for a long time. This industry has supported our economy and growth, and we desperately need a new generation of energy exports to replace it.

Renewable energy and the space to collect it is plentiful in Australia. In fact, parts of the Australian continent receive substantially more solar energy per square metre than anywhere else in the world. For example, three times more than most of Europe.

Just a 250km x 250km piece of land in the Australian outback receives enough solar energy annually to power the electricity demand of the entire world! That land area is just a few of our biggest cattle stations put together.

But how can this energy be captured and stored? What's the best way to transport it to market? Especially to overseas markets such as Japan and Korea where demand is building, rapidly. Batteries are expensive, large and heavy, and hydrogen is difficult to transport over long distances and highly flammable.

One answer is ammonia. Unexpectedly, common or garden ammonia can play a crucial role in the future of transporting Australia's renewable energy from remote areas to Australian cities and to the rest of the world. The energy of the sun (or wind, geothermal, hydrothermal etc) stored in the nitrogen-hydrogen bonds of the ammonia molecule (NH_3) is competitive with traditional fuels such as LPG and diesel.

Is ammonia safe as a fuel?

You may be already familiar with ammonia as a cleaning agent with an awful smell that will knock your socks off, but this chemical has so much more to offer. And the awful smell makes it safer to handle than petrol because leaks can be detected well below toxic levels.

From a safety perspective, multiple investigations predict that mass transportation, storage and distribution of anhydrous (water-free) ammonia poses handling and safety risks comparable to that of gasoline and liquid petroleum gas (LPG). Additionally, nearly 140 million tonnes of ammonia are already produced around the globe each year.

Currently, most ammonia is destined to become fertiliser, a crucial ingredient for growing the world's food supply. Half of the world's current population could not exist without industrial fertilisers to increase agricultural yield.

As a result, much of the infrastructure (for example, pipelines, shipping, rail, road transport routes) and safe handling practices are well established. Nonetheless, the demand for ammonia as an energy source will quickly dwarf the demand for ammonia as a fertiliser.

Sustainable ammonia from renewables, air and water

One of the starting materials needed to make ammonia is nitrogen gas, N_2. This abundant gas makes up 78 per cent of the air we breathe, but a very strong triple bond holds the two nitrogen atoms together. As a result, N_2 is incredibly inert, meaning it doesn't easily react with other chemicals. This triple bond requires activation, which is difficult to achieve.

Industrial scale ammonia production is based on a method, developed in the early 1900s, called the Haber Bosch process (HBP). However, it depends on fossil gas to make the hydrogen gas necessary as feedstock and requires intense conditions of 400-500°C and 200 atmospheres of pressure.

This means the HBP generates an enormous carbon footprint (fully 1.5 per cent of annual global greenhouse gas emissions) and is highly unsustainable in the current climate crisis. Very large industrial plants (490kt of ammonia per year) are needed to achieve reasonable energy efficiency, which at best is only about 50 per cent.

It's an uncomfortable truth that using such a carbon intensive, fossil fuel-reliant process to make fertiliser and grow our crops means our food is actually fossil fuel product. But scientists are working intensely to develop a more sustainable way to produce ammonia. And if we can do this, the potential emerges for ammonia to become a store of renewable energy that could replace coal.

Generation 1 is happening now. The carbon dioxide emissions of the HBP can be offset indirectly by purchasing carbon credits. Alternatively, carbon capture and storage technologies can be used to collect and sequester the carbon dioxide or upcycle it into small, useful molecules. This is possible but adds cost, and sequestration is not a feasible (or sensible) option in many locations.

Generation 2 involves a device called an electrolyser, which only uses water and a renewable energy source to generate hydrogen. This sustainably generated or 'green' hydrogen is fed into the HBP to eliminate its reliance on fossil fuels.

Indeed, Siemens, which manufactures electrolysers, has successfully built a demonstrator that does exactly this using energy generated by wind turbines. A scaled-up demonstrator is being installed at the Yara ammonia plant in Karatha in northwest WA.

The capital costs of electrolysers is a limiting factor in the roll out of this technology and the pressure is on in the research sector to find ways — cheaper catalysts, fewer components — to decrease this cost.

Direct nitrogen reduction to ammonia

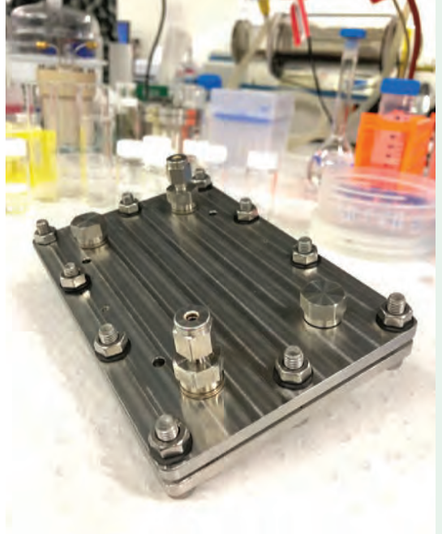
Generation 3 is based on the exciting research we do at Monash University and has the potential to free humanity from reliance on the HBP. We are synthesising ammonia by direct reduction of nitrogen gas (N_2) on specially designed catalytic electrodes, using sustainable energy.

The ammonia is made electrochemically (a chemical reaction driven by electric current) by the nitrogen reduction reaction (NRR). Solar, or any renewable form of energy, provides the electricity to drive the reaction. The nitrogen is separated from air using well-established air-separation devices.

Water is also a key component — we need 1.6 tonnes per tonne of ammonia. Since Australia

Professor Douglas MacFarlane
FTSE FAA

Sir John Monash Distinguished Professor Doug MacFarlane is an Australian Laureate Fellow at Monash University's School of Chemistry and leader of the Energy Program in the Australian Centre for Electromaterials Science. He was the Australian Academy of Science's Craig Medallist 2018 and also winner of the Victoria Prize for Science and Innovation 2018. His interests cover a broad range of materials for renewable energy generation and storage. He has published more than 700 papers and 30 patents, including papers in *Science and Nature*.



> "Imagine if you could have a small black box at your house that could generate enough ammonia from rooftop solar or off-peak electricity for your personal electricity use.

is a dry country, research into using sea water as a starting material is of high importance. The conditions of the NRR experiment are essentially ambient, up to 70°C and 15 atmospheres of pressure.

A major advantage over the HBP is that the efficiency of ammonia production doesn't decrease if the cell is run intermittently, or on a small scale. This means it can be powered by sunlight during the day and/or by sporadic wind power and it could be installed on a highly distributed, almost domestic-level scale.

Currently, certain Generation 3 methodologies only make small amounts of ammonia. On such a small scale it's crucial for researchers to ensure this ammonia is made from unreactive N_2 and not reactive N-based contaminants like NO_3 (nitrate), NO_2 (nitrite), N_2O (nitrous oxide), NO (nitrogen oxide) and ammonia itself, which are ever-present in the atmosphere and laboratories.

Experimental check lists have been detailed by our group and others explaining the protocol that needs to be followed to prove the ammonia is produced from N_2. Unfortunately, many research groups are not carefully following these protocols, and this is creating a plethora of unreliable data in the literature.

Nonetheless, there's robust confirmation that ammonia is being made from N_2 from certain Generation 3 approaches, so we are pushing forward to make the process commercially viable. It's estimated that such technology could start to roll out in 2025.

Ammonia as a fuel

Imagine if you could have a small black box at your house that could generate enough ammonia from rooftop solar or off-peak electricity for your personal electricity use: powering the refrigerator, washing machine and the TV. Ammonia powered fuel cells could even power your car.

Or, thinking large scale, the shipping industry — one of the primary users of diesel worldwide — is turning to ammonia as a way to decarbonise. Estimates show that if ammonia was used instead of diesel or heavy fuel oil, the environmental impact of shipping would be massively improved with comparable power generation. This shift from conventional fossil fuels to sustainable fuels is already becoming a reality. Volkswagen Group is developing a marine two-stroke engine powered by ammonia.

In fact, ammonia can replace fossil fuels in most contexts. Ammonia powered engines are well known and could replace petrol and diesel in all types of vehicles and generators. Japan is already using ammonia to assist in the transition away from coal-fired power generation. Ammonia can be used in turbines, much like fossil gas is used for power generation, or kerosene in jet engines. (The latter is under serious investigation in the aerospace industry.)

Alternatively, in places such as Japan where hydrogen infrastructure and vehicles are emerging, ammonia can be cracked into hydrogen and nitrogen using CSIRO's cracking technology.

In this particular renewable energy supply chain, ammonia is the energy carrier all the way from Australia to the fill-station in the overseas country, where it provides an on-demand source of hydrogen.

Ammonia can even replace coal in steel production.

Caring for the nitrogen cycle

A word of caution. Humankind must try to learn from past mistakes... we don't want to fix our carbon problem by creating a nitrogen problem! In principle, when ammonia energy is used, the products are N_2 and water, which are harmless and can be released into the environment at point of use creating an ideal, circular Ammonia Economy.

However, small amounts of unreacted ammonia and NO_x by-products are also possible. So as we hugely upscale ammonia production to encompass energy as an end use, we need careful research to keep these by-product emissions in check, and to understand their impact on marine and atmospheric nitrogen cycles (where most of the heavy lifting in processing these compounds occurs). ▶

By Professor Jocelyn McPhie FTSE

Knowing volcanoes

Last year's White Island disaster was a horrific — but growingly rare — tragedy. Professor Jocelyn McPhie explains the volcano-monitoring technology making eruptions less frequently fatal.

White Island (aka Whakaari) is an active volcano in the Bay of Plenty, 50 km offshore from Whakatane on the coast of the North Island of New Zealand. The volcano came to international attention in December, 2019, following a fatal eruption that resulted in 21 deaths.

This eruption is not the deadliest in New Zealand's history of volcanic disasters but it is no less tragic. All the victims were tourists or tour operators, expecting to enjoy an adventure on an active volcano. The key word here is "active", meaning that an eruption could occur without warning, so a visit is inherently risky.

Hazard vs risk

Assessing volcanic risk is an important task of modern volcanology. Volcanologists make a distinction between volcanic hazard (all the destructive eruption-related phenomena that could happen) and volcanic risk (the extent of the loss of life and damage likely to occur as a result). A volcano can be highly hazardous, but if it is very remote, presents low risk, at least to human communities.

The hazards posed by White Island are high because its typical style of eruption is explosive. Explosive eruptions are driven by expanding gas that breaks apart magma and wall rock around the vent. The mixture of hot particles and hot gas is expelled into the atmosphere with great force in a matter of seconds to minutes.

Also, for most of its history, the vent on White Island has been flooded by a hot acidic lake, so acidic lake water is expelled first when the volcano erupts.

The volcanic risk on White Island is a somewhat unusual case because it is uninhabited and remote: circumstances which would normally render the risk quite low. However, the island is visited almost every day by tourists who get there by helicopter or boat, and while they are on the island, the risk is very high.

The risk is heightened by the fact that all locations on the island are relatively close to the active vent (<1 km). That is because most of the volcano is under water — only the top few hundred metres are exposed above sea level.

Also, the vent is surrounded by an amphitheatre formed by a prehistoric collapse of the southeastern sector of the cone. The open side of the amphitheatre offers a good place for helicopters to land and, at the shore, a good place for tour boats to berth.

When an explosion occurs, the clouds of hot gas and particles go up above the vent but also sideways along the amphitheatre. Any one setting foot on White Island is therefore immediately in the most exposed location on the volcano.

Monitoring magma

Worldwide, there are numerous cases where human communities co-exist with active volcanoes. Very little can be done to reduce the hazards but the risk can be managed and to some extent mitigated. In simplest terms, the approach is to monitor the volcano at rest in order to then detect unrest that could lead to an eruption.

Unrest is a signal to local authorities and communities to prepare for an eruption, possibly including evacuation, and thereby mitigate the effects of the eruption if it happens. The changes that can be detected prior to an eruption reflect the rise of magma to a shallow level in the conduit below the vent. There are four types of change of importance in detecting unrest — earthquakes, gas emissions, temperature and the shape of the volcano.

A great deal of science and technology underpin monitoring. For example, White Island is continuously monitored by GeoNet, the agency responsible for providing geological hazard information for New Zealand.

Four cameras are positioned for strategic views (three on the island, one in Whakatane) and take photographs every ten minutes. Two seismometers on the island record earthquakes, the signals from which are automatically analysed to distinguish the location and type of earthquake involved.

A type of earthquake known as volcanic tremor is associated with the rise of magma that usually precedes an eruption. Because rising magma

Professor Jocelyn McPhie
FTSE

Jocelyn McPhie is a world-leading volcanologist and an Adjunct Professor at University of Tasmania. Her research contributes directly to the knowledge and understanding of fundamental physical volcanology, and the links between volcanic and hydrothermal processes. Jocelyn has visited White Island many times, as leader of a Masters Field Course in Volcanology. She also operates as a consultant to the minerals industry, providing technical advice and professional training in volcanology. She was elected a Fellow in 2014.

affects the volume and composition of gases coming from the vent and from fumaroles, especially SO_2 content, ultraviolet spectrometers are employed to measure and record SO_2 emission rate.

Surface and air temperatures increase dramatically in and around vents and fumaroles when magma reaches shallow subsurface levels. Rising magma pushes and squeezes the rocks around the conduit, producing detectable changes in the shape of the volcano ("ground deformation").

Satellites and sensors

In addition to these instrument-based monitoring techniques, the island is visited regularly by GeoNet geologists for the purpose of collecting gas and water samples, directly measuring fumarole temperatures and recording observations of any changes over time. This array of monitoring techniques is standard at most active volcanoes.

For the past few decades, ground-based monitoring has been augmented by satellite and airborne monitoring techniques, collectively referred to as "remote sensing". Remote sensing primarily contributes data on gas flux and composition, temperature and ground deformation.

Earthquake data remain tied to ground-based instruments. The remote sensing approach to data collection has the major advantage of being entirely safe and, at least in the case of satellites, the data are being collected and made available continuously in real time.

Satellite-borne instruments that measure both the ultraviolet and infrared regions of the spectrum are used to monitor volcanic sulphur dioxide emissions from large eruptions. At some volcanoes, CO_2 emissions are an important prelude to an eruption. Satellite-based remote sensing of CO_2 developed in the past decade is capable of detecting volcanic CO_2 inputs into the lower atmosphere with high precision.

Anomalies in surface temperature are detected by the Landsat Thematic Mapper™. Landsat™ images are routinely used to detect and monitor temperatures in and around active volcanoes.

With regard to ground deformation, satellite-based measurements of surface displacements have achieved mm-scale accuracy. The most widely used technique is Interferometric synthetic aperture radar (InSAR) which uses differences in the phase of radar waves returning to the satellite to generate maps of surface deformation.

Watching from the sky

Remote-sensing technology has also greatly enhanced our ability to make accurate topographic maps ("digital elevation models") of volcanoes. This data underpins our prediction of the pathways lava, floods or explosive eruption clouds are likely to follow when eruptions begin.

Aircraft, both planes and helicopters, specifically fitted with monitoring equipment may be employed to survey some volcanoes in cases where the satellite data are inadequate in resolution or of insufficient quality. The kind of data collected is essentially the same as those collected by remote sensing, although some aircraft are also capable of flying through and directly sampling the clouds produced by explosive eruptions.

Drones, also known as unmanned aircraft systems, are increasingly being used to collect data and make observations at active volcanoes. They have the advantage of being relatively inexpensive and highly adaptable to different conditions.

Drones allow volcanologists to "enter" and examine active vents and craters that are otherwise inaccessible and extremely dangerous, being unstable and filled with deadly hot gasses. As well as high-resolution images and real-time videos of what is going on in vents and craters, some are also able to retrieve gas samples.

Discovering the past

Alongside the sophisticated science and technology underpinning volcano monitoring is an equally important effort to understand and model what volcanoes are capable of. Only by knowing how a volcano has behaved in the past can we properly assess the type and severity of hazards that future eruptions pose.

This information is obtained by tracking the volcano's history, a story that can be read from the volcanic formations exposed in and around the volcano and calibrated by determining the ages of the various formations.

In some cases, historic eruptions provide a sound guide to the ages of various events but in most cases, the volcano's history is much longer than recorded human history. Determining pre-historic ages involves very precise measurement using a mass spectrometer of radioactive isotopes present in the minerals found in natural volcanic rocks. Knowing established rates of change from one isotope to another, the relative proportions of isotopes give an idea of how old the formation is.

Such a chronology of eruptions commonly reveals average eruption frequencies and in particular, the frequency of the most hazardous eruptions through the life of a volcano. Together with monitoring data, eruption histories are the main tools for predicting how a volcano will erupt in the future. The eruption history of White Island is only imperfectly known because most of the volcano is under the sea and has not been sampled, and the formal record of historic events goes back only about 200 years. The recorded history shows very clearly that eruptions such as that in December, 2019, have been frequent in the past, together with less hazardous eruptions of lavas.

The December 2019 tragedy had a life-changing impact on the survivors, the families of the victims, and the wider community. But from a scientific perspective, the eruption was "normal" for White Island, and similar events will undoubtedly occur again. As our understanding of volcanoes continues to grow, so too will our ability to save more lives. ▶

By Sarah Hayward

IMNIS makes a difference

A recent study by three South Australian universities shows that the Industry Mentoring Network in STEM (IMNIS) is having a positive impact on PhD students; expanding their professional networks, increasing their employability and providing them with the skills and knowledge they need to effectively engage and collaborate with industry.

These findings support the outcomes of the IMNIS national survey of the 2017-2018 program participants, which also showed the expansion of mentee networks, enhanced employability and increased industry-relevant knowledge and skill development.

We asked three IMNIS mentee alumni, Manuel Herduin, Maggie Lieu and Sahan Kuruneru, to reflect on their experiences participating in the IMNIS programs.

IMNIS mentee alumni commented on how their IMNIS experiences highlighted the importance of developing broad professional networks and provided opportunities to develop networking skills.

"I have learnt through the IMNIS program that the establishment of a broad professional network, from various fields, is key to success. Universities teach you what to know but not who to know. In industry, it is about who you know." — Manuel

"One of the most important things I learnt by participating in the program is the importance of networking. Networking during my PhD allowed me to connect with a wide variety of people, expand my network and allowed me to understand the types of industry roles available." — Maggie

"The IMNIS program has given me a great opportunity to network with industry leaders across Australia and to learn about career opportunities in the industry." — Sahan

IMNIS helps mentees to develop broad professional networks, increasing engagement and collaboration between industry and academia. After the completion of the 2017-2018 programs, 70% of mentees had met up to five contacts in their mentor's network, while 30% had met six or more. Additionally, two thirds of mentors were engaged, or were planning to engage, in their mentee's academic research, their research group and/or their organisation.

The South Australia IMNIS Impact Evaluation echoes these findings, showing a 37% increase throughout the year long program in the number of mentees with high or full skill competency in professional networking.

By improving their 'soft skills' and increasing their understanding of opportunities beyond academia, IMNIS helps to prepare PhD students for industry collaboration and engagement. When surveyed, 93% of mentees agreed they have "a better understanding of industry, the skills needed to succeed [and] the careers available". Mentors reinforced this with 95% agreeing their mentee had achieved the same.

IMNIS mentee alumni commented on how their mentoring partnerships helped them to prepare for a career in industry:

"The IMNIS program connected me with a mentor who helped and guided me through the development of key knowledge and skills to get my foot into the door of industry." — Maggie

"I strongly believe that my mentor provided me with the right advice and mindset for an efficient and successful start in the professional environment. I owe my positive start in industry to my mentor. We both reviewed my ambitions, strengths and expectations, and we later discussed the different routes to implement this career plan." — Manuel

"The IMNIS program has certainly given me a clearer idea of how I can l leverage my PhD knowledge and skillset to find a suitable job that aligns with my career goals and interests." — Sahan

The South Australia IMNIS Impact Evaluation also shows an increase in skills competence and knowledge understanding. Throughout the one-year program, there was a 55% increase in the number of mentees with high or full skill competency in advanced communication, a 46% increase in mentees with a high or full understanding of careers outside academia and a 42% increase in mentees with a high or full understanding of industry-academic collaborations.

In addition to fostering industry engagement and collaboration, IMNIS helps to prepare PhD students to make the move beyond academia. 84% of mentees in the 2017-2018 program said they developed knowledge and skills needed to attain an internship or job in industry and almost one-third landed an industry-based job or internship during the one-year program.

Manuel, Sahan and Maggie reflect on the impact of the IMNIS program and their mentors in getting them to where they are in their industry careers today:

"The IMNIS program has given me a great opportunity to network with industry leaders across Australia and to learn about career opportunities in the industry. My mentor and I discussed what it takes to be successful in industry. My mentor highlighted the importance of transferable skills and we discussed how to write a CV tailored to each job you apply to as well as the most commonly asked interview questions. All that hard work paid off and I managed to secure a job in my field." — Sahan

"Thanks to IMNIS, I invested a significant amount of my time in planning my future career, with the help of my mentor. One year before finishing my degree, I had come up with a career plan and listed multiple ways to reach the goals in my career plan. As a result of a very early planning of my career, I submitted my PhD on a Friday and started working as a permanent full-time engineer for a highly reputable company in my field the next Monday." — Manuel

"I was fortunate enough to be given the opportunity to work with my mentor for a short period of time in the field of clinical trials. The skills that I developed during this role enabled me to transition into a Life Science consultant role at Clarivate Analytics following completion of my PhD by leveraging both my scientific expertise from my research studies and ability to work with a range of clients." — Maggie

I owe my positive start in industry to my mentor. We both reviewed my ambitions, strengths and expectations, and we later discussed the different routes to implement this career plan."
– Manuel

Maggie Lieu (right) at the 2017 Program Launch in Victoria

IMNIS
INDUSTRY MENTORING NETWORK IN STEM

IMNIS

The Industry Mentoring Network in STEM (IMNIS) is an award-winning industry-led initiative of the Australian Academy of Technology and Engineering. IMNIS connects motivated PhD students (mentees) in science, technology, engineering and mathematics (STEM) with outstanding high level industry leaders (mentors) in a one year industry mentoring program.

IMNIS provides Australia's future STEM leaders the opportunity to engage with industry, extend their professional network, strengthen their implicit skills and get advice from an influential industry mentor. Student mentees learn what it takes to succeed in any part of the STEM ecosystem, gain a better understanding of how industry works and learn about career opportunities in other professional sectors.

imnis.org.au

IMNIS
INDUSTRY MENTORING NETWORK IN STEM

Maggie Lieu

Maggie Lieu obtained her PhD from Monash University in the field of pharmacology, immunology and cardiovascular disease. Previously, she was a Research Valet Officer at St Vincent's Hospital, Melbourne where she helped researchers, contract research organisations and pharmaceutical companies fast track ethical approval involving drugs and medical devices for clinical trials across multiple therapeutic areas. Maggie is an active player in the biotech, medtech and pharma sector and passionate about the translation of research discoveries into life-saving medicines. Following the completion of her PhD, Maggie made the move from academia into industry and is currently a Life Sciences Solutions Consultant at Clarivate Analytics. In her role Maggie helps identify and communicate solutions to accelerate innovation for pharmaceutical, biotech and academic/medical institutes and government agencies. Maggie was a mentee in the 2017 MedTech-Pharma program in Victoria.

Sahan Kuruneru

Sahan Kuruneru received his Bachelor of Engineering (Mechanical) (Honours) at UNSW in 2010. He secured a graduate mechanical engineering role at Transpacific Industries, Australia's leading waste management firm. Later, Sahan completed a Master of Research degree at QUT. Afterwards, he decided to pursue a Doctor of Philosophy (PhD) at QUT in 2015 supported by an Australian Postgraduate Award (APA) scholarship. His research was on developing advanced numerical models (computational fluid dynamics) to study multiphase solid-gas flows and particulate fouling in porous metal foam heat exchangers for the power-generation industries. Following the completion of his PhD, Sahan made the move from academia to industry. Sahan is currently employed as an R&D engineer with CSIRO in Newcastle, NSW. Sahan's job focuses on developing advanced numerical models with the prime goal of enhancing the thermal efficiency of concentrated solar thermal plants. Sahan was a mentee in the 2017 Energy-Minerals Resources program in Queensland.

Manuel Herduin

Manuel Herduin was a mentee in the 2017 IMNIS Energy-Minerals Resources program in Western Australia. Following the completion of his PhD, Manuel quickly gained an industry position in his field as a Project Engineer at Deep Sea Mooring.

Manuel completed his BSc in Civil Engineering and his MSc in Renewable Energy in France before making the move to Australia to undertake his PhD at the University of Western Australia. Manuel has a passion for the ocean and is motivated by digging into new experiences and challenges. His PhD in offshore geotechnical engineering looked at the possibility to connect one anchor to multiple floating facilities using a mainly experimental approach with a small part of numerical modelling.

IMNIS
INDUSTRY MENTORING NETWORK IN STEM

ALUMNI SURVEY

JUNE 2020

Today's influencers mentoring tomorrow's leaders in STEM.

IMNIS is a prestigious STEM industry engagement initiative that partners PhD students and early career professionals with an influential, high profile industry leader to prepare them to lead and excel within any part of the STEM ecosystem.

WHO WAS SURVEYED?

135 mentees from the IMNIS Pilot 2015-16, National Program 2017-18, and National Program 2018-19.

90%

SEE THEMSELVES IN INDUSTRY

IMNIS influenced them to consider, or actively pursue work in industry, or they have begun to work in industry already

97%

WANT TO COLLABORATE

IMNIS influenced them to consider, want or have collaborations with industry

"The IMNIS Program had a ripple effect on my life and career trajectory. Not only was I paired with an excellent mentor, I also was connected with so many more people in academia, business and industry, which has opened multiple doors for me that I never even knew existed."

INTERNSHIPS

79%

said they would be interested in doing an internship as part of the IMNIS program

CONNECTED

70%

said they are still in contact with their IMNIS mentor since their program ended

"There were limited opportunities for my academic experience to cross into industry, so I was delighted when I had the opportunity to be a part of IMNIS. It further supported my drive to move into a career that utilises my academic experience whilst learning new skills in industry/corporate. Thank you IMNIS!"

RESEARCH

65%

said the program influenced the direction of their research, including new projects

CULTURE SHIFT

People make research and innovation happen, and people drive transformational culture shifts.

Our results show that IMNIS establishes enduring connections between professionals and researchers in industry and academia. IMNIS shifts perspectives and increases industry engagement, breaking down barriers between these two sectors.

AUSTRALIA WIDE

IMNIS holds activities and events in major capital cities throughout the year

ATSE

IMNIS is an initiative of the Australian Academy of Technology and Engineering

atse.org.au

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INDUSTRY MENTORING NETWORK IN STEM

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IMNIS alumni survey results

PhD graduates and students participating in the Industry Mentoring Network in STEM (IMNIS) program are more likely to actively pursue an industry career, a recent survey has found.

The survey, conducted by the Academy of Technology and Engineering's (ATSE's) IMNIS initiative, found the majority of IMNIS alumni either work in industry or are actively pursuing or considering an industry career, compared to only about 30 per cent of PhD graduates not participating in the program.

ATSE established IMNIS in 2015 to build connection and collaboration between the private sector and academia, and equip PhD graduates with professional skills and senior networks in industry.

IMNIS mentees from the pilot program in 2015/16 and subsequent national programs in 2017/18 and 2018/19 were surveyed on their attitudes towards engaging with industry. Over half of the respondents (53 per cent) have completed their PhD.

ATSE CEO Kylie Walker said IMNIS is fostering a culture shift between industry and academia, toward more collaboration and innovation.

"It is increasing students' understanding of a huge range of potential careers enabled by a STEM qualification, as well as showing leaders in industry the value today's STEM PhD graduates could bring to their organisation and to building a more innovative Australian economy," Ms Walker said.

The survey found 97 per cent of mentees were either collaborating, keen to collaborate or were considering collaborating with industry.

A participant in the IMNIS medical technology and pharmaceuticals program in 2017-18, said while she was a PhD student she was interested in pursuing a career in industry but wasn't sure how to transition from academia.

"The IMNIS program really helped highlight the crucial role of networking and I was fortunate enough for my mentor to introduce me to her colleagues, who are leaders in their fields," she said.

"Networking during my PhD allowed me to connect with a wide variety of people, expand my network and helped me to understand the types of industry roles available."

A third of mentees said the IMNIS program revealed novel ideas or had inspired them to take a new direction with their research, with eight per cent now working on an entirely different research project.

Almost half said that since IMNIS their research had slightly changed direction; while one-third said it had done this, with eight per cent now working on an entirely different research project.

Enduring networks were another benefit of the program, with more than two-thirds of IMNIS students staying in contact with their mentor after their program ended. ▶

> "As a female engineer I have known at times in my career that I was not seen as belonging in a workplace, and this lead to demotivation and demoralisation. In inclusive cultures everyone is respected for who they are, allowing you to bring your best self to work."

By Gunilla Burrowes

Being more human @ work

Dr Gunilla Burrowes
FTSE

Gunilla Burrowes is a member of ATSE's Diversity and Inclusion Committee. She is a consultant with Gender Matters, which advises organisations on gender equity issues and provides training in cognitive bias mitigation. Dr Burrowes co-founded underwater technology company the BlueZone Group and angel investing organisation Rights House (now Hunter Angels). She also runs Eighteen04 Inc, a co-working incubator space for start-ups and scale-ups in the Clean Tech and Smart City sectors.

Industry 4.0 is here — but do our workplaces look much different to what they did under Industry 2.0? Melinda Gates says "we are still sending our daughters into workplaces that are designed for dads".

These spaces are dominated by patriarchal and hierarchical models left over from Industry 2.0 — models designed to support mass manufacturing, scientific management and Taylorism (a century-old approach to maximising worker efficiency invented by Fred W. Taylor).

With ever-more sophisticated data analytics altering and automating today's workplaces, there's no question that digital technology and AI will transfigure the future of work.

In *The Future of Jobs 2018*, The World Economic Forum reported that machines and algorithms currently handle about 29 per cent of tasks across 12 major industries. By 2022, that proportion will leap to 42 per cent of all tasks, including 62 per cent of data processing and searches.

Clearly, there will be job losses, and the creation of new jobs we are only just beginning to conceive of. But we also have to ask who will be performing these tasks, and how. These challenges are enormous, and they're here now.

I often hear that we're not keeping up with the ethical dilemmas new digital technologies are introducing. If we are to deal with these issues successfully, we need to bridge the disconnect between our human and technical worlds.

Workplaces are where the decisions about these technologies are being made. Since these choices impact all of humanity, it's important that humanity, in all its capacities, are present in these workplaces. We need to bring the entire team with us on the journey.

The places we work need to become more human-centric. As we're beginning to address the issue of a more diverse workforce, the critical issue is inclusion.

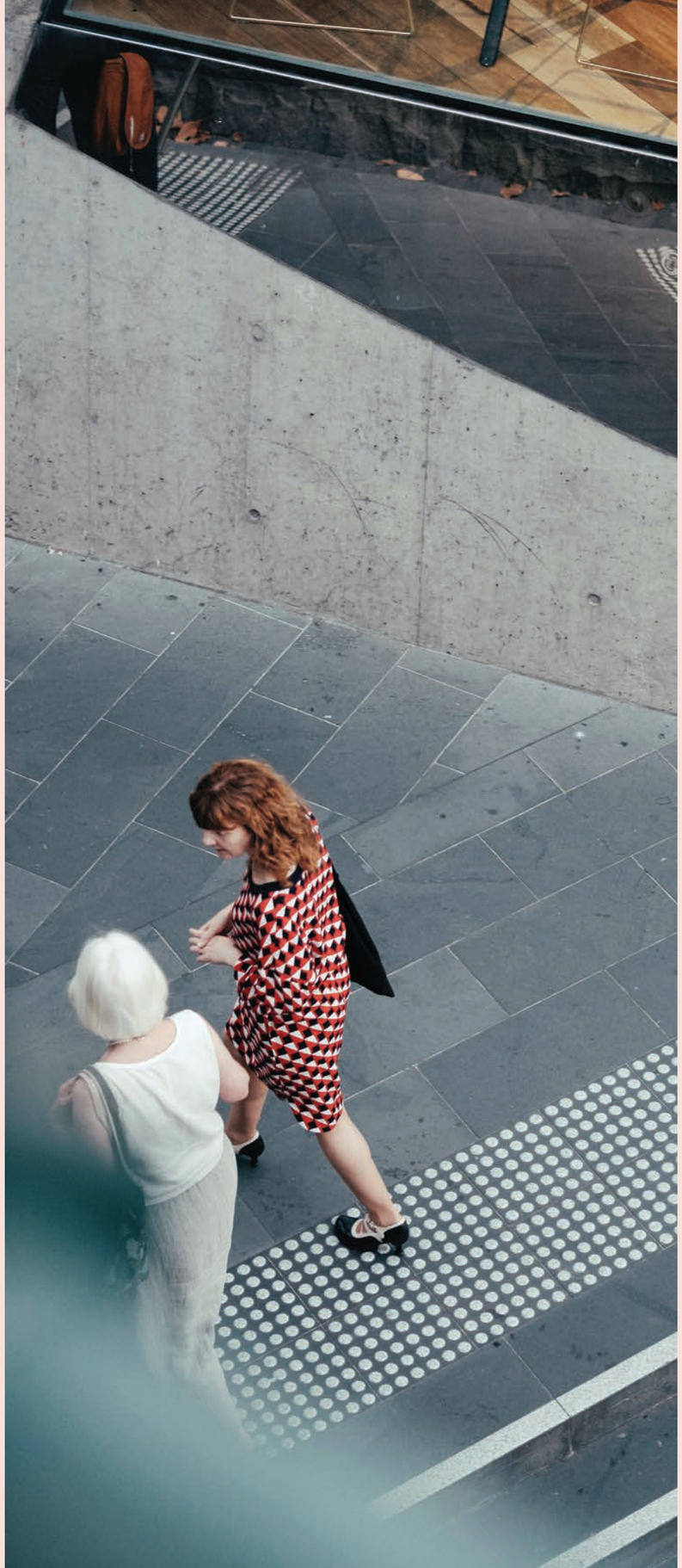
Diversity & inclusion

There's no doubt that we've made significant progress with diversity in our workplaces, and this success should be celebrated. Many organisations have increased the numbers of women and other historically underrepresented groups on their payrolls.

Improving diversity in the workplace has predominately focused on who's sitting around that table, who's being recruited and who's being promoted. This is tracked on the basis of traditional characteristics like gender, ethnicity, sexual orientation and disability.

Diversity is an easy concept for Industry 2.0 organisations to implement: a scientific approach of head counting, positive discrimination and other easy-to-understand tools to yield measurable results. Very satisfying for a traditional organisation and easy to announce in an annual report.

But to experience the full benefits of diversity, we need to now focus on inclusion. Inclusion is the rocket booster that can launch our newer more diverse organisations from low earth orbit into a new world.



Some organisations are not seeing the benefits of diversity because they haven't taken the extra step to implement the practices and behaviours necessary for real inclusion. It's time for male-dominated organisational models to change at a deeper level. Diversity and inclusion isn't just about equity — it's about strategy.

The challenge for engineering

As engineers, it's easy to blame others for not keeping up with technological change. We're dealing with the advancement of technology itself: we shouldn't have to be philosophers or lawyers concerned with the messiness and uncertainty of politics and deal-making.

However, the way the engineering profession handles technology at this pivotal moment will have subtle and powerful ramifications for our world.

The results of Industry 2.0 — the shift of agrarian workers to factories and cities — are easy to see. The social upheaval was enormous; but governments could relatively quickly understand and address it by creating the infrastructure of modern cities.

How will sophisticated algorithms implemented on the internet of things (IoT), big data analysis, machine learning and automation now affect our society and way of life? Many of these impacts simply cannot be foreseen.

Engineers, scientists and technologists are leading the discussion about our digital future, such as in ATSE's 2019 report, *Preparing for Australia's Digital Future*. Underpinning many of the 23 recommendations in this report is a mindset change where organisational leaders need to become inclusive leaders.

To manage the impact of new technologies on our society, we need to empower the whole of the workplace to participate in the development of our digital future. To do this, we need to understand inclusion.

Inclusion

The goal of inclusion strategies is to have practices and procedures that integrate everyone in the workplace, allowing their differences to coexist in a mutually beneficial way. This supports people across an organisation to work together to improve the organisation's performance and wellbeing.

This is when we will actually see the true benefits of diversity and a more "human" way to develop digital technologies.

There are a growing number of inclusion models with fundamentally similar components. The Diversity Council of Australia's Inclusion@Work model focuses on four elements that are needed for inclusion to occur in the workplace:

1. connection
2. respect
3. contribution
4. progress.

Connection means that everyone is welcome and feels that they fit in.

As a female engineer I have known at times in my career that I was not seen as belonging in a workplace, and this lead to demotivation and demoralisation. In inclusive cultures everyone is respected for who they are, allowing you to bring your best self to work.

Being asked to contribute your perspectives and talents is critical to being valued as a team member. This opens up a variety of ideas, knowledge, perspectives, approaches and styles that can help create more innovative solutions.

We all want to keep progressing in our career, whether that means through learning or being promoted — which is about equal access to opportunities and resources. None of this is rocket science, it is human nature.

For ATSE, its *Diversity and Inclusion Action Plan* is a great demonstration of the mindset change needed in organisations to progress. It uses a four-level progress model: *The Diversity and Inclusion Progression Framework for Professional Bodies* from The Royal Academy of Engineering, Science Council 2017.

Conclusion

Workplaces are in major transition as is the way we work, due to rapid developments in digital technologies, yet workplaces have not changed to understand the challenges that these technologies bring.

There is still a disconnect between our human and technological worlds, and workplaces are where we need to empower this to happen by engaging everyone to participate in the development of our digital future. Workplaces need to become more human-centric and more inclusive. If we can achieve this, everyone will benefit. ▶

Images: David Clarke and Gemma Chua-Tran / Unsplash

Celebrating STEM gender equity leaders

Eleven higher education and research institutions have taken home the internationally recognised Athena SWAN Institutional Bronze Award as part of the Science in Australia Gender Equity (SAGE) initiative.

The award recognises an institution's commitment to advancing the careers of women, trans and gender diverse individuals in science, technology, engineering, maths and medicine – STEMM disciplines.

WINNERS

AAO – Macquarie University
Department of Defence, Defence Science and Technology Group
Geoscience Australia
Murdoch University
Southern Cross University
Telethon Kids Institute
The University of Adelaide
The University of Melbourne
The University of Western Australia
University of the Sunshine Coast
University of Canberra

At the SAGE gala dinner at the Adelaide Town Hall in February, the awardees were joined by representatives from thirteen institutions announced as Athena SWAN Institutional Bronze awardees in September 2019.

Forty-five Australian higher education and research institutions have completed the SAGE pathway to accreditation, with the majority (39 organisations/86 per cent) being awarded the Athena Swan Institutional Bronze Award. SAGE Executive Director Dr Wafa El-Adhami said that 50 per cent of the sector had now completed the full cycle of accreditation for an Athena SWAN Bronze Award, the first and foundational phase of the journey to transformational change.

"This is testament to the leadership and commitment of the member institutions," said Dr El-Adhami.

Minister for Industry, Science and Technology Karen Andrews congratulated members on achieving accreditation.

"Encouraging research and higher education organisations to make meaningful improvements to their gender equity policies and practices is vital if we're going to bring about much needed change."

The Australian Institute of Marine Science and the University of Southern Queensland were also recognised for their progress towards Bronze Award accreditation, and their continued commitment to SAGE.

Established in 2015, SAGE is a partnership between the Australian Academy of Science and the Australian Academy of Technology and Engineering.

"The SAGE Athena SWAN Bronze Institutional Awards recognise organisations at the forefront of diversity practice," said ATSE CEO Kylie Walker. "We're thrilled about the ongoing impact of SAGE, our initiative in partnership with the Australian Academy of Science. It's vital that people of all genders and backgrounds are given the opportunities and support they need to contribute." ▶

IMAGE: ATSE CEO Kylie Walker; Advance HE CEO Alison Johns; SAGE Executive Director Dr Wafa el-Adhami; and Academy of Science CEO Anna-Maria Arabia.

SAGE welcomes STEM gender equity evaluation

Science in Australia Gender Equity (SAGE) welcomed the Federal Government's *Women in STEM Action Plan* and the *STEM Equity Monitor* as pivotal to driving the systemic transformation of gender equity and diversity in the sector.

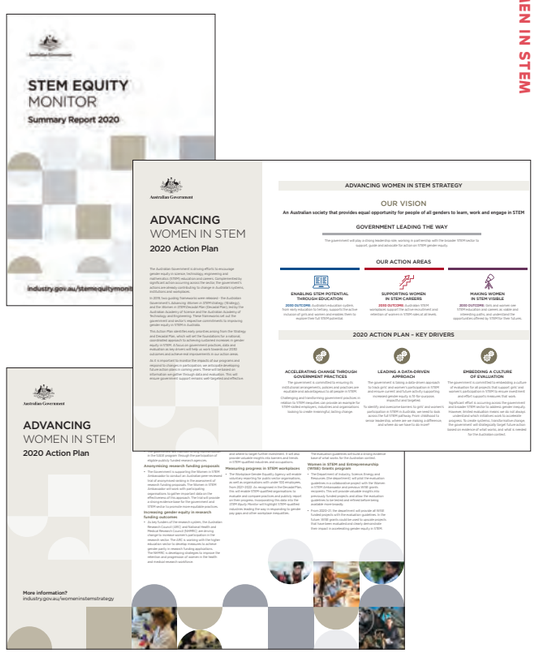
SAGE Executive Director, Dr Wafa El-Adhami, said the Government continues to play a significant leadership role as supporter, enabler and participant in advancing gender equity and diversity.

"We welcome the Government's plan of action for delivering the vision of Australia's 10-year plan for women in STEM and also an annual national data report on girls' and women's participation in science," Dr El-Adhami said.

"SAGE is one of a few national gender equity and diversity programs that has been through formal evaluation and is currently the only transformative gender equity program of its kind in Australia designed to achieve sustained cultural change via a national accreditation framework.

SAGE also acknowledged the Government reaffirming in the action plan its funding support for the SAGE program until 2021–22, as announced in last year's Federal Budget.

"We look forward to working with the Government and the sector to ensure all eligible organisations can participate and succeed in the program," Dr El-Adhami said. ▶



MORE

sciencegenderequity.org.au
industry.gov.au/data-and-publications/advancing-women-in-stem-strategy/2020-action-plan
industry.gov.au/data-and-publications/stem-equity-monitor

By Peter Pentland

A day in the life of a 7 year old

Peter Pentland

Peter Pentland is Executive Manager of the Academy's Schools Program, STELR.

STELR

stelr.org.au

The Australian Power Institute (API), along with supporting partner the Australian Academy of Technology and Engineering (ATSE), has led the development of the "A Day in the Life of a 7-year-old" program.

This program encourages curiosity in STEM for kids by providing a FREE easy to use resource kit designed to help teachers connect primary school students to the world of STEM careers, 21st century skills and increase STEM awareness.

Since 2018:

- 25 schools nationally and 850+ students have participated
- 95% of responding schools recommend the program
- 90% would participate again
- Program ratings averaged 2.6 or greater (out of a possible 3) assessed against the program objectives criteria.

The initial success of the program sees it currently being expanded in 2020/21 to schools across the country, including to schools that are practicing home based/remote learning during the COVID-19 lockdown as 90% of the resource pack is suitable for online use.

Former API board member Jane Smith realised that it was important to engage young primary school students in STEM long before they have to choose which high school subjects to study to ensure passion and confidence in STEM areas.

"We gained the sense that it was early engagement with STEM and STEM careers that we needed to focus on. It's planting the seed that STEM careers are diverse" API CEO David Pointing said.

The program looks at a 7-year-old's activities each morning before starting school and then breaks down the STEM careers that enable these activities to happen. For example, looking at what careers are needed to ensure children get water out of their taps to clean their teeth, or the electricity needed for them to have toast or the egg they eat for breakfast.

David Pointing said that because the types of STEM careers needed in society now change so quickly, it was important to give students flexible skills such as critical thinking that allowed them to easily move between different jobs, rather than train them for specific roles.

"Jobs evolve so rapidly now that students need the skills to adapt," he said. "A Day in the Life of a 7-year-old" includes six to 12 lessons and supports the Australian Curriculum in Science, Mathematics and Technologies so teachers do not have to put context around the program.

It is easy to use so teachers who do not have a STEM background are not discouraged from participating. We provide worksheets for the students and a lesson plan so the educator has all the resources they need in one place," David Pointing said.

The adaptions made to the program ensure it could be used by teachers and students in the COVID-19 lockdown and have also made it more accessible for students in remote and regional locations.

When asked to provide feedback about the program, a Primary School Teacher in North QLD who participated in 2020 responded "This program is better than any other prewritten programme or curriculum that we have ever been asked to teach. I think it's something that should be compulsory in grade 2 as it's cross curricular, easy to use and opens up those doors before they get to high school and have to start choosing their subjects which ultimately leads them to their future pathways and careers".

The 2020/21 program will start in some schools in Term 3, while others are scheduled to start in Term 4 or Term 1 in 2021. ▶

The Australian Power Institute

MORE

FREE RESOURCE PACK
Register to access the free API DIL Resource Pack for your school and / or to learn more

api.edu.au/DIL

Achievements

Bronwyn Evans named CEO of Engineers Australia

Academy Fellow Dr Bronwyn Evans FTSE has been appointed Chief Executive Officer of the engineering peak body, Engineers Australia.

Dr Evans brings a wealth of leadership, commercial and policy expertise gained across a career spanning corporate and not-for-profit roles at the forefront of engineering in Australia and globally.

Those have included CEO of Standards Australia, senior executive roles at Cochlear Ltd and GE Healthcare, as well as non-executive board experience in the construction, medical technology and digital business sectors.

Dr Evans was elected a Fellow of the Academy in 2012 and is a member of its Health Forum.

"Our board looks forward to Dr Evans advancing this work, growing our organisation through provision of clear member value and furthering the influence of our profession in the ethos of community service embedded in our Royal Charter," said Trish White, National President and Board Chair of Engineers Australia.

"An electrical engineer who has led successful corporations across manufacturing, construction, research and standards-setting, Dr Evans is well-placed to lead our organisation into its next chapter as the engineering profession transitions to take advantage of the technological disruptions and innovation of the future."

Dr Evans said she was excited to take on the role.

"With the global megatrends shaping our future relying so significantly on engineering insight and leadership it is a fascinating and important time for the profession," she said.

"I am looking forward to working closely with the Board, the staff and the broader membership to continue to grow and advance our organisation," said Dr Evans.

Lindsay Falvey wins Crawford Medal

Academy Fellow Professor Lindsay Falvey FTSE has won the prestigious Crawford Fund Medal.

For four decades, his passionate commitment to agricultural science has fuelled major advances in global food security.

Currently Chair of the International Livestock Research Institute in Nairobi, Kenya, Professor Falvey's research has taken him from the Australian tropics to war-ravaged Iraq. The Emeritus Professor of the University of Melbourne holds two adjunct appointments in Thai universities and is currently writing on the role of agricultural science in philosophy.

The Crawford Fund Medal recognises his considerable and continued contributions to international agricultural research through the Fund's programs and related activities. ATSE established the Crawford Fund in 1987.

Professor Falvey's work combines technical, social, environmental, policy and historical research in the global south. He demonstrates that Indigenous knowledge and culture is critical to sustainability, food security and human development.

As the 2019 Medallist, he delivered an oration on World Food Day at the University of Melbourne exploring global challenges in agriculture research.

"More than 30 per cent of the world was hungry in the 1960s; today it's around 15 per cent. Population has doubled since that time. The huge success of feeding an extra three billion people ranks as one of humanity's greatest feats," Professor Falvey said.

"Agricultural science underpinned those successes through a wealth of innovative research for development conducted in diverse environments and cultures around the world.

"Now, 50 years on, a new generation of agricultural scientists and thought leaders is needed to carry on this scientific and humanitarian work the face of such complex and 'wickedly' interrelated problems as world poverty and hunger, global warming, and mass migration."

Elected a Fellow of the Academy in 1997, Professor Falvey is Chair of the ICM Agrifood Award Selection Committee and an active member of the Agriculture Forum.

Murray Scott wins Composite Materials Award

Academy Fellow Professor Murray Scott FTSE has won the prestigious Scala Award from the International Committee on Composite Materials.

As part of this honour he delivered the opening plenary at the 22nd International Conference on Composite Materials (ICCM22). The conference was held in Melbourne, 11-16 August.

A certificate was presented to Professor Scott at the ICCM22 banquet at the Melbourne Convention and Exhibition Centre on 15 August.

Professor Scott is Chair of Advanced Composite Structures Australia, the spin-out company of the highly acclaimed CRC for Advanced Composite Structures, where he was CEO for over 13 years.

He has made major contributions to the development of advanced composites and has an outstanding record of achievement in engineering research, education and professional activities.

"It is a tremendous honour to be invited to deliver the opening plenary lecture named in honour of Pete Scala, who was instrumental in establishing ICCM in 1975" he said.

"I am also delighted to see ICCM return to Australia and the southern hemisphere – 22 years after the first occasion in 1997."

The ICCM Executive Council selected Professor Scott for the Scala Award (which is bestowed every two years) in August 2017.

He served as President of the ICCM from 2001 to 2003, and was elected a Life Member and World Fellow of ICCM in 2005.

The topic of Professor Scott's plenary address was "Advanced Composites Research and Innovation – an Australian Perspective".

The two co-chairs of the ICCM22, Professor Bronwyn Fox and Professor Chun Wang, are also both Fellows of the Academy.

Images top to bottom

- *Dr Bronwyn Evans FTSE.*
- *Dr Tony Gregson (left) presents Professor Lindsay Falvey FTSE with the 2019 Crawford Medal.*
- *Murray Scott FTSE (left) receiving his certificate from the ICCM President, Professor Leif Asp.*
- *Professor Kadambot Siddique AM FTSE.*
- *Dr Xiaoling Liu FTSE (left) with QUT Vice- Chancellor Margaret Shiel FTSE.*

Top crop scientist wins Friendship Award

Agriculture luminary Hackett Professor Kadambot Siddique AM FTSE has received a prestigious Friendship Award at a ceremony in Beijing.

It recognises his outstanding contributions to agricultural science and education in China over the past 15 years.

Professor Siddique, who is Director of The University of Western Australia's Institute of Agriculture, said he was humbled and honoured to be chosen for the award.

"It has been a great pleasure working with numerous colleagues and postgraduate students from China over the years," he said.

The Friendship Award is the Chinese Central Government's highest award that recognises foreign experts who have made outstanding contributions to China's modernisation and reform.

Each year it is conferred to 50 winners on the National Day of the People's Republic of China.

This adds to Professor Siddique's considerable list of honours, which includes 2014 Western Australian of the Year, 2016 UN Special Ambassador for the International Year of Pulses, and the first Australian Fellow of The African Academy of Sciences.

He was elected a Fellow of the Australian Academy of Technology and Engineering in 2005, and is a member of five of our Forums as well as the Climate Change Advisory Group.

UWA Vice-Chancellor Professor Dawn Freshwater said that Professor Siddique had made contributions to agricultural science especially in dryland agricultural systems that were of the highest international significance.

"This award is further recognition of his tireless efforts in providing research-based solutions to global issues in agriculture," Professor Freshwater said.

Xiaoling Liu named QUT Chancellor

Academy Fellow Dr Xiaoling Liu FTSE has been appointed Chancellor of the Queensland University of Technology (QUT). Dr Liu is a company director and minerals industry leader with a passion for technology and higher education.

QUT Vice-Chancellor Professor Margaret Sheil FTSE, who is also a Fellow, said the university was honoured that Dr Liu had accepted the appointment to lead QUT's Council.

"Dr Liu is a Fellow of the Australian Academy of Technology and Engineering, and has impeccable academic credentials having undertaken her PhD at Imperial College London after completing her Bachelor of Engineering at Chongqing University in China," Professor Sheil said.

"Her industry experience across several continents provides her with a diverse and global perspective that aligns perfectly with the aspirations of many QUT students and graduates.

"When seeking a Chancellor we were also looking for someone who has warmth and an understanding of higher education as an agent for deep and abiding social change."

Dr Liu was elected to the Fellowship in 2017. She is a member of the Diversity and Inclusion Committee and Minerals Resource Forum.

Dr Liu has called Australia home since 1988. Her family has lived in both Gladstone and Brisbane and she has many connections to the QUT community.

She expresses a passion for higher education saying it's the foundation of her career and without it she wouldn't be who she is or where she is today.

"I will be a champion for QUT-industry collaboration," Dr Liu said.

"I understand that industry needs graduates who are future-ready and that industry needs to develop new technology or be left behind. Universities can imagine and help develop that technology.

"With my governance experience, and ability to seize opportunity yet manage risk, as a Council we will work with management for the benefit of the entire QUT community."

Fellows celebrated on Honours lists

Fellows of the Australian Academy of Technology and Engineering have been recognised with Order of Australia honours: six on Australia Day and six on the Queen's Birthday.

Academy President Professor Hugh Bradlow FTSE acknowledged the outstanding work of these inspiring Australians.

"These honours recognise extraordinary leaders in applied science, technology and engineering whose contributions have shown how technology can make a significant contribution to society."

"On behalf of the Academy, I offer you all my deepest congratulations. We are proud of you."

AUSTRALIA DAY HONOURS

OFFICER OF THE ORDER OF AUSTRALIA (AO)

1 **Distinguished Professor Genevieve Bell**
AO FTSE (ACT)
Australian National University
For distinguished service to education, particularly to the social sciences and cultural anthropology.

2 **Laureate Professor Geoffrey Stevens**
AO FTSE (VIC)
University of Melbourne
For distinguished service to education, to chemical engineering and environmental remediation, and as a mentor.

3 **Dr Brian Harrison Walker**
AO FTSE FAA (ACT)
CSIRO
For distinguished service to science, particularly to ecosystem ecology and research, and to professional scientific bodies.

MEMBER OF THE ORDER OF AUSTRALIA (AM)

4 **Emeritus Professor Tony Guttmann**
AM FTSE FAA (VIC)
University of Melbourne
For significant service to the mathematical sciences, and to education.

5 **Emeritus Professor John O'Callaghan**
AM FTSE (ACT)
Australian National University
For significant service to information technology, and to education.

6 **Professor Laura Poole-Warren**
AM FTSE (NSW)
University of NSW
For significant service to education, and to biomedical engineering.

QUEEN'S BIRTHDAY HONOURS

OFFICER OF THE ORDER OF AUSTRALIA (AO)

7 **Dr Catherine Foley**
AO PSM FTSE (NSW)
Chief Scientist, CSIRO
For distinguished service to research science, to the advancement of women in physics, and to professional scientific organisations.

8 **Ms Denise Goldsworthy**
AO FTSE (WA)
Managing Director
Alternate Futures Pty Ltd
For distinguished service to business, particularly to technological innovation and research in the mining and manufacturing sectors.

MEMBER OF THE ORDER OF AUSTRALIA (AM)

9 **Professor Kaye Basford**
AM FTSE (QLD)
Head, School of Biomedical Sciences, UQ
For significant service to tertiary education, to the biomedical sciences, and to scientific academies.

10 **Dr Jackie Craig**
AM FTSE (SA)
Defence Researcher
For significant service to science and technology research in the defence capability field.

11 **Dr Ian Sare**
AM FTSE (VIC)
Senior Science Adviser
Aadi Defence Pty Ltd
For significant service to science and technology, to research, and to national security.

PUBLIC SERVICE MEDAL (PSM)

12 **Dr Geoffrey Allan**
PSM FTSE (NSW)
Deputy Director-General NSW Department of Primary Industries
For outstanding public service to New South Wales, and to aquaculture science.

Movers & Shakers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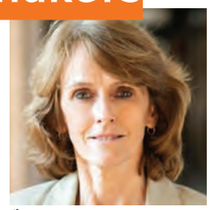
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1c


1d


1e


1f


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5a


5b


5c


5d + 35


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10a


10b


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1a Andrew Cuthbertson, 1b Cathy Foley, 1cKevin Galvin, 1d Robyn Owens, 1e Simon Poole and 1f Jenny Stauber
Professor Andrew Cuthbertson AO, Dr Cathy Foley, Professor Kevin Galvin, Professor Robyn Anne Owens, Dr Simon Poole AO and Dr Jenny Stauber were elected Fellows of the Australian Academy of Science.

2 Erol Harvey
Dr Erol Harvey was appointed CEO of the Aikenhead Centre for Medical Discovery.

3 Craig Simmons
Professor Craig Simmons joined the Australian Research Council as Executive Director, Maths, Physics, Chemistry and Earth Sciences.

4 Leeanne Bond
Leeanne Bond was named Non-Executive Director of the Aurecon Board. She was also recently appointed chair of Mining3.

5a Zhiguo Yuan, 5b Keith Hampson, 5c Laura Poole-Warren and 5d Doug MacFarlane
Professor Zhiguo Yuan AM, Professor Keith Hampson, Professor Laura Poole-Warren and Professor Douglas MacFarlane received Australian Research Council Linkage Grants for projects they are involved in.

6 John Ralston
Emeritus Laureate Professor John Ralston AO was awarded an Honorary Fellowship from the Australasian Institute of Mining and Metallurgy.

7 Rob Fitzpatrick
Professor Robert Fitzpatrick was elected a Fellow of Soil Science Australia.

8 Mary-Anne Williams
Distinguished Professor Mary-Anne Williams won an inaugural Google TensorFlow Faculty Award.

9 Bronwyn Fox
Professor Bronwyn Fox was named Swinburne University's Deputy Vice-Chancellor (Research and Enterprise).

10a David Thodey and 10b Catherine Tanna
David Thodey AO was appointed Deputy Chair of the National COVID-19 Coordination Commission and Catherine Tanna was appointed to its Board.

11 Bronwyn Evans
The Federal Government announced $28m funding for the Building 4.0 Cooperative Research Centre, which Dr Evans chairs.

12 Elizabeth Taylor
The Federal Government announced $21m funding for the SmartCrete Cooperative Research Centre, which Emeritus Professor Elizabeth Taylor AO chairs.

13 Ian Oppermann
Dr Ian Oppermann was elected President of the Australian Computer Society.

14 Johanna Westbrook
Professor Johanna Westbrook received a National Health and Medical Research Council Research Excellence Award.

15 Sue MacLeman
Sue MacLeman was appointed to the Digital Experts Advisory Committee for the Department of Prime Minister and Cabinet. Biotech Daily also named her Chair of the Year for 2019.

16a Michele Allan, 16b Jacqueline Craig and 16cRosalind Dubs
Dr Michele Allan, Dr Jacqueline Craig and Dr Rosalind Dubs were appointed to the Board of the SmartSat Cooperative Research Centre.

17 Dr Surinder Pal Singh
Dr Surinder Pal Singh was awarded the 2020 Australasian Section of the American Oil Chemists Society Award for Scientific Excellence in Lipid Research.


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18 Robert Park
Professor Robert Park and his University of Sydney team received an Australian Research Council Linkage Grant for a project combating myrtle rust.

19 Genevieve Bell AO
SRI International named Distinguished Professor Genevieve Bell the world's inaugural Engelbart Distinguished Fellow.

20 Leonie Walsh
Dr Leonie Walsh was appointed to Swinburne Council, the governing body of Swinburne University of Technology.

21 Annabelle Duncan
Professor Annabelle Duncan was appointed Chair of the Board of the Sydney School of Entrepreneurship.

22 Ana Deletic
Professor Ana Deletic was named an Honorary Fellow of Engineers Australia.

23 Veena Sahajwalla
The NSW Physical Sciences Fund awarded Scientia Professor Veena Sahajwalla a grant for the SMaRT@UNSW Recycled Glass Panel Line.

24 Alan Finkel
Dr Alan Finkel AO was presented with the 2019 David Dewhurst Award for Biomedical Engineering Excellence.

25 Rose Amal
Professor Rose Amal AC was named 2019 NSW Scientist of the Year, and is leader of the Australian Research Council Training Centre for The Global Hydrogen Economy.

26 Mike Hood
The Chinese Academy of Engineering (CAE) elected Professor Michael Hood a Foreign Fellow.

27 David Abramson
Professor David Abramson received the 2019 Pearcey Medal.

28 Carrie Hillyard
Dr Carrie Hillyard AM was appointed Chair of the Leukaemia Foundation of Australia.

29 Andrew Liveris
Five aspiring engineering leaders received scholarships through the newly established Andrew N. Liveris Academy for Innovation and Leadership at The University of Queensland, thanks to a generous donation by Andrew Liveris AO.

30 Kevin Galvin
Laureate Professor Kevin Galvin became leader of the ARC Centre of Excellence for Enabling Eco-Efficient Beneficiation of Minerals at University of Newcastle.

31 Gernot Heiser
Professor Gernot Heiser won the ACM SIGOPS Hall of Fame award for a landmark paper he co-wrote 10 years ago describing the world's first correctness proof of an operating system.

32 Sarah Ryan
Dr Sarah Ryan was appointed a Non-Executive Director of Aurizon.

33 Martin Cole
Dr Martin Cole is the new Head of the University of Adelaide School of Agriculture, Food and Wine.

34a Helene Marsh and 34b Alex Zelinsky
Professor Helene Marsh and Professor Alex Zelinsky AO were inducted as Bragg Members of the Royal Institution of Australia.

35 Douglas MacFarlane
Professor Douglas MacFarlane was appointed a Sir John Monash Distinguished Professor at Monash University.


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36 Chennupati Jagadish
Professor Chennupati Jagadish AC was awarded the 2019 IEEE Electron Devices Society Education Award, and the Australian Optical Society's W.H. (Beattie) Steel Medal. He was also elected an International Member of the United States National Academy of Engineering and appointed Editor in Chief of Applied Physics Reviews.

37 Kathryn Fagg
Kathryn Fagg AO has been appointed a Non-Executive Director of NAB.

38a Megan Clark and 38b Peter Yates
Dr Megan Clark AC and Peter Yates AM were awarded the 2019 Australian Academy of Science Medal.

39 Bogdan Dlugogorski
Professor Bogdan Dlugogorski delivered the 2020 Howard Emmons Invited Plenary Lecture at the 13th International Association For Fire Safety Science (IAFSS) Symposium in Waterloo, Canada.

40 Max Lu
Emeritus Professor Max Lu AO was named a Fellow of the Royal Academy of Engineering.

41a Mike Xie and 41b Huanting Wang
Distinguished Professor Yi Min (Mike) Xie AM and Professor Huanting Wang were awarded Australian Laureate Fellowships from the Australian Research Council.

42 John Mattick
Professor John Mattick AO received the Advance Award for Global Impact and joined UNSW's School of Biotechnology and Biomolecular Sciences.

43 Anton Middelberg
Professor Anton Middelberg was named University of Adelaide's Deputy Vice-Chancellor Research.

44 Ken Matthews
Ken Matthews AO was appointed Chair of a new independent review panel investigating Australia's regulation of agricultural and veterinary chemicals.

45 Rob Vertessy
Professor Robert Vertessy was appointed Chair of a $20m research program on the Murray Darling basin to inform water and environmental management decisions.

46a Emily Hilder and 46bPaul Haddad
Professor Emily Hilder and Professor Paul Haddad are part of Team GreyScan from University of Tasmania, which won the 2019 Defence Science and Technology Eureka Prize for Outstanding Science in Safeguarding Australia.

47 Paul Wood
Professor Paul Wood AO won the Distinguished Veterinary Immunologist Award 2019 and was appointed Chair of the Board of The Global Alliance for Livestock Veterinary Medicines.

48 Graeme Jameson
Professor Graeme Jameson AO, Laureate Professor at University of Newcastle, is a winner of the Coalition for Eco-Efficient Comminution's 2019 Technical Medal.

VALE

June Olley AM FTSE
A trailblazing seafood scientist

Professor June Norma Olley AM FTSE was a world-renowned seafood technologist and influential role model for women and girls in science.

Born in South London on 2 March 1924, she had a love of science from a young age. Although her father "didn't believe in education for girls", her mother succeeded in enrolling her in a good boarding school, a substantial expense for the working class family.

The young Olley was so devoted to her studies that her teachers blocked out the windows of the science library so she could work there at night during the London Blitz. She received a Bachelor of Science with Honours from University College London in 1944, and her PhD in 1950.

Shortly after, Professor Olley joined the Torry Research Station at Aberdeen, a laboratory focused on seafood technology. Her particular expertise was fish lipid biochemistry. She did fundamental research on the nutritional value of oils like Omega 3 and practical research on the production and use of fishmeal.

Professor Olley had an extraordinary scientific acumen and gained a global industry reputation for troubleshooting seemingly intractable problems. This was especially remarkable considering the cultural and institutional barriers woman scientists faced at the time. Over her 18 years with the Torry Research Station, she worked in countries including the United States, Israel and Italy.

In 1968, Professor Olley moved to Tasmania, where she joined CSIRO's Division of Food Preservation at the Tasmanian Research Laboratory.

There she led a number of projects, including modernising the burgeoning abalone industry and investigating the effects of heavy metal pollution on seafood stocks.

In 1976, Professor Olley was elected one of two woman Foundation Fellows of the Australian Academy of Technology and Engineering (then the Australian Academy of Technological Sciences).

Professor Olley published more than 100 papers and played crucial roles in fish industry projects across the world, from South Africa to South East Asia.

The most important work of her career was on temperature function integration, bacterial growth rates and rates of deteriorative change in stored foods. She always maintained a high level of industry liaison to ensure her work had real impact.

She attained a prodigious list of other honours, including:

- Doctorate of Science from the University of London in 1968
- Senior Vice-President of the Tasmanian Royal Society 1973-1974
- Award of Merit from the Australian Institute of Food Science and Technology 1986
- Membership of the Order of Australia in 1987
- Honorary Doctorate of Science from the University of Tasmania in 1989.

In 1989 she retired from CSIRO and became an Honorary Research Associate in the then Department of Agricultural Science and also Department of Civil and Mechanical Engineering at the University of Tasmania.

Professor Olley continued to pursue her research into aspects of fish technology and microbiology, and contributed to a number of scientific papers and a microbiology textbook.

She was a member of the Academy's Climate Change and Education Forums, Membership Selection Panel and Tasmanian Division well into her 80s.

Professor Olley's greatest legacy was her ability to lead by example and inspire young researchers (of all genders, but especially young women) to maintain high standards and to challenge conventions.

June also worked productively and collaboratively with colleagues from diverse disciplines. Many students and fellow scientists have benefited from her unique wisdom, mentoring and support.

She continued these activities, including co-authoring publications, providing feedback on research student's written work, and providing new scientific perspectives and insights to colleagues until her sudden, but peaceful, death.

Professor June Olley died on 29 July 2019, aged 95. She survived her husband Frank Cumbrae-Stewart, whom she married in 1968 in Tasmania.

Edgar Noel Fitzpatrick AM FTSE
A leading advocate for agriculture

Edgar Noel Fitzpatrick, known as Noel, was Director of the Western Australian Department of Agriculture for 13 years from 1971.

A farmer's son, he was born in 1929 at Narembeen and joined the agriculture department after graduating from The University of WA with a Bachelor Degree of Science in Agriculture in 1951.

That was the start of an illustrious scientific career, including important research into pastures and soil nutrition of then newly cleared land in the State's south in the 1950s and early 1960s.

In 1963, he moved into administration as the department's first Scientific Liaison Officer. He was appointed Deputy Director in 1969 and took over as Director in 1971, a role he held until 1984.

In 1984 Mr Fitzpatrick moved across to the Federal sphere, becoming the Deputy Secretary of the Commonwealth Department of Primary Industry and during his tenure there he helped establish the Bureau of Rural Science.

In 1988, he became the inaugural President of the Murray-Darling Basin Commission. He returned to WA and continued to contribute to agriculture as Chairman of the Western Australian Meat Marketing Corporation and the Western Australian Meat Commission.

During retirement Mr Fitzpatrick wrote *In Response to Need: A history of the Western Australian Department of Agriculture from 1894 to 2008*, which has become a great reference source for many department officers.

Mr Fitzpatrick was elected an ATSE Fellow in 1993, and was also a Fellow of the WA division of Ag Institute Australia. He was appointed a Member of the Order of Australia and inducted into the Royal Agricultural Society of Western Australia

Hall of Fame in 2006.

The Noel Fitzpatrick medal awarded at the annual Young Professionals in Agriculture Forum, run by the Ag Institute Australia WA division and the Department of Primary Industries and Regional Development, is named in his honour.

Mr Fitzpatrick died in Perth on December 6 2019.

With thanks to Farm Online

Keith Peter Edmund Daniel FTSE

Med-tech innovator put Australia on the map

Born in 1943, Keith Daniel graduated NSW University with a degree in Electrical Engineering. He went on to become CEO of Ausonics, a world leader in diagnostic ultrasound imaging. He joined Nucleus, a group of small businesses at the centre of Australian medical technology during the 1980s and 1990s.

A champion of innovation, Keith Daniel ensured the flow of research and development investment that advanced pacemaker technology, including the next generation of implantable defibrillators.

In the late 1980s, he become CEO of AMBRI BioSensors. He saw the potential for the sensor to change global medical diagnostics, and grew a small research team to over 100 people. He also founded Milvella, a company that developed disposable opthalmic devices.

A lifelong polymath, Keith had a keen insight into technology, biosciences, materials, medicine, and multiple disciplines of engineering, as well as business systems, global markets and commercialisation. He was elected to the Fellowship in 1993.

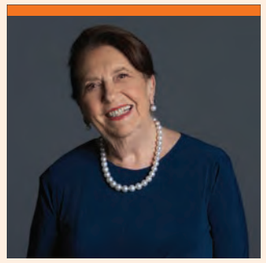
His greatest passion was people. He believed that a healthy team culture was integral to any enterprise, and his personal mantra was "treat others as you expect to be treated".

He played a leading role in hiring hundreds of technical, engineering and business people who in the most part have all gone on to further grow Australia's global innovation ecosystem.

After retiring in the 2000s, Keith helped UTS and other academic institutions develop their thinking on where Australian technology should head. He also continued to advise and mentor many colleagues and friends.

Keith Daniel died on 13 January 2020 from Parkinson's Disease and donated his body to science. He is survived by his beloved wife Ineke, four children and eight grandchildren.

With thanks to Don Darkin.



Patricia Verne Kailis OBE AM FTSE

Neurosurgeon and entrepreneur forged a path for women

Dr Patricia Verne Kailis (nee Hurse) was born in Castlemaine Victoria 19 August 1933. She studied medicine at The University of Melbourne and moved to Perth in 1958 to work at Royal Perth, Princess Margaret and King Edward Memorial hospitals.

In 1960 Dr Kailis moved to Dongara, Western Australia and became the local general practitioner. Kailis and her husband Michael established a crayfish factory and became involved in ship building, the prawning industry in Exmouth, and the pearling industry in Broome.

After moving back to Perth, she held honorary positions in neurology and genetics at Royal Perth Hospital between 1970 and 1995. Dr Kailis introduced a program for predictive testing of Huntington's disease and was involved in research into motor neurone disease and muscular dystrophy.

She went on to become a pioneer in the field of genetic counselling and a driving force in applying technology in the field of human disability services, and was named Officer of the Order of the British Empire and Member of the Order of Australia for her work.

Dr Kailis's research and development contributions in the Australian pearling industry have been critical to its ongoing success. She led the MG Kailis Group of Companies as Governing Director from 1999, and was deeply involved in numerous business, research and charitable organisations in Western Australia.

Dr Kailis was elected to the Academy in 1996, one of very few women Fellows at that time. She played a leading role in the ATSE community in WA, particularly in supporting the election of more women Fellows and mentoring them.

The Honourable Kim Beazley, Governor of Western Australia, described her as "One of the most brilliant and charitable people I have known."

Patricia Kailis died at home on 17 April 2020 aged 86, and is survived by her children Maria, George, Amanda and Alex.

Robert McCredie May OM AC FTSE

Gifted polymath "changed entire fields" of science

Lord Robert McCredie May was a leading light in biology, zoology, epidemiology, physics and public policy who contributed to the discovery of chaos theory.

Born in Sydney on 8 January 1938, Robert May completed a PhD in Superconductivity at the University of Sydney and went on to become one of Australia's most accomplished scientists.

He served as the Chief Scientific Adviser to the United Kingdom, was President of the Royal Society, and was made a Lord in 2001.

In 2001 he was also elected an Honorary Fellow of the Australian Academy of Technology and Engineering.

As well as the Crawford prize, the Blue Planet prize, Balzan prize and many more, Lord May was awarded the Copley Medal — the Royal Society's most prestigious honour, previously won by luminaries including Stephen Hawking, Albert Einstein, Charles Darwin and Dorothy Hodgkin.

Professor Joss Bland-Hawthorn, the director of the Sydney Institute for Astronomy, said May's "...career, in simple terms was getting to the bottom of what makes things complicated.

"He didn't go for titles very much. He was Lord May, Baron of Oxford but he was very unpretentious.

"He told me one night at dinner that he was the first person in the history of the Royal Society to get a swear word in the minutes. He said not even Isaac Newton achieved that."

Dr Benjamin Pope, an Australian astrophysicist who worked with May, said "he contributed not only to theoretical physics, but also to very applied knowledge, advising governments about serious issues of public policy.

"Robert May is a great example of how a scientist can contribute to all those different spheres in that way," Pope said.

"He really showed he cared about people, he had a social conscience," Pope said.

Robert May died on 28 April, aged 84.

With thanks to The Guardian Australia

Warwick Arthur Watkins FTSE

A senior figure in land surveying

Warwick Watkins was recognised at the state, national and international levels as an influential figure in surveying and spatial systems. Born in Newcastle in 1950, he studied Agricultural Science and Natural Resources at the University of New England and University of Western Sydney.

Mr Watkins was a successful state-level Rugby Union player and captained NSW Country in their successful 1978 tour of New Zealand. Briefly part of the national team, the one-time Wallaby supported the Australian sports community for the rest of his life.

He went on to lead a high-profile public service career, and served in numerous roles in the NSW Government, including:

- Director General of the Department of Lands
- Director General of the Department of Information Technology and Management
- CEO of the Waterways Authority
- CEO of the Land and Property Management Authority.

An expert in spatial information technologies, he made a major impact in the establishment and development of numerous IT initiatives including NICTA, AC3, Smart Internet CRC and CRC for Spatial Information.

His other positions included Deputy Chancellor of the University of Technology, Sydney, Deputy Chair of Australian and New Zealand Land Information Council, and Deputy Chair of the CSIRO Advisory Council on Water for a Healthy Country. In his later years he worked as a consultant.

Mr Watkins was elected a Fellow of the Academy in 2010. He died on 16 November 2019 and is survived by his wife Elaine; children Jody, Penny and Peter; and six grandchildren.

Alan Donald AM FTSE

Biologist improved animal health around the world

Born in 1933, Dr Alan Donald completed his Bachelor of Science at the University of Sydney in 1956 and his PhD at the University of Bristol in 1966.

He led a highly successful research program which developed better disease control methods and applied that research in collaboration with industry and state Departments of Agriculture.

Dr Donald was well known internationally for his substantial contributions to human knowledge of the population biology of parasitic worms. His research on the epidemiology and control of parasitic disease in sheep and cattle improved the productivity of the agriculture industry and alleviated the suffering of livestock.

Dr Donald held a number of leadership roles in CSIRO, serving as Chief of the Division of Animal Health (1983-86), Acting Director of the Institute of Animal and Food Sciences (1987-88), and Director of the CSIRO Institute of Animal Production & Processing (1988-1994).

He also chaired a number important bodies, including the Australian Animal Health Council (1995-1998) and the NSW Standing Disease Control Advisory Committee (1999-2004). In all of these positions he fostered industrially valuable strategic research which he carried through to successful applications.

Dr Donald was elected to the Fellowship in 1988, and was a valued member of the NSW Division. In 1991 he became a Member of the Order of Australia for his service to primary industry in the field of animal health.

Dr Alan Donald died on 23 April 2020, aged 86. He is survived by his wife Jane, six children and two grandchildren.

William "Bill" Ivo Whitton FTSE

Founding Fellow's mission lives on

Dr William "Bill" Ivo Whitton was born in Sandringham on 4 October 1924. The son of a famous golfer, he completed his Bachelor of Science in Chemistry in Engineering at the University of Melbourne in 1944.

After serving in WWII, Dr Whitton completed his Masters in Science investigating the dramatic, unexplained death of a man on a wheat ship in Geelong. He determined that the seawater used to wash the vessel's steel walls had caused them to oxidise rapidly, absorbing the breathable air. When the man entered, he asphyxiated instantly.

In 1948 Dr Whitton undertook his PhD at St Andrews University, Scotland, on the thermodynamics of the absorption of gasses and poisons. In 1951 he joined the research department of Imperial Chemical Industries (ICI), now Orica. A champion of the application of scientific knowledge, Dr Whitton's chemical engineering work impacted industries ranging from mining to agriculture. He gave crucial support to historic, high-risk research on the production of nylon.

In the 1960s Dr Whitton helped form the Australian Industrial Research Group, and went on to serve as its President. He worked tirelessly to encourage Australian research and development.

Dr Whitton was one of ATSE's founding members and a major force in the Academy's early development. He and a group of like-minded leaders believed there should be some sort of recognition for highly successful industrial scientists and engineers.

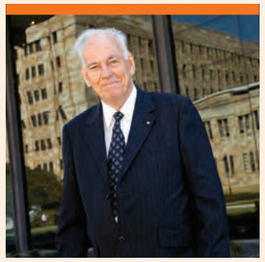
In 1983 Dr Whitton begun a five-year role as Director of the CSIRO Institute of Industrial Technology, where he looked after seven Divisions across a range of industry sectors. He later worked as a Senior Consultant at Peat Marwick (now KPMG) on wool industry technology.

Dr Whitton also spent time as a consultant to young people trying to start commercial operations through the Youth Business Initiative.

Reflecting on his illustrious career, Dr Whitton wrote that his "working life seems to have been devoted mainly to finding things of practical importance to Australia".

Dr Whitton's wife Liz passed away in 2005. They had five sons — Andy, Rob, Jim, Angus and Ian — and four grandchildren.

William Whitton died on 25 August, aged 94.



Brian Graham Wilson
AO FTSE
An education innovator with a global vision

Emeritus Professor Brian Wilson was a leading university reformer, an accomplished physicist and the University of Queensland's longest serving Vice Chancellor.

Born in Northern Ireland in 1930, he attained a Bachelor of Science in Mathematics from Queens University in Belfast and a PhD in Astrophysics from the National University of Ireland in Dublin 1956. The next year he moved to Canada, where he was based until 1979.

A noted researcher in astrophysics and X-ray astronomy, Professor Wilson published extensively and acted as project officer for rocket firings throughout the world. He worked at the University of Calgary as a Professor of Physics and Dean of the Faculty of Arts and Science.

Professor Wilson had a passion for breaking down silos and drawing together diverse fields of research. In the early 1970s he created the Faculty of Interdisciplinary Studies at Simon Fraser University in British Columbia, where he served as a Professor of Astronomy and Vice-President (research).

In 1979 Professor Wilson moved to Australia to become Vice Chancellor of the University of Queensland (UQ), which he would lead until 1995. Current VC Peter Varghese said that Professor Wilson transformed "a good regional university," into an institution "of national and international standing".

His many achievements at UQ include pioneering initiatives to tackle institutional sexism and championing research commercialisation through the 1984 founding of UniQuest, which has led to the creation of more than 100 start-ups.

He also led university reform on a national scale as Chair of the Australian Vice-Chancellors' Committee from 1987 to 1990 and the Higher Education Quality Review program in 1993.

Professor Wilson was elected a Fellow of ATSE in 1990. His many honours include Officer of the Order of Australia in 1995 and he received a Centenary medal in 2001.

In 1996 Professor Wilson retired to Paris. He died peacefully in his home on September 6, 2019. The Academy offers its condolences to his wife Dr Joan Opdebeeck, and his children Bronwen, Patrick, Brendan, Conor, Fergus and Cormac.

Dr Brian Roy Spies
FTSE FRSN
A passionate and hard-working problem solver

Born in 1949, Brian double-majored in Geology and Physics at the UNSW in 1971 and went on to earn a Graduate Diploma in Applied Geophysics on a cadetship from the Bureau of Mineral Resources, where he worked with a broad range of geophysical techniques in the Australian outback.

In 1976 Brian received the first Society of Exploration Geophysics (SEG) Foundation scholarship given in the southern hemisphere. This scholarship, and an Australian Public Service Board award, allowed him to attend Macquarie University, obtaining a Ph.D. in 1980 for the application of transient electromagnetics in deeply weathered terrains under the supervision of the late Professor Keeva Vozoff FTSE. Brian also studied electrical prospecting methods in the then USSR, and was an early pioneer in the use of the transient electromagnetic method.

In 1984 he commenced employment at the ARCO Oil and Gas Research Center in Texas where he expanded his interests to include multicomponent seismology and reservoir characterization. In 1989 Brian was awarded ARCO's highest technical award, the Outstanding Technical Achievement Award in Research, for development of the Transient Electromagnetic Probing (TEMP) corrosion detection technique.

In 1990 Brian moved to Schlumberger-Doll Research in Ridgefield, Connecticut, where he led development of deep-probing electromagnetic borehole techniques for reservoir imaging and worked on reservoir monitoring with permanently emplaced sensors.

Brian's contributions to geophysics include nine patent families and 80 publications and articles. He was on the Editorial Board of Petroleum Geoscience; a member of ASEG, SPWLA, AGU, and EAGE; served on the US National Academy of Sciences Committee for Non-Invasive Characterization of the Shallow Subsurface and, for the period 1990–1992, chaired the TLE Editorial Board and served as Associate Editor of Geophysics during 1985–1989 and 1995–1998.

His academic posts included Visiting Assistant Professor, University of California, Berkeley (1981–1984), Adjunct Professor, Western Connecticut State University (1991–1992), Honorary Professorial Fellow, University of Wollongong (2000-2003) and Senior Visiting Fellow at UNSW (2010–2012).

In 1995 Brian returned with his family to his native Australia to become Director of the CRC for Australian Mineral Exploration Technologies (CRC AMET). He was elected a Fellow of ATSE in 1998, was awarded the Australian Centenary Medal for his services to geoscience in 2003, and elected as a Fellow of the Royal Society of NSW in 2016.

In Australia, his roles have included Chief Research Scientist at CSIRO, Director of Physics at ANSTO, and in 2004 Science Manager, and later Principal Scientist Sustainability and Climate Change, at the Sydney Catchment Authority where he modelled future rainfall patterns with the aim of ensuring reliable water supplies for Australia's large population centres.

His national report on salinity mapping methods highlighted the importance of electromagnetics as the non-invasive method for determining deeper subsurface salinity. His work on the impact of longwall mining on surface water-ground water interactions and changes in chemical composition of creek water reads as relevant today as it was in 2007.

Brian has made a huge contribution to ATSE over the last 22 years. He was the Hon. Secretary of the NSW Division of ATSE during 2015–2019, a NSW delegate to the ATSE Assembly 2015–2018, a member of the ATSE Membership Committee 2013–2015, and also the Deputy Chair of ATSE's Water Forum for a number of years.

In 2012 Brian was one of the two principal authors of the ATSE Report *Sustainable Water Management — steering Australia's future in a green growth economy*, funded by the ARC Linkage Learned Academies Special Reports (LASP) scheme. It was a seminal work and is highly referenced, even today, by other water and flood management experts in Australia.

During the 2012–2013 period Brian represented the ATSE Water Forum on the steering committees for the parallel ARC Green Growth projects in the areas of Energy and Food, and was external technical editor of the book *Climate, Energy and Water* published by the Cambridge University Press in 2015.

Brian was a major contributor to the ATSE Energy Forum and was part of the organising committee for ATSE NSW's series of energy symposia dealing with the energy topics interrelated to climate science: *Intelligent Grids* in 2015, *Beyond Coal — What Will Power NSW* in 2016, *The NEM Post Finkel* in 2017 and *Energy Markets — The Consumer Perspective* in 2018.

In the later part of his career Brian took particular interest in the political and sociological barriers to acceptance of climate science. Brian was a prolific public speaker and a presenter of blogs to local groups on this topic such as Probus, Rotary, and Apex, and also to his fellow geohysicists at ASEG. In 2016 he headed the organisation of a Royal Society of NSW Four Academies forum at NSW Government House on the topic of "Society as a Complex System" which he chaired. Brian's talk was, as you might expect, titled *The Science, Psychology and Politics of Climate Change*. There were 130 attendees at the forum.

Even when Brian's health was seriously degenerating in October last year, Brian managed a video blog from his home office for the Citizens Climate Lobby on the topic of "The Psychology of Belief Systems" — which explored some of the ideological barriers inhibiting broader acceptance of climate science and its implications.

In solving any problem Brian always brought great passion and hard work. He had unique skills in strategic planning, evidence-based decision making and cross-disciplinary integration. He was a zealot but with humanity and humility. He approached every job with an outrageous sense of humour and enthusiasm, and it was more important to him to achieve the big vision than for him to get the personal credit.

Dr Spies died 8 February 2020, aged 70. He is survived by his wife Pam, children Anna and Lexi, and four grandchildren.

Prepared by Dr John Baxter FTSE with the assistance of Ted Tyne, President of the Australian Society of Exploration Geophysicists.

Gunner Axel Hambraeus
FTSE
A century of global thinking

Professor Gunnar Hambraeus was a world-renowned technologist who advanced international collaboration in the applied sciences. He was born in Orsa, Sweden in 1919, in the wake of the First World War, to a renowned priest/novelist and a musical educator.

After studying engineering at the Royal Institute of Technology in Stockholm during the early 1940s, Professor Hambraeus became Assistant Secretary, and later Secretary, of Sweden's State Technical Research Council. From 1950 to 1951 he served as Technical Advisor at the Swedish Embassy in Washington.

Professor Hambraeus had a passion for spreading knowledge about all kinds of technology, including as Editor-in-Chief of Technical and Founder of New Technology. He was a regular science communicator on European radio, and commented on the space race on television in the 1960s.

He served as CEO (1971-1982) and President (1983-1985) of the Royal Swedish Academy of Engineering Sciences, which was founded in the year of his birth and is the oldest engineering academy in the world.

Professor Hambraeus had a truly global mindset, and believed in breaking down barriers to advance technology and engineering for all of humanity.

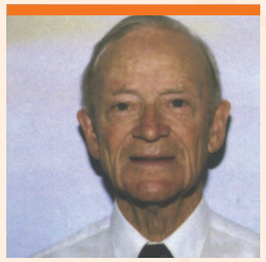
When China was opened to foreign visitors after the Cultural Revolution, he was one of the first Western figures to negotiate a research exchange with the Chinese Academy of Sciences. He also served as Chair of the Scandinavia-Japan Saskawa Foundation.

In the late 1970s Professor Hambraeus helped lead the establishment of the International Council of Academies of Engineering and Technological Sciences (CAETS) with ATSE and four other institutions. CAETS now has over 20 member organisations.

Professor Hambraeus was elected a Fellow of the Australian Academy of Technology and Engineering in 1983 and made several trips to Australia to contribute to Academy events.

He had numerous accolades and was a member of many technical and engineering academies, including the British Royal Academy of Engineering, the Finish Academy of Technology, the National Academy of Engineering of Mexico, and Academia Europa.

Professor Hambraeus died on 5 June 2019, several months after Elsa — his wife of more than 70 years — and shortly after his 100th birthday.



Norman McCall Tulloh
AM FTSE
A world leader in animal husbandry

Emeritus Professor Norman McCall Tulloh AM FTSE was renowned for his research on the factors that influence the growth and body composition of livestock.

Born in Horsham, Victoria in 1922, his Bachelor in Agricultural Science at the University of Melbourne was interrupted by WWII service in Papua New Guinea (PNG) with the Australian Landing Craft Company.

He graduated the course in 1946, and went on to complete his Masters, PhD and Doctorate of Science at the University in 1952, 1963 and 1976 respectively.

Professor Tulloh examined the effects of breed, sex and nutrition on the body composition of sheep, cattle and buffalo. He developed new statistical methods to analyse the growth of a variety of meat-producing animals.

From 1949-1956 he worked in the CSIRO's Division of Animal Health and Production, and was appointed Senior Lecturer in Animal Husbandry at the University of Melbourne in 1957. He became Professor of Animal Production in 1976 and was Dean of the Faculty of Agriculture and Forestry from 1976-1978.

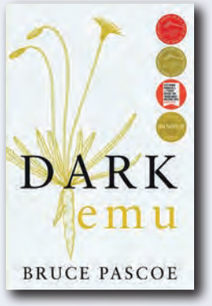
Globally recognised for his scientific contributions, Professor Tulloh conducted research in New Zealand, the United Kingdom and the United States; and consulted in Tanzania, Iran, Papua New Guinea and South East Asia.

He was elected a Fellow of the Academy in 1981 and was made a Member of the Order of Australia in 2004 "for service to research into the factors affecting the body growth and development of animals, and to agricultural science as a researcher, educator and administrator".

Professor Tulloh had a deep appreciation of the natural world, and served as Secretary and President of the Wallaby Club — a walking club founded in 1894 that organises treks around beautiful parts of Victoria.

Professor Norman Tulloh died peacefully on 5 December 2019, aged 97. He survived his wife, of 59 years Ailsa, and his children Andrew, Bruce and Judy; seven grandchildren and three great-grandchildren.

What we're reading



Dark Emu: Aboriginal History and the Birth of Agriculture

Bruce Pascoe *Magabala Books*

Dark Emu by author Bruce Pascoe continues to make waves, win awards and change the national discourse around Australia's history.

Dark Emu puts Australia's national history, origins and character in full view. Accounts from colonial explorers paint a picture of the Australian Aboriginal economy, from full scale agriculture and aquaculture, to engineering of houses, social spaces and townships.

Pascoe's evidenced account of pre-contact and early colonial Indigenous life highlights the determination of early settlers to discount Aboriginal achievements, skills and expertise.

Dark Emu explains the suppression of information about Aboriginal settlements, industry and economy that has led to systematic distortion of historical information and as a direct result, the limited understanding Australians have of true Australian history.

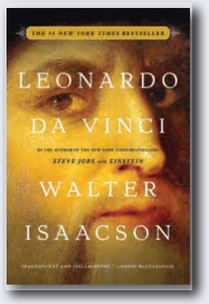
Pascoe highlights how little Indigenous innovation features in modern engineering and architectural approaches in Australia, and suggests that the industry and innovation of our First Peoples is a crucial missing piece of our historical narrative and way of life.

Australia is increasingly faced with new environmental challenges. Bruce Pascoe's Dark Emu offers a glimpse of the social and infrastructural systems best placed to support life and prosperity in the harshest seasons and conditions Australia has to offer.

Now, more than ever, we have an opportunity to study Indigenous engineering in order to yield environmentally sustainable agricultural and technological solutions to Australia's most pressing issues of climate change, biodiversity loss, fire and drought.

'People were not clinging to survival in the desert; they were thriving, and engaged in a rich and joyful life'
Bruce Pascoe

Review by Jasmine Francis



Leonardo da Vinci

Walter Isaacson *Simon & Schuster*

"The best way to approach his life is the way he approached the world: filled with curiosity and an appreciation for its infinite wonders."

In this biography, Walter Isaacson did what Leonardo Da Vinci did: combined art with STEM (Science, Technology, Engineering and Mathematics). This biography carries a compelling narrative and paints an honest and descriptive picture of Leonardo.

The text takes you through Leonardo's work of paintings and drawings. It provides you with a close experience to art history. More than that, you discover the science that Leonardo immersed himself into that influenced his work. After reading this book, I gained an appreciation for the foundations that culminated and harmonised into the Mona Lisa, encompassing her smile and every other component found in that painting.

It's a real pager turner. I often found myself moving ahead to read the text analysis, and also referring back to reflect and examine the artwork in more detail. Like a textbook, you will find yourself studying the artwork related to different topics such as maths, physics and anatomy. In parallel to the storytelling of art and STEM, this is a book of history and theories - sprinkled with Leonardo's axioms and pioneering work.

This book highlights how lifelong learning, relationships, diligence, observations, imagination and most of all curiosity shaped Leonardo's journey to improve his work and explore different topics. He was a genius and yet human - he left a trail of unfinished products and produced masterpieces.

The conclusion wraps up with twenty insightful takeaway points and summarises what you can learn from reading about Leonardo Da Vinci. If you want to immerse yourself into Renaissance art, history, and STEM, be sure to add this biography to your reading list.

I leave you with one of the takeaway points: *"Respect Facts ... we have to be fearless about changing our minds based on new information."*

Review by Dr Michelle Low

A Revolution in the Making: 3D Printing, Robots and the Future

Guy Rundle *Affirm Press*

"We always get the future wrong. We get parts of it right, but never the totality. And what is left out of our forecasts is usually that very feature of life — whether it be technological or social — that lies at the very heart of the era, when it finally arrives."

Journalist Guy Rundle's foray into the emerging world of 3D printing is a fascinating glimpse into the industries of the future, and how they could look very different from what we imagine.

Just as the technological leaps of the industrial revolution radically transfigured the social and economic life of the 19th century, Rundle argues that the still largely gestative technologies of decentralised manufacturing could have massive repercussions for the 21st.

Rundle explores three broad frontiers of technology — 3D printing, robotics, and energy — and meets entrepreneurs and communities at the bleeding edge of these developments. His subjects, who range from hobbyists to heart-surgeons, offer diverse perspectives on what could lie just over the horizon.

Rundle also poses broader societal questions about these developments. While all new tech tends to be initially implemented in the frameworks that preceded them, what do open-source information and low cost, bespoke machinery mean for our centralised, Fordist models of production?

As we look at the possibilities of a post-COVID economy, could the next wave of human advancement be more creative and democratic than the last? Or will these compounding crises force technological development in an increasingly authoritarian direction?

"Ultimately", Rundle writes, we are witnessing "a race between a future in which technology is distributed, dispersed and in the service of a humanity in control of its destiny, and one in which technology becomes a means of control unprecedented in scope and reach."

Review by Benjamin Hickey