IMPACT

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Seeking sustainability

No time to waste

ATSE Awards 2021

On Thursday 10 June we will announce the winners of our ATSE Awards 2021. These awards celebrate the achievements of Australians at the vanguard of science, technology and engineering.

All Award winners will be shared on our website on Thursday 10 June 2021

Clunies Ross Award Innovation
Clunies Ross Award Entrepreneurship
Clunies Ross Award Knowledge Commercialisation
Recognises leaders who have shared their vision and knowledge to apply technology for the benefit of Australia.

Batterham Medal for Engineering Excellence
An early career award for a graduate engineer who has achieved substantial peer/industry recognition for their work in the past five years.

ICM Agrifood Award
Acknowledges the outstanding work of two early career scientists or technologists.

Ezio Rizzardo Polymer Scholarship
Recognises the potential impact of an outstanding PhD candidate in polymer science or engineering.

David and Valerie Solomon Award
An early-mid career award for a science or technology graduate working in academia/research or industry R&D who demonstrates substantial ability to foster research-industry collaboration and knowledge transfer for the benefit of Australia.

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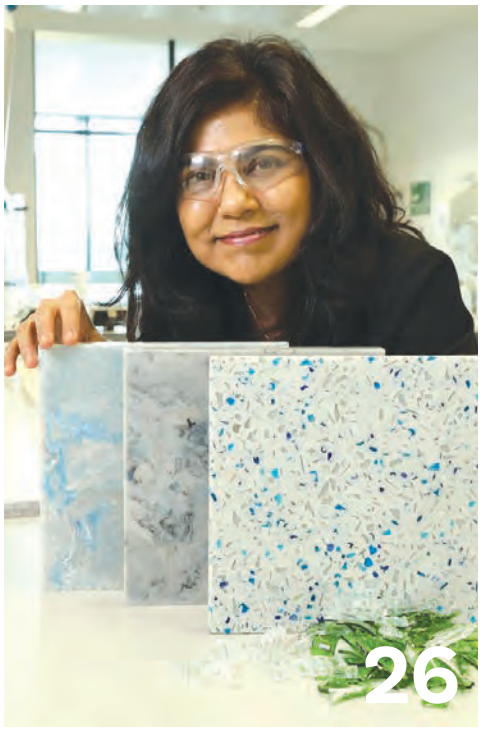
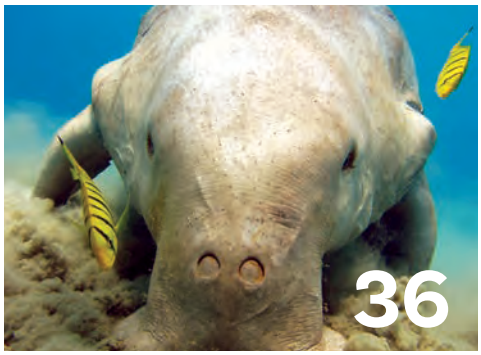
The Academy acknowledges the Traditional Owners of the land on which we meet and work. We recognise the deep knowledge and practices embedded in the oldest continuous culture on the planet - Australia's history of engineering, technology and applied science spans more than 60,000 years. We pay our respects to Elders past, present and emerging.





FEATURES

REGULARS

What will make Australia sustainable?

It is no surprise that sustainability is the most cogent issue for most of ATSE's Fellows, especially as many of the issues that threaten our planet and our lifestyle, are amenable to technological and engineering solutions.

For example:

- mitigating and adapting to climate change (including achieving net zero emissions by 2050 or sooner)
- providing food for Australia and the world
- managing our scarce water resources
- stopping the deluge of waste we are producing by repurposing it for new products
- improving our health care system and making it cheaper despite an ageing population
- stopping (or at least slowing) the extinction of species
- supporting local manufacturing
- creating flexible and reliable supply chains.

This issue of *Impact* will show that technological solutions which can effectively address these problems are not only possible, they're likely.

However, technology on its own does not solve problems. Technology must fit into a political and regulatory framework that encourages its adoption.

As an example, without regulation there is no financial incentive for producers to manage their waste. It would probably be cheaper to simply dump it somewhere.

The same applies to the waste from power generation (and other processes), namely carbon emissions. Unless you regulate their removal, human nature is such that people will not bother. Anyone who has worked in a regulated industry such as telecommunications will tell you that regulation is an essential complement to technology.

In addition to regulation, there is another topic that we as technologists and engineers need to address and that's "social sustainability". By that I mean all the factors that go into creating a socially cohesive society. These are the very underpinnings of the success of Australia: equity, the rule of law, fairness, respect, diversity and inclusion, equal opportunity and equal treatment before the law.

In my view, technology has unfortunately led to a steady drift away from these fundamental values – a situation accelerated by the COVID pandemic. There is plenty of data to show the pandemic has had a devastating effect on segments of the population while hardly impacting others.

Using US figures (and ours are likely to be similar) about 42 per cent of the population was able to use technology to work from home and maintain their income. At the same time, that group accounted for around two-thirds of economic activity .

The rest of the population was either forced to go into "frontline" workplaces (where they were much more exposed to contagion) or were out of work and seeking part-time and piece work, resulting in the increased spread of the virus (just consider the workers in our aged care facilities).

My point being that our social system is not set up to ensure equity and this undermines the sustainability of our whole society. It should not have taken a pandemic to make us recognise that forcing people into multiple part-time jobs is not a formula for the health of any of us.

Education is the key to social sustainability. While we have a sound education system, it is severely lacking when it comes to developing STEM career paths for students.

I believe the drift we have been witnessing in inequity is due to the fact that a lack of STEM training is putting many jobs out of reach for segments of our population. To ensure the sustainability of our economy and our society we need to address this with some urgency, which is why this is one of ATSE's top three priorities.

Ultimately, as technologists, if our solutions do not create social sustainability as well as environmental sustainability, we shall have failed. This is a complex challenge without simple solutions. But it is not insuperable.

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.

Sustainability is a core value of the Australian Academy of Technology and Engineering.

It's listed proudly on our Values Statement, alongside integrity and transparency, inclusion, collaboration, excellence and independence, and professional pride.

"We strive," says the statement, "to support environmental, social and economic sustainability through our activities and operations". And I'm proud to report that Fellows and the Secretariat are working in partnership to ensure the Academy is threading this value through everything we do.

Our three priority issues, as identified by Fellowship, are mitigating and adapting to climate change, enhancing research collaboration, translation and commercialisation, and exciting and educating young people in STEM. All three priorities speak to environmental, economic and social sustainability.

In our policy work, we've produced a major report laying out a pathway for Australia to become a waste-free economy while growing jobs and exports. We've publicly disseminated an expert but plain-language explainer to how Australia is tracking against its emissions reduction targets. We're creating ambitious new net zero targets and proposing the technology pathways to achieving them.

Acknowledging that Australia's original technologists and engineers are custodians of the most sustainable society on the planet, we're also incorporating Aboriginal and Torres Strait Islander perspectives into the policy submissions we make to Government inquiries and consultations.

Through our STEM careers pathways programs we're supporting the sustainability of our sector, and of the Australian economy, by nurturing a highly-skilled and diverse future workforce with science, technology, engineering and mathematics capabilities.

Our long-running, hands-on secondary education program STELR has sustainability at its core: our kits and resources guide teachers and students through applying science and engineering to build and analyse renewable energy generators. Our new coding education program, CS in Schools, is promoting Australia's digital capability with its ambitious target to deliver quality, free computer science education to every Australian school student. Our successful Industry Mentoring Network in STEM (IMNIS) program is building a thriving collaboration culture and creating nation-building career pathways for skilled graduates by connecting STEM PhD students with senior industry mentors.

With the opening of our new head office in Canberra, ATSE is applying the principle of sustainability closer to home, too. Our refit was deliberately low-impact: we're in a retro-fitted office in an older building, within walking distance to many of our key partners and Australia's political leadership, so we're cutting down on car and plane travel.

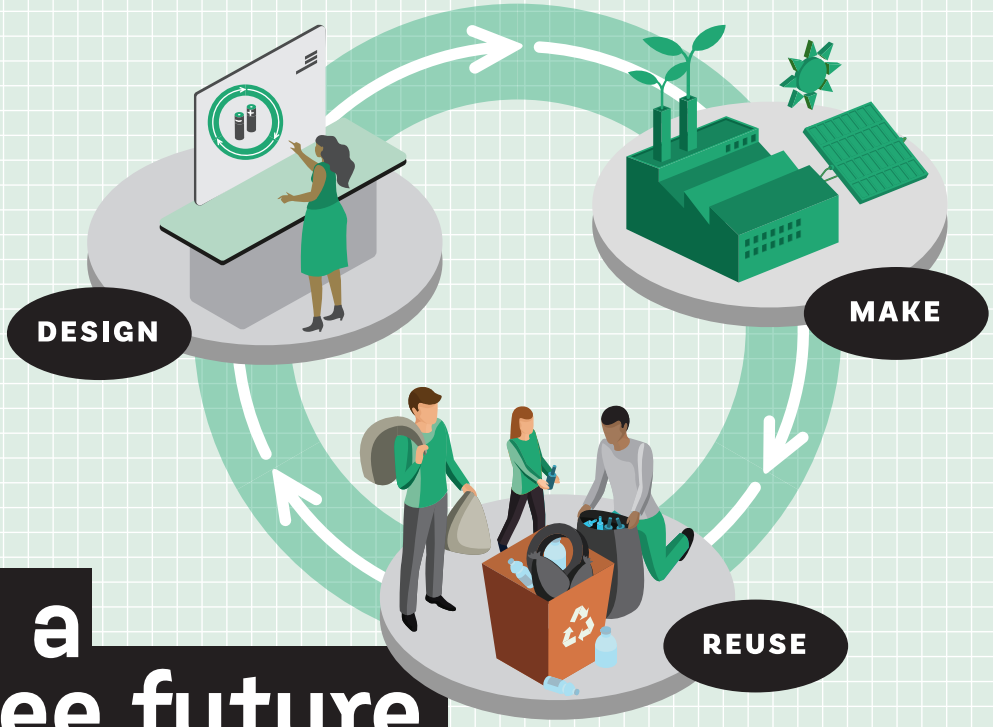
In completing the refit, we left almost all the existing walls, windows and carpets in place, and sourced our furniture from a closely-located Australian manufacturer to minimise construction waste and freight miles. And we're proud to feature as a splashback in our new kitchenette 'green ceramic' tiles composed of recycled textiles and glass, and made in a new NSW microfactory using technology invented by ATSE Fellow and materials engineer, Professor Veena Sahajwalla.

Of course, Professor Sahajwalla is just one of many ATSE Fellows working every day to apply their world-class expertise to building a more sustainable future.

As ATSE's commitment to advocating for, practically supporting, and practising sustainability continues to grow and develop, I'm proud to present to you this sustainability issue of *Impact*.

Kylie Walker
Chief Executive Officer

Kylie Walker is the CEO of the Australian Academy of Technology and Engineering.



Towards a waste free future

TECHNOLOGY READINESS IN AUSTRALIA'S WASTE AND RESOURCE RECOVERY SECTOR

Dr Susan Pond
AM FTSE FAHMS

Susan Pond is a leading scientist renowned for her work in pharmacology, biotechnology, and sustainability. She is currently Chair of the NSW Smart Sensing Network. A former Vice President of ATSE, she co-chaired the Project Expert Working Group for this report.

Phillip Butler
FTSE

Phil Butler is a national leader in manufacturing innovation. He is the creator and director of Textor Technologies, a global textiles exporter. He co-chaired the Project Expert Working Group for this report.

It's time to change how we think about waste. The ever-more complex products that surround us have shorter and shorter life cycles – even though they're made of valuable, durable materials like metal and plastic.

Current disposal practices squander the energy, resources and value locked inside these products, and gravely threaten our environment and health.

Altogether, Australians generate 67 million tonnes of waste each year. Most of that is not recycled. We're not alone – if the current global trajectory is maintained, by 2050 humanity will need the equivalent of almost three planets to produce enough resources to satisfy global consumption.

But while it's easy to "admire the problem" of waste, ATSE's report on technology readiness in the waste and resource recovery sector set out to find systemic solutions. This report is the third in a series of technology readiness reports supported by the Australian Research Council, with the first two looking at transport and health.

Through this project, a team of ATSE Fellows and other leading experts considered key questions about technology readiness in this increasingly vital sector.

What if we could design more resource-efficient products using materials that could easily be recovered and used again?

How big are the potential social, economic and environmental benefits in moving from a linear to a circular economy?

One sector's trash ...

The economic argument for a circular economy is compelling: more efficient use of resources, less waste management costs, and new highly-skilled jobs, particularly in small and medium enterprises.

There are also significant environmental, health and social benefits to an economy based on good design, reusing products and materials, and recovering resources to use again.

Just a five per cent increase in material efficiency in Australia could boost the economy by $24 billion. So what's holding us back? ATSE set out to answer this question.

Want not

The expert working group was guided by the findings of the 2018 National Waste Report, and focussed specifically on the volume and impact of waste in masonry materials, organics, paper and cardboard, plastics and glass.

We also looked at emerging waste streams such as e-waste, lithium-ion batteries, solar photovoltaic panels, and tyres, as these are increasing with little planning in place for their end of life.

The ATSE team researched extensively and consulted with stakeholders right across Australia's waste and resource recovery sector, including with multinational companies.

We tapped a rich vein of knowledge, practices and case studies demonstrating how, waste stream by waste stream, companies, government agencies and communities are making the transition towards a circular economy.

The overarching principle of the report is that materials have value at all stages of their lifecycle. We found that Australia has a huge opportunity to maximise the value of materials in its manufacturing, retail and waste ecosystem for the benefit of the economy, society and the environment.

A new policy paradigm

ATSE's report found one key barrier to this exciting future: right now, Australia does not have the right policy, regulatory and economic frameworks to support the technology investment and innovation our waste industry needs.

Any gains in resource recovery infrastructure depend on investment certainty, which in turn depends on economic feasibility and policy settings. However, we found that there is an immense appetite for change in the sector and rapidly growing consumer awareness of the issue.

Australia's waste and resource recovery sector has huge potential for innovation-lead growth. We have the necessary skills, social readiness and technological possibilities – all we need are the right economic and policy settings.

To create a thriving circular economy, we need a national framework that includes:

- long-term policy certainty
- incentive-based policies
- consistency across jurisdictions and portfolios.

Australian, state and territory governments must work together to revolutionise waste avoidance with targeted government investment and regulatory reform.

Technology-supported solutions

While technology isn't the only necessary ingredient for a circular economy, it is essential to support and guide the systemic change we need. Australia must develop, adapt or adopt numerous new and existing technologies across a number of sectors, particularly in manufacturing.

In our report, we looked at the application of technologies in three solution areas:

Conscious design
Waste is a design flaw. Good design will avoid the generation of waste, and create products that are durable, reusable, repairable or able to be remanufactured or disassembled once they reach the end of their first life.

The report provides several examples of products that have been designed to last "forever".

To quote the UK-based Ellen MacArthur Foundation: "Waste and pollution are not accidents, but the consequences of decisions made at the design stage, where 80 per cent of environmental impacts are determined."

Improved product stewardship
We need all stakeholders in the lifecycle of a product to take responsibility for its environmental, economic, health, and safety impacts.

Sensors, big data and analytics will inform these improvements in design and product innovation, material and energy efficiency, maintenance cycles and end of life treatments.

Advanced resource recovery and manufacturing
We need sophisticated and innovative technologies to recover resources, materials and energy from waste that would otherwise be destined for landfill.

Furthermore, the recovered materials must be used in new products or purposes before they can be considered "recycled". We need to develop the necessary infrastructure for processing this waste, including sorting, pre-processing, collection and reverse logistics.

Emerging waste streams such as e-waste, lithium-ion batteries and solar photovoltaic panels contain rare metals and toxic materials in much higher quantities than current products. We need the technologies to process them separately and safely.

Waste and pollution are not accidents, but the consequences of decisions made at the design stage, where 80 per cent of environmental impacts are determined.

The Ellen MacArthur Foundation

IMNIS is transitioning to an 'All of STEM' program

Australia's leading program connecting PhD students and early-stage postdoctoral researchers with high profile industry leaders is expanding.

NETWORKING & PROFESSIONAL DEVELOPMENT
IMNIS Mentees have the opportunity to participate in state and national networking events and industry-led professional development workshops.

REDI CONNECT
In partnership with MTPConnect, IMNIS is expanding the Researcher Exchange & Development in Industry (REDI) program initiative by doubling the number of Mentees in high job-growth areas.

MENTOR TOMORROW'S LEADERS IN STEM
If you're keen to invest in Australia's STEM capability by becoming a Mentor with IMNIS, please reach out to us at admin@imnis.org.au

TODAY'S INFLUENCERS MENTORING TOMORROW'S LEADERS IN STEM

AUSTRALIA WIDE

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

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

atse.org.au

IMNIS
INDUSTRY MENTORING NETWORK IN STEM

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The path forward

Based on its findings, ATSE made four key recommendations to help policymakers, industry and academia in Australia accelerate the transition to a thriving circular economy.

1. A paradigm shift to design for waste avoidance

Designers, manufacturers, retailers and consumers are faced with the reality that we must change consumption and waste habits. But inertia, policy uncertainty and market disincentives have led to slow progress.

Government can tip the scales toward new and innovative business models, but ultimately consumers must drive this demand. Changing consumer behaviour is the key solution and the Australian Government can create national marketing campaigns aimed at supporting these changes.

Companies with leading brands will change the design of their products away from packaging that cannot be recycled easily if their consumers demand it. Social scientists can prioritise research into promoting waste avoidant consumer behaviour.

2. A systems approach to increase resource productivity and recovery

The Australian Government, in collaboration with state and territory governments, should set an ambitious national resource productivity target – double by 2030. They should also set and enforce basic design standards and specifications for Australian-made and imported products.

Researchers, manufacturers and the waste and resources recovery sector also have important roles to play in these systems.

3. Big data and analytics to inform decision making by policy-makers, businesses and consumers

A deeper understanding of product life cycles will empower policymakers, businesses and consumers to make better decisions.

Industry and academia should do interdisciplinary research into the potential and applications of smart systems and artificial intelligence.

Governments should prioritise implementing consistent and harmonised data classification, analysis and reporting.

And manufacturers and designers should up their use of technologies to track critical valuable materials.

4. Targeted government investment and regulatory reform, and policy certainty

If the Australian Government expands the $190 million Recycling Modernisation Fund and adds a new stream to deal with emerging, problematic waste, it would provide clear signals and certainty for investment.

Governments should also drive demand for recovered materials by amending regulations or mandating procurement of recycled materials, introducing further landfill bans and/or levies, and investing in decentralised infrastructure to process waste and resources locally.

Continued support of Cooperative Research Centres aimed at better design and reducing waste is essential in order to create practical, economically viable solutions that work at scale.

Full circle

Together, ATSE's recommendations support and accelerate work towards Australia's ambitious targets for waste avoidance, resource recovery and recycling in the National Waste Policy Action Plan.

They also provide a guide for industry to shift towards more sustainable business practices. Readers will find plenty of inspiration in the case studies contained in the full report.

Last but not least, the recommendations provide priorities for research that will create cutting-edge technologies right here in Australia to support our shift towards a waste-free future.

Looking to 2030, we will continue to work with the Australian Government as it implements its National Waste Policy and National Waste Policy Action Plan, and the various programs that support them.

Putting the systems and conditions for a circular economy in place will empower Australia to drastically reduce the damage waste does to our environment, and transform our waste streams into income streams. ▶

Towards a Waste Free Future *was published in November 2020.*

MORE

IMPACT
The report gained considerable media coverage

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

READ
Read the full report online

atse.org.au

New Fellows 2020

A bio-engineer who is 3D printing replacement body parts, a star astronomer and the inventor of the world's most accurate clock are among the stellar crop of 25 new Fellows elected to the Academy of Technology and Engineering.

"ATSE Fellows are elected by their peers for outstanding contributions to advancing engineering, technology and applied science: these are the best of the best." Academy President Hugh Bradlow said.

Due to COVID-19, the Fellows were announced with a nation-wide online video presentation, which you can watch at:

atse.org.au/newfellows2020

Richard Bolt PSM FTSE
Principal, Nous Group and Adjunct Professor of Energy Transformation, Swinburne University of Technology (VIC)

Professor Vicki Chen FTSE
Executive Dean of Engineering, Architecture and IT, University of Queensland (QLD)

Professor Liang Cheng FTSE
Winthrop Professor, University of Western Australia (WA)

Professor Alice Clark FTSE
Deputy Director, Strategy Sustainable Minerals Institute, University of Queensland (NSW)

Adjunct Professor Trevor Danos AM FTSE
Chair, Northern Sydney Local Health District (NSW)

Distinguished Professor Kingsley Dixon FTSE
John Curtin Distinguished Professor, Curtin University (WA)

Professor Renate Egan FTSE
Professor, UNSW Sydney (NSW)

Professor Sally Gras FTSE
Professor, University of Melbourne (VIC)

Professor Elanor Huntington FTSE
Dean, College of Engineering and Computer Science, Australian National University (ACT)

Dr Steve Jefferies AO FTSE
Former Managing Director, Grains Research & Development Corporation and former CEO of Australian Grain Technologies (ACT)

Professor Stuart Khan FTSE
Professor, UNSW Sydney (NSW)

Robert Klupacs FTSE
CEO, Bionics Institute (VIC)

Professor Andre Luiten FTSE
Director, Institute for Photonics and Advanced Sensing, University of Adelaide (SA)

Professor Darren Martin FTSE
Professor, University of Queensland (QLD)

Gordon Naylor FTSE
Retired President of Seqirus (VIC)

Dr Sarah Pearce FTSE
Deputy Director, CSIRO Astronomy & Space Science (NSW)

Professor Simon Ringer FTSE
Academic Director, Core Research Facilities, University of Sydney (NSW)

Professor Shazia Sadiq FTSE
Professor and Director, University of Queensland (QLD)

Professor Cordelia Selomulya FTSE
Professor, UNSW Sydney (NSW)

Distinguished Professor Daichao Sheng FTSE
Head and Distinguished Professor, University of Technology Sydney (NSW)

Professor Mark Stewart FTSE
Professor, University of Newcastle (NSW)

Dr Vanessa Torres FTSE
Chief Technical Officer, South32 (WA)

Professor Anton van den Hengel FTSE
Co-Director, Australian Institute for Machine Learning, University of Adelaide (SA)

Professor Hala Zreiqat AM FTSE FAA
Professor and Director, University of Sydney (NSW)

Professor Willy Zwaenepoel FTSE
Dean of Engineering, University of Sydney (NSW)

Submissions from the Academy

Job-Ready Graduates Package Draft Legislation

August 2020

The Australian Government's 2020 Higher Education Reform Package represented some of the most significant changes to tertiary education in Australia in the last 30 years, and will impact current and future generations of students in Australia.

ATSE has long advocated for incentives to encourage domestic students to choose fields of study that lead to jobs of national priority, particularly in STEM, but it was disappointing to see that no new money will enter the sector to achieve this outcome under the reforms.

Along with other stakeholders, ATSE also raised concern that the funding model had the potential to provoke perverse outcomes and actually disincentivise universities to enrol domestic students in STEM subjects, but unfortunately no changes were made.

ATSE released a media statement in response to the proposed draft legislation to highlight this and other issues.

ATSE's Budget Priority – STEM skilled jobs and industry-research collaboration

August 2020

ATSE's pre-budget submission highlighted how investment in technology could address major challenges, support critical national capabilities, and create future growth industries following the economic disruption of the COVID-19 pandemic.

ATSE argued that directing such investments towards greater economic and environmental sustainability would build Australia's resilience and unlock the full potential of our future workforce.

We specifically recommended government investment in responsible technological solutions for agile and responsive modern manufacturing and supply chains, clean energy, integrated digital healthcare, and advanced data collection and analytics to provide more reliable and better equity of access to goods, services and utilities, as well as creating jobs in Australia.

The 2020-21 Federal Budget included a number of measures aligned to ATSE's pre-budget submission, including the Modern Manufacturing Strategy and the Technology Investment Roadmap.

National Water Reform Issues Paper

September 2020

In 2020 the Productivity Commission undertook its first five-year inquiry into progress on national water reform in Australia. ATSE's input into the inquiry highlighted that water will always be scarce in Australia and the challenges of managing it efficiently are only increasing along with the risks.

ATSE recommended a long-term, strategic, national approach to water management and a regular, transparent process of measuring compliance and progress of reforms. ATSE urged the Australian Government to commit to a 10-year strategy for national water reform and address responsibility and governance arrangements in the National Water Initiative.

ATSE has continued to engage with the Productivity Commission during this inquiry. Our input was explicitly used in the draft report released in February 2021 and has been reinforced through evidence provided in the inquiry's public hearings.

Higher Education Support Amendment Bill 2020

September 2020

ATSE's submission to the Higher Education Support Amendment Bill 2020 commended the Government's proposed investments in training a STEM-ready workforce and connecting industry with the tertiary research sector, but reiterated our earlier concern (regarding the Job Ready Graduates Package) that universities may receive less funding per STEM place under the new funding model.

ATSE raised these issues with the Senate Standing Committee on Education and Employment's Inquiry into the draft legislation, but these changes were unfortunately not made to the legislation. The committee's final report was released in September 2020 and the legislation was passed in October 2020.

National Preventive Health Strategy

September 2020

Based on the findings of ATSE's major report on technology readiness in the healthcare sector, ATSE recommended that Australia's preventive health strategy should focus on equity of access and health outcomes.

ATSE highlighted how technology can underpin this shift, with the most critical priority being to empower consumers and clinicians through the digitisation of health records.

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

The Government has since announced new funding to improve My Health Record, including its digital identity system, as recommended by ATSE's report, as well as the expansion of telehealth.

Review of the MRFF Priorities

October 2020

ATSE's submission recommended seven areas for the Medical Research Future Fund (MRFF) to focus on during the next 12 months:

- global health and health security
- Aboriginal and Torres Strait Islander health
- ageing and aged care
- digital health intelligence
- clinical researcher capacity
- drug repurposing
- public health interventions.

These priorities were also based on the findings of ATSE's major report on technology readiness in the healthcare sector.

The revised MRFF priorities adopted ATSE's recommendations on the need for sovereign capabilities in health and medical research.

Review of the ERA and EI assessment frameworks

October 2020

The Excellence in Research for Australia (ERA) and Engagement and Impact (EI) assessment frameworks provide a platform for Australia to encourage research quality and promote positive research culture. However, both ERA and EI methodologies face challenges in accurately assessing impact and engagement.

ATSE provided advice to the Australian Research Council based on long engagement with both of these measures, building on previous submissions about the same issue.

This response focused on enhancing the value of the ERA and EI data and outputs to end-users, and opportunities to extend their usefulness, including enhanced access to research data and open access to scientific publications.

Campus Morning Mail provided coverage of ATSE's submission on the ERA and EI assessment frameworks to the higher education sector.

Submission to the Inquiry into Higher Education Legislation

October 2020

ATSE's submission to the Senate Education and Employment Legislation Committee Inquiry into the Higher Education Legislation Amendment (Provider Category Standards and Other Measures) Bill was critical of the proposed measures, which would increase both the scale and quality of research expected of an Australian university and impose new costs, red tape and uncertainty in the sector – already reeling from the impacts of the COVID-19 pandemic.

Further, regulation of the quality of university research has never been attempted in Australia or in another comparable country. The Tertiary Education Quality and Standards Agency was not established to regulate the quality of research and has received no new funding or resources to undertake the role.

ATSE's concerns were reported in Campus Morning Mail to the higher education sector, but unfortunately, were not taken into account in the eventual design of the scheme.

National Priorities and Industry Linkage Fund

October 2020

The National Priorities and Industry Linkage Fund (NPILF) is aimed at supporting higher education to play a critical role in Australia's COVID-19 economic recovery through delivery of more graduates in areas of industry and community priority.

There is significant alignment between the NPILF's objectives and ATSE'S vision for a strong, diverse and appropriately skilled STEM workforce. However, the approach taken does not address national priorities or the needs of industry and business, and the proposed metrics for success were problematic. ATSE also recommended that industry representatives should be appointed to the NPILF guiding body.

The NPILF final report and implementation of the scheme did not follow these recommendations, but included an appendix which reiterated many of ATSE's key points and specified that Government should provide incentives for industry and SMEs to engage with universities and enhance support for Work Integrated Learning.

Modern Manufacturing Strategy Roadmaps

November 2020

ATSE recommended that targeted support and investment in Australian medical technology, including in digital health records, should be a top priority of the Federal Government's Modern Manufacturing Strategy .

ATSE shares the Strategy's vision for Australia to be recognised as a high quality, sustainable manufacturing nation, and argued that targeted and strategic investment in technology would catalyse this transformation.

ATSE's submission to the draft Strategy commended our technology readiness reports to the Department, which were mentioned and cited in both the medical products and recycling and clean energy roadmaps. The submission was also reported on in Campus Morning Mail.

Australia's Artificial Intelligence Action Plan

November 2020

Artificial Intelligence (AI) presents a pathway for economic recovery from the COVID-19 pandemic.

To break down barriers which have limited growth of the digital technology sector, ATSE recommended the Federal Government strengthen cyber security against increasing attacks and misuse of data, and build valuable datasets that underpin AI. Australian data infrastructure and governance also needs to be improved in order to fully take advantage of AI-defined networks.

CSIRO's Data61 has since received a funding boost to establish a national AI centre, and further spending has been allocated to accelerating the use of the Consumer Data Right to allow greater control of personal data in sectors such as banking and energy.

ATSE support for legislation committing to net zero emissions

November 2020

The science and lived experience of climate change is becoming increasingly clear and was brought into sharp relief by Australia's horror bushfire season of 2019-20. In its response to legislation put forward by independent Zali Steggall MP, ATSE urged the Government to take urgent action to reduce carbon emissions into the atmosphere, using legislation to create certainty.

ATSE's President Professor Hugh Bradlow and CEO Kylie Walker were invited to appear before the House of Representatives Standing Committee on the Environment and Energy to give evidence at an inquiry into the two climate change bills being proposed by Ms Steggall.

ATSE also provided a submission to the inquiry which strongly emphasised the importance of achieving net zero emissions.

ATSE highlighted the opportunities for social, economic and environmental benefit that would be created by the innovation required for effective climate change mitigation and adaptation efforts. ATSE is continuing to support this work through our net zero emissions working group.

Submission to the Productivity Commission Inquiry into a Right to Repair

January 2021

ATSE strongly supports a legislated consumer right to repair products, as recommended in our major research report on technology readiness in the waste and resource recovery sector, and provided information and guidance based on this report to the Productivity Commission's inquiry.

Repairing products rather than replacing them represents better value for consumers, requires less resources and avoids waste. It also diverts substantial valuable resources from landfill, particularly electronics which contain environmentally harmful substances in much higher quantities than other products.

ATSE recommended: creating a legislated consumer right to repair products, starting with electronics; targeting manufacturing grant programs and tax incentives toward innovative design for waste avoidance or minimisation, including repairability; creating standards and certification systems for reused, repaired and remanufactured goods to build consumer confidence and promote sustainable design.

Pre-budget Submission: Building STEM career pathways and workforce diversity to address Australia's future challenges

January 2021

ATSE urged the Government to take action on the urgent priority of mitigating and adapting to climate change, and to prioritise science, technology, engineering and mathematics (STEM) education, career pathways, and workforce diversity to ensure we have the capacity to drive innovation in Australia's recovery from COVID-19 and address future challenges.

ATSE advised Government that investment in skills, infrastructure and research to support an innovation economy were paramount as Australia recovers from the effects of the COVID-19 pandemic.

ATSE released a media statement highlighting the importance of addressing climate change in the Federal Budget.

Digital Transformation Strategy

February 2021

In response to the consultation on a refreshed Digital Transformation Strategy, ATSE urged a whole of government commitment to ensure Australia realises the full potential of current and emerging digital technologies and digital transformation.

ATSE recommended the refreshed Digital Transformation Strategy embrace a citizen-centric approach with a single portal for all government services – federal, state and local. Governments need to inspire trust in citizens that they will not lose or abuse the data.

Pleasingly, the Government's new Digital Economy Strategy, released in May 2021, provides support for a range of important initiatives and includes funding for government services such as myGov and My Health Record.

Response to the National Gene Technology Scheme Consultation Regulation Impact Statement

March 2021

Jointly, the Australian Academy of Science and ATSE strongly supported plans to future-proof and modernise the gene technology regulatory system.

Accumulated experience has shown that the National Gene Technology Scheme is no longer fit for purpose in its current form. The Scheme needs significant reform to keep pace with gene technology advancements and to address the policy problems outlined in the Consultation Regulation Impact Statement (CRIS).

ATSE recommended the Government pursue a risk-tiering model, categorising all dealings on the basis of indicative risk to enhance the sophistication of the regulatory system and enable the Office of the Gene Technology Regulator's resources to be focussed on consideration of the highest risk dealings.

Adopting the risk-proportionate model will allow greater flexibility and ensure the Gene Technology Scheme is better positioned for emerging developments in gene technology across any application.

The Academies' submission was picked up in an article by Research Professional in April.

National Water Reform Draft Report 2020

March 2021

The Productivity Commission's draft report into National Water Reform has addressed many of the issues identified in ATSE's original submission to the inquiry, but could go further.

Stronger governance arrangements should be recommended and more detail is needed on how Aboriginal and Torres Strait Islander communities will be consulted in their implementation. There should also be a stronger focus on assessing social good in water allocations and ensuring climate resilience is built in.

The Productivity Commission's draft report mentioned ATSE's previous submission to the inquiry in September 2020, which highlights that current water R&D funding levels are near historic lows.

ATSE's senior policy analyst Dr Harry Rolf has been engaging with the Productivity Commission along with former Water Forum Chair Professor Rob Vertessy, giving evidence at a public hearing for the inquiry.

Future Fuels Strategy: Discussion Paper

April 2021

ATSE's vision is for clean, affordable and reliable future fuels to power Australia to support us to reach net zero emissions by no later than 2050, at acceptable cost and reliability.

The Future Fuels Strategy sets out a positive approach to adopting low-emissions transport technologies at scale, and provides good oversight of the barriers to widespread adoption of new transport technologies.

However given transport's growing contribution to Australia's carbon emissions, ATSE encouraged a more ambitious approach to decarbonising the private transport sector. This includes introducing a national target and regulation, and boosting skills and workforce readiness. These recommendations are aligned with the submission from Engineers Australia.

University Research Commercialisation Scheme Consultation Paper

April 2021

ATSE has been working closely with the Department of Education, Skills and Employment (DESE) on the priorities for a national University Research Commercialisation Scheme, and also made a submission to the public consultation on the design of the Scheme.

ATSE has long held the view that Australia would benefit greatly from a scheme that coordinates and incentivises the translation of Australia's world leading research for commercial benefit.

However, a scheme that focuses on universities alone is unlikely to be effective as they are not always well-equipped to judge the relative likelihood of commercial success for a piece of work. To be successful, the scheme must include industry and provide incentives for investment.

ATSE released a media statement to raise awareness of these challenges and the submission, which was analysed at length in the Campus Morning Mail.

ATSE's President Professor Hugh Bradlow and CEO Kylie Walker were invited to appear before the House of Representatives Standing Committee on the Environment and Energy to give evidence at an inquiry into the two climate change bills.

MORE

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

atse.org.au

Setting a new standard for Australia's future digital technology workforce

ATSE is taking the successful Computer Science in Schools program to the next level.

CS IN SCHOOLS

Computer Science (CS) in Schools is a free program that helps schools build a robust digital technology capability in their students, and aims to set the standard for computer science education nationally.

Founded by Google Maps and eBay pioneer Hugh Williams, his partner and business executive Selina Williams and education professional Kristy Kendall, it matches computing professionals with teachers, helping them develop their coding skills in the classroom and providing innovative lesson materials.

ATSE Chief Executive Kylie Walker said the program is a natural fit for the Academy. "The Academy of Technology and Engineering is delighted to work with the CS in Schools team to bring high-quality and free computer science education to Australian secondary schools," Ms Walker said.

"The CS in Schools team's expertise in the tech sector and education is a powerful match for ATSE's strong experience in delivering science, technology and engineering education and career pathways programs.

"CS in Schools has already successfully brought quality coding education to 40 schools and an estimated 9000 students, with a particular focus on supporting girls and regional students. Together we plan to bring the program to every secondary school in Australia, to deliver DigiTech as a core subject."

CS in Schools was established under the auspices of RMIT but is now transitioning to ATSE which intends to aggressively grow the program nationally.

Research undertaken by Deloitte and the Australian Computer Society's Digital Pulse indicates there will be over 100,000 new IT jobs in Australia by 2024, but there are only 7,000 university IT graduates every year.

Co-founder Hugh Williams said if Australia is to meet that workforce need, it has to spark the interest of students earlier.

"If students don't experience DigiTech in their early secondary schooling, they are less likely to choose it later," Professor Williams said.

"But many teachers don't have the background or confidence to teach it. So that's where CS in Schools can make a difference."

Australia's Chief Scientist Dr Cathy Foley said fluency and familiarity with digital technologies is currency in this new economy.

"It's critically important that young people are taught computer science skills if we are to fill the digital jobs of the future," Dr Foley said.

"ATSE has the national reach to ensure coding can be offered in all secondary schools, and in particular, those in regional and remote locations."

CS in Schools will continue to be run as a free program and is available for the public and private education sectors.

Above: (left to right) CS in Schools founders Kristy Kendall and Hugh Williams with ATSE CEO Kylie Walker at the announcement on 21 April.

ATSE's new hub in the heart of the capital

The Australian Academy of Technology & Engineering has established a presence in Canberra, unveiling a newly refurbished office in April.

The building in Forrest is a stone's throw from politicians and policymakers in Federal Parliament.

ATSE Chief Executive Officer Kylie Walker said a lot of thought had gone into selecting the location of the office and how it would be designed.

"We kept as much as possible of the original infrastructure that was here, not just because it saves costs, but also because it speaks to sustainability.

"We know, due to our Waste Report, that the building industry is one of the biggest producers of landfill in Australia today, so we didn't want to be contributing to that as an Academy that is very proactively advocating for a circular economy, a zero waste economy," Ms Walker said.

The art on the walls, some of which is courtesy of an arrangement with ArtBank, has been chosen to reflect Australia's 60,000 years as a technology leader.

The kitchen splashback is made of green ceramic tiles, invented by ATSE Fellow Professor Veena Sahajwalla, and was featured in an Australian Story episode about her. The tiles were made by recycling old mattresses and fabrics and combining them with glass.

Ms Walker said the office is also designed to be a welcoming space for Fellows.

"The Academy is now at a place where we are working very much as a partnership team between the Fellowship and the Secretariat, so we wanted to have a space where Fellows can come and meet. We can have seminars, we can invite guests."

ATSE has retained its presence in Melbourne, with the St Kilda Road office undergoing a refresh.

Budget a missed opportunity for climate

ATSE said the 2021 Federal Budget was a missed opportunity for Australia to become a global clean energy powerhouse. CEO Kylie Walker said the Budget contains millions of dollars in new funding for fossil fuel industries, such as gas and oil, but very little to support technologies that could see Australia become a leader in exporting its sunshine.

"Most of the investment to address climate change is targeted at adaptation strategies, which are clearly necessary. But we would have liked to have seen at least an equal amount invested in accelerating and leading Australia's transition to a low emissions economy."

The budget's record $10 billion infrastructure spend has a clear focus on roads upgrades, yet there is a lack of support for electric vehicle infrastructure.

In other Budget measures, ATSE welcomes the $42.4 million set aside to co-fund scholarships for more than 230 women to pursue STEM PhD qualifications.

"Increasing investment in STEM education and research translation will strengthen Australia's capacity to rebuild after COVID and to respond to the challenges of climate change.

"We also welcome measures to support the commercialisation of critical research through a lower tax rate on income earned from patents in the medical and biotech sectors. We encourage the Government to expand its patent box scheme to include the clean energy sector as soon as possible." Ms Walker said.

Ms Walker appeared on ABC News 24 to discuss the budget on 12 May (pictured above).

New international prize for global communicators

The International Council of Academies of Engineering and Technological Sciences (CAETS), of which the ATSE is a founding member, has established two annual Communications Prizes to find the most compelling technological and engineering innovations, communicated in a way to inspire the public and aspiring young technologists.

Australian technological scientists and engineers were encouraged to submit short videos on past or current ground-breaking work which is making an impact on society and the economy.

The prize aims to champion STEM leaders who educate the general public on the important role of technology and engineering, and inspire students to consider careers in those fields. There are two categories for the prize for candidates at different stages of their careers: Engineering Success Stories and High Potential Innovations.

The Academy will adjudicate Australian entries and submit the best videos against those from international CAETS member academies.

ATSE President Hugh Bradlow said it's important for people working in the fields of technology and engineering to address general audiences in a simple and engaging manner.

"Technology and engineering make a positive impact on society and have the ability to solve real-world problems," Professor Bradlow said.

"Australia's technologists and engineers are doing incredible, innovative work, but this is sometimes poorly understood because it has not been explained in terms everyone can understand.

"ATSE hopes this competition will encourage technological scientists and engineers in Australia to not only think about their innovations but also how they are communicated."

ATSE congratulates new Chief Scientist and welcomes newest board member

ATSE applauded the appointment of Dr Cathy Foley AO FTSE FAA as Chief Scientist of Australia. An outgoing member of the ATSE's board, Dr Foley received the prestigious Clunies Ross Award in 2015 for her pioneering work in the field of mineral exploration.

Kylie Walker said Cathy Foley is an excellent choice to advocate for Australian science and to focus national thinking.

"Dr Foley has made significant contributions to the scientific community through her research and through her leadership of professional scientific organisations, including as a member of the ATSE Board and former President of Science & Technology Australia," Ms Walker said.

"Dr Foley is also a strong champion for women in STEM and we hope her appointment inspires a new generation to consider careers in science, technology and engineering."

The Academy also acknowledged the outgoing Chief Scientist, former ATSE President Dr Alan Finkel AO FTSE FAA.

"Dr Finkel has worked tirelessly to inspire young people to pursue their curiosity through STEM, and has been a strong and steady advocate for evidence-based policy and decision-making," Ms Walker said.

ATSE has selected Dr Meera Verma FTSE to join its board as a Director to fill the vacancy created by Dr Foley's resignation.

Dr Verma is a professional executive with experience spanning the global healthcare, product development and biotechnology delivery industries. She is currently running a strategic and project consulting firm for small to medium sized technology-development companies.

IMNIS expands to new areas of health and medical research

Five outstanding PhD students in the growth areas of regenerative medicine, gene and cell therapy and digital health technologies have been partnered with high-calibre mentors to develop their career pathways.

ATSE partnered with industry growth centre MTPConnect to extend our Industry Mentoring Network in STEM (IMNIS) program through the Researcher Exchange and Development in Industry (REDI) initiative.

ATSE CEO Kylie Walker said expanding IMNIS to support growth areas in the health and medical research sector will give PhD graduates a knowledge commercialisation mindset.

"The IMNIS program connects students and early-stage postdoctoral fellows with industry leaders and decision-makers, which opens the door to a broader range of potential careers to which they otherwise would not have had exposure.

"Opening up a broad range of career pathways in these specialised health and medical fields will provide enormous benefit, not just for the graduates, but also to society."

MTPConnect Managing Director and CEO Dr Dan Grant said the REDI initiative is supporting expansion of proven programs like IMNIS to develop an industry-ready workforce with the skills necessary to keep pace with a rapidly changing sector.

"As we continue to push the frontiers of medical research, and new fields develop such as regenerative medicine, we need to prioritise skills development by attracting, building and retaining world-class talent in these innovation areas." Dr Grant said.

STEM Academies strengthen regional relationships

ATSE and the ASEAN Academy of Engineering and Technology (AAET) have entered into a memorandum of understanding to strengthen collaboration between the two Academies.

ATSE President Professor Hugh Bradlow said the signing is an important occasion. "We live in a time of great peril in the sense that we've seen in the last few years a rise in nationalism, a retreat of globalism, and I think it's extremely important that we as scientists and engineers get together and collaborate across the world," he said.

"It's a global world with global problems that we need to solve together." AAET President Dr Chuah Hean Teik said.

The memorandum supports collaboration between the two Academies to:

- promote engineering and technology education, research and industrial collaboration between ASEAN countries and Australia
- promote skills and workforce development in the management, innovation and development of engineering, science and technology in ASEAN and Australia
- nurture an innovation culture within ASEAN and Australian communities, especially amongst younger people
- strengthen relationships and cooperation between scientists, engineers and technologists in ASEAN and Australia
- exchange information and publications for mutual benefit.

Professor Bradlow said Australia and ASEAN countries face similar challenges in areas such as climate and energy, waste and resource recovery, health and medical digitisation and agrifood sustainability. You can watch video of the signing ceremony at **atse.org.au/AAET-mou**

Climate change action critical for Australia's survival

ATSE says a new report on the risk and consequences of three degrees of global warming is clear evidence that Australia needs to act on climate change, and now.

The report by the Australian Academy of Science found that total emission reduction targets currently pledged through the Paris Agreement – even if implemented on time – will still see average global surface temperatures rise by three degrees by 2100.

That result would have a devastating impact on Australia's ecology and economy, as well as on the health and wellbeing of the population.

The Academy of Science's report recommends that the Australian Government revisit its emission reduction commitments and provide leadership to ensure the world is placed on a safer climate trajectory. The evidence is clear that extreme weather events will increase in frequency as the planet warms.

"The only way to reduce the risk of these unpredictable and dangerous outcomes is for a substantial reduction in the emission of greenhouse gases into the atmosphere," said ATSE CEO Kylie Walker.

"Reaching net zero emissions by mid-century is an absolute minimum if we are to avoid the worst impacts of climate change."

ATSE agrees with the Academy of Science that this must be a whole-of-economy effort which encompasses electricity generation, transport, industry and agriculture. As well as mitigating the effects of climate change, this transition will create enormous opportunity for Australia in clean, green industry.

Interview by Liz Foschia

A vaxxing time...

It's a Monday morning in mid-February and the head of the Therapeutic Goods Administration Professor John Skerritt FTSE is nervous.

He's agreed to do an interview about COVID-19 for *Impact* magazine and he's worried it will be some months before the article is published.

"Generally when I do these interviews, it's for publication that day," he says.

There's good reason. Under COVID, things can change quickly. Sometimes really quickly.

As it turns out, the interview has to be brief. Professor Skerritt has to depart for an urgent meeting at Parliament House.

The first 142,000 doses of the Pfizer vaccine are due to land that afternoon in Sydney. The following day, the TGA approves usage of the AstraZeneca vaccine.

The next phase of the pandemic begins: fight back.

Twelve months prior, the world was just beginning to understand the extent of the threat posed by a new virus that appeared to originate from Wuhan in China.

John Skerritt had been acting as the head of the Health Department during the worst period of a summer wracked by bushfires and choking smoke.

Now he had to pivot to a new danger.

"We were aware from February 2020 that this was going to be a pretty nasty pandemic," he says.

"No-one had a sense of just how broad its reach would be."

In those early days the TGA was kept busy addressing the increasing demand for hand sanitiser and disinfectant as well as providing regulatory approval for COVID tests and personal protective equipment. Managing shortages of critical medicines was also a major effort.

Then vaccines came into the mix.

"I think it was April/May we started to have the first discussions with groups developing vaccines.

"They're asking you, for example, about how far do we have to take our trials, what the level of evidence is, what would be acceptable. And regulators globally started talking with each other about the same issues about that time.

"One of the things that has characterised this for us is the very high level of global interaction."

As a member of the Health Department executive, Professor Skerritt was involved in the high level discussions about which vaccines Australia should secure for its population.

"There was a hedging of bets quite deliberately with the different technology platforms," he says.

The Australian Government settled on four promising vaccines and had high hopes for one developed by the University of Queensland with plans for its manufacture by CSL.

Phase one clinical trials with 216 participants found the vaccine provoked a strong immune response against COVID-19, halting replication.

The Government put in an order for 51 million doses.

But then it was discovered the "molecular clamp" technology employed by the vaccine triggered a false positive result when participants were tested for HIV.

It was a blow.

"That would have appeared potentially a very good vaccine," Professor Skerritt says.

> **“Even six months ago, no-one knew for example, whether a messenger RNA vaccine would actually mount an immune response or reduce the severity of the disease.”**

“But the impact of false positive responses in HIV tests would have undermined confidence.

“So we had four … now we have three.”

The other three were the messenger RNA vaccine produced by Pfizer, the AstraZeneca viral vector vaccine, and the more traditional type of protein vaccine produced by Novavax.

The Pfizer technology was still breathlessly new.

“Twelve months ago, even six months ago, no-one knew for example, whether a messenger RNA vaccine would actually mount an immune response or reduce the severity of the disease.”

One of the attractions of the AstraZeneca vaccine was that it could be made in Australia.

“You wanted to be confident the company could supply to market and the added interest in the AstraZeneca product was the ability to also locally manufacture through CSL.

“There’s a taskforce currently looking at the issue of whether Australia should be able to manufacture a wider range of vaccines locally.”

Australia almost lost its capability to manufacture vaccines at all.

CSL is currently the only local manufacturer of vaccines.

The operation was originally set up after the Second World War when CSL was then the Commonwealth Serum Laboratories. But prior to 2015, it was in a death spiral.

Gordon Naylor FTSE was CSL’s Chief Financial Officer at the time and found himself overseeing it.

“I did a strategic review of it, and it was pretty clear that it had no future as a standalone business,” he says.

“It was struggling to get scale. It never really had significant capital investment.”

He describes the vaccine sector overall as economically challenging as an investment.

“It’s generally very hard to generate long run economic returns from vaccines. These are very technically challenging products both to develop and to manufacture, requiring large upfront investments, sometimes with considerable risk. There needs to be significant scale to make the numbers work.”

He saw an opportunity when multinational pharmaceutical company Novartis decided to divest itself of its influenza vaccine offerings.

“Novartis’ influenza operation was about, I think, three times the size of what we had in CSL so we made quite an audacious acquisition.”

And so Seqirus was born, making it the second largest flu vaccine manufacturer in the world.

“The first year it was pretty ugly. But in three years’ time we did this turnaround.

He says Seqirus gave the Australian influenza operation a future, supporting seasonal influenza manufacturing, pandemic preparedness and products of national significance such as anti-venoms.

“It would have been very difficult for that organisation to prosper without it.

“Most countries lost these valuable national assets. They can’t manufacture influenza. Vaccine manufacturing is quite highly concentrated.”

The vaccine-manufacturing business put CSL in good stead when COVID struck.

It was already making around 50-million doses of flu vaccines a season in Australia and had the technology and knowledge to take on the immense task of producing sufficient amounts of AstraZeneca to inoculate a nation within a challenging environment.

“CSL is operationally excellent,” Gordon Naylor says.

He’s now no longer with the company but remains a shareholder. And while he admits to some bias, Gordon stands by his comments.

“We’re very fortunate to have access to the company and also that they have retained a substantial operational presence in Australia.

“It’s not just Seqirus, there have been investments made by CSL more broadly in biotechnology in Australia. And that’s also coming to the fore. They’re using all of those assets to support the country.”

Australia had placed a heavy reliance on the AstraZeneca vaccine when its rollout suffered a major setback in April.

A possible link was established between the vaccine and an extremely rare blood clotting disorder. The new advice was that people under the age of 50 should be given an alternative jab.

It forced a major overhaul of Australia’s vaccination strategy.

The Federal Government was forced back into the highly-competitive vaccine market.

A deal was struck for an extra 20-million doses of the Pfizer vaccine, but they are unlikely to arrive until later this year.

CSL in the meantime stated it remained committed to meeting its contractual arrangements for locally-produced AstraZeneca vaccines. Having set its course on producing that vaccine, it could not change tack to another.

So was the decision to rely so heavily on AstraZeneca wrong?

John Skerritt doesn’t think so.

“The vaccine is highly efficacious and has a major role in protecting against serious disease and hospitalisation,” he maintains.

“Given the constraints on export of vaccines from the European Union, the policy of having a significant supply of locally manufactured vaccine turned out to be wise indeed.”

The COVID-19 pandemic has highlighted a number of national public policy issues, not the least, the importance of a strong and modern manufacturing sector.

Australia may have been one of the most successful countries in responding to the virus but every week continues to bring new challenges: technical, regulatory and economic.

In the terms of overcoming this virus, it is still early days.

Postscript: In the May Federal Budget, the Government committed to provide funding to develop an onshore mRNA vaccine manufacturing capacity in Australia, but did not disclose the amount “due to commercial in confidence sensitivities”.

A virtuous circle

By Professor Veena Sahajwalla AM FTSE FAA

How viewing waste as a renewable resource is sparking a revolution

Professor Veena Sahajwalla
AM FTSE FAA

Veena Sahajwalla is an internationally recognised materials scientist, engineer, and inventor revolutionising recycling science. She is the Director of the ARC Industrial Transformation Research hubs for Green Manufacturing and Microrecyling, the NESP Sustainable Communities and Waste Hub, and the Circular Economy Innovation Network. Veena sat on the Project Expert Working Group for ATSE's Waste and Resource Recovery Report.

The industrial revolution brought about many enduring benefits to humanity, notwithstanding the enormous social and environmental costs.

More recently, the information revolution that brought about the internet and resulted in an explosion of digital tools and new technologies and businesses is adding to the benefits and costs.

Community, government and international concerns around our waste and recycling challenges are converging.

There is a growing willingness across sections of our societies to embrace the many and considerable issues we face in the management of our materials sustainability.

We are now on the cusp of a new epoch: the materials revolution.

Finite supply

The materials revolution values the sustainability of all the materials we use from our planet, which are essentially finite in supply.

Our fast fashion and consumption have outpaced society's ability and capacity to effectively deal with the consequences of a throw-away mentality.

Some of the consequences include overflowing landfills, waste stockpile fires and the devastating effects of pollution of our waterways and atmosphere.

A growing understanding about materials sustainability is at odds with the market's insatiable demand for convenience, and cheaper materials and products.

We need to rethink our attitudes to the resources we rely on for our societies to function. We need to rethink our approaches to waste.

Reduce, reuse, recycle, reform

The fact is that waste is, and should be treated as, a renewable resource.

We need to add "reform" as a fourth R to the three Rs of reducing, reusing and recycling the unwanted products and materials we erroneously call waste.

Emerging technologies are demonstrating that we can reform waste into new materials and products in ways that traditional recycling does not.

This is not to say that traditional recycling methods and processes are unwanted — far from it. They play a vital role in managing our waste.

But we also need new ways of recycling mixed and complex items like electronic waste (e-waste) so we can extract and reform the valuable materials they contain, like rare earth metals.

New government policies include rare earth metals as a national priority. As part of this priority, we should introduce the requirement to more sustainably harness the material resources contained in e-waste.

Reforming different waste types is a crucial step in the journey to create circular economies where we keep materials in use for as long as possible.

Another key step is to start designing our products and systems to more easily circulate materials back into manufacturing when they're no longer wanted.

And that is why I see a strong alignment of recycling and manufacturing taking place in the near future.

There are sobering reasons to get on with the job.

The Government's newly released National Waste Report 2020 shows our national waste increased to 74 million tonnes a year.

Of that, about 60 per cent is estimated to be recycled, but Australia's new waste export bans coming into effect from this year are expected to reduce the rate of recycling.

This is below the national resource recovery target of 80 per cent by 2030, which was set in the 2019 National Waste Policy Action Plan.

Retooling our infrastructure

Not being able to send a lot of our waste overseas adds another urgent reason to embark on the materials revolution.

Infrastructure Australia's (IA) recently released Priority List Report found that constraints on the collection and processing of recyclable waste, including product design and lack of sufficient demand, have led to recyclable waste ending up in landfill.

The report highlights the urgent need for new waste and recycling infrastructure, and lists this as its highest priority.

It says current constraints include:

- lack of space for transfer facilities
- lack of ability of material recovery facilities to process and sort co-mingled, highly contaminated waste (particularly for communities in remote and regional Australia)
- under-developed domestic reuse markets as a result of previous over-reliance on the export of waste to international markets.

IA finds Australia must recycle an additional 650,000 tonnes of waste

plastic, paper, glass and tyres onshore by 2024, putting further pressure on waste recovery and processing infrastructure.

In addition, limited landfill capacity and sorting facilities are increasing logistics costs as waste is being transferred greater distances for processing and disposal.

That is why I see a huge opportunity to not only address these challenges but also use our innovative smarts to create new technologies that lead to new supply chains and jobs.

IA Chief Executive and ATSE Fellow Romilly Madew AO FTSE rightly says, "We are at a crossroads between addressing existing infrastructure gaps and prioritising investments that will secure our future prosperity."

That is why we need a materials revolution and a much closer alliance between scientists and engineers doing the research and development, and the governments, industries and communities that will benefit from new discoveries and technologies to improve sustainability.

The materials revolution

Recycling in new ways with new technologies can be a foundation for the manufacturing of high-quality materials and products made from our waste resources.

This new level of self-reliance can enhance sovereign capability in times of pandemic disruption, and improve economic prosperity by creating new, localised supply chains.

Recycling and reforming waste materials for completely new uses — such as isolating hydrogen from waste materials like tyres and plastics to make Green Steel — should be at the centre of how we transform our sovereign manufacturing sector.

New research at my UNSW Sustainable Materials Research and Technology (SMaRT) Centre has resulted in another technology breakthrough. We have created Green Aluminium by cleanly separating the metal from plastics and other materials in mixed-materials food packaging waste.

These techniques are not just more cost effective. They also reduce environmental and social damage by introducing more sustainable inputs into this vital manufacturing process.

The UNSW SMaRT Centre is helping to align recycling and manufacturing by introducing new technologies to business partners, community groups and just about any stakeholder interested.

Our newly developed MICROfactorie technologies are increasingly being used outside of our laboratories to reform waste into new, value-added materials and products.

For instance, our Green Ceramics MICROfactorie module can transform problematic waste materials not suitable conventional recycling (such as glass, textiles and certain plastics) into new engineered products like floor and wall tiles, tables and other hard surfaces for the built environment.

Another module can reform e-waste plastics into filament as a feedstock resource for manufacturers and makers who do 3D printing.

Stronger alliances

Companies like Mirvac are embracing the challenges of being more sustainable. In March Mirvac featured many of our Green Ceramics in a new display apartment at its Pavilions development at Sydney Olympic Park.

Mirvac CEO and Managing Director Susan Lloyd-Hurwitz CEO says "the take-make-waste approach is no longer acceptable" and she and her team were working hard to find a better, more sustainable way to

provide Australians with homes and office buildings that are kinder to the planet.

NSW Energy and Environment Minister Matthew Kean commended the initiative and said the partnership "could be the blueprint for how we do sustainable development in the future."

Our journey to commercialise Green Ceramics would not be happening without valuable support from the NSW Government via its Office of Chief Scientist and Engineer's Physical Science Fund.

My vision is for decentralised and modernised recycling and manufacturing in Australia.

Increased funding from governments in this regard is extremely welcome, and while there is more to do we are making great progress.

The second round of the Federal Government's National Environmental Science Program has stepped squarely into this space, committing to fund, for seven years, a new Sustainable Communities and Waste Hub, which I will lead along with a consortium of research institutions, and industry and community partners.

We need to enable onshore and more sophisticated waste processing, recycling and reform. By making waste a renewable resource central to manufacturing, we can realise the materials revolution and ensure Australia's ongoing prosperity. ▶

Above left: Recovered materials and products created by UNSW SMaRT Centre.

Above: The unveiling of Mirvac's Pavilions apartment at Sydney Olympic Park, featuring Green Ceramics, attended by NSW Energy and Environment Minister Matt Kean; Mirvac CEO & Managing Director Susan Lloyd-Hurwitz, and UNSW SMaRT Centre founding director Professor Veena Sahajwalla.

Below left: The kitchen showcasing the splashback made from the Green Ceramics, along with some of the 'waste' materials used to create the tiles.

Below left: The kitchen showcasing the splashback made from the Green Ceramics, along with some of the 'waste' materials used to create the tiles.

Image credits: UNSW SMaRT Centre and Mirvac

By Liz Foschia

When the Mattress King met the

Old mattresses are ubiquitous.

You see them slumbering on roadsides everywhere, or sleepily propped up next to charity bins. Mostly they come to rest in tips.

They are a global environmental nightmare.

But Andrew Douglas has found a way of making mattresses gold.

His company, Mattress Recycle Australia, is based in the regional New South Wales town of Cootamundra and it services all of the state.

"Recycling is quite profitable," he says.

Councils and individuals pay him to collect mattresses and MRA shreds them.

"At the moment we're obviously able to extract the steel, which steel merchants and the steel mill up at Newcastle are willing to pay a reasonable amount of money for."

But there was one thing that troubled him.

"Our issue had been what to do with the textile component."

Until, nearly nine years ago, Andrew met Veena Sahajwalla at a sustainability conference in Wollongong.

Professor Sahajwalla is an inventor and engineer who's passionate about turning waste into a resource.

She is the Director of the Sustainable Materials Research and Technology Centre at the University of New South Wales and pioneered world-first 'green steel' technology, where hydrogen and carbon are extracted from waste rubber to make metal.

Andrew says he approached her with his problem: what to do with the material left over from recycling his mattresses.

I said "Look, this textile, it's just building up in landfill. We've really got to think outside the box."

She said "Let me take some samples. I'll take it back to my team and I'll come back to you."

Two years later she did.

"They had some prototype tiles that looked really pretty," Andrew says.

The SMaRT Centre team had developed modular technology and trade-marked it as 'MICROfactorie'.

It is able to produce a range of products for the built environment from types of waste glass and textiles that are traditionally not subject to recycling.

Mattress Recycle Australia is now using the technology and is in discussions for a commercial arrangement with the University.

Andrew sees the potential for making benchtops, splashbacks and flooring.

His plant combines the fabric from old mattresses with finely-crushed glass from beer bottles, and mixes the material with a binder before pressing it into tiles.

"We thought, there's a concept here that we should pursue. So we've had a few evolutions of the tile. And now we've got to a point where we can commercialise them."

"Our process is quite simple. There's a lot of tech involved, and a lot of science in the background, but the actual process is quite straightforward."

He says the tiles have the equivalent strength of Caesarstone.

"From our perspective it performs as well

Queen of Waste

or better than anything on the market at the moment."

The Academy of Technology and Engineering became aware of the product when it was producing its Towards a Waste Free Future report last year.

The tiles were also featured in an Australian Story profile of Professor Sahajwalla on ABC Television.

Andrew says since then he's had around four thousand enquiries from people wanting to know more.

One of those enquiries came from ATSE which was in the process of moving into new Canberra offices and refurbishing the kitchen.

The recycled tiles were installed as the office kitchen splashback.

Andrew came to see them in situ when the new office was officially opened in April.

"This is our first commercial install," he says, stroking the tiles with a proprietary air.

"We're very proud that we've got some early adopters here to showcase the green ceramics."

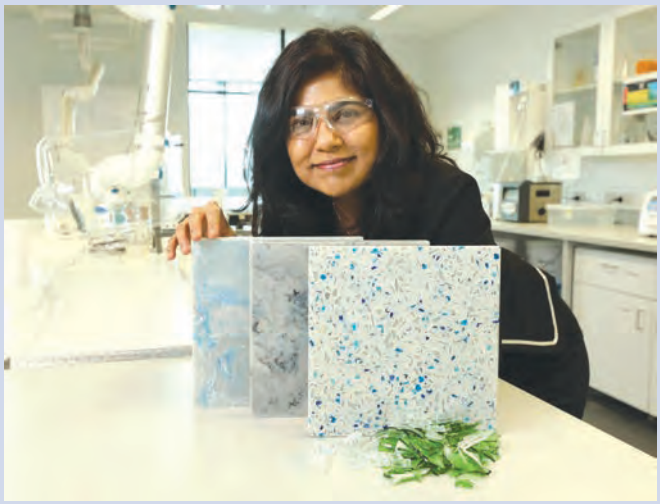
He says he's also in advanced talks with industry partners, like property group Mirvac, to explore the best way to harness and implement the great sustainability credentials of the product.

It's been a whirlwind few months.

"Now we've closed the loop, we've got this solution," he says.

Where next?

"We're looking to go to the stars!"



Top: Professor Veena Sahajwalla. Above: Professor Sahajwalla with the tiles made from mattress recycling. Above right: Andrew Douglas, Managing Director of Mattress Recycle Australia examining the splashback tiles he manufactured for the kitchen in ATSE's new Canberra office

Eight hundred million people go to bed hungry each night.

Two billion people are malnourished and lack essential vitamins and trace elements they need to live healthy and productive lives.

A further two billion are malnourished from the excessive consumption of energy-rich foods and suffer from obesity and a range of metabolic diseases.

Growing environmental challenges threaten to make this global disaster much, much worse.

By Professor Tim Reeves FTSE

The perfect storm

How can we feed the world without wrecking the planet?

Professor Timothy Reeves
FTSE

Tim Reeves has worked in agricultural research, development and extension for over 50 years. A pioneer of no-till/conservation agriculture research, he is Professor in Residence at the Dookie Campus of the University of Melbourne and Enterprise Professor in Sustainable Agriculture. In 2019 Tim was presented with the William Farrer Medal for his services to agricultural research, extension and education, adding to his long list of awards.

As well as devastating lives and disrupting economies around the globe, the COVID-19 pandemic has highlighted significant vulnerabilities in our agri-food systems.

I believe nutritional security is humankind's greatest challenge in the coming decades. It is clear that we need to simultaneously improve agricultural productivity and environmental health – this means growing more food with less land, water, greenhouse gas emissions and energy-intensive inputs like pesticides and fertilisers.

As some have put it: "How can we feed the world without wrecking the planet?"

Dire warnings

In a landmark 2009 paper, Sir John Beddington (then Chief Scientific Adviser in the UK) alerted the world to the coming "perfect storm". He forecast that by 2030, global demands for water would increase by 30 per cent, and global demands for energy and food would each increase by half.

The confluence of these challenges would gravely challenge our environmental and nutritional wellbeing.

In retrospect, his warnings may not have been dire enough. The perfect storm is already here. Some threats Beddington thought were unlikely to hit the world's 2030 "global intray" have already arrived, including a global pandemic and numerous environmental disasters.

To withstand these challenges, our agriculture systems need to be more resilient, restorative and regenerative. There are many possible approaches to developing such systems.

Big Farmer

Much of the food that is exported around the world to underpin food security in many importing countries comes from modern, technologically driven, large-scale agricultural production systems.

Australia is a good example of an exporter. The average Aussie farmer feeds around 600 people — 200 here at home and around 400 overseas.

In contrast, about half of the world's locally consumed food is produced by smallholder farmers in developing countries.

Critics refer to the broadacre farming systems common in Australia, Canada, USA and Europe as "industrial agriculture". These systems are highly productive, but depend on increasing use of fertilisers and pesticides, significant greenhouse gas emissions and trillions of litres of water (around 70 per cent of global freshwater withdrawals are used for agriculture).

Professor Reeves in the field.

Declining levels of soil carbon and nitrogen, rising pesticide resistance, and growing climate risks present substantial and well-founded doubts about the future of these systems. Under the perfect storm scenario, they are not sustainable.

The agri-food sector is also highly dependent on temporary or itinerant workers. We need more investment in learning and career development to build a workforce capable of making our food production systems sustainable, resilient, and fit-for-purpose.

The search for sustainable agri-food systems has become more urgent over the past 20-30 years, and is of paramount importance today.

Alternative agricultures

Organic and biodynamic agriculture are two long-standing approaches to restorative, holistic food production currently practiced in many developing and industrialised countries. More recently, regenerative agriculture has sparked interest from both farmers and consumers.

The following definitions come from practitioners who advocate these systems (and don't necessarily reflect my views):

Organic agriculture

- *Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity.*
- *It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems.*
- *This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system.*

(FAO/WHO Codex Alimentarius Commission, 1999)

Biodynamic agriculture

- *Biodynamics is a holistic, ecological, and ethical approach to farming, gardening, food, and nutrition.*
- *Biodynamics is embedded in the work of philosopher and scientist Dr Rudolf Steiner, whose 1924 lectures to farmers opened a new way to integrate scientific understanding with a recognition of spirit in nature.*
- *Biodynamics has continued to develop and evolve since the 1920s through the collaboration of many farmers and researchers. Around the world, biodynamics is alive in thousands of thriving gardens, farms, vineyards, ranches, and orchards.*
- *The principles and practices of biodynamics can be applied anywhere food is grown, with thoughtful adaptation to scale, landscape, climate and culture.*

(The Biodynamics Association)

Regenerative agriculture

- *Regenerative agriculture is a system of farming principles and practices that increases biodiversity, enriches soils, improves watersheds, and enhances ecosystem services.*
- *Regenerative Agriculture aims to capture carbon in soil and aboveground biomass, reversing current global trends of atmospheric accumulation.*
- *At the same time it offers increased yields, resilience to climate instability, and higher health and vitality for farming and ranching communities.*
- *The system draws from decades of scientific and applied research by the global communities of organic farming, agroecology, holistic management, and agroforestry.*

(Terra Genesis International)

These alternative management systems clearly have many commonalties and overlaps, and there is much literature on the strengths and weaknesses of each. All use less energy intensive inputs than "industrial agriculture" and may have more resilience to climate shocks.

However, critics of these systems have argued that they are often not productive enough to feed a global population still growing at around 160 people per minute. They also point to the lack of scientific evidence to support some of the claims made by advocates for these systems, particularly around soil carbon sequestration and other aspects of soil health.

There is, however, a growing portfolio of research into regenerative agriculture to verify (or otherwise) the claims and experiences its practitioners report.

Sustaining and intensifying

Sustainable agricultural intensification (SAI) is an evidence-based approach to restorative food production that aims to increase the yield of existing farmland while reducing environmental damage. Its practices include:

- Conservation agriculture: minimum soil disturbance, soil mulching, diverse farming systems including crops/forages/livestock/shrubs and trees.
- Soil health: particularly increased levels of soil carbon and nitrogen.

- Efficient water management: water use-efficiency and reduced water usage.
- Integrated pest management: greater emphasis on non-chemical management of weeds, diseases and pests and more judicious use of pesticides.
- Improved genetic resources: plants and animals that are more stress tolerant—biotic and abiotic; more input use-efficient; and with greater productivity and diversity.

Each of these elements can significantly improve the productivity of farming systems, but the synergies between them could lead to even greater transformation: the whole is greater than the sum of the parts.

An additional 'win-win' is that increased bio-sequestration of carbon in these systems would not only enhance agricultural productivity and profitability, but also significantly contribute to net-zero greenhouse gas emissions for Australia. It has been estimated that widespread adoption of SAI systems could offset over half of our total national emissions through soil carbon sequestration.

There is extensive peer-reviewed scientific literature on the benefits of all of the practices which comprise SAI, and it is generally accepted as a "scientifically sound pathway to more restorative and more regenerative agriculture."

But if this approach is to be further developed and adopted around the globe, there are still important research gaps that need to be urgently addressed. Although support for individual SAI technologies is growing, we need more large-scale experimentation to better understand how to combine these components into viable agricultural systems.

The University of Melbourne is proposing to address this gap through the development of the Dookie Sustainable Agricultural Research Platforcomparing a number of farming systems at a large "farmlet" scale.

It is my view that SAI is the best way forward to enhance our current farming systems—both smallholder and larger-scale—to successfully address the challenges to future food and nutritional security. We should make every endeavour to fully support the bio-physical research and the social, institutional and policy settings necessary for its widespread adoption.

However, if we are to ensure the future of global food and nutritional security in the Anthropocene era, we must also consider other options for our agri-food systems.

We need to change the way we think about our agri-food systems. Business as usual is going to be business in decline.

Cultivating solutions

SAI has the potential to effectively address all the challenges of the perfect storm scenario. For example, studies on cereal production systems in south Asia found that compared to traditional farmer practices, zero tillage with residue retention increased:

- average yield by 5.8 per cent
- water use efficiency by 12.6 per cent
- net economic return of 25.9 per cent.

It also reduced contributions to global warming by up to a third.

The major weakness of SAI is its continued use of fertilisers and pesticides, albeit at reduced levels and with more judicious application.

Growing innovations

Many innovative ideas on new food production systems have emerged in the past decade. These include developments around:

- peri-urban agriculture
- vertical farming
- plant-based meat substitutes
- insect protein production
- algae based foods.

Investment in these emerging systems is increasing, and it is clear that some or all will play a greater part in our food production over the shorter term - if only for targeted, high-value markets..

The agri-food sector is highly dependent on temporary or itinerant workers.

We need more investment in learning and career development to build a workforce capable of making our food production systems sustainable, resilient, and fit-for-purpose.

In addressing the perfect storm challenges, attractive features of some of these innovations include:

- reduced water usage
- reduced pesticide and fertiliser usage
- less degradation of natural resources
- reduced greenhouse gas emissions
- shorter supply chains
- less dependence on itinerant work force
- enhanced nutritional value.

It is likely that these potential solutions will complement current agri-food systems rather than replace them – for now.

Weathering the storm

We need to change the way we think about our agri-food systems. Business as usual is going to be business in decline.

Australia and the world cannot be complacent about our current food challenges, let alone future threats: another crisis like COVID-19 could strike at any moment.

The interactions between the pandemic, environment and food production aren't simple.

We need to use systems-thinking, not compartmentalised thinking, if we are to find solutions to our interconnected problems.

Future food and nutritional security is the greatest challenge facing humankind. We need science and innovation from all STEM disciplines to meet this challenge head-on.

Solar
The next energy revolution

By Professor Martin Green AM FTSE FAA

In Australia we aren't always best at claiming our big wins and contributions to the world stage: it just doesn't seem to be in our character. Yet as inventors, Australians have been responsible for bringing to life some truly iconic and lifechanging technology used around the globe every day, by hundreds of millions of people.

In the 20th century, Australians invented Google Maps, wi-fi, the black box flight recorder and the Cochlear implant, to name just a few.

For myself, I have been able to dedicate my engineering career to the research and advancement of the solar cell, the notebook-sized device able to harness the practically infinite power of the sun and convert it into electricity.

In 1983, I invented the Passivated Emitter and Rear Cell (PERC). Over the next two decades, my team at UNSW perfected it, not knowing that we would eventually see it being put to use in over 90 per cent of the world's solar panels now being made. At the time, we thought something like that was so unlikely as to be inconceivable to us, particularly at the terawatt scale now being approached.

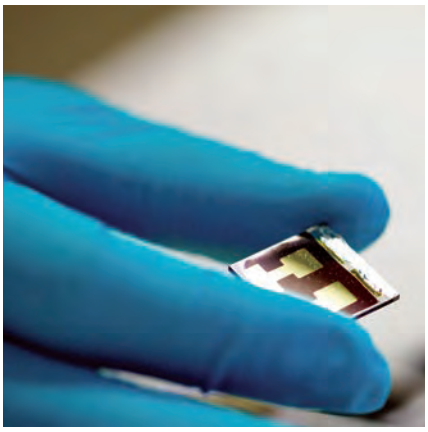
Back then, our work was motivated by setting the next world record for solar cell performance. We had set our first in September 1983, demonstrating the first 18 per cent efficient silicon cell.

Having battled to the front of the pack, we were keen to stay there. We knew we were in a prime position to be the first to achieve a landmark 20 per cent efficiency, billed as solar's "four-minute mile", although there were then several better-funded groups in the US and Japan snapping at our heels.

While some aspects of solar cell design — such as the optics — work pretty much as designed when implemented, the electronic aspects are a nightmare.

Final performance is often determined by subtle, temperature dependent interactions between trace impurities in the silicon, not to mention those coming from the lab!

This dictates the nature of cell research: incremental, painstaking, filled in turn with incredible frustration and the elation of breakthrough.



Above: Perovskite solar cell. Credit: Derwin Lau

I had outlined two main approaches to getting to the 20 per cent figure in grant proposals prepared in late 1983. One was the well-known technique of texturing the top cell surface and the second was to implement PERC.

Texturing proved the easier, with our first 20 per cent efficient cell confirmed in October 1985. This was just in time for reporting at the 18th Institute of Electrical and Electronics Engineers Photovoltaic Specialists Conference in Las Vegas, the major conference in this field, where our result was reported as a highlight.

Today in 2021, we can only marvel at where the solar industry has come to. It is a global economic powerhouse, worth over $140 billion annually. Solar power can now provide the cheapest electricity in history, according to the International Energy Agency, having dropped roughly 90 per cent in costs between 2010 to 2020.

The global uptake of the PERC cell in solar systems has grown from almost nothing in 2015 to now being at 90 per cent of all installations. These are some truly incredible figures that we are proud to have contributed to.

However, this is only just the beginning. PERC has opened up a new wave of industrial creativity, not only due to its improved conversion efficiency, but also due to increased functionality. Bifacial cells are readily made with PERC, allowing solar modules to respond to light falling on their rear and boosting output by five to 20 per cent, essentially for free.

Also, since PERC cells require rear patterning, this allows cells to be cut into smaller segments after processing, encouraging use of much larger wafers in cell fabrication. This not only reduces cell fabrication costs but also produces much larger solar modules, with these recently more than doubling in size.

Solar costs will continue to decrease as technological improvements like this are fully exploited, augmented by the economies of scale. As a result, some commentators now project a future of insanely cheap solar power.

Professor Martin Green
AM FTSE FAA

Martin Green is Director of the Australian Centre for Advanced Photovoltaics, at the School of Photovoltaics and Renewable Energy Engineering, UNSW, Sydney, where he is a Scientia Professor. He is inventor of the PERC solar cell, a fellow of the Royal Society, and 2021 recipient of the Japan Prize. He thanks Elmo Keep for her contributions to this article.

The number of jobs that will be made available in the renewables sector are already projected to well outstrip the jobs that will be displaced in fossil fuel industries.

Others describe how solar will usher in history's third major energy revolution through access to cheap, abundant energy — the first being the agricultural revolution millennia ago and the second being the industrial revolution, powered by exploiting fossil fuels.

I would hardly have believed that any of this lay in the future when I began to work with solar cells in the 1970s. The dream of a world powered by sustainable energy sources of course motivated me hugely, but that we were about to set out on a path that would one day result in a seismic shift in global energy generation and consumption was not a given.

Our first lab was set up in a meeting room off the professorial office of Lou Davies, my departmental head. Lou also helped us rescue former AWA Microelectronics equipment from the rubbish heap for our fledgling group.

We had a crack team of young researchers, among them my first three PhD students, Bruce Godfrey, Andrew Blakers and Stuart Wenham, who were driven, inspired and passionate about the possibilities of pushing the technology to new levels. All three have since been elected to the Fellowship of ATSE.

Bruce set up our lab's basic processing capabilities, followed by Australia's first solar production line at Tideland Energy, while Andrew and Stuart were key to PERC's first demonstration, then perfection.

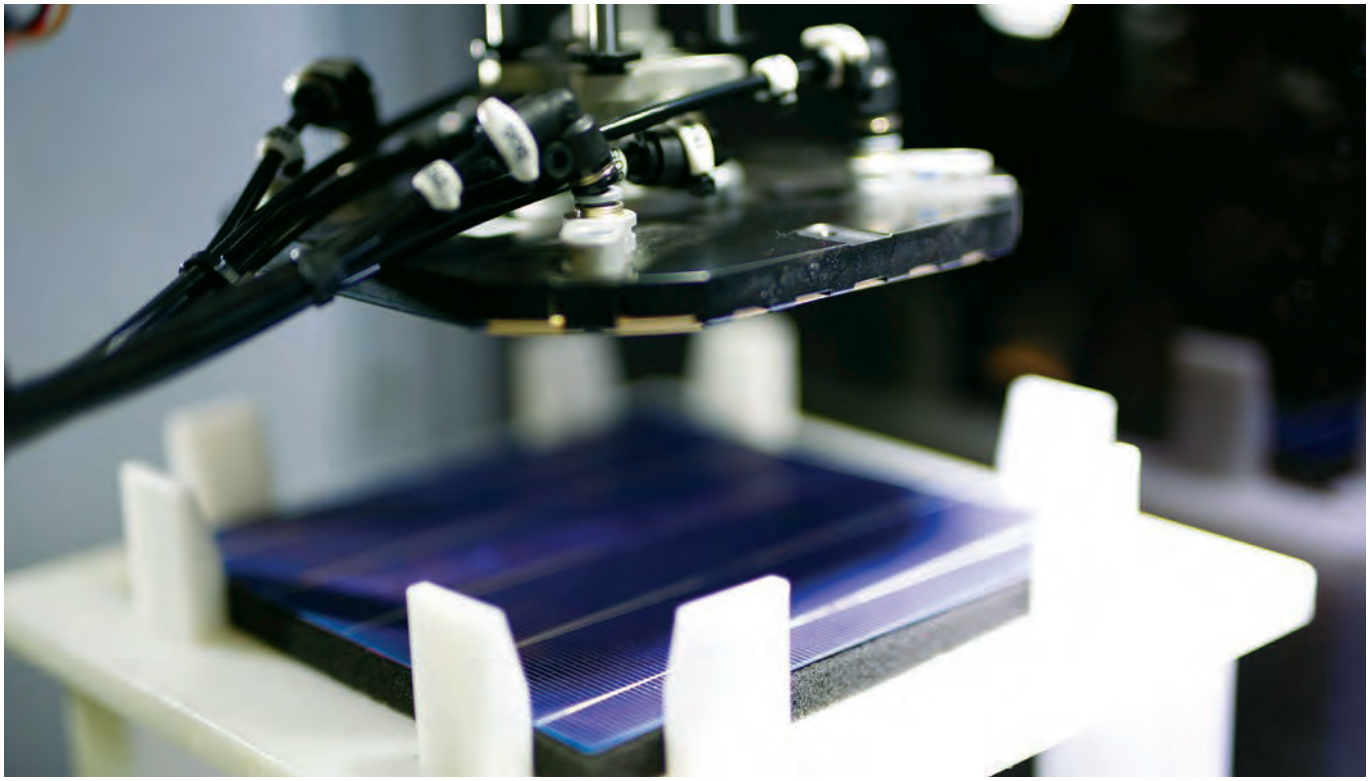
We were reinforced by my first four Chinese-born PhD students, Jianhua Zhao, Zhengrong Shi, Aihua Wang and Ximing Dai, who became Australian citizens post-Tiananmen.

They, along with our equipment guru, Ted Szpitalak, played a crucial role not only in our cell development, but in the solar cost reductions of the last decade, by founding and attracting US investment into three of the first companies manufacturing in China via Australian-Chinese joint ventures.

Our eventual success with solar cell development would lead to the establishment of our own dedicated School of Photovoltaic Engineering at UNSW in 2000: the world's first, and still going strong over 20 years later.

I'm proud to continue to work alongside some of the most talented researchers in the field from across the world, who continue to join our educational program and help us in our research.

Below: Optical characterisation of solar cells at UNSW. Credit: Derwin Lau



Above: Commercial solar cell manufacturing. Credit: Derwin Lau

Our ability to follow this remarkable trajectory was only made possible through ongoing Federal Government investment in our research. Solar technology was not a viable investment for commercial industry at the time; it barely existed as a technology at all.

In the 1970s there was great motivation to find alternative fuel sources in the wake of the oil crisis. Money flowed into projects that were aiming to solve the problems of non-renewable energy. While the oil crisis passed, the critical necessity to transition our global energy system to one built on sustainable, renewable resources has not waned in urgency.

We are still a planet with ever-rising carbon emissions, even as the capabilities of renewable sources of energy – solar in particular – continue to grow exponentially.

This points to another unique opportunity for Australia to take the lead as a global technology innovator: to lead the development, implementation and export of solar technologies and their products that will accelerate our continued transition away from fossil fuels on a global scale.

Despite its size, the solar industry of today is still in its infancy, just now catching up to the technology we demonstrated in the lab over 20 years ago.

There is still enormous scope for further improvement, such as through tandem cell stacks with the potential to double module efficiencies (think of it as being like comparing a Nokia mobile phone from the 1990s to the smartphones of today).

We are now at a tipping point where solar power is set to be not only the clear environmentally responsible choice for the world, but also the smartest economic bet. The number of jobs that will be made available in the renewables sector is already projected to well outstrip the jobs that will be displaced in fossil fuel industries.

Taking full advantage of this opportunity will require foresight at a governance level that looks beyond short cycles, or demand returns on investment in technologies are virtually instantaneous. We are laying the groundwork now for the next decades of robust economic and social benefit that would flow from the same kind of belief that was shown in backing the solar cell before we invented the PERC.

We are now undertaking work at UNSW that encompasses the full breadth of the renewable energy sector, from pushing the leading edge of new solar cell production, to graduating credentialled engineers, to granular data analysis to inform sound policy that will ensure a secure, sustainable and equitable distribution of renewable energy to all Australians.

This is our chance to be unequivocal about our commitment to ensuring we run with this opportunity for all it's worth.

To realise the dream of a truly sustainable global energy system built off the back of notebook-sized solar cells, would be to truthfully say Australian technology changed the world.

Hopefully, that we even saved it. ▶

Interview by Ben Hickey

Dugongs, disaster and making a difference

From camping with crocodiles to flying light aircraft over the jewelled seascapes of the Great Barrier Reef, Professor Helene Marsh has had an extraordinary career in environmental science for more than 50 years.

Professor Helene Marsh
AO FTSE FAA

Helene Marsh is Emeritus Professor of Environmental Science and Dean of Graduate Research Studies at James Cook University. She is recognised internationally for her contributions to marine mammal conservation and marine protected area management.

We spoke to the world leader in dugong ecology about saving species, working with Aboriginal and Torres Strait Islander communities, how tech is transforming marine conservation and her changing experience as a woman in STEM .

Hi Helene. How is the dugong going?
It depends on where. The dugong has a huge range in the waters of more than 40 countries, from East Africa across to the Solomon Islands and Vanuatu. In most of those places, it's not doing too well. The major concerns are fishing nets, especially gillnets used by artisanal fisheries, and habitat loss.

Australia is the dugong capital of the world because of the huge seagrass meadows in Northern Australia. I've just done a report on the state of the environment and the dugong is doing pretty well here. The place of greatest concern is the urban coast of the Great Barrier Reef (GBR), from Cook Town down to Bundaberg.

Has that shifted over recent years?
We're clearer about the problem in the urban coast of the GBR than we were. There were fears for the populations in southeast Queensland in Moreton Bay and Hervey Bay but dugongs seem to be doing okay there. So I don't know if we're seeing substantive change, or if the information is better now.

What's helped us get better information?
Time series of large-scale aerial surveys and basic ecological research. Because dugongs are very slow-breeding and long-lived animals (up to 70 years) you have to look over long periods of time to make sense of what's happening.

Over your amazing career you've been recognised with many awards and appointments, including this year's Order of Australia. Congratulations. What drives you?
Thank you! The biggest thing that drives me is that I like to make a difference. As well as being a practising scientist, I've been on numerous government advisory committees over many years. So I've had the privilege of seeing some of my research results translated into policy. And I find that immensely satisfying.

How have you found bridging the worlds of science and policy?
In the 1980s I became a member, and later chair, of a statutory consultative committee to advise the Federal Minister of the Environment on the Great Barrier Reef. It really opened my eyes.

I had to interact with stakeholders in a meaningful way. That made me appreciate that my values were very different to many of theirs, and that I had to respect that.

Policymaking is extremely hard – much harder than doing research, I think.

Some stakeholders you've worked with are members of Aboriginal and Torres Strait Islander communities. What did you learn from those experiences?
Well, I learned that every time I thought I knew, I didn't. I also learned that many Indigenous Australians have a very different worldview from mine. And I learned that the conservation of cultural values was incredibly important, and that conservation tools are much more likely to be effective if they reflect cultural values.

Above: Helene (left) in 1984 near Borroloola after Cyclone Kathy stranded dugongs on the supratidal mudflats.

What have been your findings on the sustainability of traditional dugong hunting?
People have been hunting dugongs in Australian waters for at least 4000 years. Australia is the dugong capital of the world: the Torres Strait is the dugong capital of Australia. We have a lot of evidence that traditional dugong hunting is sustainable in the Torres Strait and is likely sustainable in much of northern Australia.

It becomes difficult to be sure in places where there are other impacts on dugongs that have nothing to do with hunting. In many of those places, there are now Traditional Use Marine Resource Agreements or Indigenous Land Use Agreements, where Traditional Owners and Government have sat down and agreed about the rules of hunting. I think that's been fairly successful.

In many places traditional hunting is at a level that is similar to the past, and in many cases it's less, so it has to be considered in the context of other impacts.

In popular discourse, the Great Barrier Reef is often portrayed as either completely fine ("business as usual") or already doomed, ("it's too late!"). What's your view?

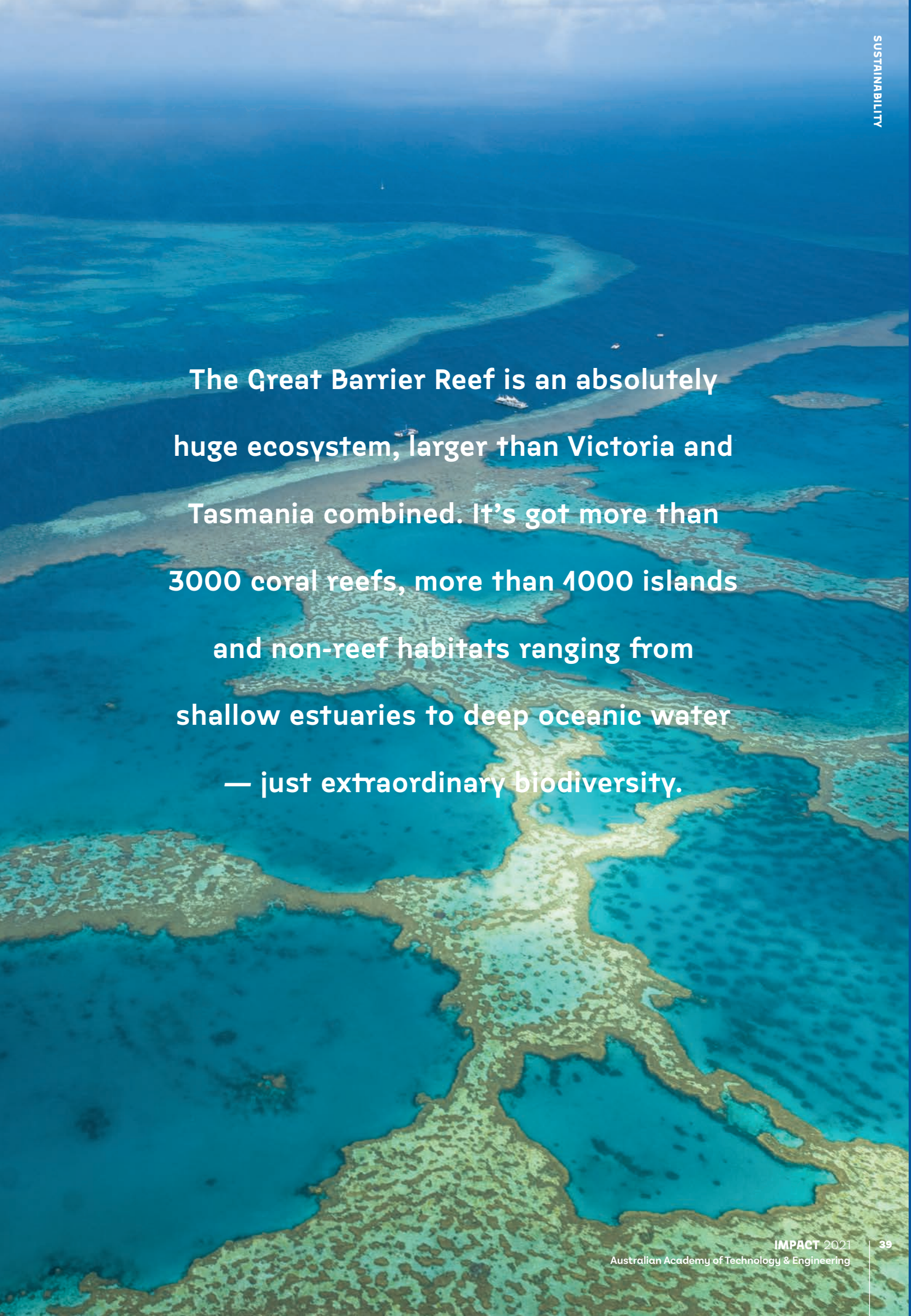
My view would be between those extremes. There's no question that coral bleaching caused by climate change has had a very severe impact on the Great Barrier Reef. It is a very serious concern that can be expected to continue. Even if we had climate change under control tomorrow, which we're not going to, the CO_2 accumulating in the atmosphere will mean we have inexorably warming seas. The risk of marine heatwaves has gone up. And so that will definitely have an effect. But the Great Barrier Reef is an absolutely huge ecosystem, larger than Victoria and Tasmania combined. It's got more than 3000 coral reefs, more than 1000 islands and non-reef habitats ranging from shallow estuaries to deep oceanic water – just extraordinary biodiversity.

And it contains numerous globally significant habitats, incredible areas of mangroves, seagrass and algae and fish and threatened species, such as dugongs and turtles.

All of that biodiversity is going to be affected by climate change, but some species and communities will be affected a lot more than others. I expect that at the end of this century, the GBR will be a different place. But I still think it will be a great barrier reef.

What steps do you think we need to take to ensure that it stays great?
We have to do as much as possible to minimise the impacts that we can do something about. Crown of Thorn Starfish control programs and stopping terrestrial runoff are both very important. We have to be careful about coastal development.

And personally, of course, I would like to see Australia contributing much more to scaling back the amount of greenhouse gases we put into the atmosphere. I appreciate that's a global problem but I believe, as a rich



The Great Barrier Reef is an absolutely huge ecosystem, larger than Victoria and Tasmania combined. It's got more than 3000 coral reefs, more than 1000 islands and non-reef habitats ranging from shallow estuaries to deep oceanic water — just extraordinary biodiversity.

Above: Professor Helene Marsh determining the age of dugongs by counting growth layers in their tusks

country, we should be doing a lot more than we're doing.

One species lost from the Great Barrier Reef area is the Bramble Cay Melomys, which scientists declared extinct two years ago – the first mammal to be wiped out by climate change after rising sea levels destroyed its habitat. What will it take to save species when the value of biodiversity isn't easy to economically quantify?

I don't know. Public awareness and education are incredibly important, because I don't think that there will be political will to make a difference if the public doesn't demand it.

The fires of 2019-2020 certainly raised public awareness to this issue, more than the bleaching of coral. The horror of seeing well-loved wildlife like koalas burned was an enormous wake up call for the Australian community.

Has that translated into meaningful change? I chair the National Threatened Species Scientific Committee, and can vouch that the Government has poured a lot of money into biodiversity recovery from the bushfire crisis.

But is it enough? The concern is exactly the same as it is for the Great Barrier Reef. If we're going to have bushfires every few years, there won't be time for the biota to recover in between fires.

The impact will be terrible. And we don't fully understand the impact of the recent fires, because that takes time.

I think the jury's out on whether these fires made the Australian population care more about biodiversity loss. Everyone got diverted last year because of COVID, and the compulsion to do something has consequently reduced, I think.

How have you seen the role of technology change over your career, and what role do you think it will play going forward?
Technology has a huge role, and I think it's very exciting. Marine mammals are really hard to study. They spend most of their time under the water so you can't see them, they live in remote places and they move huge distances.

In the last 30 years technology has helped provide key biophysical information. Only 60 or 70 years ago, in order to track a whale, people used what was called a discovery tag. This huge metal tag was fired into the whale and then it was recovered – or not – if the whale was caught and flensed. Now, GPS tracking can pick up the location of individual animals and relay it back to the satellite, even if the tracked animal only surfaces for a few seconds.

Drones are revolutionising what we can do. I've spent a lot of time doing aerial surveys from light aircraft in very remote places.

Drones can do such work better and safer. We can assess the health of individual whales and dolphins by dangling equipment from drones that can sample the blows of the animal when they breathe to check their respiratory bacteria, microbiomes and hormones.

Artificial Intelligence is being used to recognise individual animals from photographs and videos.

Genetics is revolutionising our understanding of different stocks. We can track the movement of genetically barcoded animals and use genomics, bioinformatics and environmental DNA to identify species in places that were very hard to sample before.

You completed your PhD in 1973. What was it like for women in the sciences then? How have things changed, and how have they not changed?
Well, when I first graduated I applied for my first job with a state fisheries department in Australia. (I probably shouldn't mention which one!) I got this amazing letter back, which I still have hanging in my room at the university.

They thanked me for my application, but wished to inform me that, as their scientific staff were expected to carry heavy gear and camp out with fishermen, it was not their policy to employ women. No one would get a letter like that now.

As a married women with children pursuing a serious scientific career I certainly encountered a lot of prejudice, though I didn't view it that way at the time.

In my final year of my PhD I was expecting a baby. There was no such thing as maternity leave for Australian government scholarship holders doing a PhD. So I talked to the administrators of the scholarship, and they said, "Oh just take some holidays, but come back quickly."

A few years later, in Canada, I was working part time because I had family responsibilities. I was asked, "How can you be serious about your scientific career when you're not working full time and you have young children?"

I remember saying, "Well, I'm actually serious about all my responsibilities."

Those things don't happen as often now. I still think it's pretty tough, though.

What more do you think needs to be done there? How would you improve that situation?
Some science leaders in Australia have shown that you can address these problems head on. There's one Medical Institute in Melbourne where postdoctoral fellows with parenting responsibilities for young children are allowed an extra year on their fellowships.

Rather than pretend that these problems can easily be addressed we have to actually ask people what needs to be done to overcome them.

And some of these problems are getting worse because of COVID. We've had a huge proportion of our scientific workforce lose their jobs – especially young women. And there are still so many people on short term contracts, which are really hard for anyone with significant family responsibilities.

So we're trying, but I don't think we've tried hard enough.

Do you have any advice you'd give to young people interested in pursuing environmental science today?
I do. One thing to think about is that environmental problems need a lot more than biophysical scientific expertise, or you're not going to get anywhere. I think a lot of scientists don't understand that.

We need people who understand the human dimensions of these problems and are prepared to work in cross-disciplinary teams.

Mathematical skills are getting more and more important. I would encourage every aspiring scientist to keep up their maths as long as they can, because it's very hard to pick up maths after you've dropped it.

Aspiring scientists should be fostering their skills development and seeking internships and placements as much as possible.

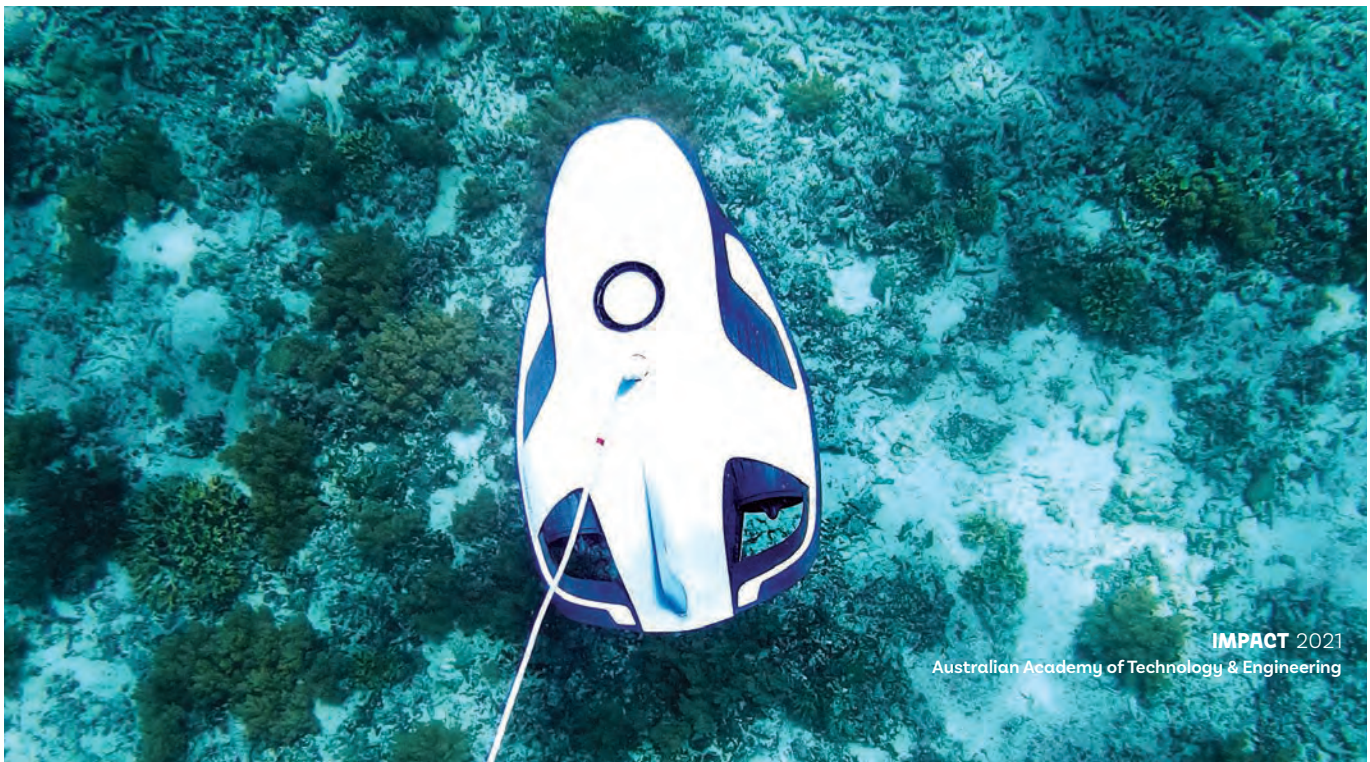
And then when they're looking for jobs, they should be thinking very carefully about what they're capable of, as well as what they're trained to do.

Often people who've done scientific training – particularly a PhD – have learnt more and more about less and less over a number of years, and can't imagine that the skills they've acquired could be relevant in any other setting.

But actually, they are. Increasingly, we're going to be looking for nimble people who can apply their very advanced skills to a range of problems.

As an application of technology, marine mammal research is truly amazing, but we have to have the political will to make a difference. We're never going to solve everything just with technology. ▶

Underwater drone exploring the seabed.



By Professor Stuart Khan FTSE

Troubled waters

Professor Stuart Khan
FTSE

Stuart Khan is a Professor in the School of Civil and Environmental Engineering at the University of New South Wales. He is a member of the National Water Grid Advisory Body.

Australia urgently needs updated water reform and infrastructure investment

Drought and flooding rains

The violence of the recent floods in Queensland and NSW is yet another symptom of our increasingly volatile climate. While the threat of drought might not be front-of-mind right now, the need to ensure Australia's long-term water security is more urgent than ever — and the next abrupt wake up call is never far off.

Many Australian towns and cities received such wake-up calls as the drought deepened during 2018, and when they came, they were loud. In New South Wales, the major inland cities of Dubbo, Bathurst, Orange, Armidale and Tamworth all came to within 12 months of running out of water.

Many smaller towns across NSW and Queensland's Southern Downs came to within six months of running out. A few, such as Walgett, Stanthorpe, Braidwood and Murrurundi effectively did run out, and relied on carting and emergency groundwater access.

Threats to water supplies became even more dire as the "black summer" bushfires of 2019/20 burnt through many forested and woodland parts of Australia. The damaged areas encompassed important water catchments, including those which supply Sydney's largest and most important water store, Warragamba Dam.

In many areas, the drought was broken, and bushfires extinguished, by torrential rainfall that occurred in February 2020. But these rains brought their own challenges, including washing large quantities of ash and debris, produced by the fires, into waterways.

Above: Hume Dam near Albury NSW

Having been severely damaged by the fires, many catchments were left in vulnerable states, with high risk of erosion and mudslides.

The organic carbon, sediment and nutrients that were transported to water storages resulted in a range of water quality management challenges for both small and large water utilities.

Making waves

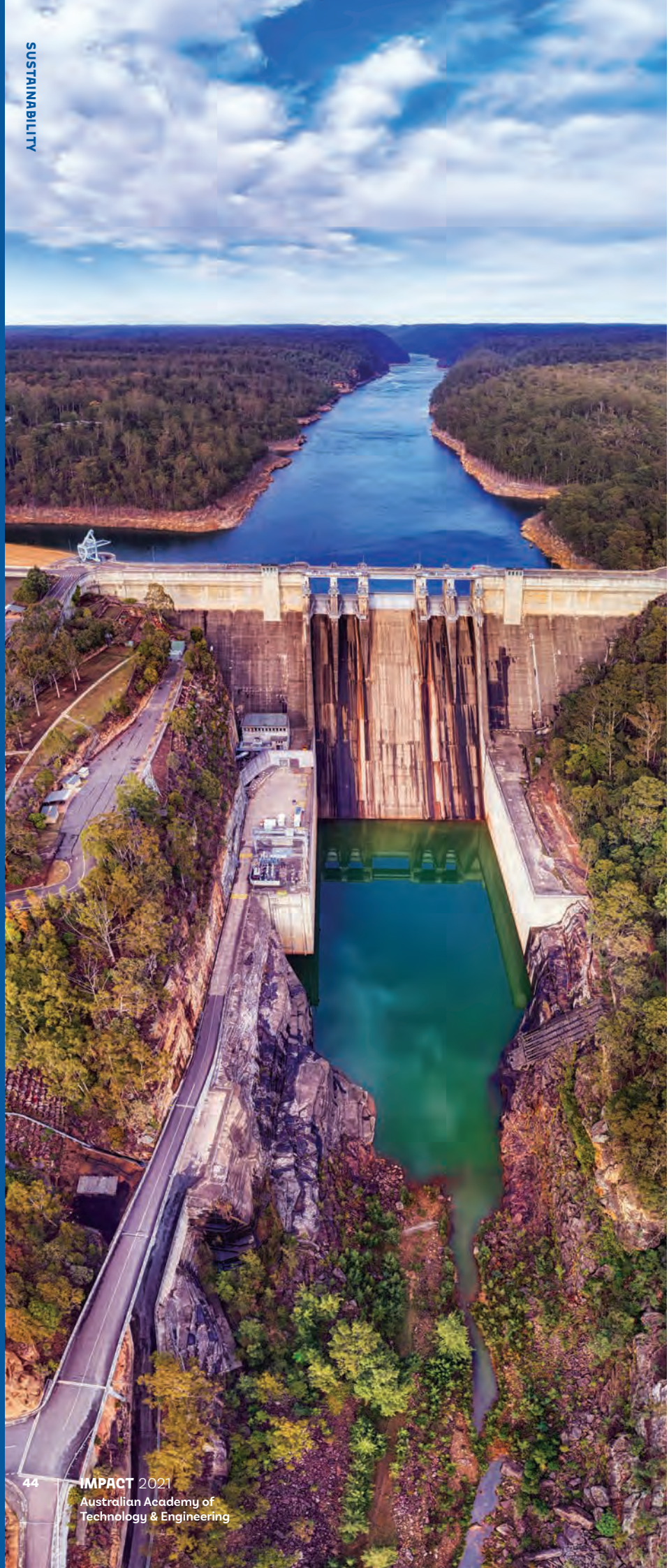
In the wake of these experiences, two important national reports point an urgent way forward for water reform and infrastructure investment in Australia.

The first was the Productivity Commission Draft Report on National Water Reform. This was quickly followed by Infrastructure Australia's 2021 Infrastructure Priority List.

In the draft report, the Productivity Commission found that much progress has been made since 2004, including improvements in efficient and sustainable resource management, establishing transparent processes for water sharing and mechanisms to formally allocate water for the environment. But despite this, a number of important challenges remain to be overcome, especially in regional and remote communities, and especially during drought.

A thirst for reform

Worryingly, the Productivity Commission criticised the fact that governance arrangements for water reform had "significantly eroded" with the loss of effective leadership structures, including the abolition of the National Water Commission in 2014.



In the absence of satisfactory governance, there is evidence that some important principles of national water reform have begun to backslide. For example, the Productivity Commission highlighted government investment commitments that have been made without first having the benefit of rigorous cost-benefit analysis.

The Productivity Commission identified a range of areas where the aims and objectives of national water reform should be updated and extended.

These include the need to better incorporate climate change and extreme weather events in water planning, securing Aboriginal and Torres Strait Islander Peoples' interests, and greater national attention to improvements in urban water management.

Bridging the gaps

Effectively addressing many of Australia's water challenges will require carefully targeted investment in a range of water infrastructure projects.

These include infrastructure to capture, store and transport bulk water supplies, as well as infrastructure to store, treat, distribute, and sustainably use urban water supplies. We also need to ensure the safe disposal or reuse of treated wastewater and sustainable urban stormwater management.

Infrastructure Australia's 2021 Infrastructure Priority List provides a comprehensive investment roadmap for Australia. However, only one water infrastructure project was determined to be at this stage of planning; the Myalup-Wellington water project in Western Australia.

In addition to the advanced project proposals, the priority list includes a range of initiatives, for which further development and rigorous assessment has been deemed to be a national priority. Among these are "bulk water supply security" and "town and city water security".

Down the pipeline

The report identifies bulk water supply security as a priority initiative we must address in the near term (0-5 years). This refers to the infrastructure used to provide water for primary industry, urban, environmental, recreational, and cultural use.

Left: Warragamba Dam – Sydney's water supply on the Nepean River

Infrastructure Australia notes that water availability for current high value irrigation areas is reducing and becoming increasingly unreliable. This is in line with future climate projections for much of southern Australia, which include decreased rainfall and more severe periods of drought.

In some cases, there may be opportunities to address these challenges with new investments in water supply infrastructure, such as efficiency projects, new water storages and pipelines, managed aquifer recharge and desalination.

Quenching our cities

Another near-term priority initiative is the need to address town and city water security.

This initiative aims to address the need for infrastructure which is essential to provide prosperity and a liveable environment for the more than 20 million people that live in Australia's towns and cities. This same infrastructure also provides high quality water to urban-based industries, supporting growth in national productivity and employment.

Infrastructure Australia has recognised a range of current challenges faced by the urban water sector. These include the impacts of climate change, population growth, ageing assets, and changing needs and expectations from users.

In particular, Infrastructure Australia has observed that "for regional towns, water utilities often rely on a single supply source, with no physical link to an alternative bulk water supply. The lack of supply diversification creates further water security risks for these communities."

From coast to coast

The report also identified two state-specific high priority water infrastructure initiatives: Greater Sydney water security, and Perth and south-western coast water security.

Greater Sydney's population is forecast to grow by almost one million people per decade for at least the next few decades.

As a consequence, it is expected to exceed eight million by the 2050s, with an estimated increase in annual water demand of 50 per cent to 65 per cent on current water use. This implies an additional water demand of around 300 gigalitres per year.

There are similar challenges for Perth and the south-western coast.

Severe and sustained declines in stream flows to Perth's surface water storages have been well documented over the past few decades. The groundwater aquifers, which provide most of the region's urban water supplies, are similarly climate-impacted by declining recharge.

Infrastructure Australia has called upon the NSW Government and the WA Government to identify initiatives and develop options to deliver long-term water security and water quality, outcomes for Greater Sydney and Perth and the south-western coast, respectively.

A watershed moment?

The Australian Government's establishment of the National Water Grid Authority (NWGA) is a very positive development.

It was established in 2020, the outcome of a 2019 federal election promise. The NWGA will oversee spending from the $3.5 billion National Water Infrastructure Development Fund under a 10-year rolling infrastructure investment program.

The NWGA has developed the National Water Infrastructure Investment Policy Framework in consultation with the states and territories. This investment framework provides a clear, long-term, strategic approach to investment in the next generation of Australia's water infrastructure for primary industry.

The framework is based on seven key principles to guide investment in nationally important water infrastructure:

- Projects should be of demonstrable public benefit and have a national interest element, including through securing the nation's water security, building resilience to future drought, supporting primary industries and promoting regional prosperity, including through the creation of jobs.
- There must be strong state support including funding contributions and involvement of the private sector and local government, where appropriate.
- The investment should provide the highest net benefit of all options available to increase access to water, taking into account economic, social and environmental impacts.
- Projects should look to address circumstances which cannot be effectively addressed by private proponents, the states or other stakeholders alone.
- Projects should align with the National Water Initiative principles, including appropriate cost recovery, and where full cost recovery is not deemed feasible, any subsidies are fully transparent.
- If providing capital, a consistent, robust analysis of costs and benefits is used and assessment of appropriate funding and financing arrangements is undertaken.
- Early involvement in project identification and development, including through the NWGA's science program, support for business case development, and close collaboration with the states and other project proponents.

Flowing forward

Well-considered urban water investment, through the NWGA, will help drive economic development in regional communities. However, support from the NWGA—funded through the National Water Infrastructure Development Fund—is contingent on a clear and significant component of that support going to primary industry.

While many urban water needs may also benefit from such schemes, there is currently no significant Australian Government mechanism to support major water infrastructure investments that don't include a major element of support for primary industry.

This leaves the Infrastructure Australia high priority initiative to "address town and city water security" without any focused Federal Government support.

The final Productivity Commission Report on National Water Reform ought to address this need and point the way to updated national water reform which includes a more engaged role for the Federal Government in supporting urban water infrastructure investment priorities across Australia.

Defending scientific values in a "post-truth" age

By Associate Professor Trevor Danos AM FTSE

Associate Professor Trevor Danos
AM FTSE

Trevor Danos is a lawyer, company director and strategic advisor with a passion for bringing STEM to government, industry and community. He chairs the Dean of Science's Advisory Council at UNSW (where he is an Adjunct Professor) the Northern Sydney Local Health District and the NSW Treasury Social Impact Investment Expert Advisory Group. Trevor has extensively studied the history and philosophy of science.

Science has not been at greater risk since the times of Copernicus and Galileo. While we may have dodged a bullet with the end of the Trump presidency, the gun is still loaded. Any self-proclaimed influencer – from the uninformed to the deliberately malign – can still command vast audiences with unsubstantiated claims.

Most political leaders (in Australia at least) have openly deferred to scientific expertise when responding to the COVID-19 pandemic. But this does not mean science has entered a new, halcyon age.

While some previously fact-shy politicians may have had Road to Damascus conversions, others use science as a convenient cover for difficult policy decisions. And there is still a rump of politicians who proudly call established facts contentious, with potentially catastrophic consequences for public health.

It is time to reflect on the importance of science, technology, engineering and mathematics, and how we can protect and embrace them in the future.

Fighting for the truth

The scientific values of scepticism, empiricism and transparency are at least as old as the Renaissance, and have been treasured in cultures across the world.

Today, society as we know it depends on science. Recent events have made it clear that without widespread acceptance of evidence-based truth, there can be no social contract.

Misinformation about COVID-19 vaccines could lead to hundreds of thousands more preventable deaths. The death toll caused by climate change denial may be orders of magnitude higher. And history reminds us that authoritarianism thrives when truth is cast aside.

The writings of authors such as Jacob Bronowski (Science and Human Values) and Carl Sagan (The Demon-Haunted World) are eerily prescient about our current predicament, and may help us out of it.

A social contract for the 21st century

We need to enshrine commitment to truth, transparency, empiricism and the protection of the environment as 21st century values across society. These values are no less important than freedoms of speech, religion, and from arbitrary discrimination.

This list of 21st century values is deliberately brief, but it could easily be expanded to include for scientists:

- tolerance and open-mindedness
- not making irresponsible claims
- the courage to make bold guesses
- not concealing error
- rejecting dogma
- encouraging collaboration
- not appealing to either prejudice or authority
- being frank about one's ignorance.

Bridging the two cultures

These social and political questions are usually seen as the domain of the humanities. But truth, empiricism and transparency are universal values.

For too long, scientists have stood aloof from these conversations – to both their and society's detriment.

Sixty years ago, in his lecture The Two Cultures, physical chemist and novelist CP Snow warned that the growing split between what are now called the STEM and HASS domains was undermining both, and isolating scientists from wider society.

Today, the dire consequences of this divide are clear. It is important to remember that science is much more than the identification and assembly of facts: it is a creative activity, deeply complementary to and inseparable from other disciplines.

Back to school

As scientists, we need to be better communicators to explain and defend the truth. Formal communications and media training should be a bigger part of university science curricula, and we should keep up this training throughout our careers.

We also need to ensure that every citizen's basic education explains and instils scientific values, not just rote facts and vocation-focused skills. School curricula should include a "civics" of science, which:

- outlines the basic history and philosophy of science
- emphasises the scientific method and critical thinking in their own right, separate from and at least as important as individual scientific accomplishments
- celebrates the important role that error and failure play in getting to the truth
- equips students to recognise and debunk bad science and pseudoscience.

A Hippocratic Oath for science

Ethics is built into medical training, and all lawyers swear to "conduct themselves well and honestly in the practice of law". Given the nature of threats we face, perhaps it is time for a "Scientific Oath", where graduands avow their commitment to truth, empiricism and transparency.

Oaths on their own do not stop bad eggs, but they can encourage ethical professional cultures, and mark a significant career milestone that graduands can take pride in. Oaths could also empower scientific professionals to call out unacceptable behaviour when they see it.

The health of science is a bellwether for the health of all of society. If we are to protect the truth, we must take action now.

"It is time for a 'Scientific Oath', where graduands avow their commitment to truth, empiricism and transparency."

By Dr Sarah Pearce FTSE

Space for diversity

Dr Sarah Pearce
FTSE

Sarah Pearce is a trailblazing physicist who helped establish the Australian Space Agency and delivered crucial computing for the Large Hadron Collider. She is currently Acting Chief Scientist at the CSIRO and has recently been appointed Australian Director of the Square Kilometre Array (SKA) project. Strongly committed to diversity, Dr Pearce is a committed campaigner for women in STEM.

As a young girl growing up in the UK, I dreamed of becoming an astronaut, and I truly believed I could achieve that.

I couldn't have understood then the challenges that many women and other underrepresented groups have and continue to face in STEM fields, or those faced by other underrepresented groups seeking to be accepted, respected, and heard.

What I know today is that a diversity of views and backgrounds leads to the best questions, and the best questions create the best science. But we don't always see that diversity.

So now as a leader in CSIRO, and in the STEM community, I see my role as creating an open and accepting environment to ask hard questions, challenge the status quo, and use diverse perspectives to push the boundaries of our scientific capability.

But how do we create that environment? There are actions we need to take on multiple fronts, but for me, the common themes are acceptance, role models, recognition, and intervention.

Intervention

I'll start with the latter, and I'll use CSIRO as an example. CSIRO became a member of the SAGE pilot of the Athena SWAN program in late 2015. We looked at every single element of working life at CSIRO to unpick where we were unconsciously excluding women, as well as other groups.

One of our toughest problems was a male dominated executive team – in 2014, we didn't have a single woman business leader! But over time we addressed that. Today we have gender balance at Board and Executive levels, and our senior leadership team sits at just below 40 per cent women.

A key challenge now is getting more women into entry-level leadership positions, which is the critical pathway to senior leadership.

When we looked at the data, it told us that women were more likely to succeed than men when applying for a promotion, but they were much less likely to apply in the first place, so we were promoting fewer women overall.

This has been a stubborn trend to shift, and one that has shown us we need to encourage and support rising female talent.

So, we are looking at ways to get more women to apply for those mid-career promotions and build our leadership pipeline.

We also need to look at how we make these first management roles attractive and realistic, with enough support, time, and resources to do them successfully. This includes on the home front, too. Annabel Crabb's book The Wife Drought reflects on the common joke shared by professional

> **“When we looked at the data, it told us that women were more likely to succeed than men when applying for a promotion, but they were much less likely to apply in the first place, so we were promoting fewer women overall.”**

women juggling work and family responsibilities – “I need a wife.”

The fact is, having a partner taking care of things at home is an enormous asset and a large contributing factor to success. And as Annabel points out, it’s an advantage enjoyed by vastly more men than women.

The system as a whole was established in the context of a scientist at work and a partner at home to look after the family. Under this arrangement, those jobs were allowed to evolve to the point of becoming unsustainable for people with caring responsibilities.

Challenging the status quo has led to some big changes in the way we work. At CSIRO, we’ve tried to remove barriers for women and those with caring responsibilities by making things like flexible working and full-time-equivalent calculations the norm.

But expectations are slower to change. For example, there is still an assumption that it is women who will take leave or go back to work part time after children are born. This is something I’m challenging within CSIRO and more broadly, as I believe we should enable greater gender parity in parental leave.

There also needs to be additional support given to care givers, and recognition of the unsustainable nature of many science positions for those with children.

As a sector, we will see more women in leadership positions if we can move to a more family friendly working culture, and more sustainable career paths. And this will be great for the men in our organisations, too.

The power of role models

Then there’s the question of attracting more women into research roles overall, which today are male dominated at CSIRO with only 34 per cent filled by women. This is a trend reflected in the broader STEM sector.

Part of this issue goes back to the women role models we show girls, as well as the male role models in STEM who model inclusive behaviour for men.

Dr Cathy Foley AO PSM FTSE, Australia’s Chief Scientist, tells the story of Kylie Minogue’s character on Neighbours in the mid-1980’s becoming a motor mechanic, and the corresponding spike in women enrolling in associated TAFE courses.

This was probably a short-lived trend, but it is illustrative. When we show girls someone relatable who they can aspire to be like, someone in whose footsteps they can follow, they can more easily imagine a future career in that role.

Superstars of STEM is a fantastic example of a program that does this well. As a graduate of the program, I’ve also been connected to a wonderful network of women scientists who have been a valuable support to me.

> “Aboriginal and Torres Strait Islander peoples were Australia’s first explorers, navigators, engineers, farmers, botanists, scientists, diplomats, astronomers, and artists.”

Men are an important part of this conversation that is often missed, but the effect of senior male leaders modelling inclusive behaviour is extremely powerful. The Champions of Change Coalition is an excellent example of this, and CSIRO’s Chief Executive, Dr Larry Marshall FTSE, is an active and passionate member.

We need the leadership of both men and women to tackle issues of gender equity, and the more visible that leadership is, the more it will be emulated.

And beyond gender, diverse role models help all children see that science can be for them, if they choose it.

Acceptance

Acceptance is one of the most important themes I’ll cover, and I want to share a story about our LGBTQI+ community in CSIRO to illustrate the impact of this.

I was the Deputy Director of CSIRO Astronomy and Space Science back in 2019 when CSIRO took part in our first Mardi Gras Parade. A request came through to light up our Australian Square Kilometre Array Pathfinder radio telescope in a rainbow of colours, and I campaigned to make this happen.

What was so fulfilling and wonderful to see was the incredibly uplifting impact it all had.

It was CSIRO openly and publicly saying to our LGBTIQ+ community – “You are welcome here, and you are part of our family.” I believe it added a whole new layer of engagement for our LGBTIQ+ identifying people within CSIRO, and a true feeling of acceptance.

It’s one thing to say you accept, and another entirely for CSIRO to march in Mardi Gras and embrace the community.

It was a proud moment for me, and I didn’t understand the impact it would have, until it happened.

Acceptance is an empowering force. When we feel accepted and respected, we contribute without hesitation, and innovation flows.

Recognition

Respect and recognition are two other powerful forces towards diversity and inclusion.

Recognition has long been an issue for Aboriginal and Torres Strait Islander peoples – recognition and respect for the Indigenous knowledge systems and traditions that have existed for more than 65,000 thousand years – long before western science arrived.

Aboriginal and Torres Strait Islander peoples were Australia’s first explorers, navigators, engineers, farmers, botanists, scientists, diplomats, astronomers, and artists.

The sustainability and adaptability of Indigenous knowledge systems is extraordinary, and science presents a tremendous opportunity for deep engagement, particularly on issues that relate to our environment.

When we recognise and respect multiple knowledge systems, we can bridge Indigenous knowledge and western science, and learn from that experience for the benefit of both our research and our society.

For this reason, CSIRO has established an Indigenous Science and Engagement program, and we are in the process of appointing our first ever Indigenous Science Director. We’ve also committed to increasing the employment of Aboriginal and Torres Strait Islander peoples across the organisation, as part of our Reconciliation Action Plan.

By including more Aboriginal and Torres Strait Islander voices in shaping our research, we can create more Indigenous-driven science that supports Indigenous peoples, culture, and Country, and drives reconciliation though inclusion.

To return to where I started now, I didn't become an astronaut, but I did go on to have a wonderfully rich career in physics and space, even if I was the only woman in the room for many of those years.

What I've learned is that we need to create space for diversity and difference in STEM, and that creating that space sometimes requires purposeful and considered intervention.

It requires powerful role models and leadership by example, and the creation of an open, accepting, and respectful environment where a wide variety of views can be heard.

When we do this, it's our differences that spark the best questions, and create the best solutions. ▶

Previous page: CSIRO shines a rainbow under the Milky Way to mark its first Mardi Gras in 2019.

Above: In the wetlands of Kakadu, rangers are using Artificial Intelligence and Indigenous Knowledge to care for Country, in a ground-breaking collaboration including CSIRO researchers. Image: Tianji Dickens.

SAGE Athena Swan program leaves the nest

Last year the SAGE Pilot program, a partnership between the Academy of Science and the Academy of Technology and Engineering, transitioned to a not-for-profit company: Science in Australia Gender Equity Limited.

Libby Lyons, the director of the Workplace Gender Equality Agency was appointed the inaugural Chair.

The Board is made up of Professor Marilyn Anderson FTSE FAA, Professor James Angus AO FAA, Dr Rosalind Dubs FTSE and Dr Bruce Godfrey FTSE.

The Chief Executive is Dr Wafa El-Adhami.

SAGE is the only gender equity and diversity program of its kind in Australia.

Its aim is to achieve meaningful systemic and cultural change within organisations by using a proven international accreditation framework, the Athena Swan Charter.

So far more than 40 Australian higher education and research institutions have been awarded the Athena Swan Institutional Bronze Award and that number is steadily growing.

"It is a credit to the leadership of these organisations that they have remained committed to eliminating gender inequity in their organisation despite the impacts from COVID-19 felt right across the higher education and research sector," said Ms Lyons.

The goal is to reach the entire higher education and research sector across all disciplines.

In February, a uniquely Australian pathway for institutions seeking to progress from Bronze accreditation to Silver opened: the SAGE Cygnet Awards.

Institutions can identify five key priority areas for action and a Cygnet award is conferred once SAGE is able to certify that sufficient progress and impact have been achieved in those areas.

Five Cygnet awards are required before an institution can apply for a SAGE Athena Swan Silver Award.

A podcast which showcases the Athena Swan journey, *Think Difference*, has so far received more than one thousand downloads. ▶

By Dr Marguerite Evans-Galea AM

Nuturing the next generation of scientists

The Academy of Technology and Engineering is building on its successful industry engagement program to ensure that the STEM professionals it is developing can inspire the next generation.

The Industry Mentoring Network in STEM (IMNIS) connects PhD students and postdoctoral researchers in science, technology, engineering and mathematics with influential industry leaders in a one-year mentoring and professional development program.

In the current 2020-21 program, IMNIS is forging 350 mentoring partnerships.

A survey of our IMNIS alumni found 90 per cent of mentees were influenced to consider work in industry or had begun to work in industry already.

Now ATSE is launching IMNIS Catalyst – an ambassador-style program that provides an opportunity for past mentees to engage more broadly throughout the STEM ecosystem.

ATSE Chief Executive Kylie Walker said Catalyst participants will be given the opportunity to share what they've learned about industry careers and the broader STEM ecosystem through the IMNIS program with their peers and with senior high school students.

"Catalyst is a powerful extension of the IMNIS initiative since it connects today's high school students with early-career STEM professionals at a time when they are making key decisions about their future studies. This ensures Australia's Year 10 to 12 students understand where a qualification in STEM can take them," Ms Walker said.

"This is a core focus of ATSE – to foster a mobile, highly skilled STEM workforce that is inclusive and diverse."

Catalyst participants will also receive science communication training, engage with industry leaders, lead an industry site visit, and participate in IMNIS events and strategy sessions.

Industry professionals Dr Navpreet Kaur and Dr Greg Bass, as well as research biophysicist Olumide Opeyemi are among the ten inaugural participants.

"I joined IMNIS back in 2017 when I was an international student and wanted to build up my network in the STEM community in Australia. I met a lot of intelligent people who have achieved a lot in their careers," Dr Kaur said.

"I want to build on my science communication skills to improve my capacity to forge networks within the professional scientific community. I hope to improve my ability to lead and mentor staff and students within my own team too," Dr Bass said.

When asked what he hopes to achieve through this program Mr Opeyemi said "To consistently nurture the next generation of effectual scientists. My work and my dream is bigger than me. It must, and will be handed over to the next generation."

IMNIS's Catalyst program is supported by MTPConnect's $32 million Researcher Exchange and Development within Industry (REDI) initiative made possible by the Medical Research Future Fund.

IMNIS CATALYST

Dr Marguerite Evans-Galea AM

Marguerite Evans-Galea is a scientist, executive and entrepreneur. She is Executive Director of the Industry Mentoring Network in STEM with the Australian Academy of Technology and Engineering, and co-founder and co-chair of Women in STEMM Australia.

Catriona Nguyen-Robertson

PhD student
University of Melbourne

Catriona Nguyen-Robertson is a singing scientist: she sings in the laboratory and contemplates immunology experiments in the shower. She studies tuberculosis vaccine strategies and hypersensitivities to antibiotics, drugs and skincare products, and is the Associate Editor for the scientific journals Immunology and Cell Biology. Passionate about encouraging diversity in STEM and engaging students in science, Catriona lectures on Science Communications at The University of Melbourne. She also engages with mentoring and outreach programs including Pint of Science, BrainSTEM and the Gene Technology Access Centre.

Fatematuz Zohora

Research Engineer & Lead Tutor
Queensland University of Technology

Fatematuz Zohora is a PhD graduate developing a sound wave monitoring tool to detect damage to pipelines in real-time and quickly address expensive leaks. Zohora is a passionate research engineer and a sessional academic at QUT. A graduate member of Engineers Australia and an Associate Fellow of Advanced Higher Education, she was one of the finalists in STARS 2018, a sessional academic teaching innovation and reflection showcase. She is looking forward to inspiring young leaders to be involved in research.

Navpreet Kaur

Senior Bioprocess Scientist
Thermo Fisher Scientific

Dr Navpreet Kaur is a biotechnology PhD student with skills in microbiology, downstream processing, upstream processing and bioprocessing. An enthusiastic team-player, she has carried out several scientific projects allowing her to showcase her skills such as attention to detail, capacity to manage time and meet deadlines, while also training students. Navpreet would like to use her scientific knowledge, passion for innovation and willingness to learn to positively influence society.

Inaugural IMNIS Catalyst participants

Edith Botchway

Postdoctoral Researcher
Deakin University

Dr Edith Botchway completed her PhD on understanding sleep, fatigue, depression, and quality of life outcomes in young adults who sustained traumatic brain injury in childhood. Her post-doctoral work involves studies examining rehabilitation models of care used in children and youth with traumatic injuries, and studies examining sleep and neuropsychological outcomes in children with acquired and congenital neurological conditions. Edith is passionate about community service and youth development, and mentors four students pursuing various careers in STEM.

Kay Myo Min

PhD student
University of South Australia

Kay Myo Min is in the final stages of her PhD investigating novel pathways involved in the growth and spread of pancreatic cancer. Kay has a great interest in innovative research with real life translations, science communication (especially with regards to bridging the gap between the scientific community and the general public), gender equity, public policy and sustainability science. She has begun to teach at her university and is also a strong advocate for student equity and supporting student culture at the university through her work as a student representative.

Thilanka Morawakage

BRACE Trial Project Assistant
Murdoch Children's Research Institute

Thilanka Morawakage is a project assistant on the BRACE clinical trial at the Murdoch Children's Research Institute. Her Masters thesis focused on the inhibition of a novel therapeutic target for the treatment of fibrosis. As an intern at the Janssen Pharmaceutical Companies of Johnson and Johnson, she provided support to the Australia and New Zealand Diversity and Inclusion Council to deliver their 2020 strategy. Thilanka has been actively involved in various other clinical research roles, volunteering programs and student societies.

Olumide O. Opeyemi

PhD student
Queensland University of Technology

Olumide O. Opeyemi is a PhD student researching the use of non-invasive in vivo MRI scans and computational fluid dynamics to diagnose occult cardiovascular disorders. Olumide was born in Ondo Town, Ondo State, Nigeria and has lived in numerous places across four continents. He was offered an Adjunct Professor position post-graduation, then returned to London to start and grow a family healthcare HR business. His work experience spans charities and non-profits, startups, IT, sales, university administration, pedagogy, and medical writing and editing.

Nick Hong Seng Lee

Laser Development Engineer
Vaxxas

Dr Nick Hong Seng Lee is a biomedical engineer working as a laser development engineer at an Australian startup commercialising needle-free vaccine delivery technology. He has previously helped companies and researchers turn ideas for biomarker detection, drug delivery and biosignal sensing into viable medical products. During his PhD he developed a non-invasive microdevice for early skin cancer detection. Nick has founded and led postgraduate initiatives, voluntary bodies and national programs for non-profit organisations, including New Zealand Red Cross and Engineers Without Borders.

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 with 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

Samantha Papavasiliou

Risk Manager
Australian Taxation Office & lecturer at University of Adelaide

Samantha Papavasiliou researches digital adoption behaviours in the Australian Public Sector to inform and tailor its communication channels. With a PhD in digital transformation and adoption, she works at the Australian Taxation Office as a Service Review and Redesign Project Manager and data analyst. Samantha applies behavioural analytics and predictive modelling to help organisations communicate with their users. She also teaches at the University of Adelaide, focusing on post-graduate project management, system design and research methods.

Greg Bass

Senior Scientist – Image Analytics and Systems Biology
CSL

Dr Greg Bass completed his PhD in computational biology and biomedical engineering. He also did an Australian Mathematical Sciences Institute internship at CSL where he developed a mathematical model of protein trafficking in cells. He now works as a senior scientist, leading a small team in the R&D department at CSL, in the Bio21 Institute. Greg develops high-throughput analysis software to quantify images of cells and tissues, using image processing techniques such as machine learning and AI.

SUPPORTED BY

REDI DEVELOPING AUSTRALIA'S MTP SECTOR WORKFORCE
Powered by MTPConnect

The IMNIS Catalyst program is supported by MTPConnect's $32 million Researcher Exchange and Development within Industry (REDI) initiative made possible by the Medical Research Future Fund.

By Camille Thomson

Students tackle the sustainable housing challenge

Camille Thomson

Camille Thompson is the National Education Program Coordinator at the Australian Academy of Technology and Engineering. Her invaluable contributions to STEM education include her work with The Australian Academy of Science, The Australian Institute of Policy and Science, and the Pint of Science podcast.

What does it take to build a low-energy home that can withstand harsh weather conditions?

One of the Academy's strategic goals is to combat climate change. STELR's Sustainable Housing module empowers students to look at the measures we can take to reduce consumption and increase efficiency in housing.

By designing their own low energy homes, students learn how heat can be transferred through convection, conduction and radiation, as well as about the thermal properties of matter. This is hands-on science: theory fundamentals with real-world applications.

Homes currently generate around 13 per cent of Australia's greenhouse gas emissions. Improving their energy efficiency is a key part of ensuring a safe climate for the course of these kids' lives.

2020 presented huge challenges for science teachers. How do we help students investigate when they can't be in the classroom? To tackle this challenge, STELR partnered with Orica to develop new remote learning modules to bring the lab to the home.

Above: Youth TV science communicator Lee Constable presenting the Sustainable Housing module. Above right: the sustainable housing set up showing the 'house' and lamp.

We recently launched the second of these. It includes three videos starring youth TV science communicator Lee Constable and Deadly Science founder Corey Tutt. Lee used the Sustainable Housing kit to show the process for determining good house colour, the best insulation and the effects of different glass.

Corey gave three short talks on sustainable housing from Indigenous perspectives. He looked at fascinating principles of engineering in nature, such as native beehives and the structures of bower bird nests.

STELR is working to include Indigenous learning perspectives in all our modules to better connect to First Nations youth and champion the rich history of Indigenous science in Australia.

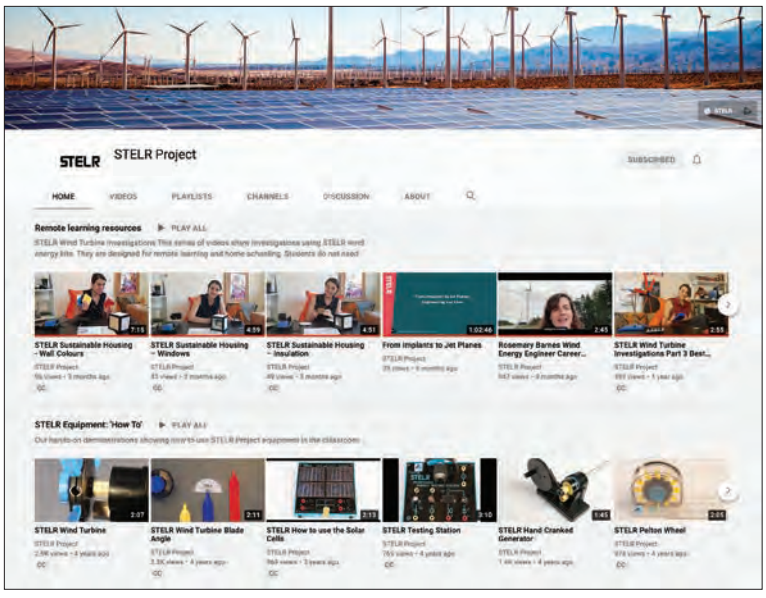
Because curiosity knows no borders, we also gave the videos Indonesian and Spanish subtitles to make them accessible to STELR's growing global community. ▶

We also developed worksheets to use with each video from the full Sustainable Housing workbook. This gave teachers the flexibility to use each as an individual lesson. These worksheets are also available in Indonesian.

Kids care about climate. By empowering them to find new solutions to this challenge, we can also help them create thousands of new jobs for the future.

STELR's sustainable housing module inspires school students with the skills, knowledge and incentive they'll need to thrive in – and protect – their future.

Find our more information about the sustainable housing module at stelr.org.au



Top: Corey Tutt, Deadly Science founder in one of STELR's sustainable housing videos.
Above: All STELR videos are on the STELR website and the STELR YouTube channel.
Subscribe to be automatically notified of any new content.

STELR

stelr.org.au

STELR

The STELR (Science and Technology Education Leveraging Relevance) Project is an in-school initiative of the Australian Academy of Technology and Engineering. Now in over 700 schools across Australia and the world, STELR delivers hands-on STEM teaching modules which focus on student-relevant issues like climate change and sustainability.

stelr.org.au

Movers & shakers


1. Huanting Wang


2. David Noon


3. Ian Oppermann


4. Andrew Holmes


5. Thomas Maschmeyer


6. John Church


7. Alan Finkel


8. Steve Powles


9. Rob Fitzpatrick


10. Sue MacLeman


11. Martin Green


12. Tony Barry

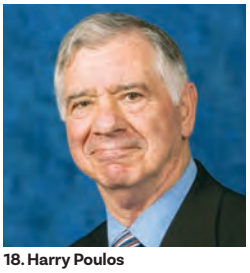

13. Cathy Foley


14. Yi-Min Xie


15. Genevieve Bell


16. Bronwyn Fox


17. Greg Ayers


18. Harry Poulos


19. Ya-Qin Zhang

20. Lindsay Falvey

1. Huanting Wang
Professor Huanting Wang was awarded the 2021 Underwood Medal from the Institute of Chemical Engineers for his work in membrane separation that supports the provision of clean water and sustainable industrial development.

2. David Noon
Dr David Noon was appointed Chief Executive Officer of GroundProbe, a mining technology company he co-founded in 2001.

3. Ian Oppermann
Dr Ian Oppermann was named chair of the inaugural New South Wales Artificial Intelligence Advisory Committee and will play a leading role on how AI is used in the state.

4. Andrew Holmes
The 2021 Australian Academy of Science's Premier Honorific Awards recognised Professor Andrew Holmes AC with the Matthew Flinders Medal and Lecture for his contributions to synthesising biological and materials science.

5. Thomas Maschmeyer
The 2021 Australian Academy of Science Career Honorific Awards recognised Professor Thomas Maschmeyer with the David Craig Medal and Lecture for his contributions to green chemistry and battery technology.

6. John Church
The 2021 Australian Academy of Science's Career Honorific Awards recognised Professor John Church with the Jaeger Medal for his contributions to oceanography and understanding the impacts of climate change.

7. Alan Finkel
Former ATSE President and Chief Scientist Professor Alan Finkel AO was appointed to the newly created role of Special Adviser to the Australian Government for Low Emissions Technology.

8. Steve Powles
Herbicide resistance expert Professor Stephen Powles received the Seed of Gold award from the Grains Research and Development Corporation.

9. Rob Fitzpatrick
Soil Science Australia gave Professor Robert Fitzpatrick the Pioneer Lecture Award, which honours an individual who has made a significant and lasting contribution to the field of soil science.

10. Sue MacLeman
MTP Connect Chair Sue MacLeman was appointed to the Planet Innovation Board as a non-executive director.

11. Martin Green
Professor Martin Green AM was awarded the Japan Prize for his revolutionary work in the field of photovoltaics.

12. Tony Barry
Dr Tony Barry was appointed President Elect of the International Federation of Consulting Engineers, the third Australian to hold the role.

13. Cathy Foley
Former ATSE board Director and renowned physicist Dr Cathy Foley AO PSM has been appointed Chief Scientist of Australia.

14. Yi-Min Xie
Professor Yi-Min Xie AM won the Victoria Prize for Science and Innovation in the physical sciences category for his leadership, determination and creativity in producing world-leading architecture and design algorithms.

15. Genevieve Bell
Distinguished Professor Genevieve Bell AO, Director of ANU's 3A Institute, was elected an Honorary Fellow of the Australian Academy of the Humanities.

16. Bronwyn Fox
Professor Bronwyn Fox, Deputy Vice-Chancellor (Research and Enterprise) at Swinburne University, received the Royal Society of Victoria's 2020 Medal for Excellence in Scientific Research.

17. Greg Ayers
Dr Greg Ayers, Former Director and CEO of the Bureau of Meteorology, was appointed Chair of the National Computational Infrastructure Advisory Board.


21. Xinhua Wu

22. Mary-Anne Williams


23. Bruce Godfrey


24. Ben Eggleton


25. Robert Park


26. Andrew Wilks


27. Peter Dowd


28. Alexander (Jack)McLean


29. Ranjith Pathegama Gamage


30. Yiu-Wing Mai


31. Hong Hao


32. Graham Currie


33. David Thodey


34. Tony Weiss


35. Justin Gooding


36. Mark Hoffman

18. Harry Poulos
Emeritus Professor Harry Poulos AM received the Peter Nicol Russell Career Achievement Award. He is a world authority on soil behaviour and his methods for designing foundations underpin some of the biggest skyscrapers in the world.

19. Ya-Qin Zhang
Software entrepreneur Dr Ya-Qin Zhang was appointed to the board of WPP as a non-executive director.

20. Lindsay Falvey
Emeritus Professor Lindsay Falvey was appointed to the Commission of the Australian Centre for International Agricultural Research.

21. Xinhua Wu
Professor Xinhua Wu, Pro-Vice Chancellor (Precinct Partnerships) at Monash University, was invited to speak at a United Nations Industrial Development Organization online event about how digital technology can further the 2030 Sustainable Development Agenda. She discussed 3D printing, agile manufacturing, industrial design metal-mechanic and aeronautic industries.

22. Mary-Anne Williams
Distinguished Professor Mary-Anne Williams, Founder of the University Technology Sydney Magic Lab, was named Michael Crouch Chair in Innovation by the University of New South Wales Business School.

23. Bruce Godfrey
Dr Bruce Godfrey, Chair of the Academy's Diversity and Inclusion Committee, has been appointed Chair of Energy Renaissance, Australia's first lithium-ion battery manufacturer.

24. & 25. Ben Eggleton & Robert Park
Professor Benjamin Eggleton, Director of the University of Sydney Nano Institute, and Professor Robert Park, Judith and David Coffey Chair of Sustainable Agriculture at The University of Sydney, were named finalists in the Eureka Prizes.

26. Andrew Wilks
Professor Andrew Wilks, Executive Chairman at SYNthesis, was elected a Fellow of the Academy of Health and Medical Services.

27. Peter Dowd
Professor Peter Dowd, Professor of Mining Engineering at the University of Adelaide, was elected President of the International Association for Mathematical Geosciences.

28. Alexander (Jack) McLean
Road safety expert Emeritus Professor Jack McLean was granted Honorary Membership of the International Council on Alcohol, Drugs and Traffic Safety.

29, 30, & 31. Ranjith Pathegama Gamage, Yiu-Wing Mai and Hong Hao
Professor Ranjith Pathegama Gamage, Professor Yiu-Wing Mai and Professor Hong Hao were listed in The Australian's 2020 list of 250 top researchers. Professor Chris Moran, Professor Bronwyn Harch and Professor Tanya Monro contributed to the report.

32. Graham Currie
Professor Graham Currie, Director of the Public Transport Research Group at Monash University, was awarded the Engineers Australia Transport Medal. This medal, last awarded back in 2014, recognises outstanding individual contributions to transport in Australia.

33. David Thodey
The NSW Government appointed CSIRO Chair David Thodey AO head of a new steering group to advise on the state's Tech Central precinct being developed around Sydney's Central railway hub.

34. Tony Weiss
The National Health and Medical Research Council (NHMRC) gave Professor Tony Weiss AM an NHMRC Leadership Fellow Investigator Award totalling $2.9m over five years, and named him an NHMRC Leadership Fellow.

35. Justin Gooding
Professor Justin Gooding , ARC Laureate Fellow at the University of New South Wales, received the Jaroslav Heyrovsky Prize for Molecular Electrochemistry from the International Society of Molecular Electrochemistry.

36. Mark Hoffman
Professor Mark Hoffman, Deputy Vice-Chancellor (Academic) and a Vice-President of the University of Newcastle, was appointed to a panel of building and construction specialists to help remove unsafe cladding across NSW.

Australian Government
Department of Defence

More, together is

increasing collaborative research

connecting universities, industry and PFRAs

growing defence innovation capability

investing in emerging and future technology

implementing new research security

Read the strategy online

Defence's *More, together* strategy sets the direction for defence science and technology out to 2030. The *One Defence science and technology capability strategic pillar* focuses on the importance of Defence collaborating and partnering with the national enterprise to build on the strengths and expertise of our national and international partners.

Defence is committed to bringing together interdisciplinary teams to create innovative solutions that generate strategic advantage while developing sovereign industry capabilities.

In supporting a technologically advanced Australian Defence Force, we encourage you to read the *More, together* strategy and be involved with this exciting initiative.

www.dst.defence.gov.au/strategy

Athena SWAN Bronze Award
Defence Science and Technology Group is a proud recipient of the Athena Scientific Women's Academic Network (SWAN) Institutional Bronze Award.

Honours

FELLOWS RECOGNISED ON HONOURS LIST

Seven Fellows of the Australian Academy of Engineering and Technology have been awarded Officer (AO) in the General Division of the Order of Australia in this year's Australia Day Honours List.

The Governor-General congratulated all 845 Australians recognised for their selflessness, commitment and dedication of service and contribution to the community.

Dr Brian O'Brien
AO FTSE
(WA) Deceased
For distinguished service to science, particularly to lunar dust research, to tertiary education in the field of physics, and to the environment.

Professor Helene Marsh
AO FTSE
(QLD) James Cook University
For distinguished service to the biological and environmental sciences, to the conservation of marine mammals, and to tertiary education.

Dr Russell Reichelt
AO FTSE
(QLD) Great Barrier Reef Marine Park Authority
For distinguished service to marine conservation, to ecosystem management of the Great Barrier Reef, and to climate change research.

Professor Mark Randolph
AO FTSE
(WA) University of Western Australia
For distinguished service to geotechnical engineering and science, to tertiary education and research, and to professional organisations.

Dr Barry Inglis
AO PSM FTSE
(NSW)
For distinguished service to science and engineering, particularly to metrology, measurement standards and research, and to professional organisations.

Professor Graham Goodwin
AO FTSE
(NSW) University of Newcastle
For distinguished service to tertiary education, and to electrical engineering as an academic and researcher, and to scientific academies.

Emeritus Professor Christopher Fell
AO AM FTSE
(NSW) Fell Consulting Pty Ltd
For distinguished service to science and engineering, particularly to nanotechnology research and fabrication, and to professional networks.

Doug Anthony

A man of coast and country

The Hon John Douglas Anthony AC FTSE was Australia's longest-serving Deputy Prime Minister and leader of the National (Country) Party from 1971-84.

He's credited with modernising the Nationals from a largely protectionist party that represented farmers to one that was more outward looking and representative of the wide range of residents in regional Australia.

Doug Anthony grew up in northern New South Wales and initially intended to run his family's dairy farm but entered politics after the unexpected death of his father who had served in the Menzies government. Aged 27 he was the youngest member of what was an all-male bastion.

He had a quick mind and grasp of policy and it wasn't long before he was appointed to the frontbench. In 1971, on the retirement of John McEwen, he became leader of what was then the Country Party, as well as trade minister. One of his first tasks was to expand Australia's trade links with Asia.

During the next 13 years he also served as Deputy Prime Minister to Prime Ministers John Gorton, Billy McMahon and Malcolm Fraser.

When Mr Fraser took his annual summer break, Doug Anthony would often run the country from his caravan at New Brighton in his electorate. He dubbed it "beach power".

In 1977, he gave the dinner address at ATS(E)'s first symposium and after his retirement from politics, he became the inaugural chair of what was then the ATSE Crawford Fund. He became an honorary ATSE Fellow in 1990 and was always a very strong supporter of the Academy.

In 2005 he delivered the ATSE Annual Oration saying he found it a great honour to be asked to speak to such a distinguished group of people. "I hope you feel some satisfaction and joy from what you are doing because it is important and too often undervalued," he said.

Doug Anthony died 20 December 2020 at the age of 90 in Murwillumbah and is survived by his wife Margot, three children and nine grandchildren.

With thanks to the SMH, The Australian and John Zillman FTSE

Brian John O'Brien

Space scientist who reached for the moon

Professor Brian O'Brien AO FTSE was an influential physicist whose historic lunar dust experiments were aboard Apollo 11.

Born in 1934, he completed his PhD in Physics at the University of Sydney in 1957. Seeing the dazzling beauty of the Aurora Australis while working in Antarctica inspired him to pursue a career in space research.

In the 1960s he worked as a Professor of Space Science at Rice University in Houston, making major discoveries about solar-terrestrial relations.

A NASA principal investigator at the thrilling height of the space race, Professor O'Brien worked closely with astronauts including Buzz Aldrin. Five of his experiments were taken to the moon itself. His historic work on lunar dust revealed the dangers it posed to scientific equipment and made moon research safer and easier.

An early advocate of the need to address climate change, Professor O'Brien headed the WA Environmental Protection Authority from 1971-1978. He later persuaded the WA Government to commit $1.7 million of funding to the Indian Ocean Climate Initiative.

In 1978 he and his wife Dr Avril O'Brien (nee Searle), a heritage expert and polymath, established an environmental and strategic consultancy which worked on a wide range of issues.

Professor O'Brien was elected a Fellow in 1993 and was an active member of the WA Division. In 2009 he became an Adjunct Professor of Physics at the University of Western Australia.

Listed in *Who's Who in the World*, his honours include the NASA Medal for Exceptional Scientific Achievement (the first Australian to receive this honour), the Centennial Medal, and a recent Order of Australia.

He continued his internationally significant space research well into his eighties, and played an enthusiastic role in the 50-year celebration of the Apollo 11 mission.

Brian died on 7 August 2020, aged 86. He and Avril had four children, nine grandchildren, and two great grand-children.

John Watt

Nuclear analyst held up an X-Ray to industry

John Stanley Watt FTSE was a world leader in x-ray radioisotope technology. After graduating from The University of Sydney with a Master of Science in 1956, he began work with the Australian Atomic Energy Commission as a Research Officer in the Isotope Division.

He became Head of the Radioisotope Applications Research Section in 1967.

In 1982, he was transferred to the CSIRO Division of Mineral Physics. He was appointed an Assistant Chief of the CSIRO Division of Mineral and Process Engineering in 1985, and returned to full-time research work as a CSIRO Fellow in 1995. He retired from CSIRO in 1997.

Mr Watt was a pioneering thinker who balanced laboratory research and field trials, and excelled in knowledge commercialisation. His breakthroughs in radioisotope x-ray analysis were applied in a range of industries, from mining to manufacturing and photography.

Discoveries he oversaw include a new method for the measurement of mass gas flow rate, a technique to analyse the copper and nickel in ore using gamma rays, and a method for eradicating termites.

Mr Watt was recognised with numerous awards, included a Centenary Medal and a Member of the Order of Australia "for service to the Australian mineral industry through the development and application of nuclear analysis techniques". He was elected a Fellow of the Australian Academy of Technology and Engineering in 1977 and was editor of the international research journal Nuclear Geophysics.

John Watt was an outstanding example of a scientist who can turn a penetrating understanding of complex physical phenomena to the solution of industrial problems. He died on 20 July 2020, aged 88. He was much loved by his wife Wendell, three children, eight grandchildren and two great grandchildren.

With thanks to the CSIRO

Maurice Mulcahy

A combustion doyen with an explosive career

Born in 1920, Dr Maurice Francis Robinson Mulcahy FTSE was a passionate scholar and a distinguished global authority on chemical kinetics.

He researched the propagation of explosives in liquids at the University of Melbourne during WWII and received his Doctor of Philosophy at Oxford University in 1948.

Dr Mulcahy began his 38-year career with the CSIRO researching the detonation of nitroglycerine under impact. He gained a reputation for keeping a cool, unruffled demeanour during extremely dangerous work in the lab. One colleague said "the retention of his limbs was ample testimony to his experimental ability."

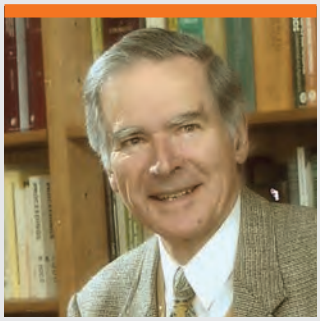
Dr Mulcahy brought his profound fundamental scientific skills to a range of practical applications, from coal combustion to atmospheric chemistry to the fouling of boiler furnaces. His acclaimed 1973 book Gas Kinetics was one of his many of publications.

In 1983 he became the first Australian to receive a Combustion Chemistry Award from the Royal Society of Chemistry. In the same year he began his long retirement, which he enjoyed with international visiting professorships; an honorary research Fellowship with the CSIRO; and his library of hundreds books covering his vast range of cultural and intellectual interests.

In 2003 Dr Mulcahy was awarded a Centenary Medal for his extensive research into the atmospheric chemistry of urban and industrial air pollution. His work influenced our understanding and management of these issues across the globe.

He was elected a Fellow of the Academy in 1980, and was a member of the Royal Australian Chemical Institute for an extraordinary 78 years.

Dr Mulcahy died on 31 January 2020, two weeks before his 100th birthday. He and his late wife Jeanne had five children and four grandchildren.



Ray Martin

Bridging the gap between academia and industry

Professor Raymond Leslie Martin AO FTSE FAA was the third Vice-Chancellor of Monash University, guiding it through a period when opportunities for growth were limited.

His ten-year appointment began in 1977 and coincided with a freeze in university funding. Seeking a path towards financial self-reliance, he built new centres for innovative research and graduate teaching at the university.

One of his projects was the birth of Montech, a high-tech consulting company owned by Monash University with the aim of marketing research and ideas rich with commercial promise. He also opened up contact with local industrial research laboratories such as BHP, Telecom and the CSIRO.

Professor Martin was a distinguished chemist in his own right. In 1968 he was awarded a Doctor of Science by Cambridge University for his contribution to the theory and practice of co-ordination chemistry and in 1978 he received a Doctor of Science from the Australian National University. He was the recipient of the Leighton Medal (1989), the Inorganic Chemistry Medal (1978), the Archibald Ollé Prize (1975) and the HG Smith Medal (1968).

When Professor Martin stepped down as Vice-Chancellor he continued until 1991 to work as a Professor of Chemistry at Monash and played a part in shaping science policy as Chair of the Australian Science and Technology Council.

In 1987 he was appointed an Officer in the Order of Australia (AO) for services to science and higher education, as well as a Fellow of the Australian Academy of Science. In 1989 he became a Fellow of the Academy of Technology and Engineering.

He's been described as a quiet, charming and approachable man and a scientist of high integrity.

He died 25 February 2020, aged 94.

With thanks to Monash University

Ron Hardwick

Manufacturing technologist applied insight to industry

Ronald Thomas Hardwick FTSE was an expert at identifying, assessing and implementing cutting-edge technologies to make companies more profitable.

Born in 1932, he studied Engineering at the University of Sydney and went on to advance a number of Australian industries, including in the paper and mineral sectors.

Mr Hardwick was a leading thinker in gas production and distribution, as well as cylinder manufacture and design. He held leadership roles at Commonwealth Industrial Gases (now BOC) and Associated Minerals.

Over his varied career, Mr Hardwick founded and directed AVT Services – a scientific vacuum and cryogenics provider – and was a Director of an automated home security company, Netra Holdings.

In 1985 he began working for Visy Paper and Pulp, where he oversaw the development of paper mills in Australia, Europe and the US, including the Tumut Paper Mill in NSW. He introduced a number of measures to improve energy efficiency and waste recovery in paper manufacturing processes.

Elected a Fellow in 2005, he was a keen member of the Energy Forum and NSW Division.

Ron Hardwick died on 2 April 2020, aged 87. He is survived by his wife Margaret, four children, seven grandchildren and four great-grandchildren.

Roy Woodall

A ground-breaking geologist

Born in Perth in 1930 to recent British migrants, Dr Roy Woodall AO FTSE FAA began work as junior clerk in the Hydraulics Division of the Public Works Department at 16.

He later completed his Bachelor of Science with honours at the University of Western Australia in 1953, and his Masters at the University of California in 1957.

Dr Woodall enjoyed a distinguished career with the Western Mining Corporation for nearly 50 years, working as a geologist (1953-1961), assistant chief geologist (1962-67), chief geologist (1967-68), exploration manager (1968-78), director of exploration (1978-95) and non-executive director (1996-2001). He was later director for Gympie Gold and Bendigo Mining.

Dr Woodall's scientific approach to mineral exploration revolutionised the industry. He introduced a new method to remove quartz from bauxite, and closely studied rock formations to find the shape and composition of mineral deposits.

Dr Woodall contributed to the discovery of crucial deposits around the country, including Olympic Dam, the fourth largest copper deposit and largest uranium deposit in the world.

He was elected a Fellow of ATSE in 1977 and made many contributions over the lifetime of the Academy. In 1981 he was made an Officer of the Order of Australia for service to the mining industry, and he was awarded numerous accolades throughout his career, including the Centenary Medal.

An influential member of many mining organisations, the Australian Geoscience Council has honoured his legacy with the launch of the Roy Woodall Medal.

Dr Roy Woodall died on 15 February 2021. He is survived by his wife Barbara, ten children, 30 grandchildren and six great-grandchildren.

Terry Cutler

A complex connector of science and arts

Dr Terrence Austin Cutler FTSE FAHA was a major contributor to public policy across an extraordinarily wide range of areas – from the humanities and arts to telecommunication, science, innovation and design.

Not only was he interested in these areas, he sought to build relationships between them. His colleagues describe him as creative, complex and conscientious.

Dr Cutler was born in 1948 and began his career in 1975 with Telecom Australia (now Telstra) as an analyst in the national telecommunications planning branch. This team was behind Telecom's decision to become one of the first digital data networks in the 1980s.

He went on to become the executive director, Corporate Strategy, overseeing major regulatory change before leaving in 1991 to establish his own advisory company, Cutler & Company.

In 2002 he was appointed to the board of CSIRO – a role he held until 2012 and which combined his interests in public policy, good business practice and corporate governance.

During this period he also chaired the Federal Government's review of the National Innovation System, which culminated in the report Venturous Australia. In his covering letter to the minister he wrote, "Innovation is not the problem; it is the answer. Innovation is not the opportunity; it is the imaginative response to opportunities."

Dr Cutler also generously devoted his time and expertise to the arts and education sectors.

He was president of the Australian Centre for the Moving Image from 2002-2005 and chair of the Australia Council from 2001-2002. He also served as a director of Cinemedia, Film Victoria, Opera Australia, The Council of the Victorian College of the Arts, the Melbourne-based contemporary dance company Chunky Move and the Library Board of Victoria.

The breadth of Dr Cutler's contribution to Australian public policy saw him elected fellowships to the Institute of Public Administration (2003), the Australian Academy of Technology and Engineering (2008) and the Australian Academy of the Humanities (2010).

He died in July 2020, aged 72.

Owen Potter

A distinguished chemical engineer making the skies clearer

Emeritus Professor Owen Edward Potter AM FTSE was a seminal figure in chemical engineering in Australia and internationally.

An original and remarkable thinker, he invented a process to dry particulate solid materials, alumina and brown coal which not only reduced emissions at power stations by 20 percent but also decreased operating costs. The invention was patented in 1981 and won him numerous awards and accolades.

Owen Potter was born in Brisbane in 1925 and on leaving school won a scholarship to study science at the University of Queensland where he graduated with first-class honours in chemical engineering. He spent the next two years working as a researcher on a training scholarship from CSIRO while studying for his master's degree in applied sciences.

In 1949 he was awarded another scholarship to study a second master's degree in history and philosophy of science at the University of London. A teaching post at the University of Manchester followed and he used the time to complete a PhD by research in chemical engineering.

Professor Potter returned to Australia in 1960 as a reader in chemical engineering at the University of Melbourne and soon after concurrently took on the role of head of the Department of Chemical Engineering at RMIT. He began a 26-year tenure at Monash University as the foundation professor of chemical engineering in 1964.

He continued to apply his mind well into his 90s, setting up and chairing a family-directed company, OEP Cross-Flow, whose mission was to commercialise globally the patents for his invention of a gas particle cross-flow contactor.

Professor Potter's wife Julia died in 2010. He is survived by seven of their eight children.

Prince Philip

An advocate for engineers

The Australian Academy of Technology and Engineering was honoured to have Prince Philip as its one and only Royal Fellow.

The Duke of Edinburgh was a strong supporter of the Academy's establishment and was inducted as a Fellow in 1977, just one year after the Academy was inaugurated.

Prince Philip met with ATSE Fellows on a number of occasions and had an interesting debate with Foundation President Sir Ian McLennan on the concept and scope of the technological sciences.

He also held engineers in high regard.

In an interview with the BBC Radio 4's Today program in 2015, Prince Philip said "everything not invented by God is invented by an engineer".

He went on to add that engineers hold the key to the future of humanity and its ability to continue to thrive on the planet.

Prince Philip died on 9 April 2021, aged 99.

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Forest Stewardship Council® (FSC®) — fsc.org
FSC is an international, non-governmental organisation dedicated to promoting responsible management of the world's forests. FSC has developed a system of forest certification and product labelling that enables people to identify responsibly sourced wood, paper and other forest products.

FSC runs a global forest certification system with two key components: *Forest Management* and *Chain of Custody* (CoC). The certification process is carried out by independent organisations called certification bodies, which assess forest managers and forest products companies against FSC standards.

Forest Management
FSC certified forests must be managed to the highest environmental, social and economic standards. Trees that are harvested are replanted or allowed to regenerate naturally. The forests must be managed with due respect for the environment, the wildlife and the people who live and work in them. This is to ensure that a forest is well-managed, from the protection of indigenous people's rights to the methods of felling trees. FSC is the only forest certification scheme endorsed by WWF, Greenpeace and Planet Ark.

Chain of Custody (CoC)
FSC chain of custody verifies that FSC-certified material has been identified and separated from non-certified and non-controlled material as it makes its way along the supply chain, from the forest to the market.

Postal envelope
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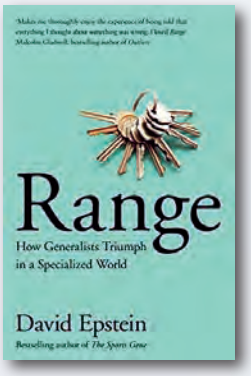
What we're reading



Range: How generalists triumph in a specialized world

David Epstein. *Macmillan 2019*

"Scientists and members of the general public are about equally likely to have artistic hobbies, but scientists inducted into the highest national academies are much more likely to have avocations outside of their vocation. Nobel laureates are at least 22 times more likely to partake as an amateur actor, dancer, magician, or other type of performer."

Range is a pop-science/self-help book that argues against the cult of 10,000 hours and obsessive specialisation, both at an individual and an organisational level, as the most effective path to success.

Instead, David Epstein tries to show that generalists are the ones who have achieved the most impactful innovations and the most memorable art, and have done so, not in spite of, but because their time spent "dabbling" in diverse interests.

Epstein's generous use of high profile case studies makes this enjoyable reading that moves along at a clip. Epstein invokes Charles Darwin, Roger Federer, and NASA's failed Apollo mission to show how broad knowledge and early sampling in different fields is an advantage. These are presented in contrast to examples of early specialisers (Tiger Woods, the Polgar sisters) who spent their childhoods perfecting their craft to excel into adulthood.

But this strength is also a weakness: while very interesting, a series of case studies does not make a strong body of evidence, no matter how compelling. Ironically, it is when the book delves too deeply into scientific literature that it becomes least convincing, especially when you check the original studies.

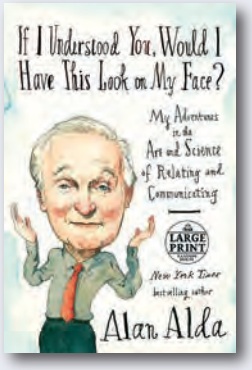
In familiar chapters, Epstein also explores how the hyper-specialisation of science has decelerated the pace of breakthrough discoveries. The cross-pollination and creativity that comes from broad knowledge or experience in multiple different schools is actively disincentivised.

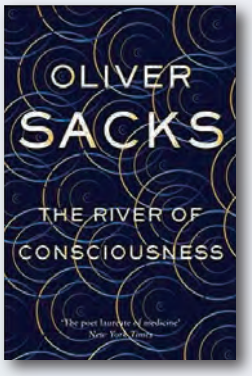
Basic research, exploratory research – which has been recently spotlighted as part of the reason we were able to develop COVID-19 vaccines faster than previously thought possible – is not encouraged under the current system that is set up to reward specialists.

If you already believe in the concept of T shaped people or being a jack of all trades, this book will do nicely. If not, you probably won't be convinced, but will leave with some fun trivia to inject into your water cooler conversations (Did you know Van Gogh's most acclaimed paintings are from the last three years of his life, after he spent his previous years trying other things?).

Don't expect any practical advice about how to become more of a generalist.

Review by Dr Esa Chen





If I understood you, would I have this look on my face?

Alan Alda. *Random House*

If I understood you, would I have this look on my face? is Alan Alda's adventure to discover how to communicate effectively. For 20 years, Alda had been trying to understand why communicating seemed so hard, especially when trying to explain something complicated.

Some years ago, Alda helped found the Center for Communicating Science at Stony Brook University in New York. Scientists, it turned out, are the perfect example of individuals who must be able to communicate effectively at a fundamental level to share knowledge with the most diverse audiences – the public, other scientists, politicians, business leaders.

In his endeavour, Alda draws on his training as an actor, his expertise in improvisation, and his experience with scientific communication to deliver a warm, funny and enlightening chronicle on communication through connection.

The book explores the need to understand others in order to communicate with them and draws on Alda's 20-year journey to figure out how to better use empathy to achieve a deep form of listening.

The book is a witty and gentle exploration of the key ingredients which make effective communication possible.

The key, as he puts it, is to truly connect with your audience. Alda reminds us that our brains are wired to receive the thoughts and feelings of others, and that most of us have the hardware already – all we need to do is connect.

Review by Jasmine Francis

The river of consciousness

Oliver Sacks. *Picador*

"Memory," writes the late neurologist Oliver Sacks, "arises not only from experience but from the intercourse of many minds." That "common mind, the general commonwealth of knowledge" unfurls through this posthumous collection of Sacks' essays: a vivid tapestry of cutting-edge research, scientific history, fascinating case studies and anecdotes from the polymath's own life.

One essay charts Darwin's epiphany that flowers sexually reproduce, and co-evolved with the insects that pollinate them. Another delves into Freud's early work in neuroscience and "dynamic and constructional view of the brain" which anticipated later research by half a century.

In *Scotoma: forgetting and neglect in science* Sacks explores the strange role that "contingency, or sheer luck" plays in the discovery, loss and rediscovery of knowledge. If Charles Babbage's "... theoretical difference engine – a computer – had been built when he proposed it 1822, might the course of science have been quite different?"

Many of the pieces chart the emergence and operation of consciousness, from the mental lives of sea-slugs to the intricacies of creative thought. Reading Sacks can even be a meditative experience: when he writes that "a single conscious visual percept may thus entail parallel and mutually influencing activities of billions of nerve cells" I imagined the protean fractal of my own neural connections processing the sight of the ink on the page.

Sacks' illustrative personal stories infuse his analysis with warmth: one charming essay examines the quirky mishearings that beset him in his 80s. Sacks finalised the contents of the collection two weeks before his death from cancer, and writes with extraordinary frankness about his own ill body's biology.

For a book that deconstructs the process of human sentience, *The river of consciousness* is amazingly humane. Lucid, lyrical and compelling, this is a great work of science communication from an endlessly curious mind.

Review by Ben Hickey

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