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AUSTRALIA

INFRASTRUCTURE RENEWAL

Building resilience through
proactive maintenance

44

HEATWAVE-PROOF CITY

Optimising our cities for
thermal comfort

52

GRID OF THE FUTURE

The transition to clean energy means
power systems need to adapt

58

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Engineering resilience

The innovative approaches preparing
Australia for future extremes



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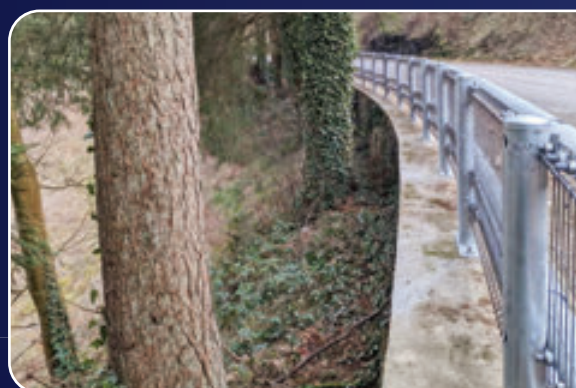
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Contents

LEADERSHIP

09

News

Chief Engineer Katherine Richards on why it's essential for engineers to lead.

13

President and CEO

When engineers lead with courage and collaborate, we unlock resilience.

14

The big picture

How climate extremes are making resilience more vital than ever.

16

Decision-maker

Dr Anne Gibbs reveals how understanding cultural drivers is vital to project resilience.

22

Career path

For sustainability leader Joan Ko, change isn't linear, but rears its head when least expected to galvanise a project.

26

Essay

Harnessing existing energy resources is almost always cheaper than building new infrastructure.

IDEAS

32

Blue-sky thinking

How do we shockproof core systems against future threats?

34

Engineering a resilient future ▼

In the face of unprecedented climate extremes, entire cities must be built to bounce back, adapt and thrive.

44

The long game

Why Australia is yet to make the most of the maintenance imperative.

52

Heatwave-proof havens ▼

Engineers are reimagining how we cool and live in a built environment threatened by soaring temperatures.

58

Power under pressure

The energy sector of the future may be at risk of catastrophe if we don't foster a more resilient system.





EXPERIENCE

90

Disaster feature

How an outbreak of waterborne disease that infected more than 400,000 people changed water treatment regulations.

66

The corrosion conundrum

It costs Australia \$78 billion each year, so how are engineers working to protect critical infrastructure from corrosion?

PROJECTS

74

Lightning fast

Meet the company delivering optical transceivers to more than half of the world's internet traffic.

78

Supply chain solution ▼

From improving lithium-ion battery safety to making AI chips cooler, high-purity aluminium is in huge demand.



84

Cleaner clinker

A new chlorine bypass system promises to reduce Scope 1 emissions from concrete manufacturing by 75,000 t.

94

The look back

Pneumatic tube transport used to be all the rage – but some would argue it never truly went away.

96

Events

Upcoming events for your calendar.

97

Resources

What you should be reading and watching.

98

The lesson learned

Dr Helen Edmonds on staying level-headed and questioning all assumptions.



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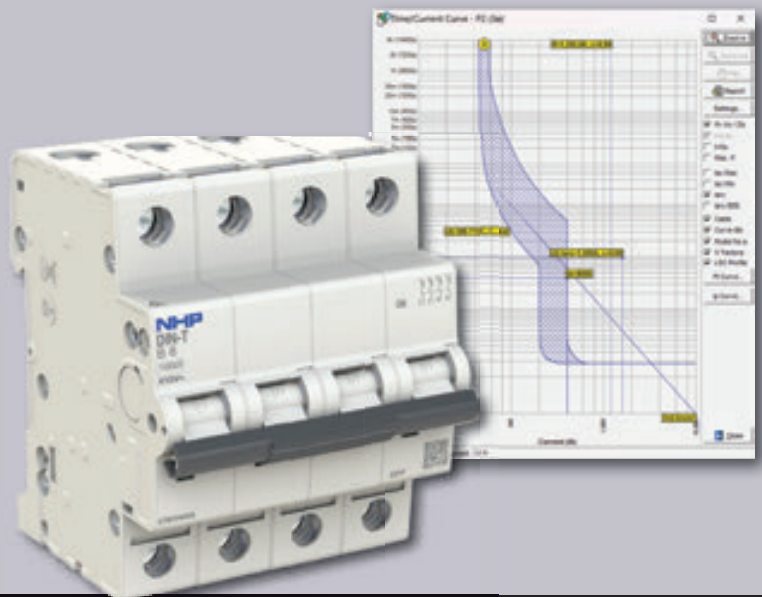


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- ✓ **Clause 2.5.7.2.3** supply circuit discrimination with option for checking protective devices less than 250amps
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- ✓ **Clause 5.7.4** earth system impedance check at 0.4s and 5s disconnect times





Words by Joe Ennis

Engineers must lead

After decades in navy engineering, Katherine Richards AM HonFIEAust CPEng EngExec isn't interested in hierarchy. She's focused on action and believes engineers should be too.

As I sat down to interview Katherine Richards, Engineers Australia's newly minted Chief Engineer, on her priorities in the role, the first thing she did was ask me about myself. This disarming technique was not a conscious gambit, but a genuine reflection of her curiosity about those around her. And that curiosity is essential to her vision for the role.

Her central goal is to change how engineers see themselves – not just as technical experts, but as leaders of social change.

"We won't solve the big problems until engineers stop being bystanders," Richards said. "Leadership isn't about titles. It's about accountability, empathy and being willing to act."

She points to engineers' diversity of experience that makes them ideal, and essential, leaders.

Richards brings 36 years of experience in the Royal Australian Navy to the role, but every engineer works to the same set of rules.

"The thing about military and civilian engineering is that the context might differ, but the principles are the same. You deliver under pressure, within constraints, but always towards a clear objective."

For Richards, taking on this new challenge was an easy decision. "I see it as a natural extension of what I've always done – enabling others to solve real-world problems that matter to our country."

Another key priority is fostering greater diversity, particularly around the low number of women in the

profession. But Richards is clear: this is not about tokenism or quotas, but a strategic imperative to help meet workforce needs.

"We need to redefine what 'normal' looks like. That means acknowledging the barriers women and other underrepresented groups face, and not shying away from complex conversations about bias and systems that don't work."

Her approach is rooted in humility. "The impact I have won't be measured by me. It will be judged by the experiences of others – by whether they felt seen, supported and empowered."

Richards outlines three major national imperatives: climate resilience, energy transformation and advanced manufacturing.

"You don't lead with titles. You lead by stepping up when it matters."

"We're already doing the work in pockets," she said. "But we need coordinated, courageous engineering leadership to take it further."

Underlying all of this is a fourth theme: sustainability. Not as a buzzword, but as a mindset. "It's about respecting the resources we use and the people involved – whether you're designing a battery or a warship."

Asked what value guides her most, Richards doesn't hesitate. "Respect. It's the foundation of good engineering, good leadership and a good society."

She added with a grin: "Also, never stop learning. I was studying quantum physics at 54. It nearly broke me – but that's what engineers do. We keep learning so we can keep creating." □



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[Leadership]



16

Decision-maker

Knowing how an asset will be used by the community will deliver better infrastructure.

13

President and CEO

Resilience engineering is a mindset, a discipline and a critical responsibility.

14

The big picture

Visualising the impact of climate disasters on infrastructure.

22

Career path

"I don't want to be the person with all the answers. I want to make it safer to ask better questions."

26

Essay

Why distributed energy resources could power at least half of the future energy system.

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FROM THE NATIONAL
PRESIDENT AND CEO



Engineering resilience

Welcome to the latest edition of *create*, focused on one of the most urgent and defining challenges of our time – engineering resilience.

While engineering has always been about finding solutions, in 2025, we're confronting

challenges that are deeply interconnected, globally shared and generational in impact.

But we remain optimistic. Because when engineers lead with courage and collaborate across disciplines, we unlock the resilience and ingenuity on which our future depends.

This issue coincides with our flagship Climate Smart

Engineering conference (CSE25), taking place this month in Adelaide. Its theme, *Resilience engineered: Solutions for our climate reality*, captures both the urgency and the opportunity before us.

As engineers, we are being called upon to respond, lead and reimagine the systems that support life, industry and society in the face of accelerating climate extremes.

Resilience engineering is a mindset, a discipline and a critical responsibility. We are witnessing climate impacts firsthand: longer and more intense fire seasons, catastrophic floods, severe droughts, rising insurance premiums and pressure on infrastructure across every sector. These impacts are being felt by communities across Australia and the globe, and the

engineering response must be equally far-reaching.

From adapting cities to withstand heatwaves and floods, to prolonging the life of existing assets through smarter maintenance, *create* speaks to the engineers who are finding new ways to make our systems not just stronger, but smarter.

None of this work is easy. The challenges we face – such as energy security, climate adaptation and critical infrastructure renewal – are more complex and urgent than ever before. With knowledge, precision and purpose, engineers are rising to the challenge.

This is the essence of climate-smart engineering. CSE25 brings us together to share expertise, drive practical solutions and accelerate collective progress. It reflects the best of what our profession offers: solutions grounded in evidence, systems thinking, innovation and an unwavering commitment to the public good.

At this year's conference, we're hearing from leading engineers, researchers, industry game changers and policymakers.

Together, we are shaping the engineering solutions that our climate reality demands – engineering a more resilient Australia for today and for the next generation.

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The big picture

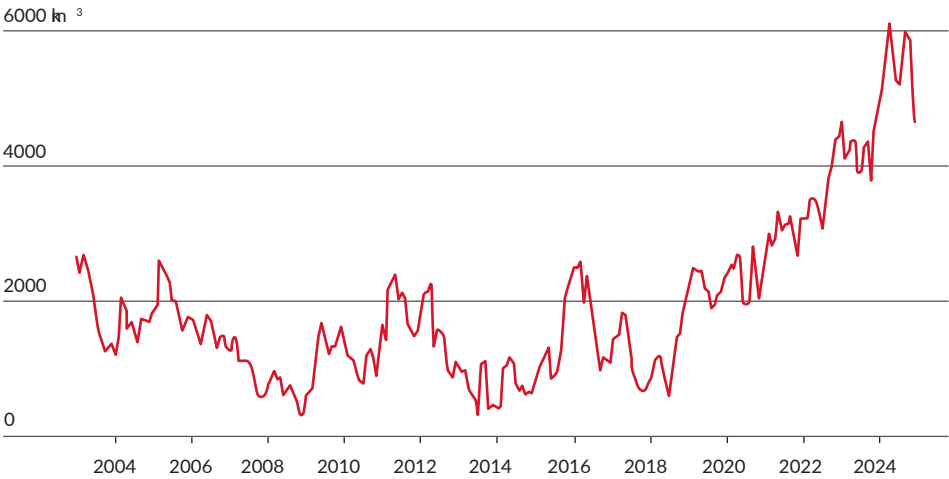
With a changing climate impacting the economy, infrastructure and more, building resilience in the built environment has never been so important.

Figure 1

Monthly intensity of droughts and floods by global area affected, Jan 2003 to Dec 2024

Wild weather

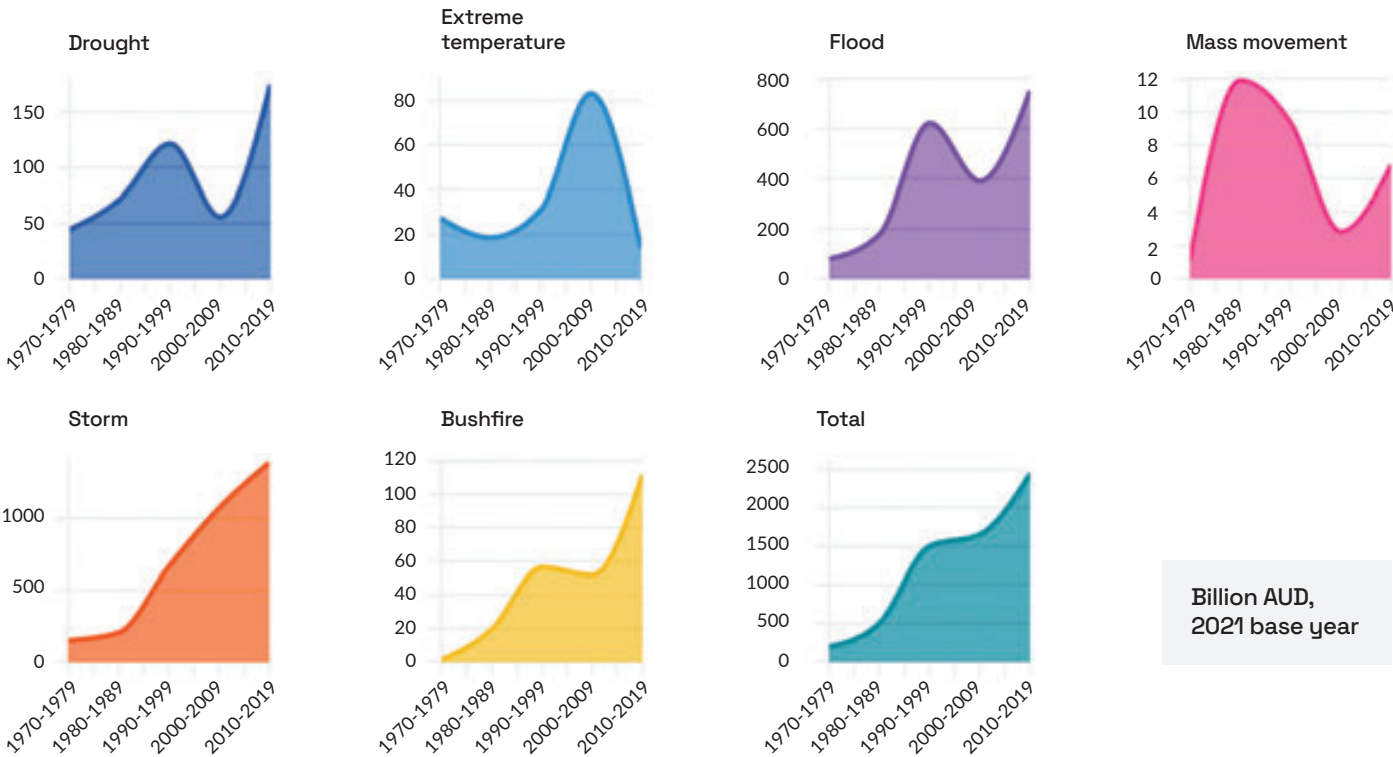
The intensity and frequency of natural disasters and wild weather have increased markedly in recent years, with a significantly greater area of the world being impacted by disasters such as droughts and floods.



Economic losses

Natural disasters exacerbated by a changing climate are exerting a heavy impact on society, the economy and the built environment. Since the 1970s, the economic cost of these disasters has increased sevenfold, with the global cost increasing from an annual average of \$198 billion in the 1970s to \$1.6 trillion in the 2010s.

Figure 2 OECD data reveals economic losses from extreme events impacted or caused by a changing climate



Billion AUD,
2021 base year

Figure 3 How climate change-induced disasters can impact the built environment

Impact on infrastructure

From flooding to droughts to bushfires, climate change affects the built environment, and transport and energy systems in different ways. As identified by the OECD, here are just some of the impacts, which reveal an across-the-board effort towards building resilience.

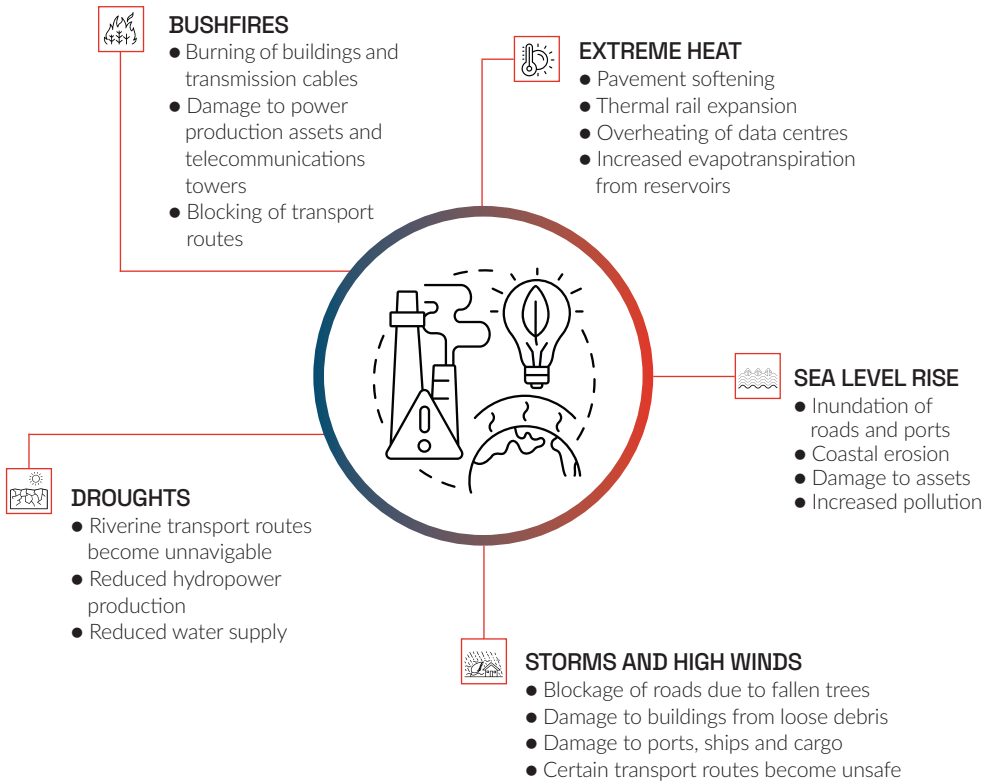
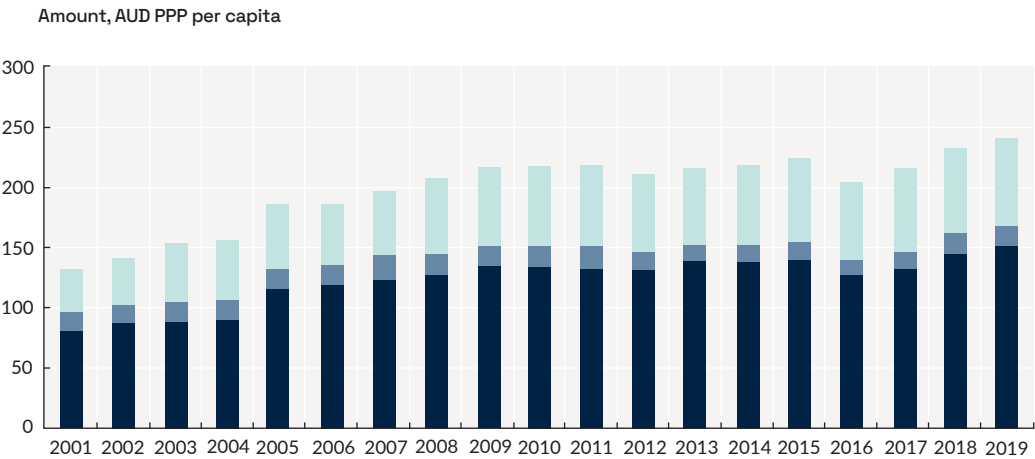


Figure 4 Climate-significant investment by level of government in OECD countries, AUD PPP per capita (real terms)



Investing in climate resilience

To address the issue of a changing climate and improve the resilience of countries' infrastructure, investment is needed. OECD data reveals an increase in climate-significant public investment from regional and local governments.

New developments present an opportunity to build the ethos of climate resilience into projects from the outset, improving the cost viability of those projects and decreasing the need to maintain and retrofit existing assets.

- Local government
- State government
- Central government

Part of this story is an adaptation of an original work by the OECD. The opinions expressed and arguments employed in this adaptation should not be reported as representing the official views of the OECD or of its Member countries.

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NASA (2025), NASA GRACE / GWI, Rodell and Li via *The Guardian*



Words by Chris Sheedy

Local insight enables stronger infrastructure

A career spent designing infrastructure solutions has proven to Dr Anne Gibbs FIEAust EngExec the undeniable connection between culturally informed engineering and truly resilient outcomes.

The purpose of resilient engineering was made abundantly clear to civil engineer Dr Anne Gibbs FIEAust EngExec, CEO of the Asset Management Council, when she travelled to the Indonesian island of Nias following a destructive earthquake in 2005.

More than 1000 people had died during the event, with around 30 per cent of buildings in the city of Gunungsitoli collapsing. A large part of the role played by Gibbs, an engineer deployed with RedR Australia, was to assess public infrastructure damage, including schools, hospitals, roads, churches and bridges.

Most of the houses that had collapsed, she realised, were built from concrete. These larger, more substantial homes typically belonged to affluent residents, while those with less wealth lived in modest, wooden houses. Those traditional houses had remained intact while the heavier concrete ones crumbled as a result of poor structural design and an absence of reinforcing and tie beams.

"It happened while everyone was asleep, so a lot of wealthier people in these houses died," said Gibbs, who has also served for several years as an adviser to the Coalition for Disaster Resilient Infrastructure.

"Then, the people in the mountains who wanted to bring their rubber to the businessmen, who would sell it onwards, had no-one to sell their rubber to. Therefore, they couldn't earn enough money to buy rice. They began to starve. Everything we do as engineers affects all of society; it all has a knock-on effect."

Gibbs has carried out similar roles elsewhere. In East Timor, under military protection, she helped women establish a

sustainable hostel after many of the region's men had been killed during Indonesian occupation. In Africa, with the United Nations Refugee Agency, she worked among refugee communities along the Rwanda-Tanzania border. And in Romania, she helped tackle waste management challenges that had significantly threatened public health.

What does any of this have to do with infrastructure asset management and resilience in Australia? Plenty, she said. And the sooner we learn these lessons, the better the outcomes will be.

Close collaboration crucial

In Australian engineering right now, Gibbs said, there is a strong focus on the design and construction phase. But, increasingly, engineers are realising that resilience and sustainability, as well as best-practice risk management, comes only from whole-of-life planning, including operation, maintenance and decommissioning, or circular repurposing.

"The operation and maintenance phase of a project represents about 80 per cent of the cost over the life of the asset," she said. "There's a great opportunity to improve how it's being done."

A thorough consideration of the operation and maintenance phase looks at material selection for the intended use for the full period, including reuse at end of life. It plans for integration with the infrastructural, human and natural ecosystems around it. And, in an age of increasing climate-induced severe weather events, it allows for climate adaptation, demonstrating a deep understanding of disaster risk reduction.

None of this is possible without close collaboration with all stakeholders, particularly end users and others in the local community.

"The reason I was successful on Nias Island was because, as soon as I went there, I went to see the town chief," Gibbs said. >

LEFT: Dr Anne Gibbs FIEAust EngExec, Asset Management Council.

"The operation and maintenance phase of a project represents about 80 per cent of the cost over the life of the asset. There's a great opportunity to improve how it's being done."



“Resilience in engineering is about breaking the damage cycle. It is an investment in the future, in the entire lifecycle. It is about risk reduction for the future and long-term planning, which demands an asset management approach.”



"He immediately gave me resources to help me, and the ability to connect to the local public works department and to others in the community, who helped me understand exactly where the worst areas were, and what was and wasn't needed.

"You need to work in collaboration with the local community if you want to be effective and provide infrastructure people will use and maintain."

All projects, whether designed for a modern city centre or in the middle of a disaster zone, must be community-driven, as opposed to engineered solutions imposed from above, or from the outside.

Gibbs's doctoral research, focusing on cultural risk in engineering projects, revealed that even the most technically sound projects can fail if they don't align with local customs, social structures or governance systems. And so, understanding the way people work, how they connect, what drives their decisions and more, is vital to project success.

A lack of understanding of the way people will use a piece of infrastructure during its life, and how they will move, live and work around it, will add cost at best. At worst, it will result in complete failure, potentially bringing injury or death.

"It may be you don't end up wanting to build the originally planned structure at all," she said. "It might be better to look at a do-nothing approach. Or perhaps it should be repurposed as something else.

"You can't just come in as an engineer and think, 'This village needs a well, so I'll do them a favour by drilling one right in the middle of the village.' Because it's absolutely possible the daily walk to get water is vital to the people in a number of other ways."

How Australia's engineers can do better

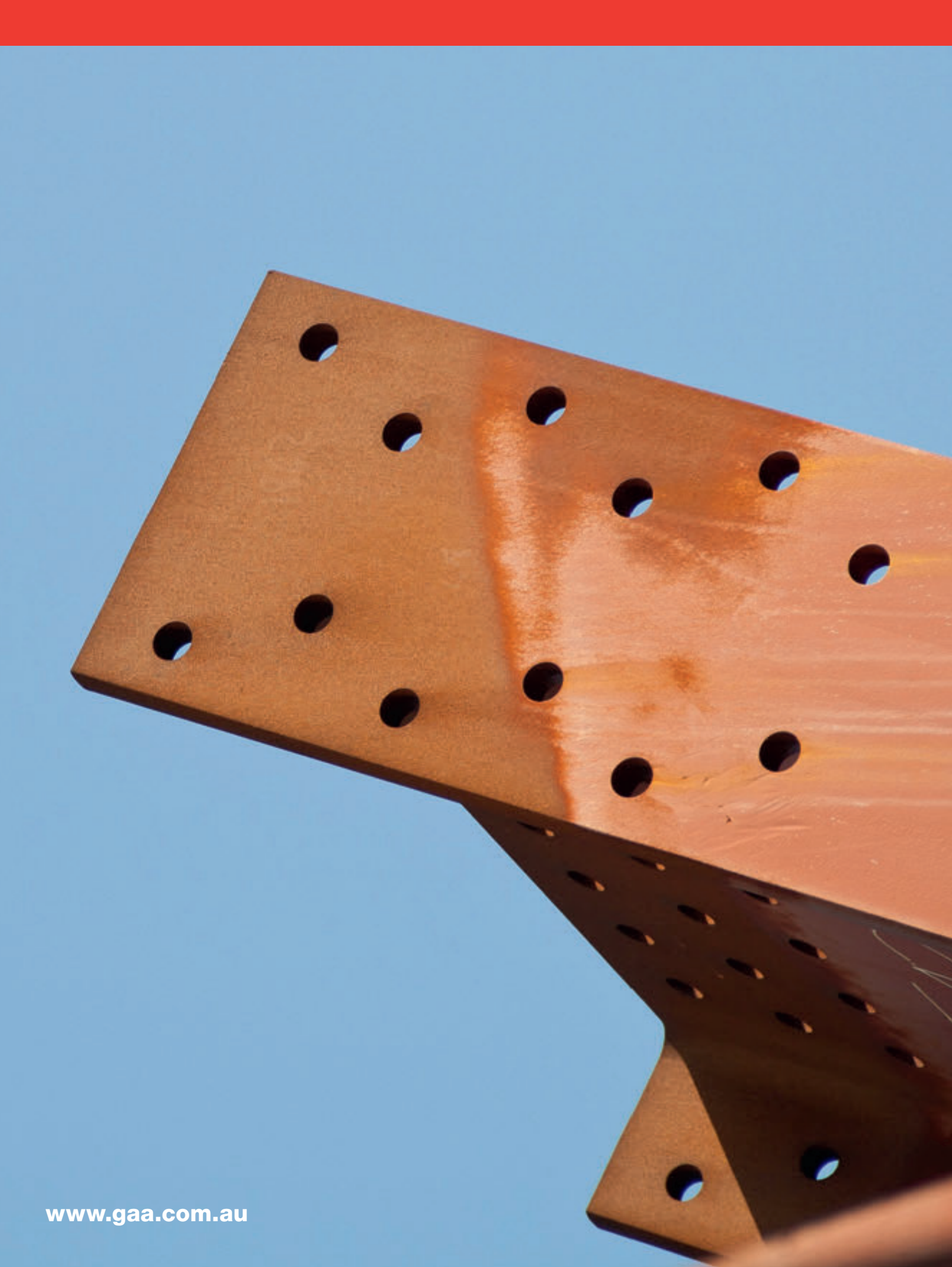
Gibbs's research, knowledge and experience confirm that resilient engineering isn't just about stronger materials or smarter technology, but also about integrating cultural understanding into decision-making.

In disaster recovery, in city planning and in all other facets of infrastructure development, engineers must work harder to factor in aspects of the human and cultural experience.

"All of this is important because, as engineers, we want to make the world a better place," Gibbs said. "We do our work because we want to improve society.

"Resilience in engineering is about breaking the damage cycle. It is an investment in the future, in the entire lifecycle. It is about risk reduction for the future and long-term planning, which demands an asset management approach.

"Most of all, it is about involving the community so you know up-front exactly how that asset is going to be used, operated and maintained. Combine that with the excellent technical engineering that we do so well in Australia, and we'll be able to realise better value from our infrastructure." □





Avoid a corrosion disaster

As a specifier for your building project, understanding the impact of the environment on steel is crucial when considering corrosion protection.

The Galvanizers Association of Australia (GAA) and its members possess extensive knowledge on the appropriate level of coatings required for various environmental conditions giving you the confidence that your coatings will comply with the Australian Building Codes Board's new ABCB Housing Provisions Table for corrosion protection.

Don't risk a corrosion disaster – trust the expertise of the GAA.

**For more information scan the QR code
and look for Advisory Note 49**





As told to Julia Abbondanza

Designing systems of resilience

From environmental engineering to systems transformation, Arup's Climate and Sustainability Leader, Joan Ko, is building a more resilient future one framework at a time.

As I stepped into the Melbourne planning panel room a decade ago, my heart was pounding. We were rolling out an evidence base to embed quantitative sustainability benchmarks into the city's planning scheme for the first time – no small feat.

Three months ago, my boss shrugged on his backpack and, honeymoon-bound, said to me, “Joan, you are now the expert”.

Now, facing a room full of barristers and panel members, I felt intimidated, but prepared. Thanks to Arup's support (and a coach), I stood my ground, answered every question and walked out knowing I could both speak the technical language and translate its impact.

That moment crystallised what resilience truly means for me. Resilience isn't just about enduring adversity; it's about taking every challenge as a moment for learning so we get better every time. Today, I carry that lesson into every project.

Whether I'm guiding drought-sensitive precinct design, advising on flood-resilient rail projects, or weaving social impact into the energy transition, my mission is the same: build places that don't just survive, but which evolve through crises.

Chasing water, not titles

I grew up in a suburban corner of Australia, the daughter of immigrants who prized stability, but also encouraged me to find work that mattered.

Engineering made sense. But I've always loved storytelling, and

I think that combination is what ultimately led me to systems thinking.

From my earliest memories, water fascinated me. Growing up during the Millennium Drought made every drop feel precious. When I first enrolled in environmental engineering at Monash University, I wasn't sure exactly where it would lead, but I knew I wanted future Australians to have the chance to experience the environment like we did.

But back then, I couldn't have told you what the job would be. It didn't exist yet.

After university, I followed my boyfriend, now my husband, to the UK. I told myself I needed something to do in case the relationship didn't work out, so I signed up for a master's in sustainable development. It turned out to be a pivotal moment.

In the UK, no one wanted to talk about drought. “Water just falls out of the sky here,” someone told me. Instead, I found myself deep in carbon policy and city design. I returned to Australia in 2010 with a completely new lens.

From local projects to regional strategy

Back home, there was a lot of momentum for sustainability. Suddenly, climate-positive precincts and zero-emission planning were on the agenda.

I drove my first major project at Fishermans Bend, translating grand decarbonisation ambitions into concrete precinct-level requirements. Watching those precinct plans go from paper to policy to pavement taught me that big visions demand rigorous processes and persistent advocacy. >

LEFT: Joan Ko, Arup.

“Resilience isn't just about how strong your bridge is. It's about how connected your community is when disaster strikes.”



LEFT:
A lot of Joan Ko's
work is relational
rather than technical.

Resilience isn't just about how strong your bridge is. It's about how connected your community is when disaster strikes.

Eventually, I stepped into management roles, but when Arup adopted Sustainable Development Goals as part of its mission, I knew it was time to go back to the "why". I called up senior leaders and said I wanted in. That conversation helped shape the creation of the climate and sustainability services team which I led in its formative three years in Australasia.

I am now stepping into a new leadership position overseeing Arup's global climate and sustainability team.

Learning from disruption

I often find that people reduce resilience to hard infrastructure – things like flood defences or backup

power systems. That's part of it. But to me, resilience is just as much about people as it is about place. I care most about whether we're learning.

From a professional point of view, there are dozens of frameworks and indicators around resilience. But the perspective I'm particularly passionate about is our capacity to learn from disruption – to adapt, adjust and improve each time.

We've had royal commissions into bushfires over and over again. We have the knowledge, but do we actually act on it? Do we share it? During an emergency response, for example, everyone's got the data they need tucked away in silos.

For example, in April this year, mobile phones stopped working during the Spain-Portugal electricity blackout. If that happened in Australia, I understand that

telecommunication providers would not be able to track power status or estimate the time for electricity to be restored. Unless we find ways to trust each other enough to use this information, we're not maximising what we know.

This is the kind of work I do: helping our clients move from insight to action, from resilience in theory to resilience in practice.

One of the most exciting shifts I've seen is that resilience is finally being seen as interdisciplinary. It's not just about assets and infrastructure; it's about communities, Country and culture.

I often remind colleagues that change is not linear. You build foundations, deep foundations, and for a long time can't see evidence of that change. Then, all of a sudden it seems like, overnight, a skyscraper is up.

That analogy applies to climate action: years of stakeholder alignment, de-risking standards and data platform builds. Then one moment, a flood-resilience investment or a net-zero precinct plan launches and everything shifts.

Listening as leadership

A lot of what I do now isn't just technical, it's relational. That's especially true when we talk about integrating First Nations

"Change is not linear. You build foundations, deep foundations, and for a long time can't see evidence of that change. Then, all of a sudden it seems like, overnight, a skyscraper is up."

knowledge into engineering and sustainability work.

Our greatest contribution to meaningful engagement is not in the outcome, it's in the process.

For a long time, engineering treated Indigenous knowledge as something we could extract, or something to slot into a report or bolt onto a project. But that mindset misses the point for me. It's not about extraction; it's about respect.

One of the privileges – and responsibilities – of my role is to create enduring structures that help us to consistently and meaningfully deliver on this respect through our work. At Arup, we appointed a dedicated First Nations project leader, Melanie Grills, to help reframe our expectations. It means these questions aren't just a “nice to

have”, but are a core part of our work as leading project engineers.

We also need to be honest about the bias in our systems. As engineers, we're trained to prioritise written and quantitative information. That excludes a lot of knowledge that's passed on orally or experientially, which is central to First Nations cultures. Our job isn't to replace that knowledge with our own. It's to create space so that Traditional

Owners can lead, inform and shape outcomes in ways that honour our shared responsibilities to Country.

I apply the same principle in leadership. I don't want to be the person with all the answers. I want to be the person who holds the space, someone who makes it safe to ask better questions and helps people see themselves as joint custodians of their organisations, community and place. □

RIGHT:
Visualisation of
Plummer Street in
Fishermans Bend,
Melbourne. Image:
City of Port Phillip
BELOW: Aerial view
of Fishermans Bend.



The distribution revolution

While Australia has more rooftop solar per capita than any nation, policy and regulation lags mean the potential for distributed energy resources to expedite the energy transition is yet to be fulfilled.

Words by Dr Gabrielle Kuiper



This is an edited extract from the Accelerating the energy transition essay series. The full essay can be found on the Engineers Australia website.

Distributed energy resources (DER) are small-to-medium-scale energy resources connected to the distribution network, either in front of or behind the meter.

There are three broad categories of DER:

- Distributed generation – Electricity generated at or close to the site of use
- Energy storage – Capturing energy locally produced at one time for use at a later time
- Flexible demand – Appliances or machines which are able to have their time of use altered passively or dynamically

Greater uptake and better integration of DER has the potential to speed up and help lower the overall cost of Australia’s transition to 82 per cent renewables by 2030.

Far from being “at least 20 per cent of our energy solution”, DER could be at least half of the future energy system.



ABOVE:
Dr Gabrielle Kuiper,
Institute for Energy
Economics and
Financial Analysis.

Solar leadership

Australia is the leading country in rooftop solar (RTS) when measured in watts per capita. This means, to date, households and businesses have invested well over \$25 billion in DER. With Federal Government subsidies having commenced on 1 July 2025, they will soon invest many billions in home and business batteries.

RTS is now capable of meeting at least half of the underlying energy demand across the National Electricity Market (NEM) in the middle of a sunny day.

Occasionally, the entire state of South Australia is fully supplied with electricity by RTS in the middle of the day. This first occurred on 23 September 2023, when RTS supplied 101 per cent of South Australian electricity (see Figure 1).

DER’s future in the energy system

The Australian Energy Market Operator’s (AEMO) Integrated System Plan (ISP) projects that by 2050:

- RTS and other distributed solar will be the largest source of generation capacity at 86 GW.
- 79 per cent of households will have rooftop solar.
- 56 GW/660 GWh of storage capacity will be needed.
- Coordinated consumer energy resources storage will be 37 GW.

However, even AEMO’s 2024 ISP step-change scenario is conservative as it does not assume any vehicle-to-grid capacity before 2030. >

Figure 1: Installed rooftop solar capacity by year

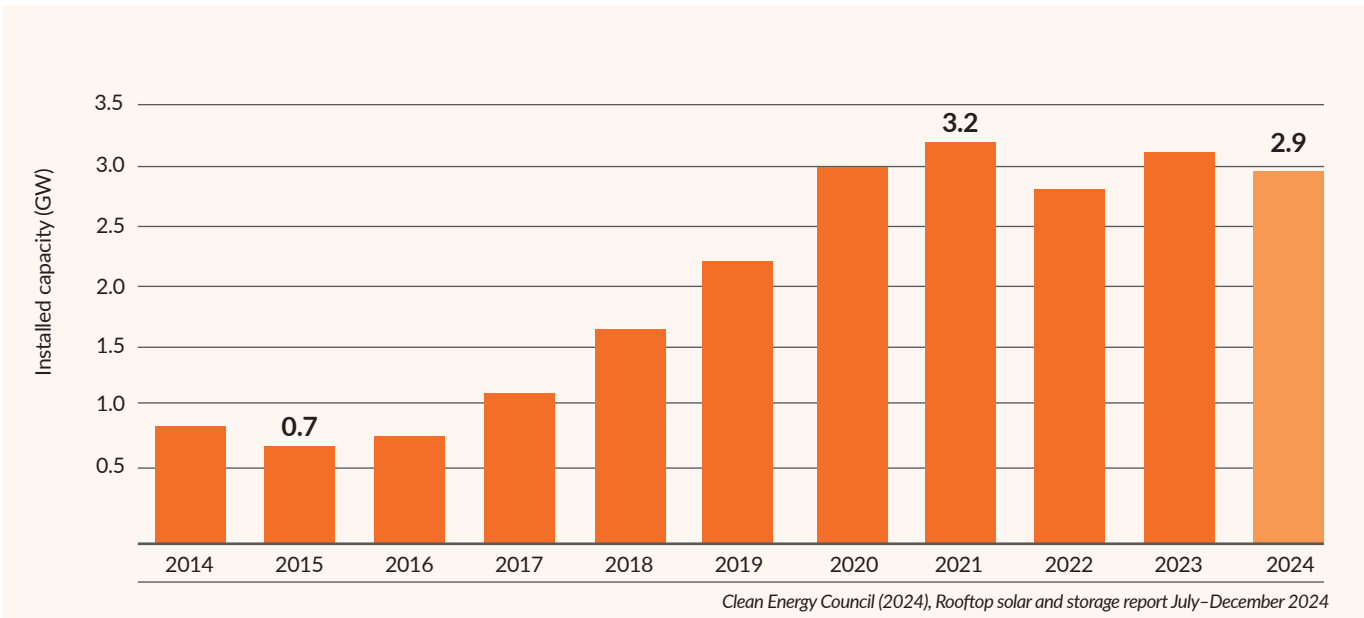
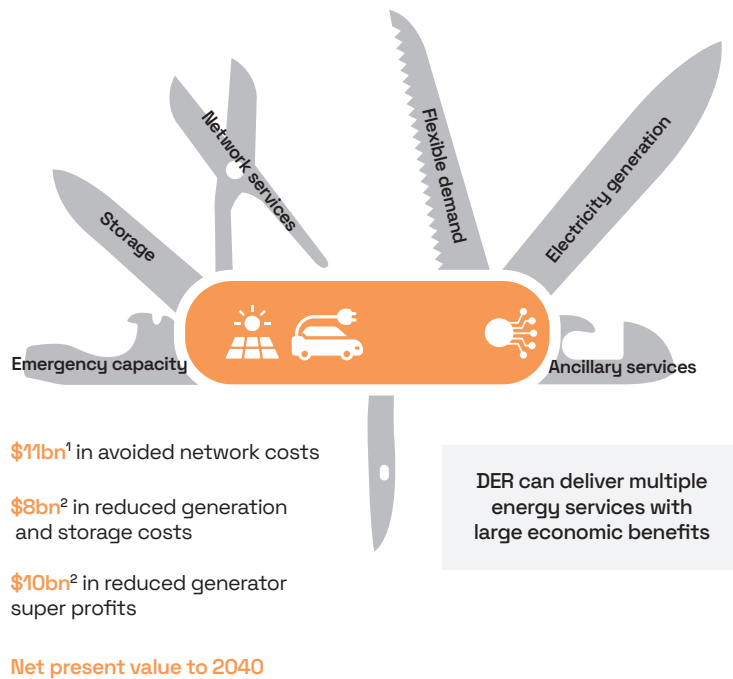


Figure 2: Estimated benefits of Distributed Energy Resources (DER) to the National Electricity Market (NEM)



1. Baringa Partners. Potential network benefits from more efficient DER integration. 18 June 2021.
2. NERA Economic consulting. Valuing Load Flexibility in the NEM. 1 February 2022

Swiss army knife of the grid

Especially when aggregated, DER, like a Swiss army knife, can provide multiple services to an electricity system. A meta-analysis found that they could deliver at least \$19 billion in net present value by 2040. This included \$11 billion in reduced transmission and distribution augmentation and replacement costs, and \$8 billion in reduced large-scale generation and storage costs.

In addition, economic consultants NERA identified a further potential consumer benefit of \$10 billion in reduced generator super-profits through the smart, flexible use of DER (see Figure 2).

Data flow challenges

Distribution networks were originally considered a passive termination of the transmission network with unidirectional power flows. A one-directional electricity grid delivered affordable and reliable energy through a “set and forget” design. Advances in technology, specifically low-cost solar panels, changed all that.

Now, distribution network operators need greater visibility of the low-voltage network for both operation and planning purposes. Solar Analytics’ DER Visibility and Monitoring Best Practice Guide lists common sets of static and dynamic data for eight

use cases, compiled in consultation with industry (see Figure 3). This space, where data science meets AI meets power electronics, is fast evolving.

Voltage management

Around 2019, there were industry concerns about exports from solar systems increasing voltages in LV networks. The results of a study commissioned by the Energy Security Board showed voltages were running above the 230 V NEM standard 95 per cent of the time. However, it was also discovered that the underlying cause was not rooftop solar, but operational procedures developed in response to large air-conditioning loads being installed in the 2000s and 2010s and a slow transition by distribution networks from 240 V to 230 V.

Rooftop solar was in fact a victim of high voltages, as rooftop solar systems trip when the network voltage reaches 258 V, which was happening more than was necessary.

Flexible exports

Given the lack of visibility at the LV level and traditional conservative approaches to network operation, distribution networks have generally set the export limit for household solar systems to 5 kW per phase. However, as the average household RTS system is now over 8 kW, these static limits can curtail the contribution of RTS to the grid, especially for homes that are empty during the day, and so reduce the return on investment for these households.

SA Power Networks has developed software that sends a dynamic operating envelope (DOE), “flexible export” limit of up to 10 kW to solar inverters. This innovative software means solar households in South Australia have the potential to double their exports 98 per cent of the time. In July 2022, consultants Cutler Merz found most DNSPs plan to incorporate DOEs within the next five years.

However, there are two regulatory issues: there is no harmonisation with several different approaches to the definition, publication, communication and enforcement of DOEs underway; and there is no compulsion for distribution networks to implement DOEs. This is one area where engineers can and should be engaging with the energy market bodies to ensure best practice in DER integration.

Future savings

Individual or aggregated DER can substitute for augmentation or replacement within existing networks. Harnessing DER to provide network

“Harnessing DER to provide network support services is almost always cheaper than building new infrastructure.”

Figure 3: Low-voltage visibility value streams

Issue	Value stream	Parameters required	Measure interval	Update rate	Sampling density
1.	Network state estimation and performance	Voltage (assumes voltage and current available at substation)	5-10 min	Real time (could be monthly)	> 2 per cent of premises, greater fidelity at higher density, ideally 75 per cent of “nodes”. Twenty per cent required for MV.
2.	Fault identification	Voltage and current	1-5 min	Real time	> 2 per cent of premises. Note millisecond likely required for broken neutral.
3.	DER hosting capacity	Voltage, active/reactive power generated and consumed	5 min	Monthly	Two sites per feeder, with greater certainty/redundancy from greater coverage
4.	DER compliance	Active/reactive power generated, voltage	5-10 min	Monthly	>20 per cent DER, with greater accuracy and compliance at 100 per cent coverage
5.	Constraint management	Capacity, voltage active/reactive power generated and consumed	10 s-5 min	Real time	Participating DER
6.	Constraint reporting	Capacity, voltage active/reactive power generated and consumed	10 min	Weekly/monthly	At least one customer per LV feeder; more increases accuracy.
7.	Orchestrating DER	Capacity, voltage active/reactive power generated and consumed	10 s-5 min	Real time	Participating DER. Note that full orchestration will require 1 min or better.

support services is almost always cheaper than building new infrastructure.

In addition, owners of DER can be paid, increasing their return on investment and reducing all consumer bills. This could reallocate revenue from distribution networks to DER owners.

Back in 2017 ENA and CSIRO's Electricity Network Transformation Roadmap forecast \$16 billion in avoided network infrastructure investment by 2050 paying DER owners more than \$2.5 billion per annum for grid support services.

Catalyst for success

The smart integration of DER into distribution networks could result in cheaper, faster decarbonisation. This depends on innovative engineers both developing the technical solutions and engaging with policymakers and regulators

to ensure they understand the opportunities and remove barriers in a timely fashion.

The technical limitations on the integration of DER are not what is currently holding this back, it is the conservative mindset of those steeped in a 20th century grid.

For the revolution in distribution, we need to recognise status quo bias and be less concerned with how the system has operated in the past. We need to be more like Emmett “Doc” Brown in *Back to the Future*: agile, innovative and harnessing lightning to change history. □

Dr Gabrielle Kuiper is a guest contributor to the Institute for Energy Economics and Financial Analysis and guest speaker at CSE25.





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[Ideas]

32 Shockproof

How can Australia protect its infrastructure against the unknown.

44 Automation's advantage

Remote operations are enhancing our ability to maintain the built environment.

52 Cool change

New materials and systems can go beyond adaptation to make our cities more resilient in a changing climate.

58 Grid of the future

Retiring coal plants and rising renewables are forcing a major redesign of the electricity grid.

66 Crippling corrosion

Techniques such as cathodic protection can help engineers prevent corrosion from damaging infrastructure.

34 Storm of change

Engineering standards are changing as Australia realises that mitigating the impact of disasters won't be enough.

BLUE-SKY THINKING

How can Australia shockproof its core systems and infrastructure against existing and future threats?



SUSAN KREEMER PICKFORD
FIEAust CPEng EngExec is Principal Engineer at Engineers Australia.

Looking to the future, at the evolution of infrastructure delivery, I think engineers will increasingly bring critical thinking and creativity to the forefront. The traditional approach of designing with the end in mind has already shifted to designing with redeployment in mind. This will continue to be a trend.

Every stage of infrastructure delivery – planning, design, execution and redeployment – must be built around life recycling, rather than the finite lifecycle of infrastructure.

We will be guided by tailored design solutions, shaped by geographical conditions, environmental and resource constraints, and real-time data.

Technology will be the key to building these assets, but also to maintenance. Robotic systems and electronic surveillance will help us manage and install replacement parts, keeping

infrastructure operational with minimal disruption.

And, as engineers, we will be front and centre solving new and increasingly complex challenges.

Australia must move to more circular practices to achieve sustainable infrastructure delivery. This can be achieved through devising and implementing systemised circular principles. Technological integration will be core to optimising design specifications, material use and advanced construction methods – to minimise waste and maximise resource recovery and reuse.

We also need to manufacture component parts locally, eliminating the need for lengthy shutdowns caused by supply-chain issues. Most of all, we need to overcome the resistance to change entrenched and outdated operational models that hampers progress.

Engineers will lead this change. We are skilled in adaptation, drawing from testbeds of global innovation, enduring curiosity and a drive to do better.

“The traditional approach of designing with the end in mind has already shifted to designing with redeployment in mind. This will continue to be a trend.”



PROFESSOR CHERYL DESHA
FIEAust CPEng EngExec is Science and Innovation Director at Natural Hazards Research Australia.

For Australia's systems and infrastructure to serve us well into the future, we need to embed nature in how we reduce risk, build resilience and adapt to escalating disruption.

Nature positive disaster risk reduction solutions offer a clear path forward, blending ecological restoration with disaster mitigation to create systems that not only withstand shocks, but regenerate through them.

Rather than rely solely on grey infrastructure, we must integrate blue and green solutions – such as mangrove restoration, green firebreaks and floodplain rewilding – into urban and regional planning.



These nature-based approaches have proven benefits, from reducing storm surge and bushfire intensity to boosting biodiversity, carbon sequestration and community wellbeing.

We must reorient public and private investment. Recognising disaster risk reduction in nature markets, green bonds and adaptation funding would incentivise long-term outcomes. Projects such as irrigated green firebreaks or wetland restoration in flood-prone regions can demonstrate efficacy and inform scale-up. Partnering with First Nations peoples is also essential: landcare practices have safeguarded Country for millennia and should be central to national strategy.

Australia needs to value not just the upfront cost, but the compound returns of ecological resilience, risk reduction and community benefit. We've seen these principles in action in the Netherlands, China and the US. Now it's our turn to lead with an Australian model that protects both people and the planet.

“Australia needs a systems lens – valuing not just the upfront cost, but the compound returns of ecological resilience, risk reduction and community benefit.”



TODD BATTLE
is Chief Executive, Australia,
at Aurecon.



Join Susan Kreemer-Pickford and Professor Cheryl Desha at CSE25 at the Adelaide Convention Centre, 27–28 August 2025.

The biggest opportunity for Australia to future-proof our core systems and infrastructure is to solve our productivity problem.

We currently rank 16th out of 24 OECD countries for productivity, with construction trailing behind. Our vast geography and small population increase the strain of sluggish productivity while core systems require ongoing development.

We face an imperfect storm of building generational

“We’re trusted advisors. We should leverage this privilege to be bolder in our decision-making, and advocate more proactively for change.”

infrastructure within a highly-regulated, resource- and budget-constrained environment, slow to adopt innovation at scale. True resilience demands considered investments with a systems-based approach – acknowledging interdependencies and prioritising mission-critical assets early.

Investing in resilience up front helps reduce disruptions, lower costs, and strengthen long-term social, economic and environmental outcomes.

Sometimes disruption sparks innovation. COVID did, and now the Brisbane 2032 Games gives Queensland a catalyst to reconsider approval and delivery systems.

We certainly need collaboration and early engagement. Aurecon's partnerships in the water sector demonstrate this, achieving better community outcomes and stronger water resilience.

Our work with QIC, using the UNDRR Scorecard, establishes asset resilience baselines to help prioritise improvements.

The profession faces a question: Can the burning platform of lifting productivity provide the external catalyst to approach problems differently?

Engineers possess the curiosity and problem-solving skills to design complex systems. Now is the time for collaborative, digitally-enabled, scalable, cost-effective and fit-for-purpose engineering. And it may require breaking a few of the rules of physics, leaning into speed, and embracing risk.

We're trusted advisors. We should leverage this privilege to be bolder in our decision-making, and advocate more proactively for change. □

Engineering for a storm of change

WORDS BY CHRIS SHEEDY

So much more than a buzzword, resilience has come to represent a professional imperative for engineers. In the face of unprecedented climate extremes, entire cities must be built to bounce back, adapt and thrive.



BY THE NUMBERS

AN ESTIMATED SEA
LEVEL RISE OF

0.2-0.3 m

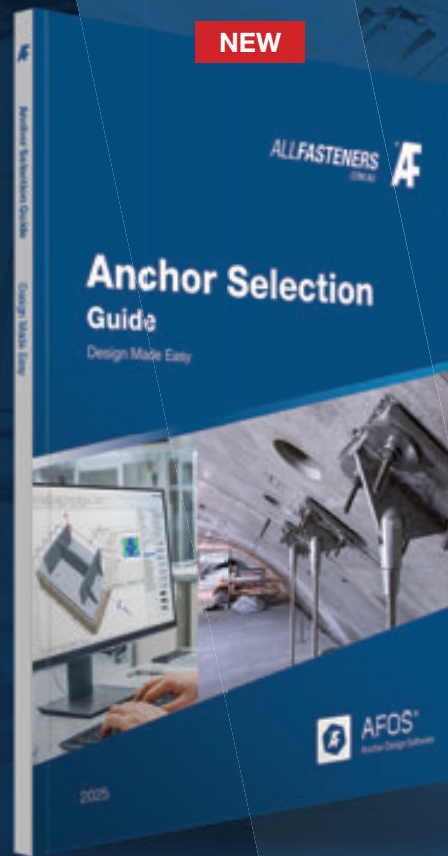
BY 2050 MEANS THAT

1-in-100-year

EVENTS WILL BECOME
ANNUAL EVENTS
IN SOME REGIONS BY THE
END OF THE CENTURY

Sources: CSIRO, IPCC

IMAGE: Brent Paterson.



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As transmission towers across Queensland and Victoria are knocked down by extreme winds, homes in NSW partially collapse into the sea, and bridges and culverts in remote regions are destroyed by bushfires, severing lifelines to rural communities, serious questions are being asked about resilience in the built environment.

In an age of climate change, engineering is experiencing entirely new challenges that suggest something more than building to code is required.

In the Australian engineering space, the standards, roles and expectations are shifting dramatically as a new realisation dawns: mitigation of disasters alone simply won't cut it.

"It's possible resilience still means the same thing that it always has, but our context has changed," said engineer Samantha Peart, Global Head of Sustainability for Hassell.

"Different shocks and stresses have come to the fore. Previously, we've had a lot of focus on designing out risk, as opposed to adaptation. But now, adaptation is becoming more of a focus as science tells us the actions we've taken thus far are not mitigating the risks."

Michael Nolan, Principal and Director of Climate Risk and Resilience at Aurecon, agreed. "We're seeing greater failures as impacts are larger than the buffers we design as engineers," he said.

The climate has already shifted, it seems, but the codes haven't caught up.

"If everyone automatically uses current engineering and design

"Take flooding as an example – one approach builds barriers to keep water out; the other accepts its inevitability to a certain extent and asks how spaces can adapt, absorb and even benefit from it."

standards, that's great – if climate change has been already factored in," Nolan said. "But there are a lot of design standards that we'll be waiting another 10 years before they upgrade, maybe even longer. They all really need to factor it in – now.

"A good example is the massive number of transmission towers going up as part of the renewable energy transmission infrastructure, using the existing >



ABOVE: Samantha Peart, Hassell.

standards which don't incorporate increasing extreme wind from micro-storms. We've already seen multiple failures in the last three years."

Infrastructure failures have also revealed themselves in Brisbane and Lismore as a result of floods, across NSW and Victoria during fires, in the Northern Territory, Western Australia and Queensland after cyclones, rain and supercell storms during South Australian heatwaves, and elsewhere.

"What's the difference between designing out risk and designing for adaptation?" Peart said. "It's rarely that black-and-white, but take flooding as an example – one approach builds barriers to keep water out; the other accepts its inevitability to a certain extent and asks how spaces can adapt, absorb and even benefit from it.

"For residential buildings, there once was a focus on designing out active conditioning systems – reducing energy use, cutting emissions and minimising climate impact.

But now, instead of naturally ventilated buildings that eliminate air conditioning, we're seeing advocacy for airtight buildings where active cooling systems are smaller and highly efficient, and where ventilation happens in a controlled, optimised way."

We once engineered and designed with the idea of controlling nature, Peart said. However, the more severe the weather events, the more those control mechanisms are failing.

Then there's the fact that resilience is about a lot more than weather.



ABOVE:
Flooding in Lismore;
Adam Davis,
AECOM.

Broader than climate

While resilience in engineering is heavily driven by climate change-induced extreme weather events, the topic is much broader than that.

Adam Davis, AECOM's Technical Director, Sustainability and Resilience, said resilience is not just about infrastructure bouncing back after an extreme weather shock event. It's also about the vulnerability of people, services, governance arrangements and natural ecosystems.

Davis was involved in the Rockefeller Foundation's work as part of the 100 Resilient Cities initiative, intended to "help cities around the world become more resilient to natural, social and economic shocks and stresses".

"They adopted the global

definition of resilience, which was more a systems-based approach to addressing disruptions," Davis said. "It defines resilience as the capacity of a city's systems, businesses, institutions, communities and individuals to survive, adapt and grow, no matter what kinds of acute shocks and chronic stresses they experience."

A classic example, he said, was the fact that New York City's Emergency Management team was planning and preparing for a major hurricane event. However, during the decade leading up to Hurricane Sandy in 2012, the city suffered a major terrorism event and an anthrax attack in 2001, the Global Financial Crisis of 2007, a passenger plane crashing in the Hudson River in 2009, as well as other serious infrastructure



failures, and more.

"They came to the realisation that they needed to apply a holistic approach to address all types of shocks," he said. "Through the work from the Rockefeller Foundation and more, a lot of government agencies and industry groups have adopted a similar approach to resilience planning."

Nolan, also referring to New York's resilience planning, said a lot of effort went into convincing the client to raise the runways, taxiways and aprons at John F. Kennedy Airport (JFK) by one metre. That effort paid off when Hurricane Sandy hit, with JFK being the only operating airport in the state of New York.

"LaGuardia Airport was out

of action for six to eight weeks," he said. "It also meant that emergency responses, and other things that reduce the cost of a disaster, were greatly improved."

For companies working in high-risk and confined-space environments, resilience must go beyond conventional responses. Ervin Hung, Strategic Solutions Operations Manager at pipeline infrastructure solutions provider Interflow, explained that resilience is also about continually innovating the approach to complex engineering challenges.

"There must be a priority on solution designs at the concept stage to incorporate key themes, such as lowest carbon footprint for the entire lifecycle of the proposed solution, engineering >

"If everyone automatically uses current engineering and design standards, that's great – if climate change has been already factored in. But there are a lot of design standards that [will take] 10 years before they upgrade."

Fail-safe vs fail-soft

When the concept of mitigation was a greater focus than adaptation, the concept of "fail-safe" was the priority. And in many infrastructure and other projects it still is, for good reason.

While fail-safe remains the ideal, the reality of legacy networks and operational constraints means engineers must plan for both.

"Engineers aim to design for fail-safe systems that prevent further escalation by isolating faults quickly," said Ervin Hung, Strategic Solutions Operations Manager at Interflow. "But in practice, we're often working with ageing pipelines where immediate



ABOVE: Ervin Hung, Interflow.

replacement isn't possible at times. That's where fail-soft principles come in, building in the ability to detect, respond and maintain partial service when things don't go to plan."

In trenchless rehabilitation, where access and disruption must be minimised, this approach translates into smart monitoring, staged renewals and prioritising high-risk assets. It's not about accepting failure; rather, it's about managing it wisely when it happens, without compromising safety or service delivery.

In the built environment, a good example is the renaturalisation of surface water courses in urban environments.

Rather than a straight, concrete

canal designed to channel water away as quickly as possible during a significant rain event, there is an acceptance that flooding will sometimes occur. As a result, a fail-soft option is a meandering stream, where the community can walk the footpaths, and enjoy the plant and bird life, but which also copes with flood events thanks to its soft surface.

"You've got to design with nature, as opposed to against it," said Samantha Peart, Global Head of Sustainability for Hassell. "Engineers must plan how this can happen, and allow for the quality of life or use of the space to continue, or pause and rehabilitate in the quickest way possible."

out critical safety risks and advancing trenchless water technologies,” Hung said. “Every solution we develop must consider and prioritise these elements.

“It means when we make decisions, we are in the right headspace to not just consider excellent design principles, but also the safety of our people, a constant reduction of our carbon footprint and a drive to utilise leading trenchless technologies.”

Even in the pipe maintenance and repair space, resilience is about more than the environment.

And so, Davis said, organisations such as the NSW Reconstruction Authority are now going to great lengths to understand the community criticality of assets as part of disaster adaptation planning.

“It’s about enabling informed investment in the right places,” Davis said.

However, Nolan argues that it’s not happening fast enough. The cost of resilience must be factored into all infrastructure investment decisions.

“It can actually result in a lower cost of capital,” he said. “But right now, the conversation isn’t mature enough.”

Considering the neighbours

Rebecca Miller, SMEC’s ANZ Manager for Sustainable Futures, has long held roles that explore the relationship between physical and social infrastructure. Resilience in its true form, she said, is about the consideration of a broad range of externalities, of a diverse and cascading range of shocks and stresses.

“Take a heatwave in Western Sydney, for example,” said Miller, who was involved in the early days of the Resilient Sydney

program of works, in partnership with the Rockefeller Foundation. “A heatwave represents a shock event, but key stressors that underpin and amplify the impact of a heatwave can vary, and include societal challenges such as housing affordability, or lack thereof.”

This brings issues such as social equity and poverty into the resilience discussion. On other projects, such as those associated with delivering large-scale transport infrastructure, for instance, other issues may come into play. These might include planning for and responding to digital network failures, pandemics and physical terrorist attacks.

“If parents are on a train to pick up their kids from school or daycare, and end up stuck or stranded, we need to consider the knock-on effect,” Miller said. “Resilience is about interdependency and interconnectivity.”

Too much of modern-day engineering is about drawing a line around a site and only considering what happens within that line, Peart said.

“Engineers and other built environment professionals are often engaged to work within a clearly defined site boundary – the red line around the building or plot of land. But too often, that boundary becomes a blind spot. Aside from utility connections like energy and water, we rarely consider the broader systems that the project is part of,” she said.

And so we end up with issues such as the flood wall around Victoria’s Flemington Racecourse that an independent report found contributed to increased flooding across hundreds of neighbouring homes and businesses.

“That is an example of not considering the systemic impacts of interventions,” Peart said. “That has to change – every



ABOVE:
John F. Kennedy
International
Airport, New
York; Flemington
Racecourse,
Melbourne.

project needs to be understood in its full climatic, ecological, social and economic context, to ensure places and spaces are resilient and adaptive and are not creating problems for others.”

Identifying opportunity

Engineering for resilience isn’t just about focusing on and planning for potential negatives. The assumption of a broader point of view enables the identification of opportunity, Peart said.

“A heatwave represents a shock event, but key stressors that underpin and amplify the impact of a heatwave can vary, and include societal challenges such as housing affordability, or lack thereof.”



IMAGE: AAP.

"Our approach includes examining biodiversity, transport and natural systems," she said. "We assess social dimensions such as social value, health and wellbeing, and inclusion. Physical factors such as flooding risk, sunlight access, energy supply and local context also play a role. We apply these multiple lenses at the site level, then progressively outward, recognising the interconnected systems that extend beyond immediate boundaries."

"We're changing the way we understand place before we start engaging in design. We can see our spheres of influence, and leverage our position with more knowledge to get change happening. Perhaps we can adapt to flooding rather than cause it. Perhaps we can partner to integrate energy storage on a site to benefit the broader community."

Miller, who helped develop

the resilience category and credits for the Infrastructure Sustainability Council's rating tools in a past role, and who was also the inaugural Chair of the Expert Reference Panel on Climate Change and Resilience for the Green Building Council of Australia, said some engineering and construction businesses are already doing excellent work around this.

"Landcom has done great work in this space with regards to community resilience," she said. "The team at Stockland also thinks about things differently in their project delivery."

An example she shared related to one of Stockland's Queensland shopping centres, where they're not just thinking about environmental design, but social outcomes too.

"They don't just have change facilities for parents with babies – they also have adult change >

ABOVE:
Coastal erosion on the Sunshine Coast prompted innovative erosion management strategies.



ABOVE:
Rebecca Miller,
SMEC.



CASE STUDY: Hay Point Export Terminal

Client: BHP Mitsubishi Alliance
Building design services: Aurecon

Proving that engineers have had resilience on their radar for quite some time, in 2010 an expansion of the Hay Point Export Terminal, the metallurgical coal-loading terminal for five Bowen Basin mines in Queensland also included improvements to boost resilience around weather events.

These improvements included cyclone-rated offshore structures, high-voltage switchrooms, cyclone moorings, elevated substations, and robust stormwater management.

Modular construction reduced weather-related risks, while reinforced trestles and conveyors enhanced durability against storm surge, flooding, and extreme weather, ensuring safer, more reliable operations.

By protecting the longevity of the terminal, which had operated since 1971 and is now capable of exporting 55 million t of coal per annum, chances of supply chain disruption were minimised.

The more resilient design began with a redefining of extreme weather events, ensuring a realistic baseline. Within a digital environment, new design criteria combined numerical and physical modelling to test the seawall and offshore structures. Physical wave modelling and advanced wind tunnel testing added rigour to the process.

BY THE NUMBERS

NUMBER OF EXTREME
HEAT DAYS IN 2019

33

TOTAL NUMBER OF EXTREME
HEAT DAYS BETWEEN 1960
AND 2018

24

Source: Australian Bureau
of Meteorology

Actions from governments

Across the nation, state and federal authorities are stepping up their resilience planning processes and practices. However, current progress is uneven and sometimes occurs in stops and starts.

"Infrastructure Australia has embedded resilience into its assessment framework for infrastructure," said Adam Davis, AECOM's Technical Director Sustainability and Resilience. "At the state level, some authorities are well ahead. Transport for NSW, for example, has been embedding climate resilience considerations into delivery for over a decade.

"The NSW Reconstruction Authority is also proactive in this space. They're undertaking resilience planning for all regions across the state.

"Across these regional areas, they're developing an understanding of the resilience of assets that support its communities, and what disasters they are most vulnerable to. They're engaging with local councils and asset operators as part of this planning process, and will use the information collected to help inform future adaptation planning and investment decisions."

However, the same levels of commitment and maturity are not apparent across all states.

For engineers, Davis said, this evolving landscape contains a call to action. They need to be at the table at the earliest stage in infrastructure delivery to help other stakeholders understand design thresholds, tolerances and interdependencies that could make or break a system, and to help plan the next generation of resilient infrastructure.

facilities and quiet spaces where elderly people can rest and reorientate themselves."

Role of engineers

What does all of this mean for engineers? They need to be in design conversations at the earliest possible stage, Hung said.

"Even engineers with very specific knowledge focusing on one particular part of the process can add great value to that front-end process," he said.

Davis said there are two good reasons engineers belong in those early planning discussions. The other is because, when a major event occurs, it is engineers who will be required to get things up and running again.

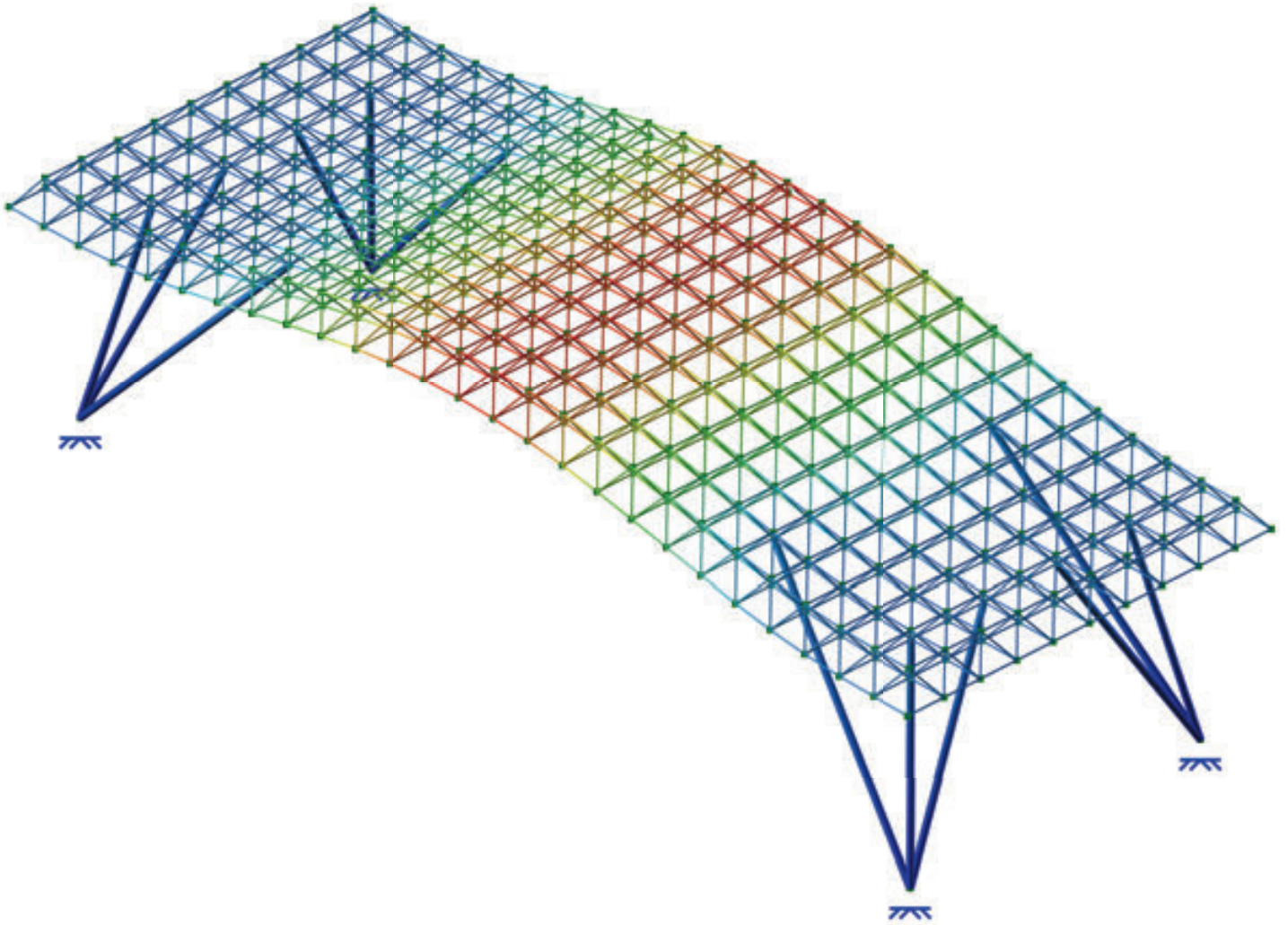
"Because of that," he said, "they have the greatest knowledge and tangible experience in coming up with solutions or actions to address all of the risks."

Peart said engineers need to feel empowered by the knowledge that their advocacy and influence skills are just as important as their technical skills.

"Feel empowered to do more than just respond to the brief. Feel empowered to go further upstream. That technical depth and curiosity is special; it can help convince people to do something differently to get better outcomes. Sometimes, engineers don't feel like they could or should do that, but they must." □

"There must be a priority on solution designs at the concept stage to incorporate key themes, such as lowest carbon footprint for the entire lifecycle of the proposed solution."

IMAGE: Getty.



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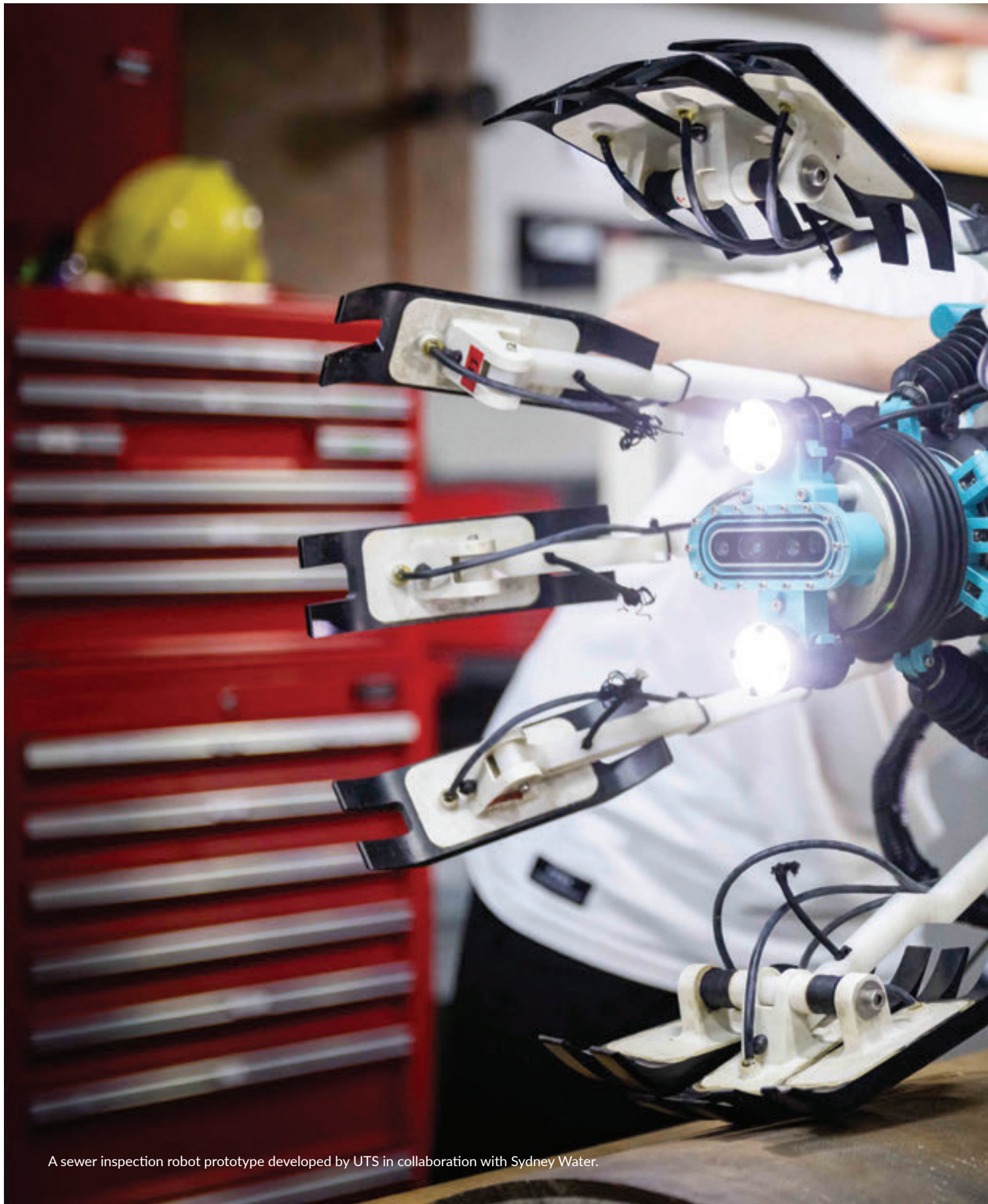
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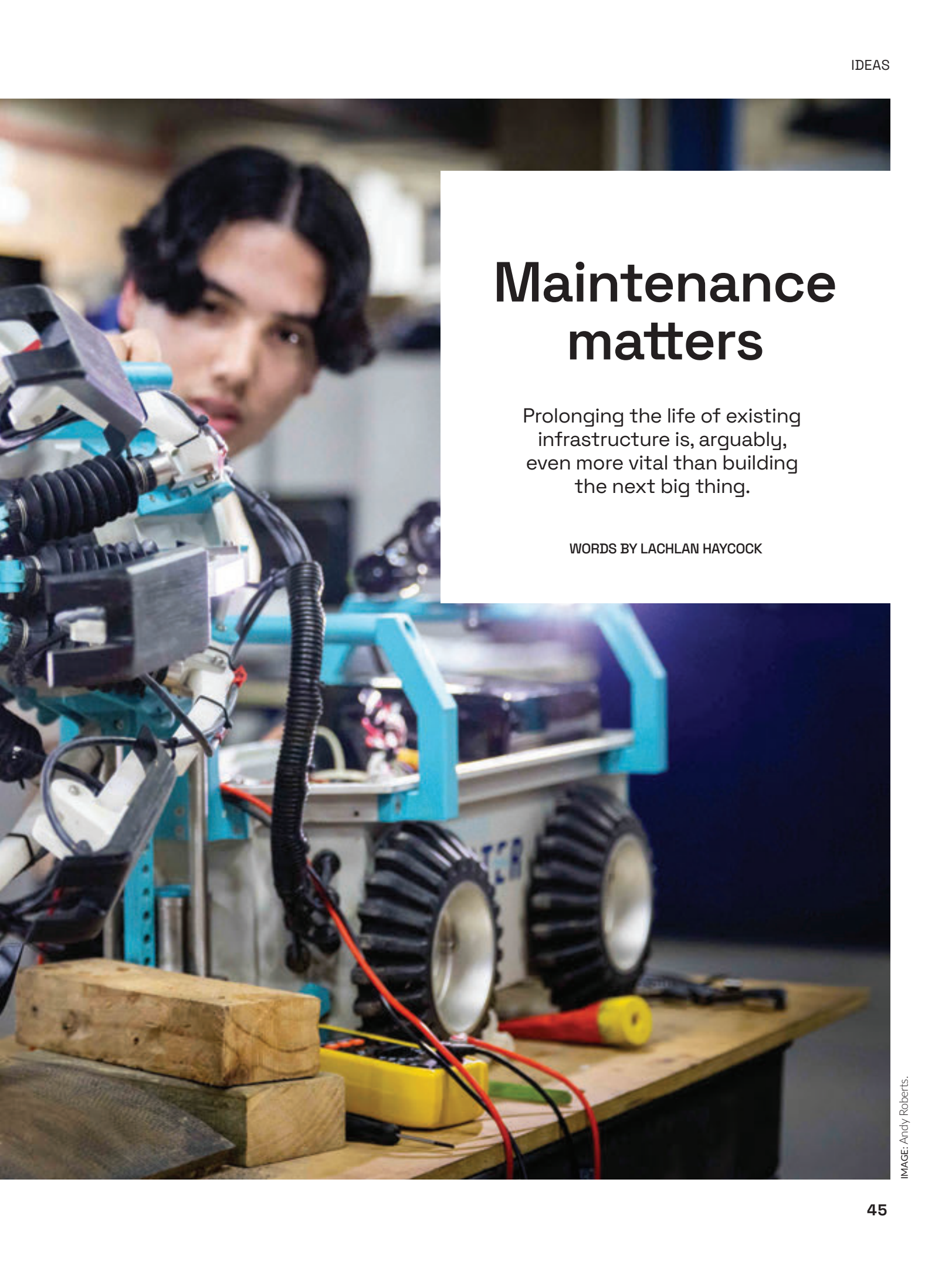
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A sewer inspection robot prototype developed by UTS in collaboration with Sydney Water.



Maintenance matters

Prolonging the life of existing infrastructure is, arguably, even more vital than building the next big thing.

WORDS BY LACHLAN HAYCOCK

The opening of a new bridge or skyscraper is always big news. A tunnel boring machine breaking through is cause for celebration, and even sod-turning ceremonies get their 30 seconds on TV, plus coverage on social platforms.

But spare a thought for the unseen agent discreetly ensuring these high-profile infrastructure assets have their time in the sun for years to come – namely, the act of maintenance. It's a seemingly never-ending enterprise that is critical to the long-term resilience of Australia's built environment, not to mention core systems of water, energy and transport.

"Take maintenance in the field of subsea engineering, where there's no room for error," said Dr Hema Wadhwa, Associate Data and Analytics (Asset Management and Performance) at Aurecon. "Once a piece of equipment or asset is placed on the seabed, it's down there for good. You can't always send someone down to quickly fix it or apply a new coat of paint. So, by design, engineers must have a lot more options to fall back on when it comes to maintaining the asset."

As an example, Wadhwa described the Jansz-Lo gas fields off the coast of Western Australia, where engineers have installed various sensors to monitor if the asset is operating within the design parameters, and avoid catastrophic failures. The sensors themselves have backups, so the critical information is not lost if the sensors fail.



ABOVE: Remote maintenance of rail infrastructure in Dubai.



ABOVE: Dr Hema Wadhwa, Aurecon.

"These are learnings we can take to other industries," she said. "We ought to more often design systems the way we do in subsea engineering, where you don't have any other option – and where the decisions made are actually the most efficient way of doing things."

For Charlie Jewkes, Managing Director – Water, Power & Energy at WSP Australia, the scale of the maintenance challenge in a country such as Australia is such that many engineers may struggle to articulate the value of investment.

"We need to be able to talk about water security, population

growth and all of these things in a way that enables the people who make the decisions – the politicians, typically – to realise it's a worthwhile investment to put money into upgrading a desalination plant as opposed to a new sports stadium, for example," Jewkes said. "From a political investment perspective, maintenance always comes very low down in the priority list against something new that might be worth headlines and a few votes."

"That represents a challenge for engineers in every infrastructure sector, including water. Maintenance is very unsexy stuff in the public realm, which can make things difficult."

Ad hoc to high-tech

To address the maintenance challenge, innovative approaches are being implemented across Australia's solar and wind farms, and grid-scale battery installations, changing up maintenance requirements and practices. Jewkes sees it as a two-pronged topic.

"On the one hand, Australia has some very old and well-established infrastructure," he said. "In the water industry, we have pipes, reservoirs and pump stations that are 100 or more years old in some areas. And, unfortunately, we often still take a very traditional approach to maintenance when addressing leaking pipes, cracks on the face of dams or rusting pump stations."

This traditional approach is typified by ad hoc inspections, manual labour and repair done only when something is breaking or deteriorating.

On the other hand, Australia also has new wind, solar and battery systems technology coming online, "developing somewhere between quite quickly to incredibly quickly".

"There's quite an industry emerging in the maintenance of wind turbine blades. This involves repairing little divots, reforming the ageing blades – effectively sharpening them, if you want to use that analogy – to improve their aerodynamics. There's all sorts of specialist products and services coming online." >

"Identifying faults sooner can save millions of dollars. If you wait until a sewer collapses, it's going to have a large impact on the environment, society and economics. The trouble is, it's very hard to tell where the next burst is going to happen."



ABOVE:
David Philpot,
FMT.

RIGHT: FMT's rail robotics solutions in action.



ABOVE:
Charlie Jewkes,
WSP.

Automating rail jobs make them safer, cheaper and more productive

*Words by David Philpot,
Co-Founder and Chief Technology
Officer of FMT*

Conducting rail maintenance inspections around high voltage, at heights, near moving trains and under carriages puts people at significant risk. In today's world, we can minimise exposure to such hazards by integrating robotics into the maintenance of railways, rollingstock and associated infrastructure.

We have developed three automated robotic solutions specifically for rail: ARIIS (Autonomous Rail Infrastructure

Inspection System), TRES (Train Examination System) and RFD (Rail Facility Drones).

ARIIS moves along the tracks to measure things such as track gauge, rail and sleeper condition. It operates autonomously and allows us to identify the areas of a rail network that require further attention. In Dubai, we've seen ARIIS reduce the total inspection time for about 100 km of track from more than 2400 human hours to just 700 – a 70 per cent reduction.

TRES moves around trains to conduct detailed inspections. It takes RGB images and very dense point clouds with precision down to 0.1 mm. We can then compile maintenance reports identifying what needs to be repaired.

RFD is an autonomous drone-dock system designed for critical infrastructure assets and facility inspections. It can access hard-to-reach areas without placing people in hazardous work environments.

As Australian rail operations expand – particularly in dense population centres – there are maintenance operations and depots that were designed to operate a certain number of trains. Over time, the number of trains and the number of trips has increased significantly, but depots haven't increased in size. That created a challenge: how do you boost productivity without expanding the footprint? Being able to automate maintenance activities means these trains can have a faster turnaround, helping avoid tens of millions of dollars in expansion costs.

I think infrastructure maintenance is largely undervalued by society. We have good electricity suppliers, water suppliers, roads and rail. They're often not thought of as exciting topics, but they're absolutely critical. There's a lot of efficiencies to be gained in maintaining them more efficiently. Because without them, society grinds to a halt.





One of the oldest wind farms in the country, at Canunda in South Australia, was commissioned in 2005 and was expected to be operational for around 20 years, Jewkes said. It has now passed that milestone owing to effective maintenance over its lifetime by owner Engie.

“Engie and Vestas, the turbine manufacturer, have recently reassessed the serviceability of Canunda, and have revised its decommissioning horizon to 2035. That’s an additional 10 years of high-value energy generation. So, the original investment case is probably looking at least 50 per cent better, as it is still operating well within its serviceability parameters. It makes much more sense to keep an asset operational for longer

through smart maintenance practices, than to put valuable capital into a replacement.”

Proactive, not reactive

Moving from high in the air to underground, it’s not only subsea infrastructure and ageing wind farm blades that are the focus of maintenance-minded engineers. Australia’s sewerage systems – not the most pleasing environments at the best of times – also need attention.

The country boasts 110,000 km of underground sewer infrastructure, which can be inspected either using CCTV or human operators. Not only do they function as something of an “unintentional torture chamber”, in the words of Professor Sarath Kodagoda, Director of the UTS

Robotics Institute, but they can also prove highly dangerous.

“The tunnel might be no more than 1.5 m in diameter,” Kodagoda said. “The interior is smelly, humid, noisy, confined and dark. There are mechanisms in place to reduce noxious gases and so on, but it’s still not an ideal environment in which to work.”

Kodagoda’s team was tasked to work with Sydney Water to identify a solution to keep people out of these environments. The outcome was an autonomous robotic system which can be lowered through an access hole in place of a human.

“We’ve been working with Sydney Water for many years to develop systems where the robot device can be deployed for water and wastewater

ABOVE: Sarath Kodagoda, UTS Robotics Institute.

infrastructure maintenance and regular inspections.

"Once it enters the sewer, we activate what we call 'floaters' to give the robot better stability. It's connected to three-dimensional visualisation magnetic-based sensors, and a ground-penetrating radar-based system, which we mount on a robotic arm. The ground-penetrating radar with magnetic sensors is used to measure the thickness of the concrete left in a pipe, so it can tell whether it should be replaced or renovated.

"We've deployed this in several locations around Sydney, including Toongabbie in the west and near the airport south of the CBD."



ABOVE: Sandra Burke, GHD.

BELOW: New renewable technology is coming online extremely fast.

"Rather than call a refrigeration mechanic or a plumber to the site every time there was a failure, they could benefit from a more planned program of maintenance, and issue a contract for the bulk of work – which would see cost efficiencies come back to them."

The benefit of early detection of faults, for Kodagoda, speaks to the principles of proactive rather than reactive maintenance.

"Identifying faults sooner can save millions of dollars," he said. "If you wait until a sewer collapses, it's going to have a large impact on the environment, society and economics. The trouble is, it's very hard to tell where the next collapse is going to happen."

Critical assets

Taking a more principled approach to engineering the built environment is increasingly viable given the proliferation of digital analysis tools, said Sandra Burke MIEAust, RPEQ Business Group Leader – Asset Management Australia at GHD. Her time in asset management has led to a realisation of systems-based thinking.

"Implementing good asset management practices is about looking at your asset criticality," Burke told *create*. "It's not just about evaluating your assets, but also identifying which are your critical assets, and what are the key points of failure and potential

risk, whether it be from flooding, cybersecurity or something else.

"Say you're a government agency providing statewide services, and the state's population is set to boom. You need to consider the shifting demographic centres, the risk of bushfires and floods, the amenity of services and how they are going to be provided. So it's critical to do that infrastructure planning and remain cognisant of asset criticality and resilience – and also phase those assets in a time that is when they're needed."

Burke also described working for a client in remote Australia that provides residential housing for its staff, which proved "a brilliant exercise on a small scale to know that we could have some real impact and benefit to a small community".

"They wanted a good grasp on their asset base and how they might secure maintenance contracts to service their assets. Our task was to build staff capability, and help them understand their assets, both at an asset and a component level, so they could develop longer-term procurement contracts for essential trades.

"Rather than call a tradesperson to the site every time there was a failure, they could benefit from a more planned approach, and issue a maintenance contract for the program work – which would see cost efficiencies come back to them."

The long game

Burke has seen a promising shift in asset management and maintenance management across government and private entities.

"There is a raft of legislation and guidance material around asset management, and how public and private entities do asset management," she said. "When I started my asset management journey over 20 years ago, New Zealand was leading the way. Australia quickly >



came on board, realising the benefits it would bring, and then we saw the International Standards Organisation coming up with an international standard for asset management, which has been globally accepted. And, of course, there are now many organisations, such as the Asset Management

“For about 30-40 years, manufacturers did the same thing they’d always done, but just swapped out steam engines for electric motors. We didn’t understand the true benefits of redesigning the process for some decades.”

Council and the Institute of Public Works Engineering Australasia, providing guidance to industry on this issue.

“I think the government as a whole has embraced asset management over time, such that we are now progressing through the maturity of asset management – which is great to see. Private industry has also quickly adopted mature maintenance management practices to increase reliability, asset integrity and reduce production downtime.”

Wadhwa believes more progress is needed, but a brighter future is visible.

“I don’t think, as a country, Australia is there yet in terms of

effective and resilience-minded maintenance of infrastructure,” she said. “If we were, we wouldn’t be talking about it now.

“I’m reminded of the transition that human industry made from steam engines to the electric motor. For about 30-40 years, manufacturers did the same thing they’d always done, but just swapped out steam engines for electric motors. We didn’t understand the true benefits of redesigning the process for some decades. I think we’re at the same stage now, where we are using digital asset strategies to help us reformulate maintenance plans. We’re getting there, but we haven’t quite brought it all together yet.” □

Impressive longevity

Here are five examples of infrastructure that have outlived, or are expected to outlive, their predicted lifespan thanks to good maintenance.

1 PARKES RADIO TELESCOPE ▼
Originally intended to operate for 20 years, the 63-year-old telescope’s longevity is a result of constant upgrades, including a new ultra-wideband receiver that can scan a huge range of radio frequencies, and CSIRO-developed phased array feeds.



2 STORY BRIDGE ▼
At 85 years, Brisbane’s Story Bridge must now undergo major restoration. The bridge’s footpaths were closed in early 2025 after rust was discovered on steel reinforcements.



3 GOULBURN WEIR ▲
Located on the Goulburn River about eight kilometres north of Nagambie in central Victoria, the Goulburn Weir is Australia’s oldest major irrigation structure. Constructed in 1887-91, the weir was refurbished in 1988 to stabilise and partly reconstruct the structure.



4 SEMAPHORE WATER TOWER ◀
This masonry structure was constructed in 1880 in Adelaide. Rather than be demolished, there are plans for the site to be redeveloped as a residential and commercial space that retains the original tower structure.

5 MOSMAN BAY ▼ SEWAGE AQUEDUCT
This small but sturdy aqueduct, opened in 1901, has survived for more than 120 years following maintenance and upgrades in 1968, which involved the installation of pipes and replacement of wooden flats with concrete paving.



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Heatwave-proof city

As climate change drives temperatures higher across Australia's cities, engineers are reimagining how we design, cool and live in the built environment.

WORDS BY JOE ENNIS

Australia's bushfires and floods have a powerful grip on our collective imaginations, thanks in part to the seemingly inevitable fatalities that accompany them. But the average number of deaths caused by these highly visible disasters each year is easily eclipsed by even the most conservative count of deaths from a much less visible foe – extreme heat.

Extreme heat days are more than three times as common in Australia today compared to before 2000 and are expected to double in frequency again by 2050. Though this is a problem for all Australians, the urban heat island effect means cities are uniquely affected, because an abundance of concrete, steel and asphalt amplifies already rising temperatures. So how can engineers design new approaches that go beyond adaptation, to make our cities resilient to the change that is already upon us?

Passive performance

The first line of defence against heat begins before a structure is built. For Jessica Holz CPEng, Associate, Sustainability at Aurecon, the key lies in applying passive design principles at a building and precinct scale.

"Optimised building orientation, shading and facade design can significantly reduce energy demand," Holz told *create*. This includes strategic positioning to manage solar gain, efficient insulation and glazing, and the use of operable shading devices. These principles aren't new, but modern modelling tools now enable site-specific designs that maximise thermal comfort with minimal energy input.

Importantly, many passive features can also be retrofitted. "Shading – whether with awnings, eaves or modular structures – can be added to existing buildings," Holz said. "They reduce solar load and improve comfort, and can be modelled to suit the building's sun path and its urban context."

Smarter systems

As mechanical cooling becomes more widespread, managing its environmental burden is a key priority. Holz advocates for mixed-mode systems that combine passive ventilation with mechanical systems prioritising efficiency and indoor air quality.

"In residential and education settings, we often see split systems recirculating the same air," she said. "You might feel cool, but a lack of fresh air means carbon dioxide and pathogen levels can be dangerously high. We shouldn't sacrifice health for cooling."



ABOVE: Jessica Holz CPEng, Aurecon. Hear her speak at CSE 25 at the Adelaide Convention Centre, 27-28 August 2025.



Engineering solutions for a hotter future

Australia's climate is warming at pace. Since 1910, the national average temperature has increased by more than 1.5°C, with CSIRO and the Bureau of Meteorology confirming this trend is accelerating rather than stabilising. Heatwaves are now more frequent, begin earlier and persist longer. Urban environments are particularly exposed due to the urban heat island (UHI) effect where dense-built form, low-albedo surfaces and minimal vegetation can elevate city temperatures by up to 4°C above rural surroundings.

This isn't just about comfort: in hot climates, according to Matt Santamouris' models, "a 1°C decrease in ambient temperature can lead to a 4-6 per cent reduction in heat-related mortality". Elevated temperatures contribute to increased mortality, exacerbate mental health risks and significantly impair economic productivity, with worker output dropping by as much as 70 per cent under extreme conditions.

In response, engineers are deploying targeted, evidence-based interventions. They are not only mitigating urban heat; they're driving resilience, reducing emissions and enhancing human wellbeing across Australia's changing urban landscape.

PHASE CHANGE MATERIALS

Phase change materials (PCMs) are used on roofs to enhance thermal comfort by passively regulating indoor temperatures. They absorb excess heat when ambient temperatures rise, melt during the day and release that stored heat when temperatures drop – typically at night – by solidifying.

This thermal buffering reduces reliance on mechanical heating and cooling, particularly during peak demand periods. By flattening indoor temperature fluctuations, PCMs create a more stable and comfortable internal environment for occupants. They're especially useful in lightweight constructions or buildings exposed to variable climates, where they can also be integrated into walls, ceilings or floor systems. PCMs support energy efficiency while improving comfort, but have very little impact in mitigating the UHI effect.

RETHINKING AIR-CON

When it comes to air-conditioning, "we've become accustomed to an absence of sensation", Jess Holz said. This has led to an overestimation in building energy simulations, leading to inefficient design outcomes.

CSIRO research shows that many buildings could maintain comfortable indoor conditions with little or no mechanical cooling, depending on design choices. Simulating 2000 buildings across 83 Australian climates, the study found that some design parameters consistently improved both comfort and energy performance. However, others offered trade-offs – better comfort but higher energy use, or vice-versa. The key takeaway: the most energy-efficient buildings are those where occupants feel comfortable without air conditioning, suggesting future codes should weigh comfort and energy use equally.

WETLANDS

Urban waterways and wetlands function as effective heat sinks by lowering surrounding air temperatures through evapotranspiration. Unlike concrete or asphalt, which absorb and radiate heat, wetlands cool the environment while also improving biodiversity and stormwater management.

Jessica Holz advocates for their integration into precinct-scale design, noting that "a well-placed wetland or creekline can create its own cool microclimate". She emphasises the value of restoring or constructing wetlands in urban areas, not just for cooling, but for creating "stepping stones for species and delivering nature-positive outcomes." When combined with shading and permeable surfaces, urban wetlands offer a powerful, multifunctional response to extreme heat.



PHOTOVOLTAIC GLASS

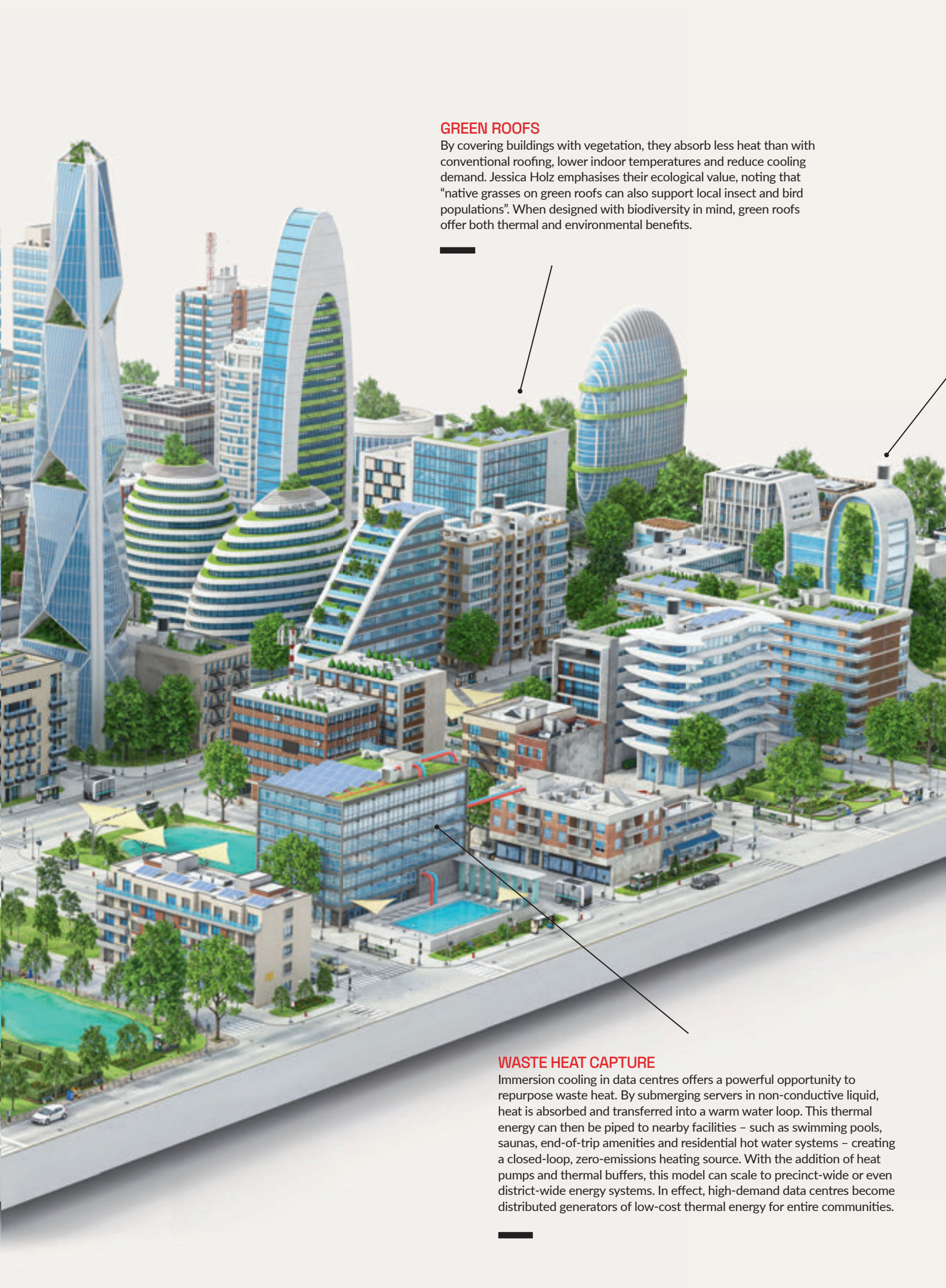
Australian company ClearVue is developing a transparent PV glass that makes efficient use of the light coming through the window. It generates solar power by redirecting UV and infrared light to edge-mounted PV cells. This reduces solar heat gain while allowing visible light through for natural daylighting and clarity.

The model of a 36,800 m², 40-storey ClearVue BIPV-equipped office building was assessed across 15 global cities. At 40 per cent window-to-wall ratio (WWR), PV systems met more than 85 per cent of annual energy needs in all cities, achieving net zero or better in 11 locations. Greenhouse gas reductions peaked at ~1,600 t CO₂e/year (43 kg/m²) in high-emission, high-solar areas. PV output ranged from 51-148 per cent of building demand, depending on WWR and city.



BUILDING MANAGEMENT SYSTEMS

Building management systems technologies can help lower heat emissions and energy consumption across precincts by optimising ventilation and reducing unnecessary mechanical cooling. "You can track and respond to actual usage, rather than over-cooling entire buildings," Holz said. This allows facility managers to shut down cooling in unoccupied areas and adjust temperature setpoints during peak demand, reducing vented heat.



GREEN ROOFS

By covering buildings with vegetation, they absorb less heat than with conventional roofing, lower indoor temperatures and reduce cooling demand. Jessica Holz emphasises their ecological value, noting that “native grasses on green roofs can also support local insect and bird populations”. When designed with biodiversity in mind, green roofs offer both thermal and environmental benefits.

WASTE HEAT CAPTURE

Immersion cooling in data centres offers a powerful opportunity to repurpose waste heat. By submerging servers in non-conductive liquid, heat is absorbed and transferred into a warm water loop. This thermal energy can then be piped to nearby facilities – such as swimming pools, saunas, end-of-trip amenities and residential hot water systems – creating a closed-loop, zero-emissions heating source. With the addition of heat pumps and thermal buffers, this model can scale to precinct-wide or even district-wide energy systems. In effect, high-demand data centres become distributed generators of low-cost thermal energy for entire communities.

WINDCATCHERS

A fundamental cooling technology in parts of northern Africa and the Middle East for millennia, windcatcher towers are finding favour in more and more buildings across the world. The towers use prevailing winds and the stack effect to naturally circulate air inside buildings, sometimes harnessing evaporation for further cooling effect. Companies like the UK's Monodraught are updating the technology such as heat exchangers and controllable louvres to maximise efficiency regardless of wind direction.

CANOPY PROTECTION

Nature plays a critical role in mitigating the UHI effect by cooling ambient temperatures through shade and evapotranspiration. Vegetation, particularly mature trees, blocks solar radiation, while water released from leaves and soil reduces surrounding heat.

Holz noted that "intact ecosystems can lower local temperatures", especially when integrated at a precinct scale. Green corridors can create cooler microclimates. Unlike hard surfaces that trap heat, natural landscapes absorb less solar energy and release more moisture. Incorporating nature into urban design not only reduces heat, but also supports biodiversity and human wellbeing.

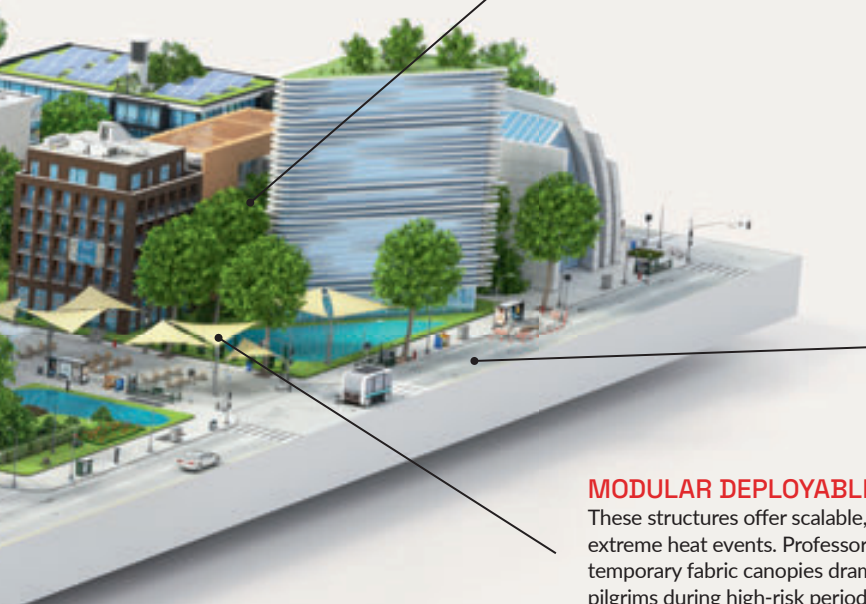
COOL PAVEMENTS

In Adelaide, a trial of reflective road coating applied more than 14,000 m² across two suburbs and had significant results. Surface temperatures were reduced by up to 11.5°C, and ambient air temperatures dropped by 1.1°C at night. The coating had a solar reflectance of 36 per cent, compared to 6 per cent for standard asphalt.

These reductions improve pedestrian comfort, reduce localised heat stress and lessen thermal load on nearby buildings. When deployed at scale, cool pavements can support broader cooling strategies, particularly when paired with supercool materials or vegetation. As the Adelaide trial noted, careful site selection and ongoing monitoring are key to long-term effectiveness, especially in balancing glare, durability and community feedback.

MODULAR DEPLOYABLE SHADES

These structures offer scalable, fast-to-install solutions for cooling public spaces during extreme heat events. Professor Matt Santamouris highlights their use in Mecca, where temporary fabric canopies dramatically reduced surface temperatures and protected pilgrims during high-risk periods. When combined with supercool materials that reflect up to 95 per cent of solar radiation, these structures can amplify cooling effects, lowering local temperatures by several degrees. These systems could be rapidly deployed in schools, transport hubs or vulnerable communities during heatwaves.



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Building management systems (BMS) are evolving to meet this challenge. Modern BMS tools give facilities managers real-time visibility over system performance and energy use. “You can track temperature trends, identify inefficiencies and isolate unoccupied zones for cooling shutdown,” Holz said. “That’s essential in large buildings where different spaces have different needs.”

Cooling materials in a warming world

New advances in materials science are offering scalable solutions to extreme urban heat. Professor Matthaios Santamouris, Professor of High Performance Architecture at UNSW, has developed a series of cool and supercool materials capable of significantly lowering surface and ambient temperatures in cities.



ABOVE:
Professor Matthaios Santamouris, UNSW.

Traditional cool roofs reflect sunlight, reducing surface temperatures and energy demand. “With conventional cool materials, we’ve seen urban cooling of up to 2°C, and building energy savings of 30-40 per cent,” Santamouris said.

But his team’s next-generation “supercool” materials promise to go further, reflecting up to 95 per cent of solar radiation while emitting heat through the atmospheric window (a part of the spectrum that allows heat to escape directly to space). These materials can be up to 10°C cooler than ambient temperature under direct sunlight.

Crucially, these benefits no longer require aesthetic compromise. “We’ve developed coloured supercool materials using fluorescent pigments that maintain reflectivity while avoiding glare,” Santamouris said. “That means they can be used on vertical facades, not just roofs.”

In Riyadh, Saudi Arabia, the recent deployment of these materials led to a 4.5°C reduction in ambient temperature and cut building cooling demand by 35 per cent. The potential for Australian cities is significant.

Natural mechanisms

Urban design that incorporates biodiversity can also act as a thermal regulator. “Nature-positive design provides shade, releases water vapour and enhances local ecosystems,” Holz said.

Intact vegetation and water bodies can reduce urban temperatures through evapotranspiration. Converting stormwater drains into wetlands,

for example, brings measurable thermal benefits alongside ecological ones.

“Nature is opportunistic,” Holz said. “Give it space and it will return – bringing shade, cooling and resilience.”

Even small changes can make a difference. “Native grasses on green roofs can support insects and birds. They’re undervalued, but vital. Every plant becomes a potential stepping stone for species dispersal.”

Health challenge

The stakes go far beyond comfort. Santamouris cites rising mortality, increased hospital admissions for mental health and drops in worker productivity as serious side-effects of urban heat. “Above 28°C, suicide rates increase significantly,” he said. “Productivity can fall by more than 60 per cent at extreme temperatures.”

In communities with limited access to air conditioning – such as First Nations communities in the Northern Territory – indoor temperatures can reach 45°C. Trials of cool roofing materials in these contexts have shown reductions of 10-15°C indoors, offering immediate health and safety benefits. “We need to stop thinking of heat mitigation as optional,” Santamouris said. “The cost of doing nothing will be many times higher in health, energy and lost productivity.”

Systems-level opportunity

A truly heatwave-proof city won’t rely on any single solution. It will combine nature-based design, advanced materials, better buildings and smart systems, guided by local knowledge and powered by engineering expertise.

“The opportunity is enormous,” Holz said. “We can embed resilience, improve health and lower emissions – all by designing smarter cities.” □

BY THE NUMBERS

IN HOT CLIMATES, EVERY

1°C

INCREASE IN TEMPERATURE ABOVE THE DAILY MEAN RESULTS IN A

1.3%

INCREASE IN REPORTS OF ATTEMPTED SUICIDE

Source: Australia and New Zealand Journal of Psychiatry

USING SUPERCOOL MATERIALS IN URBAN ENVIRONMENTS LED TO A

4.5°C

REDUCTION IN AMBIENT TEMPERATURE, REDUCING COOLING DEMAND BY

35%

Source: UNSW Riyadh, Saudi Arabia

“We need to stop thinking of heat mitigation as optional. The cost of doing nothing will be many times higher in health, energy and lost productivity.”



Power under pressure

WORDS BY GEMMA CHILTON

A changing climate, retiring coal plants and rising renewables are forcing a major redesign of the electricity grid. At every level, engineers are leading the transition to a more resilient system.



Australia's power grid is being pulled in every direction. Coal is retiring, renewables are flooding in and climate extremes are straining infrastructure. What was once a predictable, one-way supply chain is now a fast-evolving system with risks coming from both nature and cyberspace.

Engineers are scrambling to keep pace – integrating rooftop solar and batteries, reinforcing old lines, designing a grid that can bend without breaking. The goal isn't just to keep the lights on; it's to build a system that can adapt, recover and evolve. A resilient grid by design.

For Neil Greet FIEAust CPEng EngExec – civil engineer, retired army colonel and energy resilience expert – resilience isn't just about physical infrastructure. It's about mindset.

"Energy security requires national security-style planning, which is always in motion, addressing change," he told *create*.

Greet, a Board Member of the Engineers Australia College of Leadership and Management, sees the system being squeezed from all sides, including by short-term political thinking, a constrained workforce, fragmented markets and a lack of a coordinated national risk assessment. And as the grid grows more digitised, its exposure to cyber threats increases.

Greet isn't convinced we're moving fast enough to address these factors.

"The electricity grid will be exposed to them and will not have reached full potential by 2040," he said. "It may in fact suffer from cyber-attacks from adversaries."

Greet's concern is not just technical but systemic. He warns that, without careful planning, the energy transition could deepen inequities and erode resilience.

"As with all failures of resilience, it's the vulnerable that suffer first, then, eventually,

it destabilises the overall system."

While warnings of an "energy death spiral" – where wealthier households invest in solar and batteries, leaving others to shoulder rising grid costs – helped spark reform, today's picture is more nuanced. More than four million households have rooftop solar, and many earn income by exporting to the grid.

Yet even this model is shifting: new pricing structures will allow networks to charge for exports during periods of network congestion. These reforms reflect a broader trend toward two-way energy flow – and the growing value of a reliable grid connection.

Still, as electricity use is forecast to double by 2050 with the electrification of transport, industry and homes, the challenge remains: how to ensure all Australians can participate in and benefit from the transition.



ABOVE:
Neil Greet FIEAust
CPEng EngExec,
Engineers Australia;
Merryn York, AEMO.

Join Neil Greet
at CSE 25 at the
Adelaide Convention
Centre, 27-28
August 2025.



Grid of the future

Merryn York is an electrical engineer and Executive General Manager of System Design at the Australian Energy Market Operator (AEMO), the independent body responsible for operating Australia's electricity and gas markets, and ensuring the reliable delivery of energy. Her job is to make sure the future grid can deliver secure, reliable and least-cost electricity – even as coal retires, renewables rise and the climate becomes less stable. >

"There's increasing tension between the energy market's economic drivers and the technical requirements of a resilient, secure grid."

“One of the biggest challenges is shifting from the system we have today – built around baseload and peaking generation – to one built on renewables and firming,” she said. Firming refers to technologies and strategies such as batteries, pumped hydro and flexible gas, which can rapidly supply power when renewable output drops.

AEMO’s latest Integrated System Plan, published in June 2024, includes a coordinated roadmap for transforming generation, storage, transmission and system operations in the national electricity market. It sets out the best available view of what Australia’s electricity system could realistically look like by 2050 – a grid that is low-emissions, affordable and able to maintain reliability as energy use patterns shift and coal retires.

“A resilient system needs a mix of renewables, storage, flexible gas and robust transmission, so energy gets where it’s needed, when it’s needed,” York said.

A critical part of this mix is infrastructure that can deliver multiple services – which York refers to as a “no regret” plant. Gas generators fitted with clutches, for instance, can operate in synchronous mode without burning fuel, helping to maintain frequency and voltage stability as coal units are retired. By retaining the stabilising benefits of traditional generation while reducing emissions, they offer a practical bridge to a more renewable, decentralised system.

Separate entities

For Nathan Ting, Principal Engineer at Cell Engineering and Chair of the Engineers Australia Electrical College Board, the



“Microgrids support decarbonisation while building resilience, ensuring that the transition to clean energy includes those most impacted by climate change and energy poverty.”



ABOVE: The Nyngan Solar Plant in Western NSW; Nathan Ting, Cell Engineering.

resilience challenge goes beyond system design. It’s about enabling engineers to act.

“There’s increasing tension between the energy market’s economic drivers and the technical requirements of a resilient, secure grid,” he said.

Neil Greet put it another way: “The power system and the marketplace remain two separate entities. One part is a ‘mechanical’ system maintained and improved by a workforce. The other is a virtual auction room where electricity retailers buy power. This lack of integration means it is difficult to make change.”

Ting also highlighted regulatory barriers and a lack of technical input in policymaking as key risks, noting that engineering insight is too often absent from rule-setting, which slows the implementation of practical, technically sound solutions.

“We need to enable engineering-led decision-making that allows for innovation without compromising safety or reliability,” he said.

As the grid shifts from synchronous to inverter-based generation, engineers face the challenge of rethinking protection schemes, maintaining system



BY THE NUMBERS

INVESTMENT IN LARGE-
SCALE RENEWABLE ENERGY
PROJECTS IN AUSTRALIA

\$9 billion

500%

INCREASE ON 2023

Source: Clean Energy Council

Microgrids: Resilience and equity at the edge

Many remote Indigenous communities rely on ageing single-circuit feeders that stretch up to 100 km through bushfire-prone terrain. These long lines are expensive to maintain, frequently disrupted by extreme weather events such as storms, and slow to repair, often leaving communities without power for days.

Microgrids offer a resilient alternative. By generating and storing energy locally – typically through solar photovoltaics, batteries and small-scale diesel backup – they reduce dependence on vulnerable infrastructure while improving reliability, safety and affordability.

“Microgrids can operate independently from the main grid during outages caused by storms, bushfires or equipment failures,” said Dr Umme Mumtahina, an engineer and renewable energy researcher at CQUniversity. “This enhances energy security and supports community resilience in the face of frequent disruptions.”

Mumtahina is leading a Queensland-based project to improve energy outcomes in a remote Indigenous community. It combines distributed energy resources, demand-side management, and advanced control systems – co-designed with the community to ensure the solutions are both technically sound and culturally appropriate.

But building microgrids isn't straightforward. Engineers must coordinate diverse components in real time, manage system stability without traditional inertia and plan for future growth.

Interoperability, cybersecurity and respectful access to local energy data also require careful attention.

“Microgrids support decarbonisation while building resilience, ensuring that the transition to clean energy includes those most impacted by climate change and energy poverty,” Mumtahina said.

In remote Australia, microgrids are more than backup. They're a pathway to energy equity, community empowerment and climate justice.

strength and ensuring frequency stability in a system with far less inherent inertia – the stabilising effect of spinning generators. These developments demand not just more sophisticated modelling, but a reimagining of how power systems are designed and controlled.

The engineering workforce must also grow to meet the demands of a grid in transition. “Local uptake of engineering as a career remains a concern,” Ting said, noting the need to train not just engineers, but also the trades and technicians who will build and maintain the infrastructure.

“Engineers will play a huge role in the transition of the power system,” York added. “Much of our focus at AEMO relates to power system analysis and operation, and these skills are in high demand. [This includes] assessing the technical capability of new generation to connect to the power system, developing power transfer capability equations that can be used in the dispatch engine that runs every five minutes to keep the power system in balance, and many other activities.”

Beyond operational roles, she said, engineers are also essential >



ABOVE: Dr Umme Mumtahina, CQ University.

in construction, environmental assessment and infrastructure delivery – all critical to building a system that is secure, reliable and ready for the future.

Regulatory shift

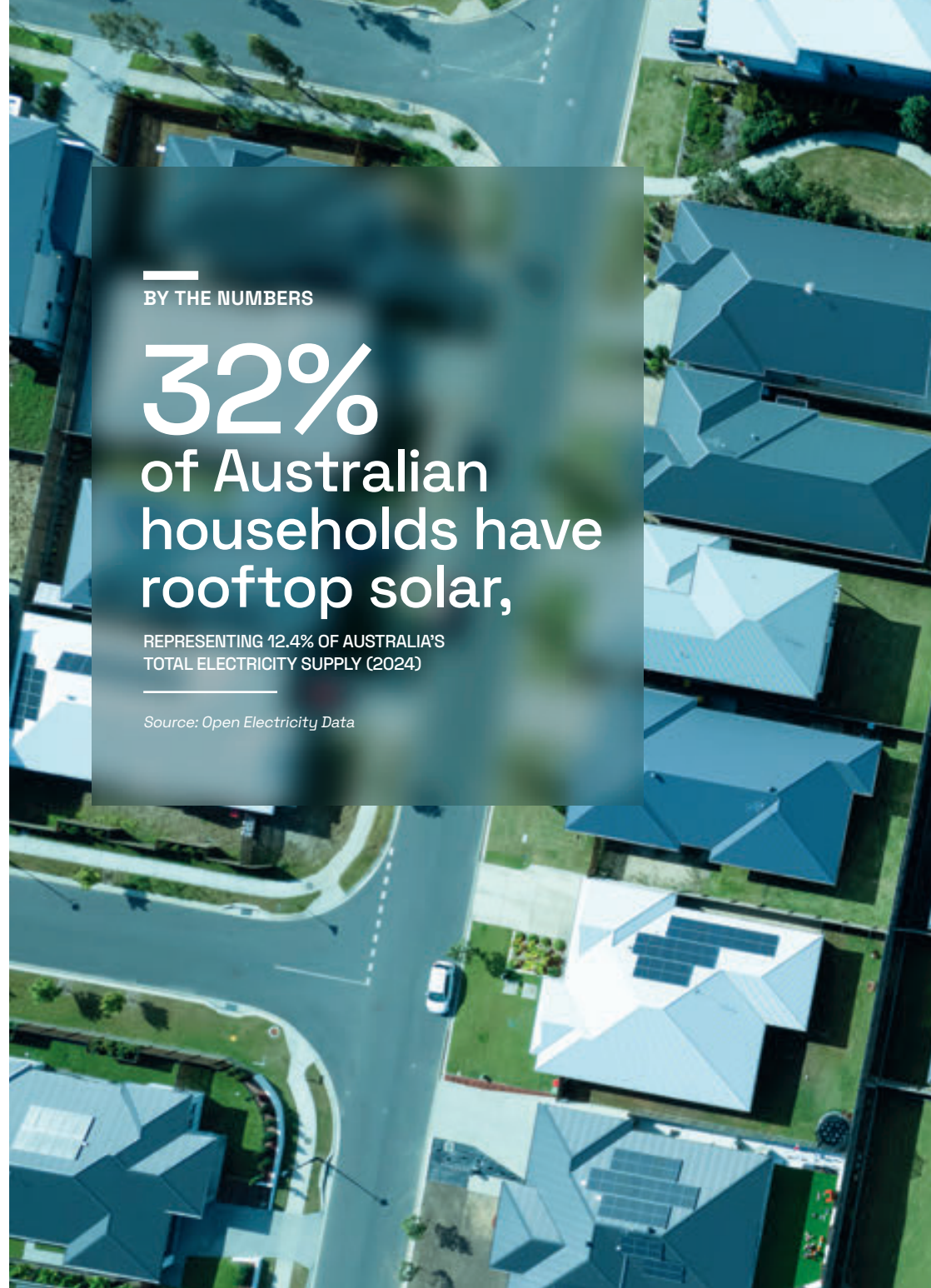
The call for improved alignment between technical need and regulatory support is already gaining traction. In early 2025, the Australian Energy Market Commission introduced a draft rule to formally recognise distribution network resilience in the National Electricity Rules.

“This framework would support DNSPs [Distribution Network Service Providers] in efficiently planning and investing in network resilience, while providing clearer guidelines to support consumers impacted by power outages caused by extreme weather,” AEMC Chair Anna Collyer said in a statement.

The draft rule complements the Australian Energy Regulator’s recent development of a Value of Network Resilience, providing a method for assessing the consumer benefit of investing in resilience measures. Together, these changes represent a structural shift in how resilience is considered – not just in emergencies, but in everyday decision-making.

Virtual power plants (VPP)

As the grid grows more complex, engineers are designing for uncertainty. Grid-forming inverters – which help stabilise voltage and frequency such as traditional generators – are being deployed to support system strength. Microgrids are being trialled to keep essential services running during outages.



BY THE NUMBERS

32%
of Australian
households have
rooftop solar,

REPRESENTING 12.4% OF AUSTRALIA'S
TOTAL ELECTRICITY SUPPLY (2024)

Source: Open Electricity Data

One example is Project Symphony, a collaborative pilot in Western Australia that involved AEMO, Western Power and Synergy. It tested how thousands of customer-owned devices – rooftop solar, batteries and smart appliances – could be orchestrated as a virtual power plant (VPP). It showed that VPPs substantially reduce power system costs and help alleviate

ABOVE: Project Symphony tested how rooftop solar can become a kind of virtual power plant.

local network constraints improving reliability, security and real-time visibility of distributed energy resources. New standards are also emerging to ensure these assets respond dynamically to changing grid conditions.

Operational practices are changing too. Engineers at AEMO are updating forecasting models and scenario planning tools to better anticipate



RIGHT: An EV connected to a bidirectional charger as part of the CSIRO V2G trial; and Dr Sam Behrens, CSIRO.

largest transmission project – was initiated in response to the 2016 “black system event” in South Australia, when a severe storm caused a statewide blackout. The loss of multiple transmission lines and the resulting drop in system strength exposed the fragility of SA’s connection to the rest of the grid.

In the wake of this event, EnergyConnect was fast-tracked as a solution to provide a stronger, more flexible link between SA and the eastern states, enabling renewable energy to flow between NSW, SA and Victoria for the first time.

Central to AEMO’s 2024 Integrated System Plan, EnergyConnect has been engineered with resilience features including dynamic reactive support (which helps manage voltage on the grid), automated systems for detecting faults, and a phased approach to increasing its power transfer capacity – beginning with 150 MW and planned to scale up to 800 MW as more stages of the project are completed. >



Driving the grid: How EVs could power homes

At Essential Energy’s Innovation Lab in Port Macquarie, a CSIRO-led trial is exploring how electric vehicles (EVs) can become part of Australia’s future energy system, not just as transport, but as mobile energy assets.

The project is testing vehicle-to-grid (V2G) technology using EVs connected to a simulated household fitted with rooftop solar, battery storage and common appliances. Bidirectional chargers allow the vehicles to store excess solar energy during the day and discharge it into the home or grid during peak demand, helping manage load and reduce reliance on centralised infrastructure.

The lab includes appliances such as air conditioners, hot water systems and pool pumps, all controlled to reflect different usage patterns. This enables testing under various real-world scenarios, including solar soak (using energy

during peak solar hours), self-consumption and export to grid. The aim is to tailor V2G integration to Australia’s regulatory standards, household behaviours and grid characteristics.

“An EV can have more than five times the battery storage of a stationary storage system, and V2G technology will allow us to leverage that and use it in the home,” Dr Sam Behrens, CSIRO’s technical lead for the collaboration, said. “It can also be used to support the grid, enhancing reliability and resilience by flattening peak loads.”

The trial also highlights existing challenges. EV owners in Australia may face regulatory hurdles when connecting V2G systems, with evolving standards not yet designed for two-way energy flows.

Still, the potential is clear: EVs could soon power not just our journeys, but our homes and communities too.

conditions that could destabilise the grid. That includes more granular weather modelling, probabilistic load forecasts and assessments of how the system behaves during rare but high-impact events.

One of the most significant examples of resilience-focused infrastructure in recent years is Project EnergyConnect. The 900 km interconnector – Australia’s



In a 2014 Engineers Australia report, *Energy Security for Australia: Crafting a comprehensive energy security policy*, co-authors Greet and security policy expert Athol Yates argued that “all Australian jurisdictions should incorporate the building of improved resilient energy systems as part of disaster risk reduction programs and post-disaster ‘build back better’ programs”.

However, this hasn’t happened and projects like EnergyConnect only highlight Australia’s too-often reactionary approach to resilience investment. “We wait for disasters to react instead of investing in infrastructure prior to a disaster,” Greet said.

Driving change

York, Ting and Greet each bring a different lens, but they converge on a central truth: engineers are not just managing the transition – they are driving it. From system architecture to community consultation, engineering expertise is central to making the future grid work under real-world pressures.

But technical skill alone isn’t enough. It must be matched by planning foresight, policy support and the capacity to adapt as conditions change. As the climate shifts and technology evolves, so too must the frameworks, assumptions and tools that

ABOVE:
275 kV towers
between
Robertstown and
Bundey substations.

underpin the system. As Greet put it: “There is an urgent need to recognise that energy resilience is a way of thinking, and responding to complex change is not a fortunate by-product of past regulation and rules.”

This isn’t just an Australian challenge – it’s a global one. On 28 April 2025, Spain experienced an unprecedented nationwide blackout that left much of the Iberian Peninsula without power for up to 10 hours. The outage was triggered by the sudden loss of 15 GW of generation – around 60 per cent of Spain’s electricity supply – within just five seconds, causing cascading failures across the grid.

While investigations are ongoing, early commentary has highlighted factors such as low system inertia, high reliance on inverter-based renewables, and limited interconnection with neighbouring systems as possible contributors to the event.

Other countries offer valuable insights, but Greet cautioned against assuming any one nation has it figured out.

“There is no nation or region that demonstrates strong grid resilience in practice,” he said. “There are localised nodes that are resilient – that is where people, politics, production and consumption align – but all nations have vulnerabilities, perhaps leading in one area, but then lagging in others.”

Resilience isn’t a fixed destination but a moving target, shaped by evolving risks, shifting technologies and the decisions we make along the way.

“It would be a mistake to wait for ‘perfect’. We must continue to be part of the global transformation.” □

“There is no nation or region that demonstrates strong grid resilience in practice ... All nations have vulnerabilities, perhaps leading in one area, but then lagging in others.”



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Material issues

WORDS BY JONATHAN BRADLEY

Corrosion remains one of the most persistent and expensive engineering challenges in Australia. But engineers are working with new materials and advanced coatings to push back against the forces of nature.

The failure of vital infrastructure often begins long before there are visible signs. Everything might seem in working order – structures stable, materials sound, surfaces intact – but, beneath that surface, environmental forces are at play. Exposure to moisture, stress and chemical agents gradually initiates corrosion, undermining the integrity of materials over time. Minor imperfections expand, connections weaken, and what starts as a slow, silent process can escalate into sudden, costly failure. It's not a dramatic fiction but a constant, complex problem engineers must anticipate and manage in the real world.

"Corrosion is a bit like corruption," Professor Srdjan Netic, Director of Ohio University's Institute for Corrosion and Multiphase Flow Technology, and an affiliated scholar at Western Australia's Curtin Corrosion Centre, told *create*. "It's destructive. It can lead to complete collapse."

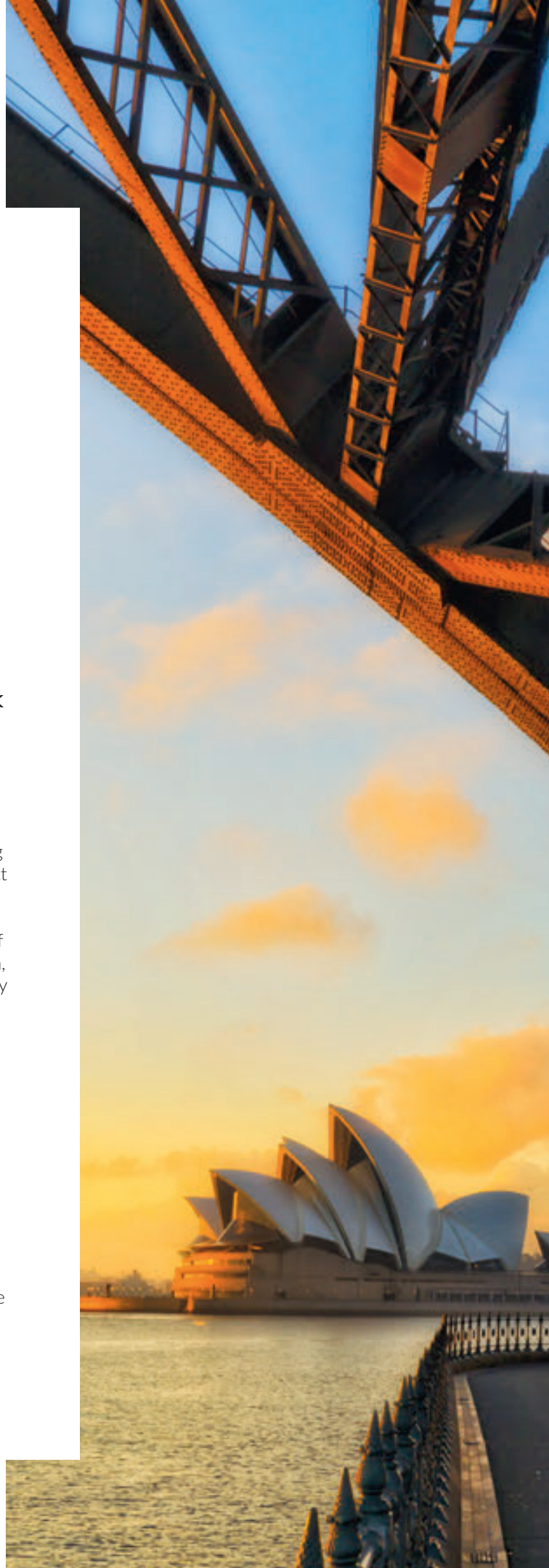
However, he said, while corruption eats away at the social fabric, corrosion does its work on infrastructure.

It's a problem that no-one, whether politicians, business or the broader population, likes to think about until it's too late.

"Corrosion is the last thing on the list until it becomes the first – when something fails," he said. "A lot of those things we can prevent and solve upfront in the design and operational phases. We don't have to wait for failures."

Land and sea

Research from the US's National Association of Corrosion Engineers estimated the global cost of corrosion to be \$3.9 trillion – equivalent to 3.4 per cent of the global gross domestic product.



BY THE NUMBERS
ESTIMATED GLOBAL
COST OF CORROSION**\$3.9 trillion**

EQUIVALENT TO

3.4%

OF THE GLOBAL GDP

That amounts to a high of \$78 billion each year in Australia alone, according to the Australasian Corrosion Association. Its impact affects sectors economy-wide, including oil and gas, water and wastewater, defence, construction and infrastructure.

Monash University's Professor Nick Birbilis said public safety and cost reduction are reasons to make transportation more corrosion-resistant and therefore more resilient, but he sees environmental opportunity too.

"If we can make infrastructure that lasts a really long time, we don't need to replace it, and then we start being much better in terms of sustainability," he said. "There's an old saying that either you call the corrosion engineers in early, or you'll definitely call them in later."

With the process of corrosion taking place at the intersection between materials and the >



ABOVE:
Professor Srdjan
Nesic, Institute
for Corrosion
and Multiphase
Flow Technology;
Professor Nick
Birbilis, Monash
University.

environment, when it comes to transportation, urban infrastructure has different challenges to rural, and coastal locations require a different approach to those inland.

"In an urban setting, with a lot of cars, there's more carbon dioxide, which increases the type of corrosion called carbonation. So buildings in the inner city are far more prone to this than those in rural areas.

"Similarly, coastal structures near the water are far more prone [to corrosion] because of the amount of chlorides that are

in the environment and airborne particles that contain salt."

That means Australia, a country whose population is largely confined to cities along the coast, is particularly susceptible.

"A huge proportion of Australia's population and infrastructure is in what we call the marine environment, which extends some tens of kilometres inland," Birbilis said. "The aerosol spray from the ocean penetrates quite far inland, so most of Australia's critical infrastructure is in marine environments."

As a result, much of the land-based infrastructure faces similar corrosion challenges to infrastructure at sea.

"For port structures, and [other] structures that are absolutely critical, we do very



ABOVE:
Professor Kod Pojtanabuntoeng, Curtin Corrosion Centre.

BELOW:
What remains of collapsed Morandi Bridge connecting the A10 motorway in Genoa, Italy. The southern stays gave way explosively due to corrosion, with damage causing 43 casualties on 14 August 2018.

regular early inspections to try and understand if corrosion is happening," Birbilis said.

These inspections will often be matched by ongoing repairs and maintenance.

In rare cases, costly stainless steel might be used as the reinforcement for a structure's concrete foundations, said Birbilis, citing the Sydney Opera House as an example. With the much-older Sydney Harbour Bridge, however, the solution is to repeatedly repaint the structure to safeguard it from the sea air.



The right choice

"The best thing is to choose the right material for the given environment," Associate Professor Kod Pojtanabuntoeng, of the Curtin Corrosion Centre, told *create*.

"If we build everything from gold, platinum or titanium, it may be okay from a corrosion perspective, but the cost and the strength of the material won't match what we need from these materials in that given environment. That's when you have to compromise.

"That's why carbon steel is the most used in all of the cases: because it's the cheapest type of material, and then you couple it with the prevention, such as a [protective] coating."

Birbilis said selecting a corrosion-resistant material is ideal.

"And if you've got a material that might be corrosion-prone, but is in an inert environment, you're also okay."

Even when using corrosion-resistant alloys, you still need to ensure that they are appropriate to the relevant environment, Pojtanabuntoeng said.

"In a high-chloride environment, which Australia is known for, corrosion can manifest in a different way. When we look at carbon steel, it corrodes everywhere – everything turns red. But stainless steel would [experience] pitting – pinholes here and there."

In an attempt to devise ever more innovative corrosion-resistant materials, researchers have recently turned to AI, Birbilis said.

"There have only been a few developments in the history of corrosion-resistant materials," he said. "A good example is stainless steel, which was a discovery rather than an invention."

Devising new materials that

match the properties corrosion engineers seek is complicated by the sheer number of potential alloys that can be created.

AI, Birbilis said, allows researchers to speed-run a mix-and-match process.

"If you were to experimentally make alloys and try them with a traditional production of materials, you'd need as long as the universe has been in existence to do all the experiments," he said.

"In machine learning and AI, we have the ability to accelerate materials design digitally and screen a large list of candidates. This area has been emerging globally in the last couple of years."

Beyond material solutions, corrosion experts are continuing to refine electrochemical responses.

"Cathodic protection is a way of protecting steel from corrosion through either sacrificial anodes or through an impressed current method, where you supply some electrons – you literally plug your structure into a wall – and you supply electrons to it," Birbilis explained.

"If you supply electrons to a metal, it drives down the driving force for corrosion because it has a surplus of electrons and it doesn't want to oxidise."

An early example of this technique, he said, was pioneered in Australia's transit networks. >

"Some of the earliest use of cathodic protection was in inner Melbourne, because infrastructure was corroding as a result of stray current from the tram network."

COUNTING THE COST

The cost of corrosion is estimated to account for 3.4 per cent of global gross domestic product, and as much \$78 billion each year in Australia alone.

"It's massive," said Monash University's Professor Nick Birbilis. "Here's an industry that sits beneath the surface that costs so much, and the visibility and awareness of it just isn't there."

When it comes to resilience, infrastructure – and particularly transport infrastructure – matters greatly. The Australasian Corrosion Association highlights bridge collapse as the "most visible" form of corrosion-related catastrophic infrastructure failure. Build Australia estimates the yearly cost of corrosion-related infrastructure maintenance, including bridges, at \$8 billion.

"Transport networks are the pillars of the economy," write economists Angela Stefania Bergantino, Alessandro Gardelli and Lucia Rotaris in a review of resilience data studies.

"A resilient and efficient transport network, intended as the set of links, nodes and transport services (e.g. toll roads, public transport services, airline services), enables the movement of goods and people and promotes trade and cohesion between regions and societies."

A 2023 report from the International Transport Forum insists that resilience should be a "core objective of transport policy".

"Resilient transport systems continue to function or recover quickly in case of disruptions, minimising the cost to society and the economy," the report said. "Inoculating transport systems against breakdowns requires making the notion of resilience an integral part of transport policies, strategic planning, infrastructure appraisal, competition policies and transport-related indicators."

"Some of the earliest use of cathodic protection was in inner Melbourne, because infrastructure was corroding as a result of stray current from the tram network."

And it's an area in which Australia has remained innovative. Just this year, a closed-loop smart cathodic protection technology developed by Deakin University's Dr Mike Yongjun Tan was awarded the Materials Performance Corrosion Innovation of the Year Award at the Association for Materials Protection and Performance conference in Nashville.

The technology monitors materials in real time and automatically adjusts protection levels to mitigate complex and localised forms of corrosion.

Aerial stress

While transit by land and sea is subject to a broad range of corrosive environments, air travel must endure all of these and more. In the sky, material failure from hard-to-detect flaws such as stress-corrosion cracking can have particularly catastrophic effects.

Air transport has distinct features that shape the kinds of corrosion to which it is susceptible: planes operate in harsh environments and in a wide temperature range, move rapidly between high altitudes and ground-level, and can be exposed to fuel leaks and pollutants.

"Corrosion can target a small location, a very small micro-structure that we cannot see," explained Tan, who is Professor of Applied Electrochemistry and Corrosion Technologies at Deakin.

"We've had in the past a lot of aircraft incidents due to this

RIGHT: Galvanic corrosion due to differing anodic index between the bolts and the plate. Image: D3j4vu at Wikimedia Commons.



"Galvanic corrosion requires two different elements or two metals to contact with electron flow between them. If we put a layer of graphene in between them, that can prevent the electron flow and hence stop corrosion."

stress-corrosion cracking, so in the corrosion engineering area, we have spent a lot of time and a big effort has been made to investigate it – how to stop it and how to change the material."

One engineer working to strengthen the material we use to keep our planes in the sky is Dr Mukesh Bhasin, who conducted his doctoral research into graphene-reinforced aerospace polymers at RMIT University.

He told create he keeps three aims in mind when it comes to aircraft materials.

"Number one is safety, number two is maintenance cost, and number three is weight and performance."

Traditionally, planes have been constructed from aluminium to address the weight and performance metric. It's a light metal and, when used in alloyed form, a strong one.

But aluminium alloys are susceptible to corrosion, usually addressed through coatings and surface treatments. When aircraft engineers began introducing stiffer and lighter carbon composites into aircraft design, they were looking to improve performance.

"Because of the change of material, we were inadvertently also working to reduce corrosion – but that was not the primary goal," Bhasin said. "Composite is a carbon-fibre reinforced plastic."

And while plastic doesn't rust, composites are still at risk from galvanic corrosion, such as might occur where plastic meets metal inserts or fasteners, and stress corrosion that forms cracks in which moisture can collect.

Bhasin wants to improve the next generation of carbon composites by integrating into their structure the nanomaterial graphene, which he describes as having "phenomenal properties".

"Because graphene is one single layer of carbon, it creates a barrier which is impermeable to any gas or liquid," he said. "We are able to block the agents for corrosion, which can be moisture, oxygen or other electrolytes which have to come into contact with the metal."

Although graphene is usually highly conductive, it can be engineered to act as an insulator, meaning it prevents galvanic corrosion through electrical isolation.

"Galvanic corrosion requires two different elements or two metals to contact with electron flow between them," Bhasin said. "If we put a layer of graphene in between them, that can prevent the electron flow and hence stop corrosion."

There is also potential for graphene to be adapted as a smart material that stops cracks from growing after they appear, and even self-heal. Some experimental forms are even being adapted



ABOVE: Dr Mike Yongjun Tan, Deakin University; Dr Mukesh Bhasin, RMIT University.



to act as indicators of other problems, letting engineers and maintenance crews know to investigate a material before a problem gets out of hand.

"If we put nanoparticles within the matrix, we can make it generally conductive," Bhasin said. "Any separation of material can be sensed through the reduction in the electrical conductivity."

Return to form

When talking about their life's work, corrosion engineers can sometimes sound fatalistic; their outlook almost turns philosophical.

"Corrosion is unavoidable. It is

a process that returns the metals to the original mineral state in which they came from," Nesic said. "It's just progression. You can't stop it, but you can slow it down so that things can last for as long as we need them to last."

We might live in a corroded world, but that's what inspires Nesic and others to continue innovating.

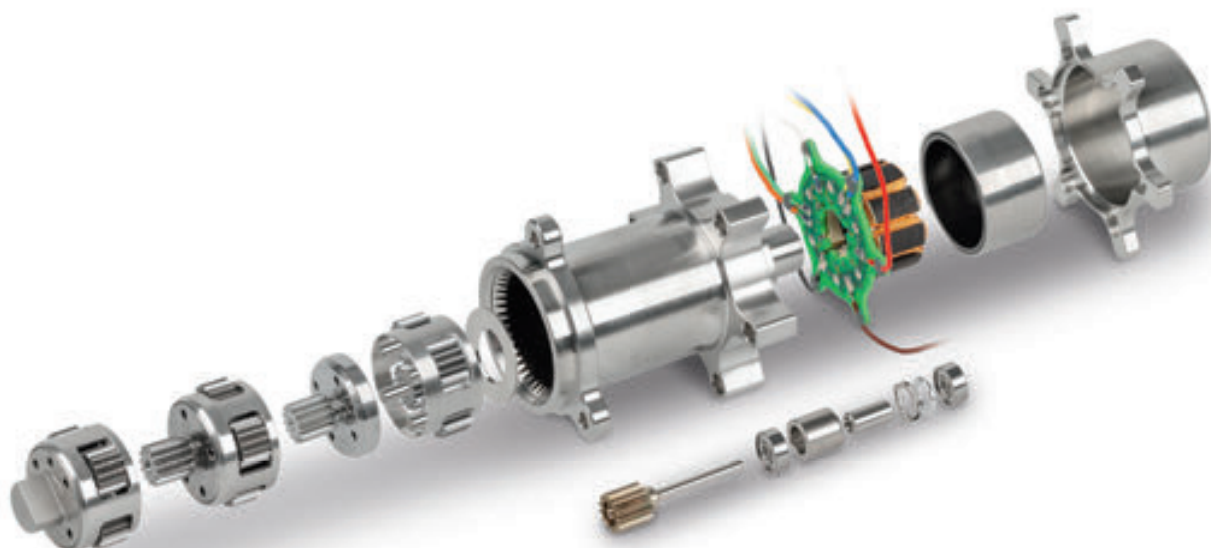
"It's that thermodynamic driving force that wants metals to go back to basically being ores," Birbilis said. "But we do know enough now for designing how to stop that. That's where we need to do really well, so our infrastructure can last."

"We are constantly fighting to understand and research what corrosion does ... My goal is to understand the enemy in order to be able to fight it."

ABOVE:
Stress-corrosion
cracking in aircraft
has led to increased
maintenance efforts.

Nesic said he wants to equip engineers with the best possible knowledge to help them produce infrastructure that lasts longer.

"We are constantly fighting to understand and research what corrosion does and how it does it," Nesic said. "My goal is to understand the enemy in order to be able to fight it." □



Perfectly tuned to Mars

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[Projects]

84 Cementing alternatives

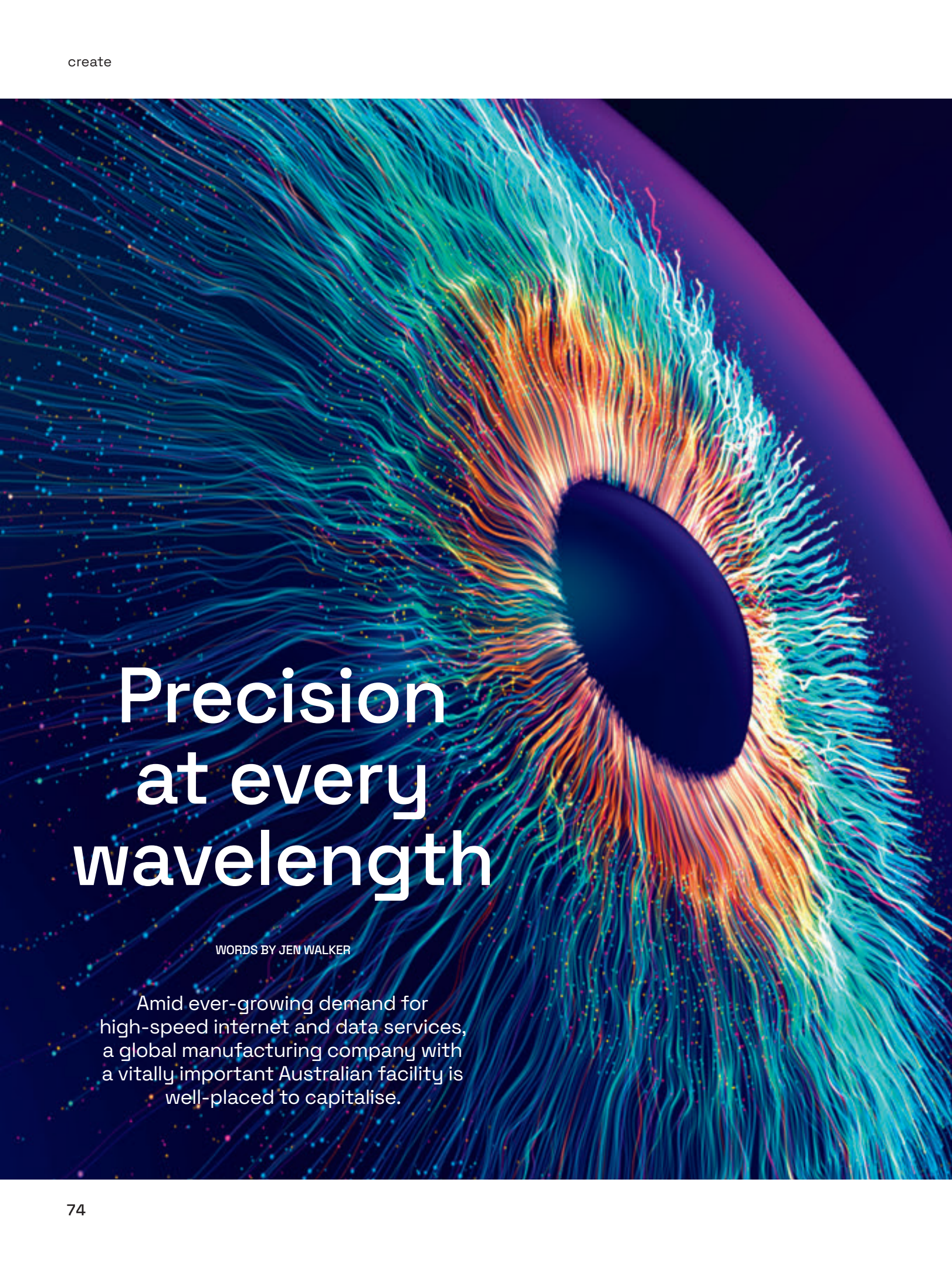
A new chlorine bypass system will drastically slash emissions at this cement facility.

74 Fibre-optic finesse

Half the world's internet traffic passes through switches based on this company's original invention.

78 Alumina advantage

"We've engineered the process from the ground up to deliver unmatched purity at commercial scale."



Precision at every wavelength

WORDS BY JEN WALKER

Amid ever-growing demand for high-speed internet and data services, a global manufacturing company with a vitally important Australian facility is well-placed to capitalise.

The wavelength management company Finisar has achieved no fewer than 15 world firsts. They include the first liquid-crystal on silicon wavelength selective switch (LCoS WSS) in 2006, the first flexible-grid WSS in 2010, the first quad WSS in 2020 and, earlier this year, the first low-cost edge WSS – with plenty of others in the years in between.

It's fair to say the company is committed to innovation and is benefiting from its relatively high research and development spend (more than 15 per cent). It is estimated that half the world's internet traffic passes through switches based on Finisar's original invention.

A WSS is an optical device used in fibre-optic communication networks to route individual wavelengths (channels) from an input fibre to one or more output fibres without converting the signal to electrical form.

Finisar specialises in wavelength management components and subsystems, which it supplies to networking equipment manufacturers to allow end-users to adjust the capacity of their internet data streams to suit different needs.

"The markets we are in constantly require new products," said Senior Director of Engineering at Finisar Jon Bulman. "We're on a never-ending path of evolution and it's very much part of our business."

Bespoke products

To maintain this momentum, the company's Sydney base blends engineering, research and

development and manufacturing, which this caters for the complexity of the design of its products as well as the precise specifications required for its machines. In the one place, the teams designs its own automated machines, writes the software and develops test instruments alongside the product design process.

For example, for its WSS switches, the team sends laser light through the optical circuit as it is being assembled, and manoeuvres the position of each component based on the optical properties being measured.

"In most manufacturing, you put something in place using an x-and-y coordinate, but we make machines that actually send laser light through the product, analyse the outcome and then drive the motion control feedback on the outcome of the light," Bulman said. "We make our own instruments to both send the laser signal and detect it.

"The other interesting thing is, if you have a series of optical components and you move one of them, the beams of light will then hit the next part in a different way. So we have to move all the components simultaneously and find a solution for that set of parts."

Some of those components are measured in nanometres, so precision is key.

A new product then goes through a testing stage which also fine-tunes the machine that made it. Once a prototype is ready, it is sent with its customised machine and software to the company's site in either South Korea or China, where it is replicated to scale up production of key subassemblies.

The assembly work in China is only for the optical components, which is quite a labour-intensive activity. The hermetically sealed optical subassembly is sent to Sydney where it is integrated into >



ABOVE:
Jon Bulman, Finisar.

What is Flexgrid?

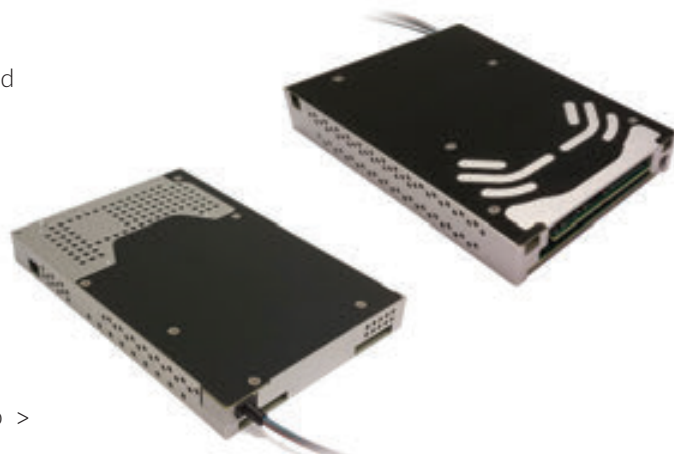
Finisar said its Flexgrid technology allows users to customise channel spectral shapes. As the data rate of transceivers increased over time, the spectrum of the transmitting lasers became too wide for standard, fixed channel width switching to work.

Utilising the inherent flexibility of the LCoS, Flexgrid allows dynamic reassignment of pixels to generate new phase patterns, enabling wider spectral channels suitable to higher data rates.

This flexible channel spacing can be increased after deployment of the WSS, allowing the network to adapt to new transmission formats and data rates.

Flexgrid future-proofs customers' networks because they can seamlessly increase data rates without having to replace the WSS in the network. It allows for agility, efficiency and scalability in optical networks.

BELOW: Finisar's wavelength selective switch.



a module with electronics and software.

From here, the product is calibrated to meet the customer's requirements.

"By sending light into it and characterising that individual product's optical performance, we can determine images that need to be put on the LCoS that will give us the output we need.

"We learn the algorithms to create the images by interrogating the unit. Using AI, the systems actually learn how to program products, and the more products of that type we make, the more efficient the software systems."

Consistency and control

Retaining this level of control within the organisation is a key strategy for the company's resilience. The final assembly operation and integration in Sydney keeps the technology in-house, while the people who work on improvements have immediate hands-on access to the product.

The factories in Korea and China are connected to a central

database, recording test data parameters, which allows the team in Sydney real-time visibility of every step of every product being assembled. If there is an issue, they can turn off the machines. All materials used are barcoded to ensure only the correct components are being used and allowing full traceability back to suppliers.

Finisar has cemented itself in a future-proof industry. Its initial customers were telecom companies such as Nokia and Huawei, though their markets have now evolved to include internet service providers.

"The evolution of our products are really for the increase in data traffic driven by the expansion of AI, which creates

"Using AI, the systems actually learn how to program products, and the more products of that type we make, the more efficient the software systems."

AT A GLANCE

50%

OF THE WORLD'S INTERNET TRAFFIC PASSES THROUGH SWITCHES BASED ON FINISAR'S ORIGINAL INVENTION

OPTICAL COMPONENTS ARE INDIVIDUALLY ALIGNED WITH SUB-MICRON PRECISION

AN OPTICAL COMPONENT MADE BY FINISAR HAS A FEATURE SIZE OF

300 nm

FINISAR IS THE ONLY WSS MANUFACTURER GLOBALLY WHICH DOESN'T SHIP FROM A LOW-COST ASIAN COUNTRY

Source: Finisar

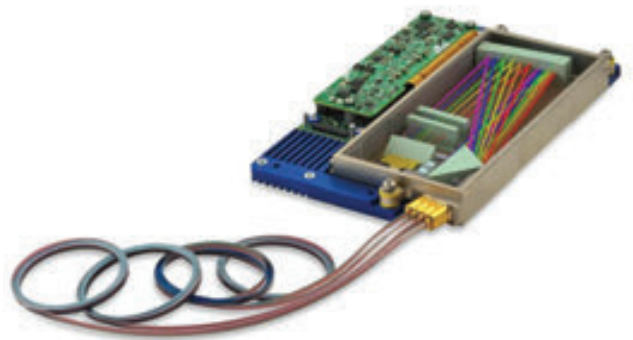
How wavelength selection switches work

An incoming optical fibre carries many channels of data, each at different wavelengths – this is called dense wavelength division multiplexing. Through the WSS, network operators can decide which wavelength is directed to which of the many output optical fibres, directing data to different parts of the network in the process. An additional functionality allows the output power levels of the different wavelengths to be controlled.

The core switching technology

relies on a liquid crystal on silicon (LCoS) device. The LCoS silicon backplane consists of thousands of individually addressable pixels. By applying a voltage to each pixel, a periodic phase pattern can be generated in an overlying liquid crystal layer. This alters the phase front of the reflected light, effectively steering the direction of light incident on the LCoS to a desired direction.

A prism and diffraction grating are used to disperse the multiple wavelengths of light in the incoming beam over the surface of the LCoS. Essentially, the LCoS acts like a programmable mirror. By altering the phase profile of the liquid crystal layer over the pixels, each wavelength can be steered independently



ABOVE: Visualising the interior of a wavelength selective switch.

to an output fibre (or port) of the WSS.

Incorporating WSSes into modern fibre-optic networks allows network operators to locally add or drop network traffic or support mesh networks and traffic reconfiguration.

a need for higher bandwidth communications between data centres,” Bulman said. “That will drive a future need for our products beyond what’s traditionally telecom.

“Ninety-five per cent of data travels through optical fibres – whether it’s our internet, mobile phones, watching Netflix, at some point it all converges to go across multiple fibre networks.”

Finisar is looking beyond these core networks, and has just released a new low-cost edge WSS platform designed to optimise network efficiency while reducing costs.

“Sometimes our customers, when we show them our products, are astounded by how few components are inside. If you look at our competitors, they’re full of little glass components, all doing separate functions. We’ve taken a different approach of having fewer physical parts, but each part has a more complex function.

“This has two positive aspects to it. One is that there’s simply

fewer components in the finished box. The other is that it’s more amenable to the process of automating the assembly. These things go together and enable us to make products for sectors of the market that are more price-sensitive. We can see ways to automate the manufacture of products that will provide very good performance.”

Hunger for innovation

Bulman believes one of the main challenges facing the company is that, currently, the opportunity to increase sales is largely dependent on a customer designing a new system that needs more capacity.

“To expand our reach into different customers and their applications, our engineering team is constantly being pushed to develop new technologies

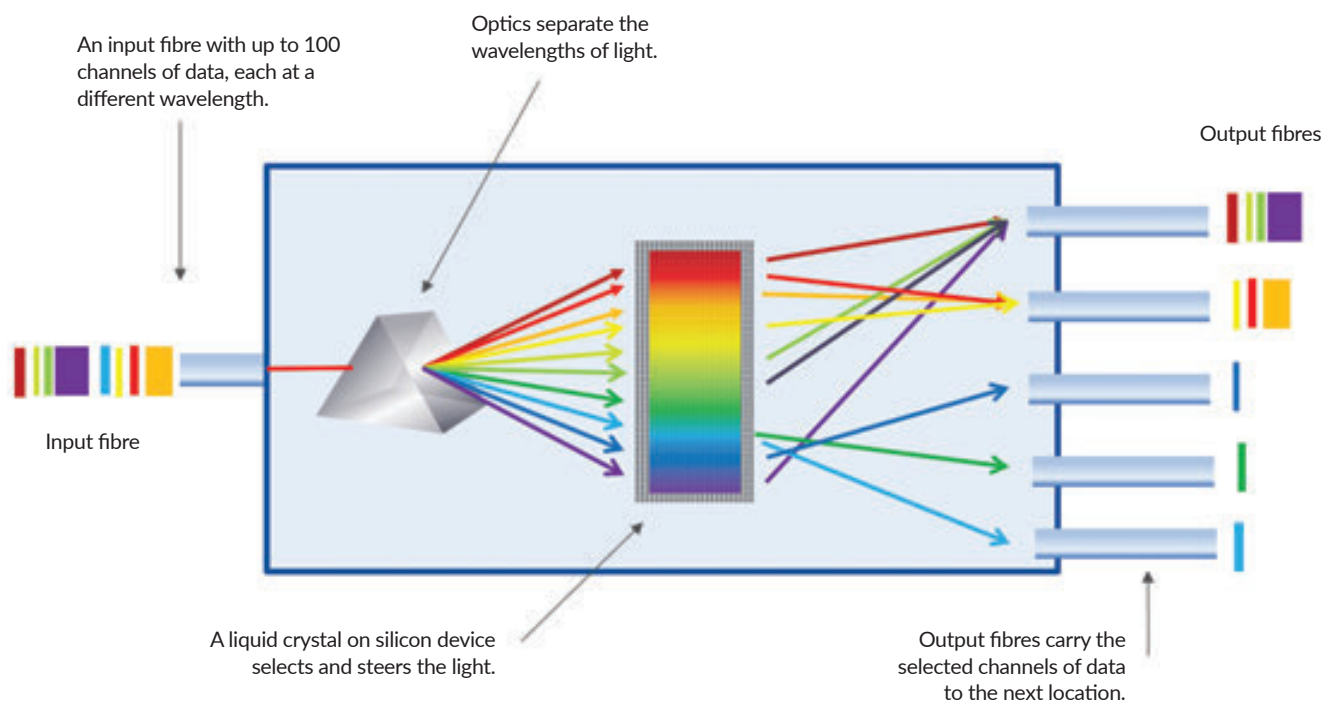
and new approaches, and, in a way, that’s what makes it fun,” Bulman said. “But it also means that our engineering activity has to be very carefully focused on understanding what the customers want and how to deliver that in the shortest possible time.

“And some of these changes are quite radical – the evolutionary steps can be big.”

Another resilience challenge is the potential for trade friction, especially relevant to an organisation that exports 100 per cent of its products.

“We are very much considering where parts should be made. Where is a reliable source of materials? Where can we assemble things which won’t be impacted by trade issues? How do we make sure we are fully compliant with any trade restrictions? It’s obviously a different type of work from traditional technology and design development, but it’s becoming an equally important part of resilience.” □

“Considering where parts should be made [is] becoming an equally important part of resilience.”



Alpha performance

A breakthrough Australian process is increasing the purity of aluminium materials while boosting the global decarbonisation project.

WORDS BY LARISSA FOSTER



High-purity alumina (HPA) is a material of the future that is in huge demand today. This value-added mineral is a

critical ingredient in breakthrough technologies – from improving lithium-ion battery safety to making AI chips cooler and faster, to enabling more efficient lithium extraction.

In the industrial hub of Gladstone, Queensland, Alpha HPA is at the forefront of the material's refinement into ever-higher grades of commercial purity. The specialty aluminium materials and technology ASX-listed company has developed a world-first process for purification and refining. A technology that not only generates fewer emissions, but also results in near-zero waste.

"The idea of producing high-purity alumina isn't new – but the way we do it is," said Rob Williamson, Managing Director of Alpha HPA. "We've re-engineered the process from the ground up to deliver unmatched purity at commercial scale, with near-zero waste and drastically lower emissions. It's not just an evolution – it's a step-change that positions Australia at the forefront of a critical global supply chain."

Outstanding hardness

An odourless crystalline material, aluminium oxide is notable for its high thermal conductivity, low electrical conductivity, and outstanding hardness and strength that make it a material of choice for various industrial applications.

A refined form of the non-metallurgical material, HPA must consist of more than 99.99 per cent aluminium oxide.

Classifications of HPA are indicated by the number of nines in its purity level. A 4N ("four nines") HPA signifies at least 99.99 per cent purity, 5N is at least 99.999 per cent purity and 6N is at least 99.9999 per cent purity.

These levels are achieved through processes that minimise trace impurities, such as electrolysis or zone refining.

The rapid development of high-tech fields has seen aluminium's purity requirements increase. As the evolution of AI unfolds, demand for power-hungry data centres is seeing the exponential growth of HPA's use in thermal management.

HPA provides multiple performance benefits when it is used as a cooling agent in the advanced semiconductor chips needed to power AI data centres, which as a by-product produces enormous amounts of heat.

Traditionally, high-purity silica has dominated the market as a semiconductor heat sink. But with thermal conductivity 25 times higher than silica, HPA is becoming the most in-demand semiconductor material.

"Silica will still have a place in lower-performing chips, but when it comes to high-performance applications – like GPUs and power semiconductors – high-purity alumina is becoming the material of choice," Williamson said. "HPA delivers the cooling performance needed to keep next-gen chips running efficiently and reliably."

Enter Alpha HPA

Alpha HPA's innovative manufacturing process is capable of selectively extracting alumina from a proprietary solution using a solvent extraction process with "scalpel-like precision", Williamson said.

The hydrometallurgical technology was first commercially used in the 1970s and is commonly used for copper, zinc

and rare earths. Williamson is understandably coy on Alpha HPA's proprietary process for aluminium extraction, which is based on established solvent extraction (SX) technology.

"Solvent extraction is essentially a way to selectively purify metals, almost like a molecular-level filter that isolates the element you're targeting," Williamson said. "What we've done is take this proven hydrometallurgical technology and refine it specifically for aluminium. To the best of my knowledge, we're the first to successfully achieve this level of precision and purity for high-purity alumina."

The traditional production methods for HPA rely on

outdated, emissions-intensive technology, typically synthesising it from aluminium metal feedstock. This is energy-intensive and produces high carbon and chemical emissions, along with a significant amount of waste.

Alpha HPA uses a chemical aluminium hydrate feedstock sourced from Rio Tinto. It looks like bricklayers' sand, Williamson said, and it would notionally go on to become smelter-grade alumina. It is dissolved in acid and polished before Alpha HPA's proprietary Smart SX Technology process performs the highly selective extraction of Al^{3+} cations from aluminium-loaded liquor.

The aluminium-loaded organic solvent is then transformed



ABOVE:
Rob Williamson,
Alpha HPA.
BELOW:
Alpha HPA's First
Project facility in
Gladstone.



"Silica will still have a place in lower-performing chips, but when it comes to high-performance applications – like GPUs and power semiconductors – high-purity alumina is becoming the material of choice."

through two crystallisation steps into an intermediary product that can be calcined to HPA. The loaded organic stream can be directed to any acid stream to generate 5N+ purity aluminium precursors (salts), or 4N+ boehmite or alumina. Byproducts are sent to mining explosives company Orica, a 5 per cent shareholder in Alpha >

HPA, and returned as reagents in an almost waste-free process.

The company's proprietary technology creates a growing range of high-purity aluminium materials – aluminium oxides, aluminium hydroxides and aluminium nitrates – of an ultra-high purity that is considered a best-in-class low-alpha feedstock.

"It's so pure that we eliminate uranium and thorium," Williamson said. "That's critical because these elements emit alpha radiation which can ionise the materials within the nanolayers of a semiconductor. When that happens, electrons are displaced, which leads to data errors or, worse, premature failure of the chip itself.

"We're achieving uranium and thorium levels below one part per billion – essentially at non-detectable levels. We can't technically claim zero, but it's significantly lower than the five parts per billion typically seen in competitor products."

Energy transition

Another standout application for Alpha HPA's proprietary alumina relates to batteries. HPA is widely used to coat the separator between the anode and cathode to provide multiple battery-performance benefits, including an improvement in thermal capacity and reducing the rare risk of fires in mobile phones and EVs.

"We are particularly focused on battery safety, using our aluminium nitrate as a precursor to coat the graphite anode within the lithium-



"We didn't need to invent any mechanical apparatus. It's tanks, mixers, filter presses, dryers, rotary calciners ... off-the-shelf equipment. The innovation lies entirely in chemistry, not machinery."

ABOVE:
Testing at the company's product development centre in Brisbane.

ion cells," Williamson said. "That aluminium oxide coating plays a critical role in halting the chain reaction that can occur when the battery experiences trauma. In essence, it prevents thermal runaway, while also allowing the battery to operate at slightly higher temperatures, which can improve charging and discharging performance."

Alpha HPA's materials are also proving essential in the global

energy transition through their role in chemical mechanical planarisation slurries, used to polish high-performance semiconductors, especially silicon carbide (SiC) substrates.

"Our material is used in the polishing step for three types of semiconductors – silicon carbide, gallium nitride and sapphire," Williamson said. "These are fundamental to power-switching devices in EV battery systems, solar PV systems, wind turbines – essentially any application requiring high-power switching."

Recent testing has shown that Alpha HPA's materials deliver more than 50 per cent higher removal rates on SiC wafers compared to conventional abrasives, underscoring their performance advantage in next-gen semiconductor manufacturing.



Brand new facility

Australia is the world's largest exporter of alumina, but does not currently produce commercial quantities of high-purity alumina.

Alpha HPA's new purpose-built, renewably powered facility will change that. Currently under construction, the full-scale facility is expected to begin producing HPA in 2027. An estimated annual output of 10,000 t per year will make it the world's largest single-site manufacturing facility for high-purity aluminium materials.

The commercial plant will also deliver 4N purity HPA at a cost significantly lower than any other commercial process currently on the market.

"The underlying concept of producing HPA hasn't changed," Williamson said. "What we've done is perfected it to make sure it's commercially viable at scale."

A hydrometallurgical plant like this has to have a tight mass balance, ensuring all elements are accounted for in every stream, and that impurity levels don't accumulate to a point where they compromise the economics. Many technologies work well in a lab beaker, but their waste streams are too costly to manage at industrial scale."

Rather than relying on experimental equipment, Alpha HPA has designed the facility around proven, standardised hydrometallurgical systems.

"There's nothing exotic about the hardware," Williamson said. "We didn't need to invent any mechanical apparatus. It's tanks, mixers, filter presses, dryers, rotary calciners ... off-the-shelf equipment. The innovation lies entirely in chemistry, not machinery."

ABOVE:
The new facility's output will reach an estimated 10,000 t per year.

BY THE NUMBERS

70%

LOWER TOTAL CARBON EMISSIONS THAN CONVENTIONAL PROCESSES

10,000 t

OF HPA BEING MANUFACTURED PER YEAR AS OF 2027

PROCESS RECYCLES CLOSE TO

100%

OF PROCESS REAGENTS AND STREAMS

120

ADDITIONAL FULL-TIME JOBS CREATED ONCE FULLY FUNCTIONAL IN 2027

By solving the accessibility of large-volume, high-purity aluminium nitrate, Alpha HPA says it has unlocked the potential of fast and affordable application of aluminium-oxide coatings onto both cathode and anode active materials.

"It's a disruptive technology with the lowest carbon emissions, giving us a significant commercial advantage. It's very exciting times and great to be moving way further down that value chain in Australia."

The Australian Government's support of \$400 million for Alpha HPA's Gladstone facility is part of the Critical Minerals Strategy ambition to "increase Australia's footprint in downstream processing" of critical minerals. □



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Cementing resilience

WORDS BY ELLE HARDY

A new chlorine bypass system at Berrima Cement Works will double the use of alternative fuels at the plant over the next three years, reducing its carbon emissions by up to 150,000 t annually.

Boral's Berrima Cement Works supplies approximately 40 per cent of the cement used in NSW and the ACT, making it a critical asset in Australia's construction industry.

The technology behind a chlorine bypass, commissioned in 2024, will enable the firm to meet its decarbonisation targets and reduce its reliance on emissions-intensive fuels such as coal, driving smarter, cleaner cement manufacturing.

The integration of the chlorine bypass will allow the cement works to increase its use of alternative fuels to 60 per cent by 2026. Additionally, the system contributes to a reduction in the emissions intensity of clinker production by up to 11 per cent due to decreased calcination emissions and some improved thermal efficiency.

Managing the transition

Boral made a strategic decision in 2018 to pivot away from coal in favour of biomass and other zero-carbon fuels, a course which a number of cement plants around the world had already adopted.

"We decided on the bypass because we have one kiln which produces about 1.5 million t of clinker



"They're fine at high temperatures, but when operating at cooler temperatures, potassium and sodium chlorides become solid – which builds up deposits in the system."



ABOVE:
Boral's Berrima
Cement Works.

annually, which then makes the cement," Rajeev Ramankutty, Boral's Executive General Manager of Cement, told *create*.

"Every tonne of cement produced at Berrima generates around 683 kg of carbon dioxide, with 65 per cent coming from the decomposition of limestone and the other 35 per cent from fuel."

With the industry standard for clinker usually at 800 kg of carbon

dioxide, the facility was already ahead, but it wanted to continue to reduce its carbon footprint.

Ramankutty said Boral began its transition to using waste-derived fuels conservatively. "We used wood from construction demolition waste, which is quite a benign fuel to burn as it doesn't have many nasties in it – but the availability of this fuel is limited."

Tasked with reaching 60 per

cent coal substitution by 2026, the engineers had to consider waste-derived sources of fuel, such as PVC plastics, which presented a technical hurdle due to the substantial amounts of chlorides and sulfides they contain.

"When burning different fuels in the kiln, there is a lot of volatility, particularly related to chloride, sulfide and the alkali cycles," Ramankutty said. "They're fine >

“The pace at which we have moved is really impressive compared to [other] more mature countries which have gone down this path. Some European countries are burning 80-90 per cent waste fuel, and that’s where we want to be.”

at high temperatures, but when operating at cooler temperatures, potassium and sodium chlorides become solid – which builds up deposits in the system.”

Such build-ups are extremely difficult to manage, causing blockages that can interrupt operations or even force a full kiln shutdown. They also present a safety risk because the materials are so hot they flow like water, and have been responsible for severe burn incidents at other facilities around the world.

The nitty gritty

Managing and mitigating chloride content in gas streams is crucial for both operational efficiency and environmental compliance in cement manufacturing.

“The chlorine bypass process begins by extracting the gas stream, which contains chlorides among other compounds. This gas exits the kiln system at extremely high temperatures, typically around 1,200°C.

“It then goes through an air quenching system housed in a mixing chamber, where it is mixed with atmospheric air, and the temperature drops to about 400°C. A vertical heat exchanger

then further reduces the temperature to less than 200°C.”

This staged cooling is essential because chlorides, which are initially present in gaseous form, begin to solidify once the temperature drops below their melting point of around 700°C.

Once solidified, the chloride particles can be efficiently captured using a bag filter system. The resulting dust can then be recovered by shaking the filter to release the dust.

“The reason why you need to cool down is that bag filters don’t like very high temperatures,” Ramankutty said. The recovered dust, rich in chlorides, is then reintegrated into the cement grinding process, further reducing plant waste. “While there are regulatory limits on chloride content in cement, this system allows us to remain well within those standards.”

Fueling the fire

Moving from coal to alternative fuels in cement production has three key environmental benefits: the straight reduction in carbon emissions from tripling the use of waste-derived fuels, transforming waste liabilities into energy assets, and easing the burden on landfill systems.

Presently, the Berima plant uses a mixture of products, including wood chips, used automobile tyres, and refuse-derived fuel, the latter of which is responsible for most of the chlorides.

With emissions reduction on track, the engineers are now turning to a broader range of materials that would otherwise be destined for disposal. “We’ll be looking at things like recovered industrial waste oil, and shredding plastic wrappers and other light packaging materials into very fine particles for combustion,” Ramankutty said.

The diversity of alternative fuels helps in securing their



ABOVE:
Rajeev Ramankutty,
Boral.

BY THE NUMBERS

4.9% p/a

**THE CEMENT INDUSTRY’S
COMMITMENT TO
REDUCING ITS EMISSIONS**

30%

**ALTERNATIVE FUEL
SUBSTITUTION USING OF**

73,000 t

OF WASTE-DERIVED PRODUCTS

75,000 t

**REDUCTION IN
SCOPE 1 EMISSIONS**

47,000 t

**OF COAL EACH YEAR
WILL BE DISPLACED**

683 kg

**OF CARBON DIOXIDE IS
PRODUCED FOR EVERY TONNE
OF CEMENT AT BERRIMA**



ABOVE:
Operating the kiln
at the Berrima
facility.

long-term supply. The bypass's flexibility in being able to use any type of fuel also avoids build-up in the process, which is key to alternative fuel program success.

"The way to look at the bypass is that it is the key enabler in unlocking the potential of burning fuels," Ramankutty said.

By allowing the kiln to tolerate fuels with high chlorides, sulfides or other volatile contents, it ensures the safe processing of more difficult-to-handle waste, which it often considered undesirable due to the operational risks it poses.

This expands sourcing options and adds economic value.

"In some cases, we receive gate fees for accepting and processing

specific waste fuels – otherwise it can cost between \$200 and \$300 per tonne just to put it in landfill."

Burning ambitions

The benefits of the bypass system show it is more than just a technical upgrade – it's an investment in long-term resilience. It allows the Berima plant to burn a broader range of alternative fuels safely and efficiently, while cutting carbon emissions, reducing landfill pressure and creating new income streams.

After a feasibility study highlighted the benefits of the bypass system for the cement works, it required a substantial capital investment of around \$20 million, with the NSW

Government supporting the project with a grant amounting to almost a quarter of the cost.

Since the bypass came online, it has tripled the plant's alternative fuel use to around 45 per cent, with a clear pathway to the 60 per cent target. In the process, it will help Boral to reach its 2030 decarbonisation targets.

However, Ramankutty said the engineers don't intend to stop there.

"The pace at which we have moved is really impressive compared to [other] more mature countries which have gone down this path. Some European countries are burning 80-90 per cent waste fuel, and that's where we want to be." □



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Jones Bay Wharf, Sydney



Learn more

Pictured - Engineering Project of the Year 2024 Winner
The New Fitzroy Bridge River Project

[Experience]

90

Turbidity trouble

When water quality monitoring processes at a Milwaukee plant weren't up to the task, disaster struck.

96

Upcoming events for your calendar

Upcoming events for your calendar.

97

Resources round-up

Technical journals, blogs and podcasts that might interest you.

98

"You can't trust a number"

When modeling with data, it's not enough to only check your outputs.

94

Pipe dreams

Forget Elon Musk's hyperloop – the best applications of pneumatic conveying are arguably the simplest.

DISASTER

Outbreak

Words by Lachlan Haycock

After more than 400,000 people were infected with a waterborne disease in Milwaukee in 1993, a new federal regulation was introduced to improve water treatment standards.



Cryptosporidiosis, a waterborne disease caused by the parasite *Cryptosporidium*, is spread by infected faeces, and causes watery diarrhoea and stomach cramps.

A widespread outbreak of cryptosporidiosis infected at least 400,000 people in Milwaukee, Wisconsin, in April 1993 after being transmitted through the public water supply. Residents reported a range of symptoms including watery diarrhoea, abdominal cramps, fever and vomiting.

An estimated 69 people, predominantly people living with AIDS, died as a result of the cryptosporidiosis outbreak. It had a substantial health care and social impact, costing an estimated \$31.7 million in total medical costs and \$64.6 million in lost productivity.

Turbidity trouble

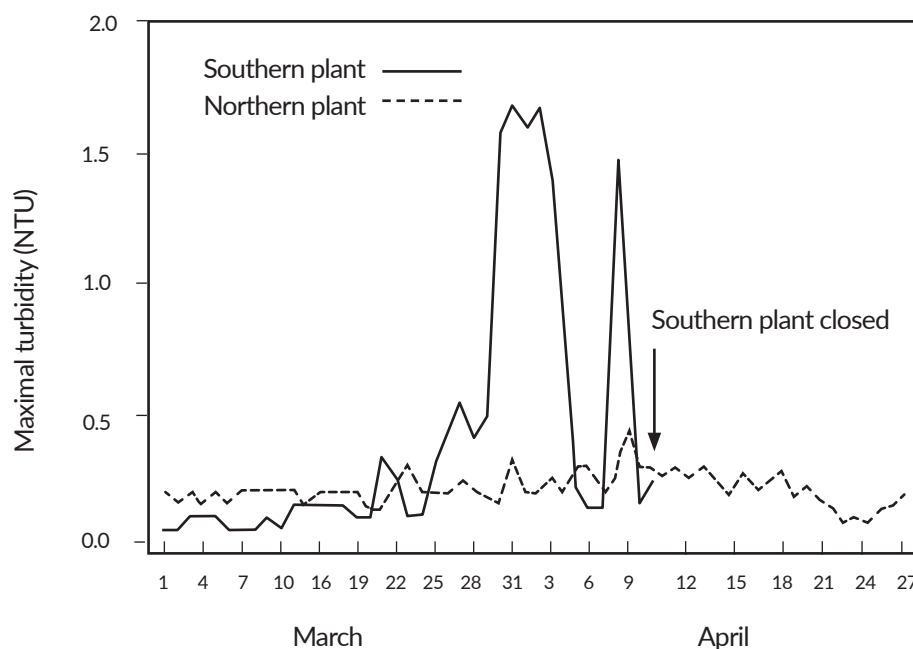
Initially, the reasons for the outbreak remained unclear. Theories abounded, including contaminated melting water from nearby Lake Michigan entering the water supply.

In an article published in *The New England Journal of Medicine*, Mac Kenzie et al. identify the cause as cryptosporidium oocysts, which carries the infection between

IMAGE: Getty.



Figure 1: Maximum turbidity levels in March-April 1993



hosts, entering the filtration system of Howard Avenue Water Purification Plant, a large plant in the city's south.

Water from Lake Michigan was obtained by Milwaukee Water Works (MWW) and supplied to businesses and homes around the city. Treated water, later supplied to customers, was investigated by Mac Kenzie et al., and found to have an increased level of turbidity (which describes the haziness of water). Turbidity levels became "unprecedented" for the period of 23 March to 5 April.

As shown in Figure 1, turbidity levels rose in the second half of March before peaking multiple times at or above 1.5 nephelometric turbidity units.

"Water-quality measurements at the MWW southern plant were within the required limits," Mac Kenzie et al. wrote. "However,

unlike the plants involved in the previous outbreaks [of cryptosporidiosis in the US], the MWW plant had no evident mechanical breakdown of its flocculators or filters.

"Inspection of the southern plant revealed that a streaming-current monitor, which can aid plant operators in adjusting the dose of coagulant, had been incorrectly installed and thus was not in use. In addition, monitors designed for continuous measurement of the turbidity of filtered water were not in operation."

Water at both MWW plants was treated with a range of methods. This included polyaluminum chloride, a coagulant designed to enhance the formation of larger particulates; mechanical flocculation, which encourages the particulate matter to clump >

"Water-quality standards and the testing of patients for cryptosporidium were not adequate to detect this outbreak."

together; sedimentation and rapid sand filtration. The filters were cleaned by backwashing them with water that was later recycled through the treatment process.

Turbidity peaks of 1.7 NTU on 28 and 30 March 1993 were in spite of an adjustment of the polyaluminum chloride dose at the Howard Avenue Water Purification Plant.

Mac Kenzie et al. concluded that “water-quality standards and the testing of patients for cryptosporidium were not adequate to detect this outbreak”.

“The number of both laboratory-confirmed and clinically defined cases of cryptosporidium infection with an onset of illness before [23 March], when the turbidity of treated water increased, was higher than expected, suggesting that cryptosporidium oocysts had entered the water supply before the increase in turbidity was apparent.

“This occurrence would not be without precedent. In England, a waterborne outbreak of cryptosporidium infection associated with a filtered water supply occurred while the turbidity of treated water remained less than 0.5 NTU.”

“Plant design and water-treatment procedures should be improved to maintain the quality of treated water at a level that will make the presence of oocysts unlikely.”



Changed regulations

One of the contributing factors in the failure to prevent high turbidity, Mac Kenzie et al. wrote, was the difficulty in identifying the right amount of polyaluminum chloride in the water. To address this, the MWW reinstalled the streaming current monitor after it became clear contamination had occurred.

“The recycling of filter backwash water may increase the concentration of oocysts in water passing through filters. Therefore, this practice has been discontinued.”

Further, the MWW installed continuous turbidity monitors on each filter bed, complete with an alarm system and an automatic

shutdown if the filtered water’s turbidity exceeded 0.3 NTU. More frequency monitoring of the particulars in both untreated and treated water was also instituted.

Mac Kenzie et al. suggested improved monitoring processes are, unsurprisingly, critical to ensuring higher standards of water quality.

“Until an inexpensive, rapid and sensitive means of detecting and quantifying cryptosporidium in treated water is available, we believe that water-treatment plants should consider instituting continuous monitoring of treated water for turbidity, particularly of filter effluent, and particle size.

“Plant design and water-treatment procedures should be



improved to maintain the quality of treated water at a level that will make the presence of oocysts unlikely.”

The crisis precipitated a new federal regulation that led to extensive water testing. The Interim Enhanced Surface Water Treatment Rule (IESWTR) was introduced to enhance the removal of particulate matter from drinking water treatment systems.

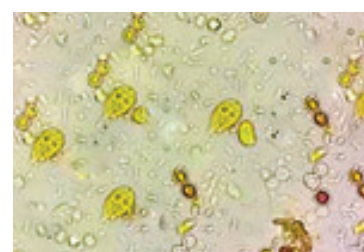
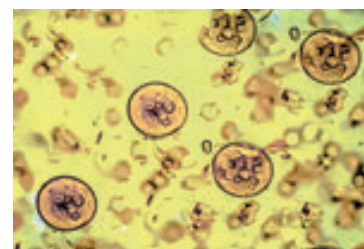
Critically, expanded reporting requirements were instituted. The rule mandated that:

- The combined filtered water effluent turbidity must be less than or equal to 0.3 NTU in 95 per cent or more of the measurements taken each month, while not exceeding 1.0 NTU at any time.
- Existing requirements for the removal of *Giardia lamblia* and viruses should be continued. This included a 3-log removal or inactivation of *Giardia* and a 4-log removal or inactivation of viruses.
- All surface water systems serving 10,000 people or more must achieve at least a 2-log removal of *Cryptosporidium*.
- New microbial profiling and benchmarking requirements should be followed. □

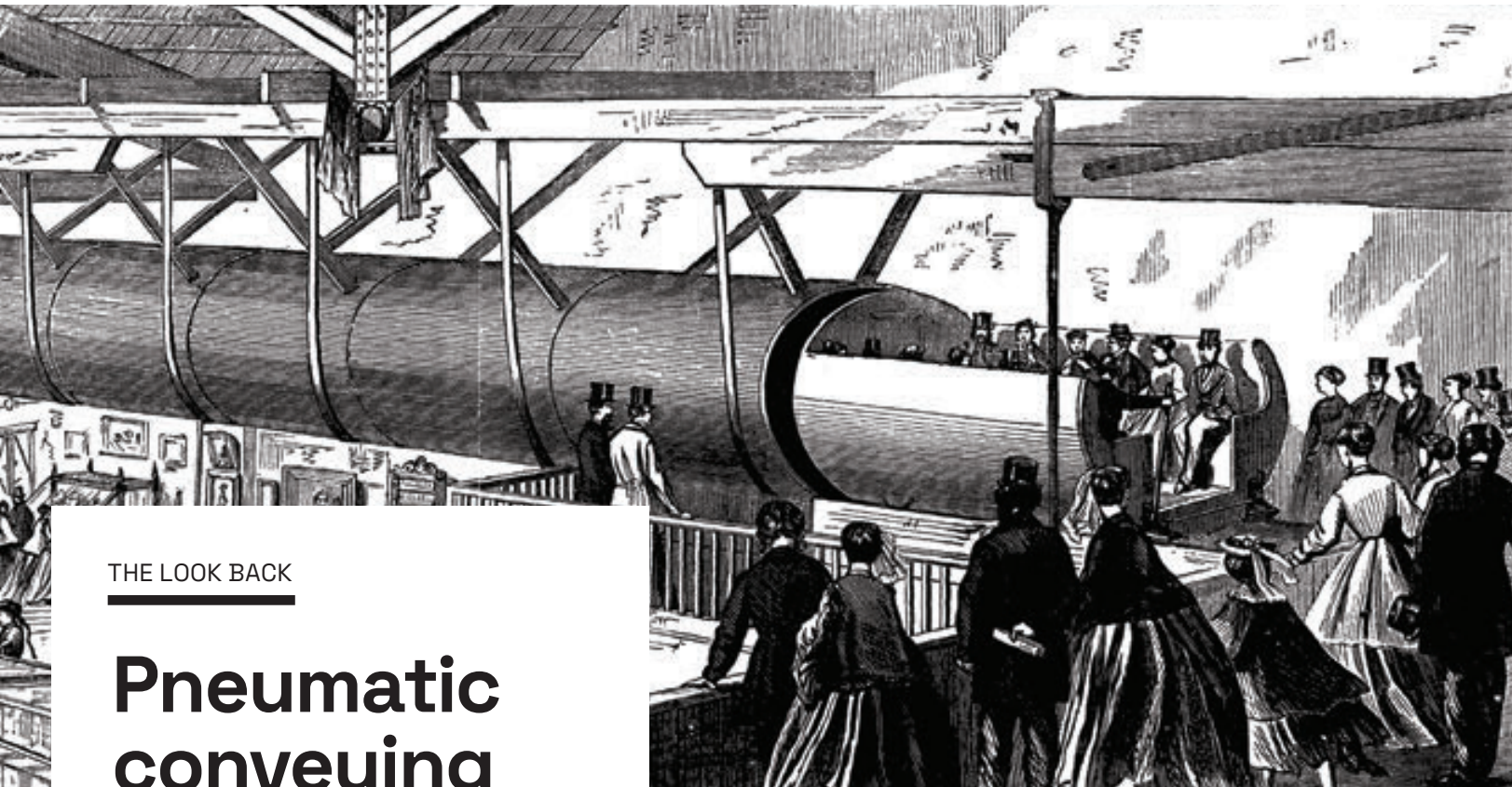
LOCAL PARALLEL

Cryptosporidium and *Giardia* pathogens were inadvertently released into the water supply in Sydney in July-September 1998, causing a water crisis. Residents across the city were told to boil their water to minimise the chance of infection.

An inquiry commissioned by the NSW Government mandated a clearer delineation of duties for Sydney Water and the Sydney Catchment Authority, and improved monitoring of water treatment facilities.



Access references for this story.



THE LOOK BACK

Pneumatic conveying

Pneumatic tube transport may seem to have gone the way of steam engines, but its unique characteristics mean not only does it live on, but so does the dream of pneumatic transit.

Words by James Chalmers

Picture the scene: a wealthy, high-profile inventor makes headlines in cities across the US, promising to revolutionise transit by using air pressure to convey passenger carriages down a tightly fitting tube at unheard-of speeds.

We're not talking about a 2013-era Elon Musk touting the hyperloop, but the 1870 creation of New York's first subway – Alfred Ely Beach's Pneumatic Transit.

Built in secret, the short demonstration line ran beneath Broadway for just 90 m. A single, richly upholstered carriage seated

22 and fit snugly inside the 2.4 m wide tunnel, propelled along at 16 km/h by a 44 t steam-powered Roots blower. When it reached the end of the line, it tripped a switch, reversing the blower's baffles and pulling the carriage back. In its first year, it carried more than 400,000 people.

While this pneumatic transit line never took off, it came at the beginning of a golden age for pneumatic transport.

Quick dispatch

The first known pneumatic tube transport system, built in 1853, connected the London Stock Exchange to a telegraph company 200 m away, allowing for timely financial news to be shared and replacing runners who had carried messages between the buildings.

Within decades, pneumatic systems had been installed across the UK, Europe and North America. They used compressed air or vacuums

to propel cylindrical carriers through networks of tubes. Their speed and low operating costs made them immensely popular for moving small items – mail, documents, cash, even merchandise – within and between businesses. In Scotland's Aberdeen, a pneumatic line connected the fish market to the post office to speed the sale of the perishable commodity.

Some at the time were thinking bigger than a few letters. In 1860s London, for example, a few kilometres of tunnels 150 cm wide carried carriages bearing up to 6 t of parcels (and even the occasional passenger) at 50km/h.

The fullest expression of the potential of pneumatic dispatch systems might have been the Poste Pneumatique of Paris.

Construction began in 1866. By 1934, it had expanded to 427 km of route, connecting 130 post and telegraph offices. In 1945, it was handling an estimated 30 million shipments annually.

ABOVE: A drawing of New York's Pneumatic Passenger Railway in 1867.

It finally closed to the public in 1984, while a government system stayed in use until 2004.

Route blockers

These systems posed numerous engineering challenges beyond planning and building the system. They included maintaining the system's airtightness, preventing and locating the leaks that could sap the efficiency and performance of the system.

The most critical challenge, however, was dealing with the blockages that could halt operation entirely. When carriers got stuck, operators would first try reversing airflow to dislodge them. If that failed, many deployed specialised, markedly heavier carriers to shunt them free.

For more stubborn obstructions, one solution was to fire a pistol near the tube opening. A recording cylinder and chronograph were used to precisely time the returning echo, allowing operators to pinpoint the obstruction's location before physically accessing the tube.

Hospital efficiency

While pneumatic transport systems have fallen from public view, overtaken by newer technologies, they remain popular in a surprising number of niches. The most widespread is probably health care. Most major hospitals still use pneumatic transport systems, facilitating rapid and hygienic movement of pathology samples, medication, documents and blood products.

In 2016, the newly built Royal Adelaide Hospital unveiled the southern hemisphere's largest pneumatic tube hospital system. The network serviced by its 72 stations, features many advancements missing from pneumatic transport's golden age, including real-time carrier tracking, powered by radio-frequency identification.

Pneumatic tube systems are

also still often found in banks and casinos, where the technology allows for highly secure movement of cash and other valuables.

The broadest application of pneumatic transport systems do away with canisters altogether. Pneumatic conveying systems are found throughout the materials handling world, popular for moving dry-bulk materials and powders, from sugar to mineral ore to cement. Some of these systems can easily transport upwards of 60 t an hour while minimising dust and spillages.

There are even a few examples of pneumatic garbage collection, including on New York's Roosevelt Island.

Pipe dreams

Almost exactly 150 years after New York's Pneumatic Transit line carried its last passenger, the concept got a high-pressure boost when Elon Musk published a white paper proposing a so-called hyperloop.

The paper described an ultra

high-speed passenger and freight transportation system, composed of capsules in low-pressure tunnels, kept at 1 hectopascal – less than 1/1000th of sea-level air pressure. Friction would be minimised by using air bearings. Later iterations of the concept proposed electromagnetic propulsion.

In the following decade, proposals to plan and build hyperloop routes emerged everywhere from the US to South Korea to India to Norway. Backers argued the technology offered numerous advantages over high-speed rail, including speeds potentially near-sonic, reduced energy demands and simpler construction. However, despite countless press releases and promotional mock-ups, not even a full-scale prototype has yet been demonstrated.

The challenges that have dogged these projects range from regulatory – getting approval to build dead-straight tunnels between major population centres is no small task – to technical.

"A steel tube on pylons," wrote Canadian Professor Emeritus Vaclav Smil, "would have to be engineered to maintain the thousandfold pressure difference between its inside and outside walls that threatens to crush it, and it would have to do so reliably along hundreds of kilometres of the track while also supporting the pressure generated by the rapidly moving pods and coping not just with overall thermal expansion along its course, but with the differential thermal expansion between the tube's top and bottom." □

BELOW:
A pneumatic tube transporter in a hospital; the hyperloop concept.



Events

AUGUST to NOVEMBER 2025

AUGUST

18-21**AUG 2025**

Australasian
Coasts and
Ports Conference
2025

Location: *Adelaide***Website:** *coastsandports2025.com.au*

Take a deep dive into multidisciplinary challenges in coastal and port engineering at this year's Australasian Coasts and Ports Conference.

Last chance to register.**27-28****AUG 2025**

Climate Smart
Engineering
(CSE) Conference
2025

Location: *Adelaide***Website:** *engineersaustralia.org.au/cse*

Designed by engineers, for engineers, this is your final opportunity to join the conversation shaping solutions for our climate reality. Seats are limited, so act fast to secure your place.

Last chance to register.

SEPTEMBER

11-19**SEP 2025**

Engineers
Australia
Excellence
Awards local
events

Location: *Various***Website:** *engaus.org/excellenceawards*

Recognise local impact and join us across the country as we announce our national finalists for each division in the project and people categories and unveil the winners of the Achievement Awards.

Register now.

NOVEMBER

10-14**NOV 2025**

Australasian
Tunneling
Conference 2025

Location: *Perth***Website:** *atc2025.com.au*

Join leading professionals, engineers and innovators for five days of keynotes, cutting-edge technical sessions and in-depth discussions on the latest advancements and challenges in the underground industry.

Register now.**25-28****NOV 2025**

Hydrology and
Water Resources
Symposium 2025

Location: *Canberra***Website:** *hwrs2025.com.au*

Experts and policymakers from Australia and the Asia-Pacific will explore resilient water solutions amid climate challenges. Gain insights from experts shaping the future of hydrology, policy and water management.

Register now.**29 Sep–4 Oct 2025**

**IUPESM World Congress
on Medical Physics
and Biomedical
Engineering 2025**

Location: *Adelaide***Website:** *wc2025.org*

Don't miss the world's leading forum for biomedical engineering and medical physics. Join more than 1000 scientists, engineers, researchers and health innovators to explore the future of sustainable and equitable health care.

Last chance to register.**13 Nov 2025**

**Engineers Australia
Excellence Awards
gala dinner**

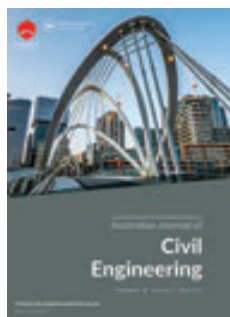
Location: *Sydney***Website:** *engaus.org/excellenceawards*

Join us for a prestigious black-tie gala dinner as we celebrate the people and projects redefining what's possible in Australian engineering.

Registrations open in September.

Resources

JOURNALS

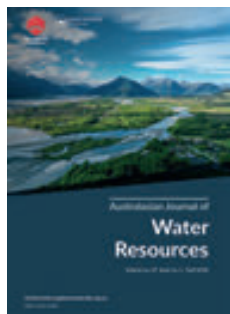


CIVIL

Basic and drying creep of ultra-high performance concrete

This study demonstrated that there is little difference in magnitude between basic and drying creep, indicating that basic creep is the governing mechanism.

<https://bit.ly/44SRyLd>



WATER

Insights from experience and avenues for change: a conceptual framework for learning and applying futures thinking in the water sector

This paper proposes a theoretical framework for the iterative learning and application of futures thinking in water governance, and how that learning and application can be expanded through reflexivity towards transformation.

<https://bit.ly/43AFKuF>



MECHANICAL

Experimental study and multi-objective optimisation of CNC turning parameters of AL6061 materials

This paper investigates the effectiveness of feed rate, depth of cut and cutting speed on material removal rate and surface roughness of CNC lathe machines on AL6061 materials.

<https://bit.ly/4jCZh3P>



ELECTRICAL

Multimodal knowledge graph construction for intelligent question answering systems: integrating text, image, and audio data

This study proposes a multimodal knowledge graph construction framework that combines advanced machine-learning techniques with human guidance to address this challenge.

<https://bit.ly/3SQvA43>

RESOURCE RECOMMENDATIONS



Find your niche

More than just an online forum, Reddit can be a source of helpful information. Catch up on the latest engineering news, network with peers and ask questions about others' work.

reddit.com/r/engineering



World at your fingertips

From deep dives into the latest innovative construction techniques to must-view personal development webinars, there's a little bit of everything on EA OnDemand.

<https://bit.ly/4h6v5wv>



Mapping the industry

The New Atlas website captures developments in areas as diverse as robotics, quantum computing, transport, AI and medical devices.

newatlas.com



Engineers Australia members have access to a plethora of technical journals free of charge.

 THE LESSON LEARNED

Dr Helen Edmonds FIEAust CPEng EngExec

Dr Helen Edmonds was a newly minted graduate when she found herself in unfamiliar territory performing quantitative risk analysis for offshore oil and gas platforms in the North Sea.

As told to Joe Ennis

I was working in Aberdeen about 10 years after the Piper Alpha disaster that killed 167 workers. The regulations for offshore rigs had shifted dramatically. Every platform operator had to submit a safety case proving that individual risk was below the risk of fatality of a deep-sea fisherman. I landed a job with DNV (Det Norske Veritas) doing quantitative risk analysis on some of the biggest offshore projects.

My job was to model all the hazards: from helicopter travel to dropped objects to the consequences of a gas leak igniting.

I first trained as a civil engineer back in the 90s. During my degree I did some work experience in water engineering and hydraulic modelling, so when I found it hard to get work on graduation, I decided to go back to study for a PhD in fluid mechanics. This made me desirable to DNV who liked to hire “smart, numerate people” and skill them up on the job.

KEY LESSONS

01

Always check your inputs. Get them right before you model anything.

02

Interrogate assumptions. Don't rely on instinct alone.

03

Lean on your network. Engineering is a team sport.

I had confidence in my abilities and assumed that this would neatly translate into any engineering field. But suddenly I was assessing fatality risk to the people working on these rigs. The stakes were high and I found that the translation of skills wasn't as smooth as I expected.

While I could grasp the physical principles behind things like gas dispersion and ignition, I didn't know enough to tell if my modelling outputs were sensible.

It all came to a head when I was working on a risk assessment for the expansion of a Conoco gas complex. I made some basic but critical mistakes, such as inputting data in the wrong data units.

The models ran, but the outputs were clearly way off.

The numbers didn't make sense, deadlines slipped and tempers frayed. With these projects, every day delayed came at a huge financial cost. I doubled down, looking to myself to try to solve the problem, but eventually it became obvious I needed help – so I approached the project manager. He was understandably frustrated at first, but he then helped me trace the problem back to incorrect inputs.

That experience taught me a foundational lesson: start by questioning your inputs, not your outputs. Rubbish in, rubbish out. You can't just trust a number. You need to understand where it came from and what it means. And making sure you use the correct units might help too.

It's a lesson I still carry with me. Now, leading a wastewater utility in local government, I often ask my team: “What is that assumption based on? Where does the underlying data come from?” And if they can't tell me, we dig deeper.

I've also learned the value of building a network. I'm naturally introverted, but over time I've developed a circle of peers I can call on when I need a second opinion. We're part of a profession. But more than that, it's a community of knowledge. As an engineer, you're never as alone as you think. □

Dr Helen Edmonds FIEAust CPEng EngExec is Head of Wastewater at Mount Barker District Council in South Australia, and a member of the Engineers Australia College of Leadership and Management.



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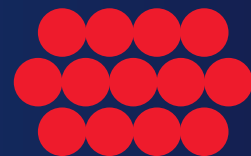
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