ENGINEERS AUSTRALIA

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ENGINEERS AUSTRALIA

create

Engineering. Making Life Happen.

Plan of steel

Australia has all the ingredients to be a green steel superpower. So how do we make it happen?

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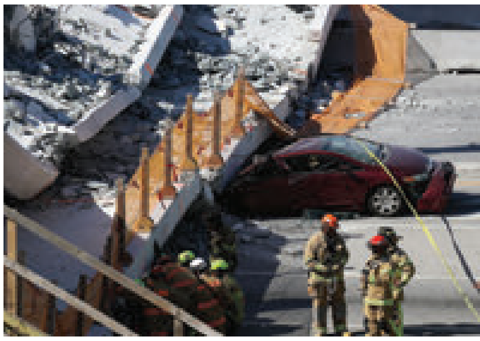
EXPERIENCE



PROJECTS

ENGINEERS
AUSTRALIA

Engineers Australia National Office
11 National Circuit, Barton, ACT 2600
Phone 02 6270 6555
engineersaustralia.org.au

For all subscription enquiries, please contact the Engineers Australia Member Services Team
memberservices@engineersaustralia.org.au
1300 653 113

Mahlab

Editorial Director: James Chalmers
Commissioning Editor: Joe Ennis joe@mahlab.co
Production Editor: Lachlan Haycock
Creative Director: Gareth Allsopp
Art Director: Caryn Isemann
Advertising Manager: Katrina Gilroy katrina@mahlab.co

CONTRIBUTORS:
Professor Andrew Blakers
Jeremy Bowden
Larissa Foster
Elle Hardy
Kevin Gomez
Oliver Gordon
Rosalyn Page
Jamie Seidel
Chris Sheedy
Petra Stock

369a Darling Street, Balmain, NSW 2041
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YOUR SAY

Call to action

I read with interest the letter from G Page about powerline security (*create*, April 2024). Without powerlines, generation of power and its distribution are not possible. They are key strategic assets for the community.

Some powerlines might not meet current expected wind loads, which have changed over time. We should remember that many powerlines are probably at or approaching their original design life. Many were built as part of the Snowy Hydro and related power expansion projects from the 1960s-80s.

State governments should consider which powerlines in their networks do not meet current wind load codes. This information can help them define the extent of the problem and lead to elegant engineering solutions.

G MCENTEE

Lending a hand

As a retired member of the institute, I still read with great interest the journal for Engineers Australia.

Accordingly, I read your article on young engineers volunteering their time and expertise for the benefit of the community (*create*, April 2024). This struck a particular chord with me as I have been engaged with volunteering work in the Pacific Island for years, particularly in Vanuatu.

Through my involvement with Rotary, my wife and I have just completed a new school building in a remote village on the Island of Espiritu Santo. We have also fitted solar panels to give the children and staff the opportunity to work at night and supply enough electricity to power a small number of laptop computers.

"I am looking for engineers who would be prepared to volunteer their time and expertise to design a suitable outdoor shelter."

Our club still has sufficient funds available to build an outdoor shelter at the school, but of course these are limited. The shelter needs to be designed to withstand the cyclones which are all too prevalent in this area.

Hence, I am looking for engineers who would be prepared to volunteer their time and expertise to design a suitable outdoor shelter for the children to play sports and have activities under some sort of shelter.

Please let me know if you are interested and I will be able to provide more details.

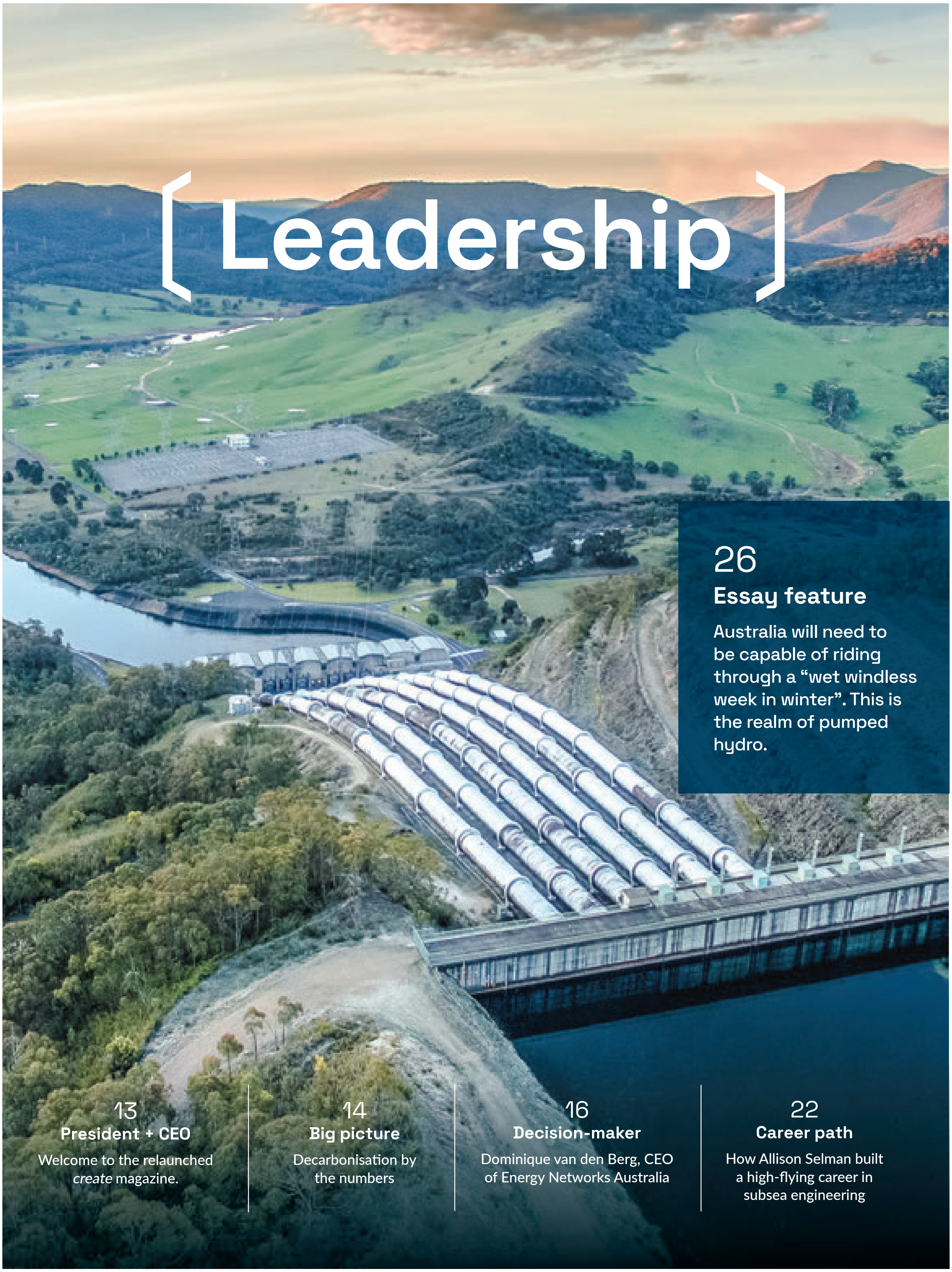
MERVYN ALLAN CANN OAM

Editor's note: *Please respond via the letters email address. All correspondence will be forwarded to the author.*

create
welcomes feedback from the community

Do you know of an exciting project we should write about? Is there an outstanding engineer in your midst? Are you working on an innovative technology that you'd like to share with your fellow members? Are there engineers out there doing their bit to help the community? Do you want to comment on an article you've read in *create*?

Email *letters@engineersaustralia.org.au* and we'll be pleased to consider your suggestions.



[Leadership]

FROM THE NATIONAL PRESIDENT AND CEO

Decarbonisation and the energy transition

Decarbonisation is the topic on every engineer's mind right now. In the first edition of the relaunched *create*, we go deep into what it's going to take to decarbonise Australia.

First, let's talk about the new-look *create*. More modern, immersive and visual than ever before, we have listened to your feedback in making this change.

The longer format will feature more in-depth analysis and insights on the big issues of our time and the innovative engineering associated with them.

The move to a quarterly publication is also a more sustainable option and a better reflection of our commitment to supporting a carbon neutral world.

Combined with the introduction of compostable wraps, these changes will result in annual net carbon savings of 100 t, reduce paper consumption by 60 t, and prevent more than a million single-use plastic wraps going to landfill each year.

This edition has a focus on decarbonisation and the energy transition, just ahead of our Climate Smart Engineering Conference (CSE24). Engineers are critical to facilitating the nation's – and the world's – decarbonisation journey.

Our cover feature discusses how steelmaking can be decarbonised. With its abundant iron ore, renewable energy potential and engineering talent, Australia could lead the world's green steel transition. It is a challenging sector to substantially decarbonise, but there are promising signs that we can get there.

Carbon Measurement Fundamentals for Engineers is a new resource developed by our members with support from Engineers Australia. It enables all engineering disciplines to gain an understanding of emissions, quantification techniques and carbon accounting. Quantifying emissions is key to improving design, construction and operational carbon efficiency.

create also asks if we are ready for take-off. Energy and weight dynamics mean aviation is one of the hardest sectors in which to abate emissions, so what fuel options will give us leverage?

In the age of AI, data centres are extremely power-hungry and heat-generating, and demand is set to soar. What can engineers do to reduce their impact on climate change?

Enjoy the next 100 pages of reading – it's a fascinating and illuminating mix of engineering and engineers, showcasing the impact of the profession in making life happen.

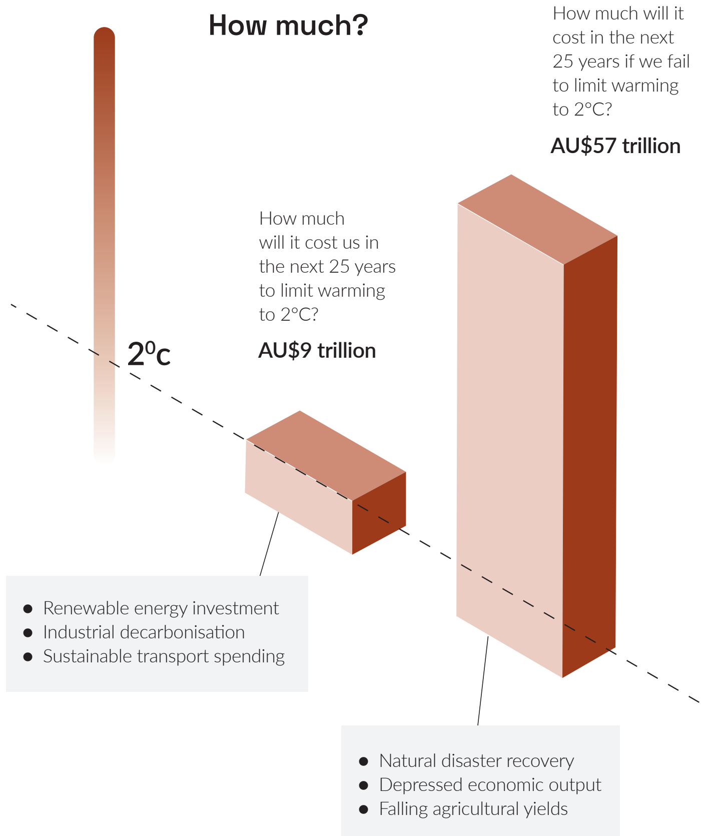
Dr Raj Aseervatham
FIEAust CPEng
APEC Engineer IntPE(Aus),
National President
nationalpresident@engineersaustralia.org.au

Romilly Madew AO
FTSE HonFIEAust, Chief Executive Officer
ceo@engineersaustralia.org.au

The big picture

Decarbonising Australia is more than just a challenge – it's also an opportunity to transform the country's economy and workforce, particularly in the hardest-to-abate sectors.

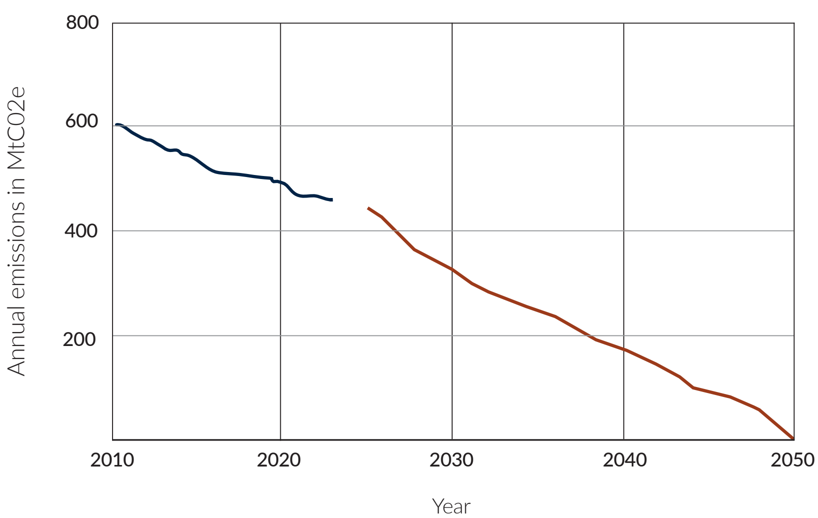
How much?



By when?

How quickly must Australia decarbonise to hit net zero by 2050 and meet global ambitions for limiting warming to 2°C?

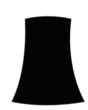
Annual emissions in MtC02e vs year



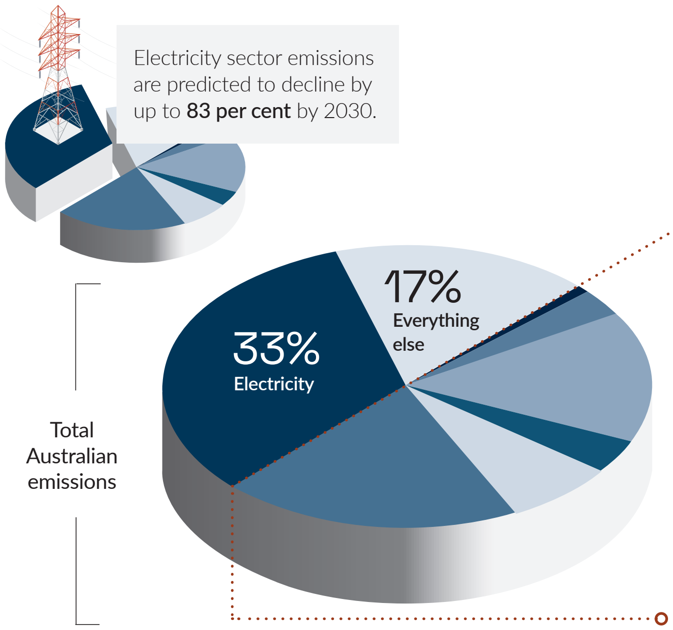
This means cutting our annual emissions by an average of 18 MtCO2e a year for the next 25 years. That's equivalent to, annually:

Removing more than **7,000,000** average internal combustion-engined cars from the road

Forgoing **200 billion** passenger hours of international travel – **7700 hours** per Australian

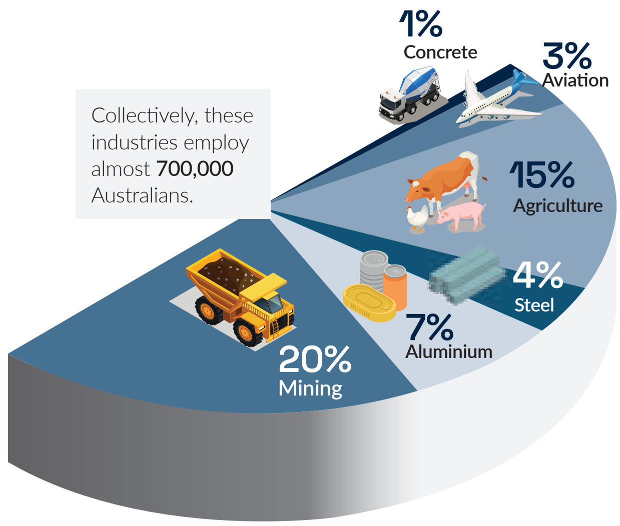


Closing **1.3** Bayswater power stations, Australia's largest power plant



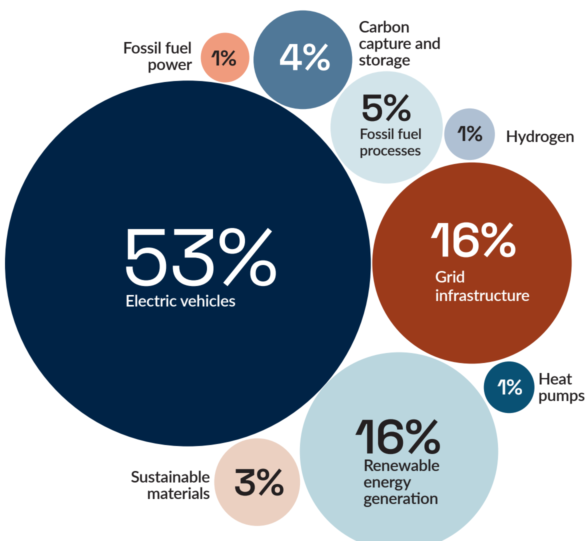
Abatement challenge

Half of Australian emissions stem from harder-to-abate sectors. This total is set to climb dramatically higher as other sectors, – particularly electricity generation, light vehicles and buildings – decarbonise quickly.



Investment now

Decarbonising Australia requires unparalleled investments. The energy sector alone is expected to need $2.85 trillion in investment up to 2050.



Estimated energy sector investment needs

Jobs boom

The massive infrastructure works needed to decarbonise by 2050 would spur an enormous jobs boom.

	Rapid decarbonisation	Business as usual
New annual construction jobs	64,000	32,000
New ongoing operations and maintenance jobs	129,000	76,000

■ 10,000 jobs per year (Rapid decarbonisation) ■ 10,000 jobs per year (Business as usual)

SOURCES

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Words by Joe Ennis

The great generation reversal

The challenge is clear. Australia has committed under the Paris Agreement to a 43 per cent emissions reduction target by 2030. That's only six short years away.

In 2020, nearly 80 per cent of Australia's electricity needs were met by fossil fuels. To meet our 2030 targets, the country needs to reverse that equation and generate 82 per cent of electricity using renewables within a decade.

It's a big ask, but Australia is making progress by flicking the switch on some major projects.

"The first and biggest challenge is removing coal from the grid", said Dominique van den Berg, CEO of Energy Networks Australia.

And it's not hard to see why. Australia's reliance on coal is heavy but reducing. According to National Electricity Market (NEM) data, 59.8 per cent of Australia's electricity in 2023 was generated from coal. But that's 15 per cent down on a decade ago thanks to the growing influence of renewable power.

"We are on the right path to removing coal and while it sometimes feels slow in this space, we have definitely made progress and are so far ahead of where we were only a decade ago," van den Berg said.

"Australia is also leading the world in the adoption of rooftop solar, making a significant contribution towards our renewable energy target."

This is a view reinforced by the 2024 Clean Energy Australia report, which tells us that 39.4 per cent of Australia's power supply in 2023 was generated from renewable sources, including adding nearly six GW of renewable capacity and $5 billion in investment in large-scale storage solutions.

RIGHT: Dominique van den Berg, Energy Networks Australia

Firming generation

Shoring up the grid will require 'firming' power to complement Australia's growing renewable generation capacity. Battery storage is one form of firming.

"At grid-level, battery storage will help firm the variable output from solar and wind power," she said, "and there is more 'low hanging fruit' in the distribution network to unlock, to maximise how we use the infrastructure we already have."

In the short term, this firming power can also be delivered by gas-powered generators, which can be fired up in a matter of minutes. But this relies on a secure supply of natural gas to these plants that hasn't been easily achievable in recent years.

"The challenge is getting the gas to where it's most needed at the right time. We have a work to do to make sure this happens, as we saw in the southern states' recent winter.

Industrial decarbonisation

Decarbonisation of industry will take more than transforming the electricity grid, van den Berg pointed out. Other fuel sources need to be considered.

"A lot of the more obvious plays have already been made with the proliferation of solar and wind power across the country, but heavy industry currently using gas cannot readily electrify – or it's too expensive to do so and they need another pathway to decarbonise.">

"In 2020, nearly 80 per cent of Australia's electricity needs were met by fossil fuels. To meet our 2030 targets, the country needs to … generate 82 per cent of electricity using renewables within a decade."

That's where renewable gases such as biomethane and green hydrogen could find a place.

"Biomethane is very interesting. It can be substituted into existing natural gas pipelines and networks with no appliance or network upgrades, so it stands to reason we should look to how we can best use this resource to decarbonise sectors that cannot easily electrify."

"We need to get biomethane recognised as a legitimate decarbonisation pathway, and tradable in that sense for potential use in aviation or industry."

Van den Berg also pointed to government support for hydrogen production. "The recent Hydrogen Production Tax Incentive is a good start to this. However we believe there is more that could be done including exploring a renewable gas target as part of the Australian Government's six sectoral decarbonisation plans."

Electrolyser technology is also developing rapidly – several Australian companies are claiming 95 per cent efficiency and lower costs – helping to drive progress.

Policy and regulation

"Australians should be very proud of their regulatory system, but the reality is that it was built for the one-way flow of electrons," van den Berg said. "It was a stable way to get efficiency from the grid. With solar on rooftops and more consumer energy resources coming online every day, there's a two-way energy flow that now needs to be accounted for and used in a way that maximises the benefits for all customers."

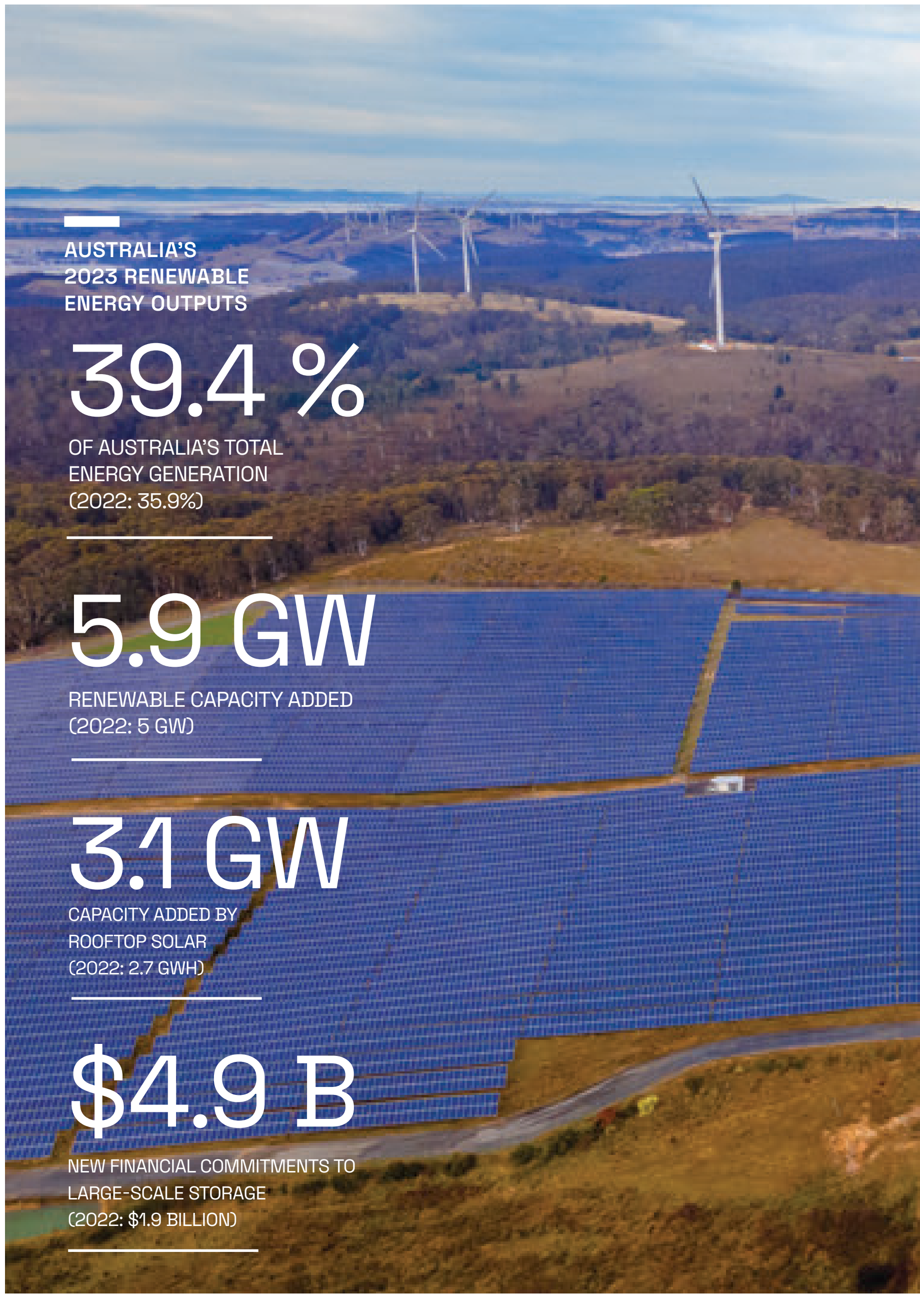
Though the economics of transitioning to clean energy are a lot clearer from an industrial perspective – with the recent CSIRO GenCost report stating that renewables are the cheapest option for new build power – the change will still need strong government policy and regulation, and consultation with industry.

"There needs to be a conversation between regulators, networks, retailers, aggregators and customers as to how we get the most value from these assets."

With the cost of developing renewables rapidly decreasing, Australia is also seeing the development of massive amounts of grid storage to help stabilise the system. Some projects at the planning stage have a capacity upwards of five GW.

This is evident in the development of Renewable Energy Zones (REZ) across the country. Sometimes called modern-day power stations, these zones bring together multiple forms of renewable energy and storage in one location.

The Central-West Orana REZ northwest of Sydney will be the nation's first, having recently secured planning approval.



SOURCE: *Clean Energy Australia 2024*, Clean Energy Council

"We are already generating almost 40 percent of our electricity via renewables, and it is working. We need to stay on track to and continue to implement solutions that drive up renewables and ultimately bring down our costs."

3 WAYS TO ENSURE A STABLE ENERGY TRANSITION

01
TAKE ADVANTAGE OF SYNERGIES
“Build generation and storage close enough together, and close enough to high-consumption industries.”

02
SOCIAL LICENCE
“We need to take industry and the public on this journey. There must be a shared belief that this is the right thing to do.”

03
COLLABORATION
“There is no one answer to the energy question. We must look at a diversified mix of energy inputs and storage to make sure Australia thrives.”

This project alone aims to leverage economies of scale to deliver 4.5 GW of new network capacity and two GW of long-duration storage.

Accelerating the uptake of EVs

Away from industry, the second-biggest challenge is breaking Australia’s reliance on the internal combustion engine. This is an area where Australia lags behind.

In a recent international survey of vehicle owners, a staggering 49 per cent of surveyed Australians responded that their next vehicle would still have an internal combustion engine. This number is likely driven by a perceived lack of charging infrastructure.

Even so, that’s a “frightening statistic”, van den Berg said, indicating the social licence Australia still needs to build among the general public to make the energy transition a success.

“It’s a chicken and egg scenario,” she said. “We need to combat customers range anxiety and give them the confidence to purchase an EV as their next car. The distribution networks can support this role out, in a way that is equitable and cost effective. The more chargers people see around their neighbourhoods, the more confidence they’ll have to buy an EV.” □


Miranda Rey-Fleming
Water Engineer
Hasan Muttakin
Structural Engineer

Words by Lachlan Haycock

Testing the waters

In a new feature tracking the paths of influential engineers, Allison Selman outlines her rise to the top in subsea engineering.

Working at the bottom of the ocean has helped propel the career of Allison Selman FIEAust CPEng to great heights. She was recently appointed the Managing Director of Atteris, an engineering consultancy working across subsea, pipeline and renewable energy assets.

"Becoming a director was not something I necessarily thought possible," Selman told *create*. "My industry is extremely male-dominated, and there aren't many women who operate at a director's level. I certainly didn't plan for it to happen this way."

Since 2013, Selman has worked for Atteris in an asset integrity and engineering function, ensuring that equipment runs the way it should and faults are anticipated before they happen, to minimise risk.

She is also the founder of Women In Subsea Engineering (WISE), a non-profit working to improve gender diversity and inclusion in the offshore industry, and the head of ocean videography company Glass Bottom Films.

"I enjoy working for small companies with a family-like environment," she said. "You get to work very closely, very cohesively with employees. Larger companies can be quite impersonal and competitive, and you sometimes find yourself in situations that don't align with your values."

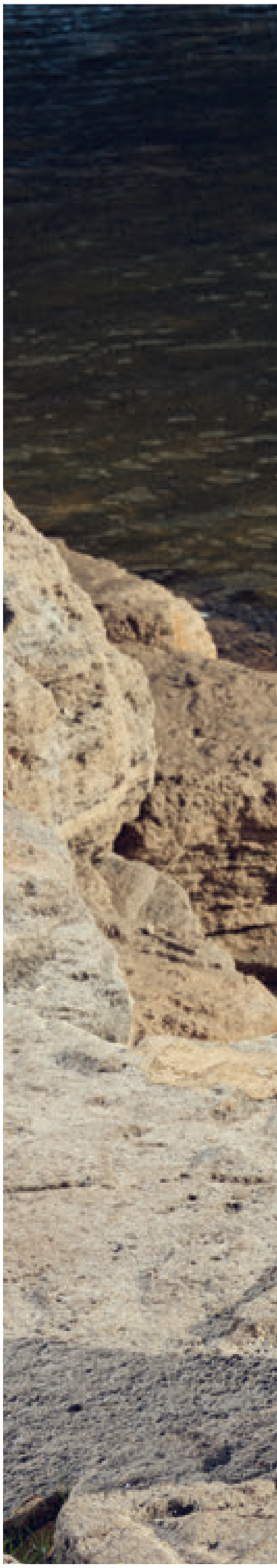
Moments of truth

Rather than a taking predetermined path to her current work, Selman has worked across as many different companies as possible to broaden her experience.

"Before joining Atteris, I played around to find out where my strengths were," she said. "I never stayed for more than three or four years at a single business – long enough to develop a feel for how things operate."

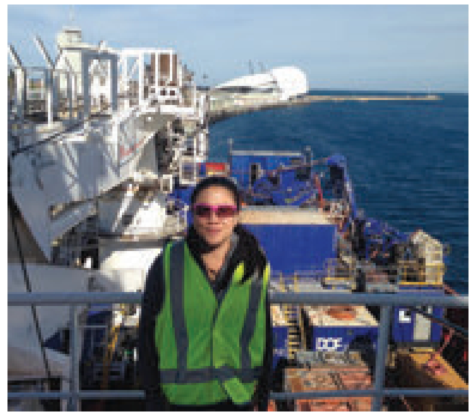
A key turning point was electing to move overseas to take on a secondment role as a senior integrity engineer at BP Indonesia, a role that took her to Jakarta, where she stayed for three years.

"No-one else wanted to put their hand up," Selman recalled. "But I did, as a young engineer, and it was one of the best decisions I've ever made because I got to learn about setting up an engineering office, growing a team, training and onboarding new staff, and more. >



RIGHT: Allison Selman FIEAust CPEng, Atteris

"So many of the managers in this industry are of the alpha male personality type."



ABOVE: Selman is also an underwater videographer.

"It's about what keeps you energised, because it's a completely different feeling when you enjoy going to work."

"I'm still in touch with my manager at the time, who really sparked my interest in the business side of engineering."

Selman's background in commerce, marketing and management put her in good stead to step up. But she admits facing down demons all the same.

"So many of the managers in this industry are of the alpha male personality type," she said. "When I first nominated myself for the Managing Director position at Atteris, I kept comparing myself to these people – and even considered not nominating at all.

"I faced some pushback from people who said I didn't have the right attributes. But who says one person's attributes are better suited to a role than another's?"

To address doubts both internal and external, she completed a company directors course via the Australian Institute of Company Directors, enrolled in the Women in Leadership Development (WILD) Board X Program, and participated in governance and leadership training via the Engineers Australia College of Leadership and Management program.

"Through programs such as these, I've had the privilege of learning about how boards should be run, and connected with other leaders who have different management styles. And in terms of my own style, I lean heavily towards collaboration and teamwork."

"They thought I was mad"

A natural extension upon Selman's professional grounding was becoming Chartered with Engineers Australia, which she described as an easy decision.

"As a female engineer working overseas, I lacked an established network and all I could fall back on were my credentials," she said. "When I was younger, people would often see me walk into a meeting and they'd assume I was a secretary or the coffee lady.

"Becoming a Fellow of Engineers Australia, too, was a decision I made from a leadership perspective. I did it to represent and encourage other women to step up and be recognised for their achievements. That is still an area we struggle with."

That struggle, however, normally ends up paying dividends.

"When I started working for Atteris – a medium-sized company rather than a large international firm – everyone thought I was mad," Selman laughed. "But I wanted to follow my personal preferences and make a difference. It's about what keeps you energised, because it's a completely different feeling when you enjoy going to work and the people you see each day." □

Professor Andrew Blakers

Under the hydro pump

Pumped hydro currently provides most of the energy storage for the electricity industry, offering large-scale, low-cost, off-the-shelf energy storage in unlimited quantities.

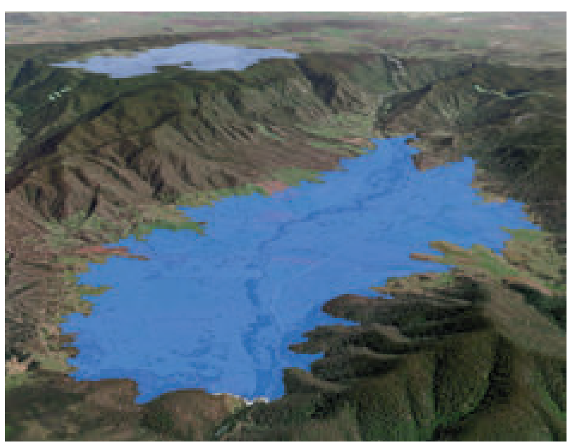
Australia's future solar-dominated energy system will need long duration storage capable of riding through night-time and a "wet windless week in winter": 10-100 hours or more. This is the realm of pumped hydro, with its very low energy storage cost and its operational lifetime of a century or more. The long-duration energy storage requirements in the 2030s will be much larger than current energy storage needs.

Pumped hydro energy storage

Pumped hydro energy storage (PHES) constitutes most current energy storage for the global electricity industry. PHES typically entails two reservoirs, separated by an altitude difference of 100–1600 m, spaced several kilometres apart and connected by a pipe or tunnel containing a pump turbine. Water is pumped uphill on sunny and windy days and returns downhill through the turbine to recover the stored energy when required.

The water can shuttle uphill and downhill in a closed-loop cycle for many decades. The round-trip efficiency of pumped hydro energy storage is typically 80 per cent.

This article is an edited extract from Engineers Australia's forthcoming Accelerating the Energy Transition series. Read the full article alongside Alan Finkel's view on the critical barriers to transition and Neil Greet's take on energy security.



LEFT: Class AA 500 GWh site near Araluen in Australia, with a head of 600 m.

ABOVE: The Global Greenfield Pumped Hydro Atlas. Red-dot sites would cost about half as much as the yellow-dot sites, according to the cost model.

LEFT: Aerial view of Tumut Power Station 3. Image: Alamy

Most existing PHES is located on rivers, usually in conjunction with hydroelectric systems. There is often resistance to construction of new dams on rivers. However, most potential PHES sites are located away from rivers ("off-river") because most of the global landscape is located away from rivers. For off-river PHES, the two reservoirs are typically located in hilly country, and unconnected to any river, and have combined flooded area in the range 1-10 km^2.

The Australian National University produced the *Global Pumped Hydro Atlas*, which lists about one million PHES sites around the world that do not require new dams on rivers. Energy storage volumes shown in the atlas are 2, 5, 15, 50, 150, 500, 1500 and 5000 GWh. About 100 times more sites are shown in the atlas than would be required to support a fully decarbonised global economy of 10 billion affluent people.

Users can pan, zoom and rotate to a scale of 30 m and download 26 items of technical information for each site. They can select the 3D terrain map setting to visualise individual sites.

Pumped hydro storage comprises both an energy cost ($/GWh, reservoirs) and a power cost ($/GW, tunnel and powerhouse) that can be sized independently. The marginal cost of increasing the storage volume (hours of storage) is low – simply increase the dam wall height, while the tunnel and powerhouse remain unchanged.

Good sites in the atlas are marked with red dots (Class A or Class B) while premium sites are marked with triangles (Class AA) or stars (Class AAA). Premium sites are characterised by large-scale (0.5-5 GW of power for dozens of hours); large head (400-1600 m); large slope in the range 5-25 per cent (head divided by horizontal separation) and large water-rock ratio in the range 5-25 (ratio of the volume of stored water to the volume of rock needed to construct the reservoir walls). Premium sites in the *Global Pumped Hydro Atlas* have an indicative cost as little as one tenth that of Class E sites.

Greenfield sites in the atlas require two new reservoirs, while bluefield and brownfield sites use existing lakes and old mining sites respectively. Ocean sites use the ocean as the lower reservoir. Seasonal storage sites slowly (over weeks or months) draw from or discharge water to large nearby rivers.

Pumped hydro in Australia

Australia has extraordinarily good long-duration pumped hydro energy storage sites. It has approximately 5000 good PHES sites and only needs about a dozen (depending on size); energy planners can afford to be very choosy. Storage volume in Australian sites ranges >

up to 5000 GWh – equivalent to 5000 big batteries (one GWh each) or 50-100 million EV batteries.

Australia has three existing pumped hydro systems (Tumut 3, Kangaroo Valley, Wivenhoe), two under construction (Kidston, Snowy 2.0), and dozens of proposed projects including Pioneer Burdekin, Borumba and Battery of the Nation.

Snowy 2.0 has two GW of storage power and 360 GWh of storage energy (larger than all the utility batteries in the world combined) at a cost of $12 billion, which equates to $33 per kWh for a system that will still be operational in a century. This is far below the cost of equivalent batteries. However, batteries are better for storage up to a few hours. Both PHES and batteries are required for an optimum energy storage system.

Water and land requirements for pumped hydro are small. Averaging across 150 Australian Class AA greenfield sites reveals water and land requirements below one GL and 10 hectares per GWh respectively.

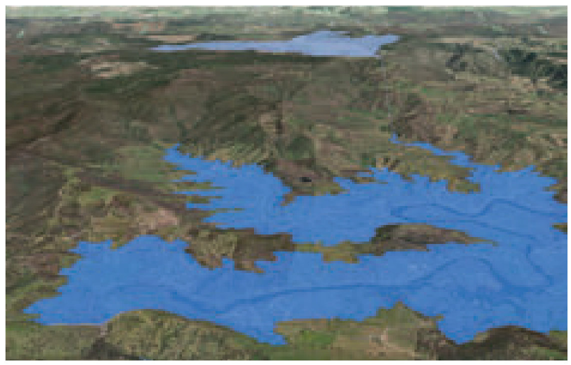
The water is recycled indefinitely between upper and lower reservoirs. For comparison, 8000 GL of irrigation water was applied to two million hectares of crops in Australia in 2022.

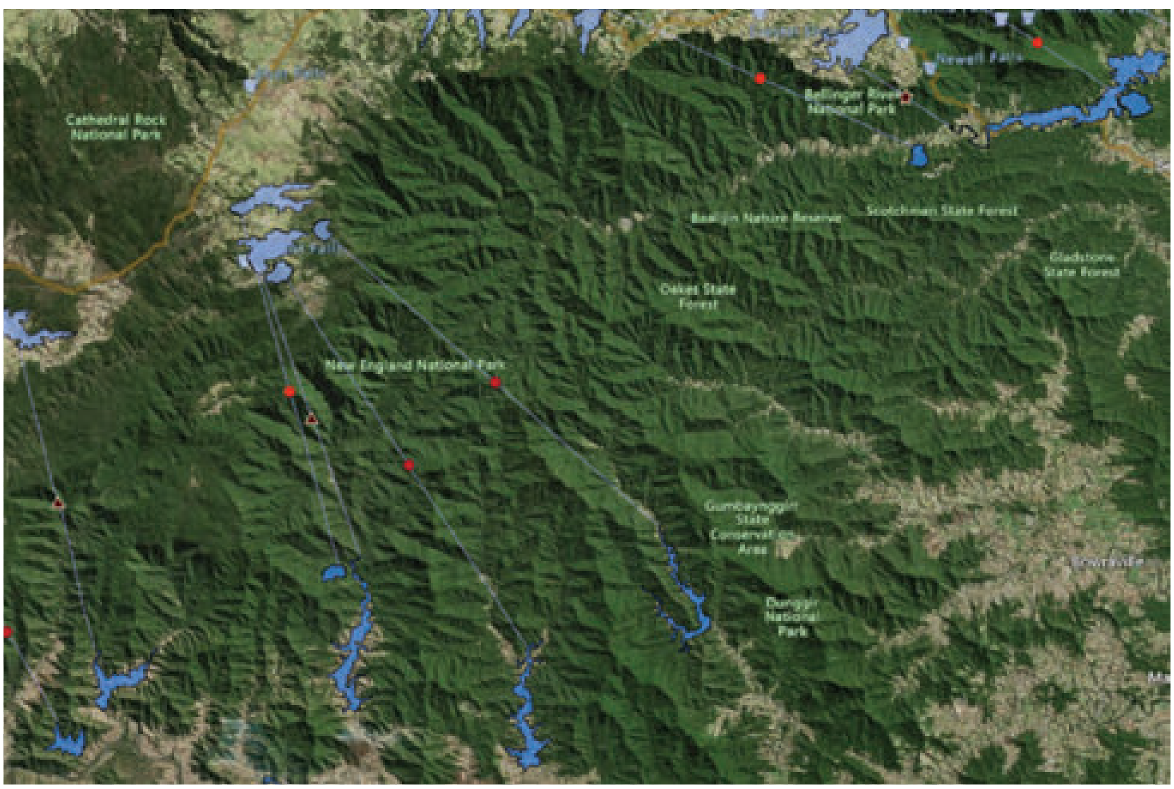
If Australia's entire future energy storage requirement of about 1000 GWh were to be met using off-river PHES, the water requirement for the initial fill would be about 1000 GL spread over a construction period of about 20 years. This amounts to about five litres per person per day (equivalent to half a minute of a morning shower). The land requirement would be 100 km^2 which is equivalent to 3.3 m^2 per person – about the area of a king-sized bed.

All other things being equal, a site with double the head compared with another site would have double the energy storage and double the storage power, but considerably less than double the cost. Heads in Australia range up to 1300 m.

Large head is an important attribute. It is striking how many pumped hydro proposals in Australia utilise heads below 300 m when much larger heads are readily available. For example, a sample of 150 Australian Class AA sites with energy storage volume of 50, 500 and 1500 GWh reveals typical head of 600 m.

The images on these pages show interesting sites from the atlas. The Lithgow site is at a strategic location just west of the Blue Mountains. New high-power transmission into Sydney to accommodate the



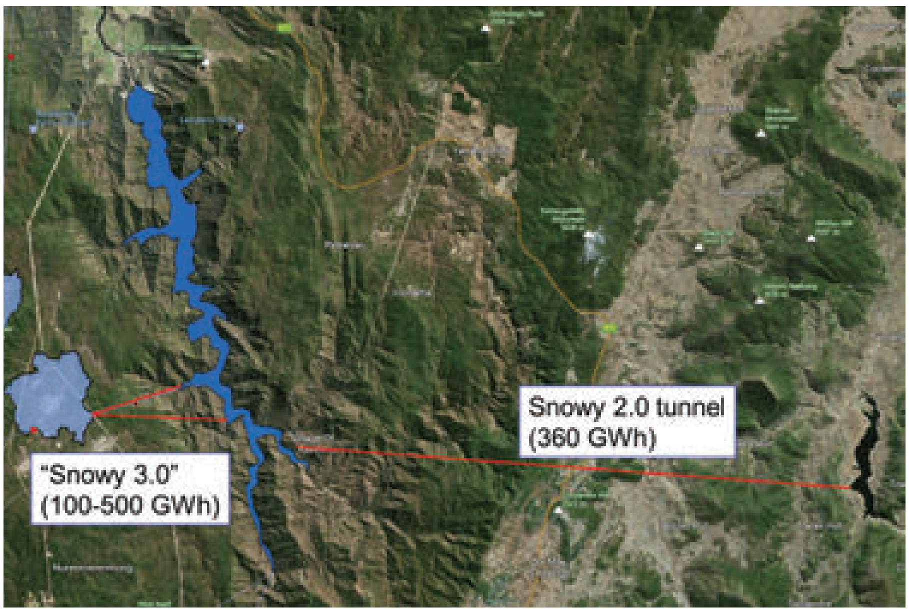


LEFT:
150 GWh Class AAA and AA sites near Coffs Harbour with heads of 700-1300 m

ABOVE:
Hypothetical Snowy 3.0 pumped hydro site

RIGHT: Aerial panorama of Snowy River and Hydro Surge Tower near Mount Kosciusko National Park. Image: Getty

BELOW: Class AA bluefield site (150-500 GWh) located near the Snowy 2.0 tailrace



"electrification of everything" is constrained by national parks. Placing a large buffer storage inland from these national parks to absorb the daily output of solar and wind farms allows maximum use to be made of the existing transmission. The site is close to the 500 kV powerline that runs from the Hunter Valley south to Goulburn, which allows the storage to service existing transmission entering Sydney from the north, west and south-west.

The sites near Coffs Harbour are typical of the Great Dividing Range, comprising upper and lower reservoirs in generally cleared land with steep forested land in between. A tunnel can connect the upper and lower reservoirs with low disturbance to the land in between. Pioneer Burdekin has such a configuration. In the case of Coffs Harbour, heads of up to 1300 m are available.

There is a Class AA bluefield site (150-500 GWh) located near the Snowy 2.0 tailrace, on the west side of Talbingo Reservoir. Once the Snowy 2.0 tunnel is finished, it may be possible for the tunnel boring machine to tunnel west beneath Talbingo Reservoir and then build the required four kilometre-long tunnel for a "Snowy 3.0". This would allow continuity for the Snowy 2.0 workforce, tunnel boring machine, tunnel-lining concrete plant, work camps, transmission easement and access roads.

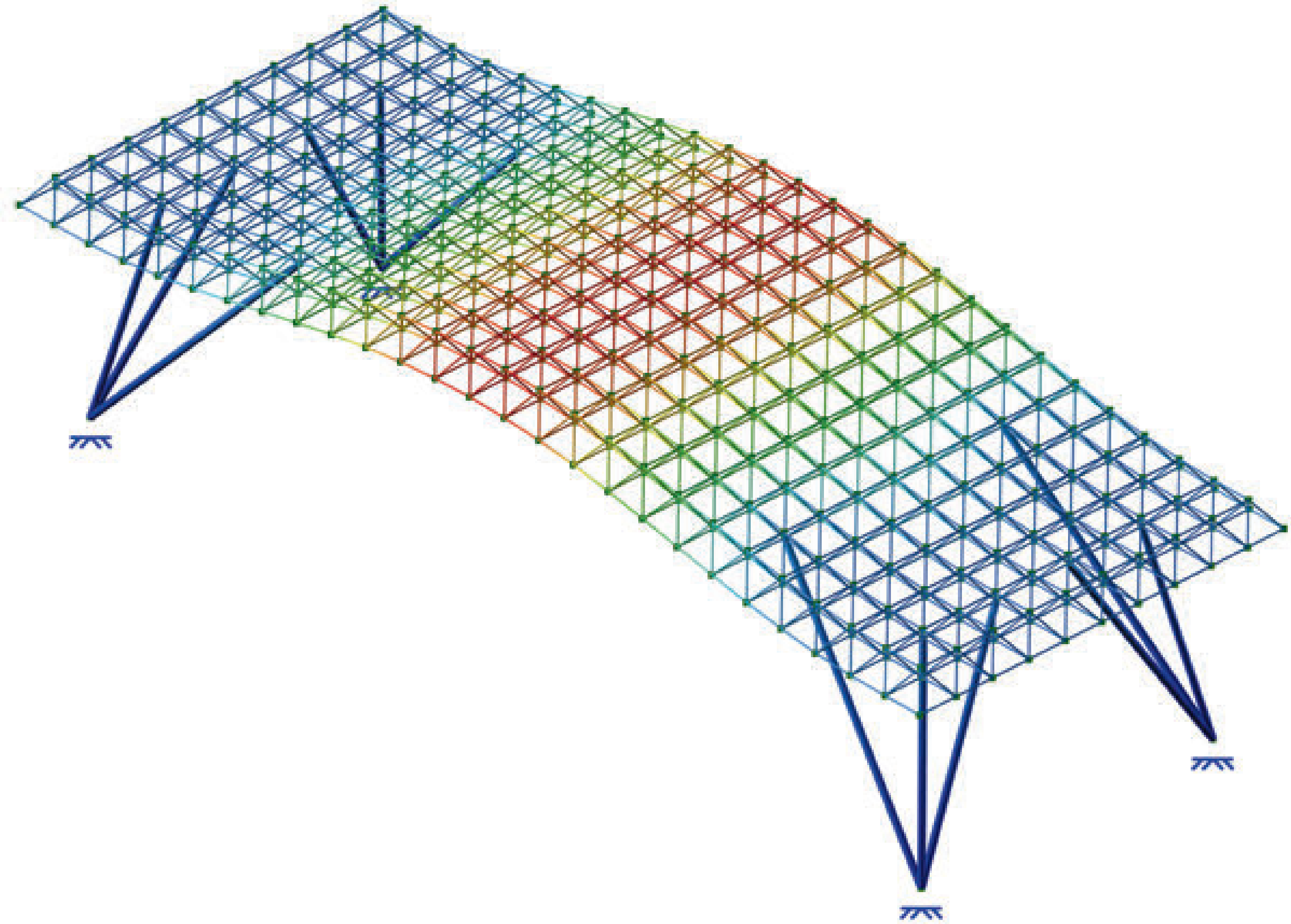
Pumped hydro in Tasmania can buffer Tasmanian wind generation to ensure maximum load factor in existing and new Bass Strait power cables. In South Australia, heads of 300-600 m are available in 15-150 GWh sites near Port Augusta. Development of such sites would provide South Australia with a large energy storage buffer in case of failure of transmission connection to the east. It would allow the excellent solar and wind resources in this region to make maximum use of the existing transmission into Victoria and New South Wales.

In Queensland, the Pioneer Burdekin and Borumba pumped hydro proposals offer storage energy and storage power of 170 GWh and seven GW respectively. This is a large fraction of the ultimate storage requirements for Queensland.

Victoria has many greenfield and bluefield site options northeast of Melbourne from which to choose. There are also interesting brownfield options that utilise the Yallourn, Hazelwood and Loy Yang coal mining sites. Perth has relatively few good pumped hydro options because maximum available heads are about 200 m. Interestingly, the Pilbara has several large sites that could support the mining industry. □

PROFESSOR ANDREW BLAKERS
is a world-renowned leader in renewable energy development and Professor of Engineering at the Australian National University.

Images sourced from the Pumped Hydro Storage atlas: bit.ly/3zOg7LH



[Ideas]

Words by Joe Ennis

Measuring up: low-carbon fundamentals

When it comes to climate change, engineers sit at the nexus of theory and practice. Being critical to facilitating Australia's decarbonisation journey, it is essential they are equipped to measure, understand and mitigate embedded carbon costs.

***Carbon** Measurement Fundamentals for Engineers* is a new resource developed to enable all engineering disciplines to gain an understanding of emissions accounting and the associated tools and techniques.

"The huge international effort going into the categorising and accounting of carbon emissions has created a daunting complexity," said Nolan Bear FIEAust EngExec CPEng, Past Chair of the Australian Cost Engineering Society (ACES).

This led to the establishment of the Carbon Measurement Working Group, a member-led initiative of Engineers Australia, with the aim of educating engineers on the principles that underlie all embodied carbon measurement. Bear hopes the work of this group can bring consistency and rigour to the Australian engineering community.

ABOVE: Nolan Bear FIEAust EngExec CPEng

It's essential that engineers use common methodology and consistent definitions when making their measurements.

"Classification of emissions will allow for essential comparisons between projects and companies," Bear explained. "But if the fundamental estimates of carbon emissions are unreliable, then the credibility of this reporting will be challenged both locally and globally."

"With the introduction of mandatory climate-related financial disclosures from 1 January 2025, this guide is designed to help prepare engineers for that."

Climate-smart

The Carbon Measurement Working Group is just one group sitting under the Climate Smart Engineering (CSE) banner.

There are many member groups under CSE, all working towards developing practical tools and guidance across a range of critical climate-related issues.

"This is the real, tangible work going into decarbonisation," said Damian Ogden CompIEAust, Group Executive, Policy and Public Affairs at Engineers Australia. "This is where we see members leading the conversation on these important

issues, rolling up their sleeves to get the work done."

Influence

As prominent influencers in the selection, design and implementation of projects, engineers identify interdependencies, synergies and relationships between elements of products and projects. They engage across all creative disciplines and all sectors of society, making them ideally placed to identify carbon reduction opportunities and risks.

"Engineers already have the technical basis to identify the carbon emissions of what they plan and build, and this guideline identifies the common elements to all carbon estimates," Bear said.

Though not all engineers need to be fully versed in all the complexities of carbon accounting, they must understand fundamentals to support carbon assessments, evaluate results, and inform project and operational decision-making.

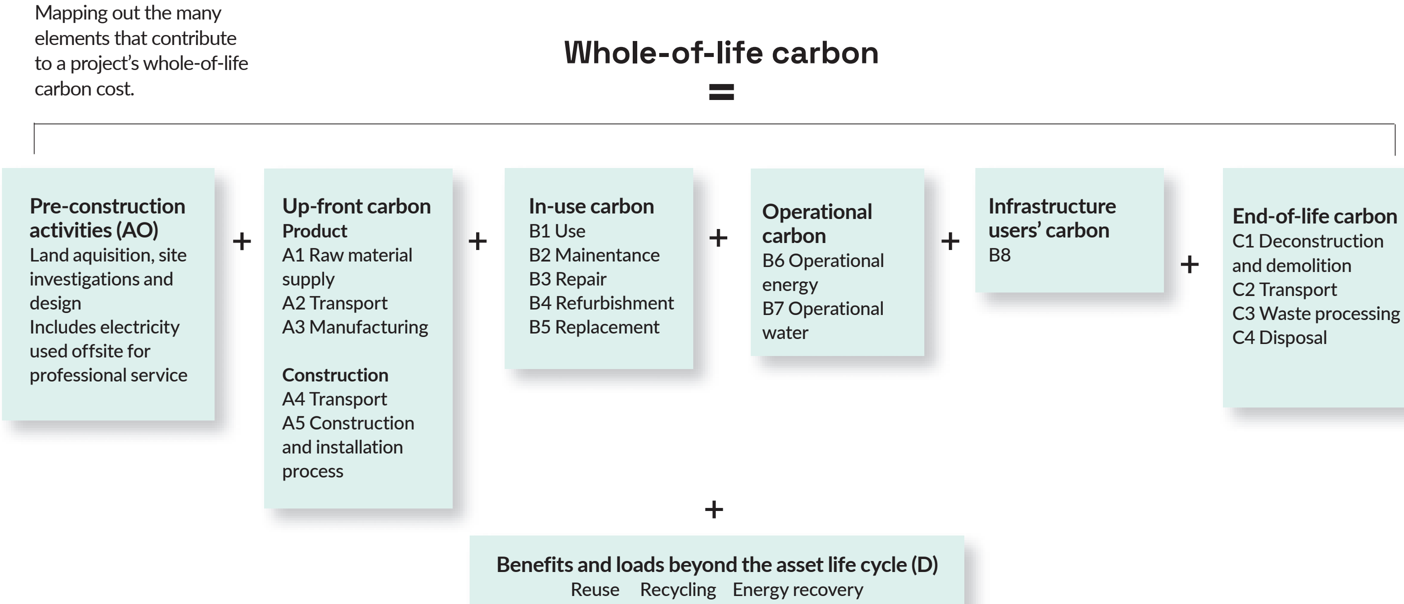
Timing

Simon Koger, Climate Change Manager at Engineers Australia and convenor of the working group, pointed to the timeliness of the release of this guide.

"With the introduction of mandatory climate-related financial disclosures from 1 January 2025, this guide is designed to help prepare engineers for that," he said. "But it's also pitched at a level where a range of other professions such as development managers or project managers can pick it up and gain insight into how to respond to the new requirements." □

Read the full guidelines. bit.ly/3zUT95H

BELOW: Mapping out the many elements that contribute to a project's whole-of-life carbon cost.



BLUE-SKY THINKING

If you were designing a greenfield major city, what would be a key strategy or design principle to minimise emissions and maximise sustainability?

LUCIA CADE *FIEAust*
is an Independent Director at Infrastructure Victoria and Non-Executive Director at Urban Utilities (Qld) and Engineers Australia

I imagine a new city designed around people and how they will experience living. A city that is safe. Where there is equitable access to work, health and education; safe water; clean environments and energy; and green parks and streets.

Infrastructure is a key enabler of the social wellbeing and economic growth that underpins that experience. Around 70 per cent of Australia's greenhouse gas emissions are attributed to infrastructure across its life and in how it is used. The effort invested getting these strategic long-term assets right from the outset pays long-term dividends.

Urban planning in my city would support co-locating zones that lead to efficient infrastructure. This has a flywheel effect for decarbonisation and sustainability. For example, zoning industries using water and energy next to water and waste treatment plants producing water and energy.

In my city, urban planning would also focus on the community scale, not just the whole-of-city scale, because we know that community connection is important to long-term health and wellbeing.

I imagine a water-sensitive city that boasts green open spaces, street trees, urban food precincts, nature-based drainage and clean urban streams.

Houses and buildings would be designed using sustainable architecture principles and materials to enable whole-of-life benefits for energy, air flow, waste and light. These would be designed on a human scale, not too high and not too sparse, at a 'gentle' density.

It would be a smart city, digitally interconnected and with equitable access for all; one with IoT, sensors, infrastructure that supports autonomous vehicle travel and visual imagery to support safety.

And transport would be effortlessly intermodal, supported by the smart city technology, making it easy to combine bus, train and tram public transport with riding and walking as well as driving.

These are all design principles and technology solutions that exist now – we just need to apply them. No need to wait. What is stopping us?

"Urban infrastructure is a key enabler of the social wellbeing and economic growth that underpins that experience."

DR EDMUND ANG *FIEAUST CPENG*
is a Technical Director of Strategic Engineering for ANZ at AECOM

The key principles I would adopt in designing a greenfield major city would be circular economy and resilience, which work in tandem to achieve long-term sustainable outcomes. With a circular economy, I would establish a design philosophy ensuring we prioritise the reuse of existing materials, and that all key materials used in building are easily dismantled and can be continuously repurposed.

For instance, solar panels at the end of life must be able to be recycled, reused or repurposed – perhaps into aggregate for concrete mixes. When the structures incorporating those concrete mixes are demolished, it should be suitable as a recycled concrete for other

usage: maybe modular bricks for home building or pavement.

This approach must be incentivised through sustainability or tax credits, or a simplified environmental approval process.

Separately, we must ensure our city design remains resilient in our pursuit of sustainability.

Recent disasters from around the world, both natural and human-made, from wildfires to floods, have shown that a single disaster can undo decades of sustainability benefits. For a resilient design, we must think probabilistically – because one disaster that may seem improbable could undo years of emissions reduction.

Wildfires will continuously occur, and their consequences can be disproportionate. A study estimates the CO^2 emissions from global wildfires equates to 10-20

“Separately, we must ensure our city design remains resilient in our pursuit of sustainability.”

per cent of fossil fuel emissions. To design for resilience, I would require overdesign in some cases, such as in fire protection, because this can reduce risk and consequences. In the long term, the additional resources consumed would still result in a net gain for sustainability.

For example, for cities in bushfire zones, recycled concrete, which has a lower strength but good fire properties, can be used as pavement or retaining walls doubling as fire breaks in parks.

Sustainability, only when designed with resilience in mind, can result in a legacy for generations to come.

DORINA POJANI
is Associate Professor of Urban Planning at the University of Queensland and author of *Trophy cities: A feminist perspective on new capitals*

“The city’s public transport backbone is a sleek, efficient network of electric trams and driverless shuttles.”

Imagine stepping into a place where private automobiles are a relic of the past. Welcome to Pedalopolis, a city of about half a million inhabitants, designed from the ground up to be car-free. In Pedalopolis, the streets pulse with life. People walk, cycle and scoot. The city’s public transport backbone is a sleek, efficient network of electric trams and driverless shuttles. These silent, pollution-free vehicles glide smoothly through green corridors, connecting all districts. At key transport hubs, you can hop off a tram and onto a shared e-bike or e-scooter, ensuring that your final destination is always within easy reach.

A fleet of e-taxis provides door-to-door travel for people with disabilities, elderly people and people traveling with young babies. No more traffic jams or stressful commutes – just smooth, effortless travel for all. Pedalopolis is a cyclist’s paradise: bicycles have priority on all streets, whereas motorised travel is limited to one or two dedicated lanes for taxis, shuttles, trams, emergency vehicles, waste collection trucks and delivery vans. Secure bike storage and charging and repair stations are conveniently located, so you can ride with peace of mind.

Instead of sprawling malls, in Pedalopolis you’ll find charming streets lined with small shops run by local artisans and merchants. Pedestrian plazas are filled with farmers markets, street performers and outdoor cafes. Community gardens provide additional fresh produce, reducing the need for long-distance transport.

Pedalopolis does not shun technology. Smart infrastructure ensures efficient energy use, with vehicles that adjust their electricity consumption based on real-time data. Waste is minimal, with comprehensive recycling and composting programs which further reduce travel demand.

The city’s digital ecosystem connects residents to services and amenities at the touch of a button, eliminating spurious travel.

Pedalopolis combines ecology, convenience, beauty and wellbeing. □

Green steel

WORDS BY OLIVER GORDON

Steel is one of the most important – but hardest – sectors to decarbonise. With its abundant iron ore, vast renewable energy potential and engineering nous, Australia could lead the world's green steel transition – but only if it plays its cards right.


superpower

Steel is the planet's largest-emitting manufacturing sector, responsible for a staggering seven per cent of global greenhouse gas (GHG) emissions. Unfortunately, it is also one of the hardest sectors to decarbonise. But decarbonise it we must, and fast, if the world is to limit global warming to a relatively benign 1.5°C. And of all countries, Australia may well have a disproportionately important role to play in that process.

From bridges and buildings to cars and ships, the modern world is built on steel; but, with its ubiquitous turbines, panels and pylons, the decarbonised world of tomorrow will have an even more voracious addiction. It will need steel more than ever.

Much of today's steel does not come into existence without the aid of Australian iron ore and metallurgical coal. In fact, converting Australia's iron ore into steel emits more than 1.5 Btpa of CO_2 – triple the country's domestic emissions.

With its abundant iron ore reserves, vast renewable energy potential and acclaimed engineering workforce, Australia has the potential to become a global leader in green steel, helping global industry decarbonise while transforming its economy in the process. Indeed, with the recent Future Made in Australia initiative, the federal government has left no doubt about the importance of sovereign manufacturing capabilities to the country's green future.

That future, however, is far from assured and there remain structural impediments to Australia's green steel metamorphosis; both its government and industry must act fast and expediently to ensure the opportunity does not pass them by.

"Our ability to produce green steel cheaply will play a significant role in meeting our global ambitions towards decarbonisation."

ABOVE:
Dr Stuart Walsh, Monash University

Increasing demand

The global steel industry currently produces approximately 1885 Mtpa, with each tonne requiring around 1.6 t of iron ore to produce, and emitting around 1.9 t of CO_2. As demand for steel rises in the future, particularly from Africa, and the industry fails to decarbonise as

rapidly as other sectors like power production and transportation, the sector share of GHG emissions is forecast to increase.

As the world's largest producer of iron ore – contributing close to 40 per cent of global production – and fifth largest producer and largest exporter of metallurgical coal, Australia is positioned auspiciously in this transition.

"While some of the extra demand will be met through recycling, the current rates of raw iron ore production will need to be maintained or increase into the future to meet the increased demand for steel," said Dr Stuart Walsh, a senior lecturer in resources engineering at Monash University.

Emissions from steel must drop by 50 per cent by 2050, and then continue to decline, to hit climate targets, according to the International Energy Agency. At the same time, the net zero transition could require an additional 170 Mtpa of steel, on average, to 2050 – around 10 per cent of current global steel consumption.

"So we're moving into a world that needs less emissions, but more steel," said Dr Marcus Haynes, module leader of Lithospheric Geophysics and Economic Fairways, Geoscience Australia. "Our ability to produce green steel cheaply will play a significant role in meeting global ambitions towards decarbonisation."

The dominant steelmaking technology today involves using coking furnaces to heat coal to make coke, which is then put into a blast furnace with iron ore. The coke is converted into carbon monoxide, which extracts the oxygen from the iron ore, leaving elemental iron, which melts to the bottom of the furnace. That liquid iron is then sent on to the basic oxygen furnace to have its carbon level set, turning it into steel.

ABOVE: Dr Marcus Haynes, Geoscience Australia

Targeting emissions

Most of the emissions come from getting the oxygen off the iron ore, and that is where the green alternatives come in. Instead of blast furnaces, a technology called direct reduction of iron (DRI) pelletises the iron ore before running synthetic gas (hydrogen and carbon monoxide) through it. The synthetic gas takes away the oxygen as steam, leaving solid elemental iron, which a producer can then sell or melt in an electric arc furnace. To decarbonise DRI, producers can either add carbon capture and storage technology to catch the emitted CO_2. Or, if they have an external heating source, they can use pure hydrogen instead of coal, in a process called H2-DRI.

Alternatively, there are two types of electrolysis technologies: aqueous electrolysis submerges the iron ore in acid and zaps it with electricity, making the oxygen bubble off; and molten oxide electrolysis heats powdered iron ore with electrodes until it melts and releases the oxygen.

"At present the most advanced methods of green steel production involve the direct reduction of iron ore using hydrogen," Walsh said.

Indeed, green hydrogen is seen as central to the decarbonisation of steelmaking. Substituting coal with natural gas can reduce the carbon intensity of steel by 50 per cent; but if the hydrogen is generated from electrolysis – and the whole >

ironmaking," said Dr Tessa Leach, an industrial researcher at the net zero research organisation Climateworks Centre. "If the nation acts now to make the most of its renewable superpower potential, generations of Australians could work in these clean industries, transforming the economy and our industrial regions."

But the country does not have it all its own way, and it could still be left behind if the industry gathers pace elsewhere. That's because even though Australia is the world's largest exporter of iron ore, some of the new techniques rely on ore with a higher purity than it currently exports. Additionally, its coal exporters could also lose income, as the country is the largest exporter of the coking coal burnt in furnaces using traditional steelmaking technology.

Around 96 per cent of Australia's mined iron ores are high-grade hematite ore, which is currently only suitable for steel production in coal-consuming blast furnaces. Most current hydrogen-based green steel approaches, however, require magnetite ore.

"Fortunately, Australia also has substantial magnetite ore reserves," Leach said. "And, as well as mining magnetite, new technologies could make hematite ore compatible with green steelmaking."

In fact, Australian research has developed both new methods for processing hematite and new steelmaking technologies, often aided by funding from the Australian Renewable Energy Agency (ARENA). For instance, major companies such as Rio Tinto, BHP and BlueScope are collaborating to develop electric smelting furnace technology, aimed at enabling the use of lower-grade iron ores in green steelmaking, and are hoping to commission a pilot project in 2027.

GFG Alliance also achieved a milestone with the production of high-quality magnetite pellets, enabling the use of hydrogen as a reducing agent in the DRI process. Calix has developed the Zero Emissions Steel Technology (ZESTY), a technology using hydrogen to reduce iron ore. And Fortescue Metals is developing an industrial-scale prototype plant that integrates H2-DRI with a new type of smelting technology.

96%

OF AUSTRALIA'S MINED IRON ORES ARE HIGH-GRADE HEMATITE SUITABLE FOR STEEL PRODUCTION IN COAL-CONSUMING BLAST FURNACES

Magnetite ore
Required by hydrogen-based green steel approaches

A nascent industry

Although Australian green steel is still a nascent industry, the global Green Steel Tracker reveals the country is currently one of the world leaders for project announcements, alongside the likes of Germany, Austria, Sweden, China and South Korea.

"However, we're largely looking at the rollout of pilot plants to the end of the decade," Haynes said.

In particular, there's a focus on the production of green iron, with Fortescue, Green Steel of WA, China Baowu, Rio Tinto and POSCO all announcing DRI projects in the country. In terms of steel production, there are a couple of key projects Haynes believes are worth keeping an eye on: Liberty Primary Steel's Whyalla steelworks in South Australia, which is aiming >

> "If the nation acts now to make the most of its renewable superpower potential, generations of Australians could work in these clean industries, transforming the economy and our industrial regions."

ELECTRIFIED PROCESS USING RENEWABLE ENERGY REDUCES CARBON INTENSTIY BY

95%

ABOVE: Tessa Leach, Climateworks Centre

process electrified using renewable energy – then the carbon intensity can be reduced by 95 per cent. However, in contrast to coal, hydrogen is difficult to transport.

"The costs of producing and transporting hydrogen may change the equation in terms of which regions are more or less likely to be able to sustain a competitive green steel industry," he said.

Globally, the green steel industry is still in its infancy. In terms of low-carbon steel, at the moment there is only Aço Verde do Brasil's 0.6 Mtpa biomass-fuelled green steel plant in operation in Brazil. The major focus outside of this has been on the deployment of a handful of natural gas-fuelled ironmaking and steelmaking plants geared towards a longer-term transition to green hydrogen. The majority of steelmakers – at least those with declared targets – are aiming to be carbon neutral by 2050; however, there's momentum growing in Europe with Sweden's SSAB and Germany's Salzgitter both setting targets in the early-2030s.

"Collectively, there's a lot of activity going on in the EU – especially in Sweden, Germany and Spain," Haynes said. "This is likely due to a higher market appetite for green steel and a supportive regulatory environment."

When the EU's Carbon Border Adjustment Mechanism arrives in 2026, it will impose a tariff on carbon-intensive imports such as steel. The mechanism is designed to prevent carbon leakage, protecting the emergent green steel industry from direct competition with non-green producers.

According to Haynes, H2 Green Steel is the most advanced of the European cohort – construction having started construction on a five Mtpa green steel plant in Boden, Sweden, to be operational by 2030. However, outside of the EU, Vulcan Green Steel has also started construction on a five Mtpa facility in Duqm, Oman.

Natural advantages

Australia has all the natural advantages and trade relationships to make it a key green steel hub of the future. As well as being the world's largest exporter of iron ore, supplying key markets in Asia, the country has a strong engineering workforce, ports and industrial nous. The production of green steel requires all these elements, as well as world-class renewable energy potential to power green ironmaking and steelmaking.

Australia hasn't built a new steel mill in more than three decades. But that is about to change with the Collie green steel recycling mill set to be operational by 2026 and a planned hydrogen direct reduced iron (DRI) plant also on the cards for 2028.

"The recently announced Future Made in Australia framework also suggests the nation has the political will to pursue green steel, particularly hydrogen-based to deploy a 1.5 Mtpa electric arc furnace in the coming years, initially using hydrogen from natural gas, but with an aim to transition to green hydrogen in the longer term; and Green Steel WA's project to develop a 0.5 Mtpa electric arc furnace in Western Australia.

Steely ambition

Looking ahead, thankfully for Australia's green steel industry, the two main challenges it faces are shared by its competitors: developing green steel technologies that can process lower-quality iron ore; and reducing the cost of hydrogen production enough to make green steel price-competitive.

For the latter, Haynes believes the country should look to invest in developing industrial storage of hydrogen in underground salt structures, which can be up to 90 per cent cheaper than above-ground storage.

For Dr Changlong Wang, a research fellow at Monash University, the key will be advancing the country's hydrogen production capabilities, specifically through large-scale electrolysers.

Investing in H2-DRI processes and developing electric arc furnaces to be powered by renewable energy are other vital steps for the industry, Wang said. And the strategic co-location of hydrogen production facilities with iron ore mining operations could further optimise costs and logistics, making Australian green steel more competitive globally.

Strangely, while Australia produces vast amounts of the raw materials needed for steel, it produces very little of that steel onshore. In fact, more than 20 per cent of the steel used in the country is currently imported from overseas.

"We face an uphill battle if our goal is to compete directly with international steel manufacturers

in other countries, who benefit from pre-existing supply chains, production facilities and industry expertise," Walsh said.

But trade in DRI could be a "win-win" that allows Australia to leverage its natural advantages in raw materials and renewable energy, while helping its trading partners to decarbonise their existing heavy industry. A related engineering challenge, however, would be the adaptation of ports and other infrastructure to help Australia move up that steel value chain to export H2-DRI instead of iron ore.

"In short, while technical innovation is needed, engineers will need to operate in a fast-moving policy and business environment, building our capabilities, learning from what others are doing, and helping authorities to plan ahead," Leach said.

To its credit, the government has demonstrated commitment to developing the green steel industry through several key initiatives. The $2 billion Hydrogen Headstart program, and its follow-up with another $2 billion, are significant steps, alongside the Future Made in Australia Fund fostering innovation and manufacturing capabilities. The $2 per kilogram tax credit for green hydrogen production incentivises the transition by

lowering production costs. Also, the South Australian government has supported the industry by fast-tracking land approvals and infrastructure development.

But more is needed, according to Wang. Skills development will be key, including workforce training programs focused on renewable energy technologies, hydrogen production and advanced steelmaking processes. The government should also provide further financial incentives such as subsidies, tax breaks and low-interest loans to encourage investment in green steel technologies; and carbon pricing mechanisms can make green steel more competitive by internalising the environmental costs of traditional steel production.

"And international partnerships and export strategies will help Australia access global markets for green steel," Wang said.

Nonetheless, the good news for Australia is that it has all the raw materials the world requires to get to net zero; allowing the country to decarbonise at home while helping others follow suit abroad. Overall, the Superpower Institute predicts that Australia could reduce international emissions by seven per cent.

"This is Australia's superpower potential," Leach said. □

ABOVE:
Dr Changlong Wang, Monash University

COMMENTARY

Dr Raj Aseervatham FIEAust CPEng, Engineers Australia National President

The bottom line is key

Steel production accounts for seven per cent of global greenhouse gas emissions. Future steel demand is expected to increase over time, driven by rapid urbanisation and generating huge demand for applications such as buildings and high-speed rail.

Because of this carbon intensivity, Engineers Australia foresees many technologies evolving to produce green steel. However, engineers will need to couple their technological ingenuity with an eye to lowering the unit cost of production.

Green steel costs will need to be competitive with, or better than, the traditional carbon-intensive process to gain wide acceptance.

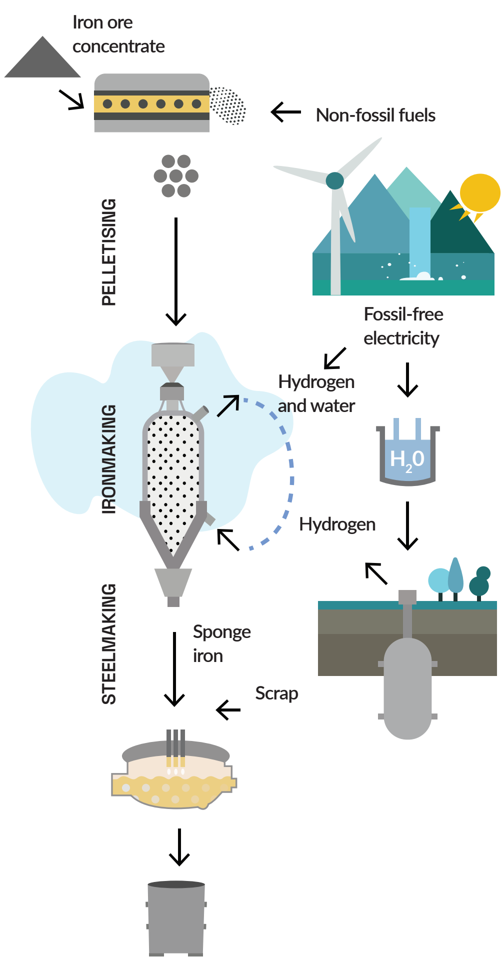
Countries with rapid urbanisation trends (many of which are in Asia and Africa) are still developing economically; any premium on green steel costs that flows into retail markets, impacting cost-of-living factors, may not support penetration to those important markets.

That penetration is vital to achieving global decarbonisation targets.

But that is what engineers do best – develop new technologies and scale up to deliver cost-competitive, sustainable solutions to humanity's challenges.

Four types of green steel

Words by Jeremy Bowden



01

Direct reduction of iron via hydrogen: Hybrit model

Up to 80 per cent of steelmaking emissions come from the conversion of iron ore to metallic iron. Using green hydrogen and renewable power makes this reduction process carbon-free.

Among the methods that employ this approach, the Hybrit model is closest to commercial adoption. Developed in Scandinavia, iron ore pellets or lumps of hematite are fed into the top of a shaft furnace. Hydrogen is heated to 800-900°C and blown in mid-furnace. As the hematite (Fe_2O_3) descends through the hydrogen, it is reduced first to magnetite (Fe_2O_4), then wüstite (FeO) and eventually to metallic iron which is collected at the base of the furnace.

Flue gases include water vapour, which is condensed and released, and unreacted hydrogen, which can be recycled and mixed with fresh hydrogen in the heater, before reinjection. The full reaction is $Fe_2O_3 + 3H_2 = 2Fe + 3H_2O$.

The system can use renewable electricity to produce the heat and green hydrogen, making it a completely carbon-free process.

02 ▶

Calix's ZESTY reactor

This is another hydrogen reduction approach, from an Australian company, in its early days of development. As with other hydrogen reduction approaches, hydrogen removes oxygen from the iron ore to produce metallic iron and water. However, ZESTY separates the heat source from the reaction, which ensures hydrogen is not combusted or used as a fuel and is easily recycled.

In this way, ZESTY replaces inefficient combustion with precise and renewably powered electric heating. Using green power, minimal green hydrogen and the elimination of additional processing steps, ZESTY claims it offers among the lowest-cost green options.

The approach can use intermittent renewable power, and waste or lower-grade ores, with no need for pelletisation or fluid beds. ZESTY is quick-response and easily scalable.

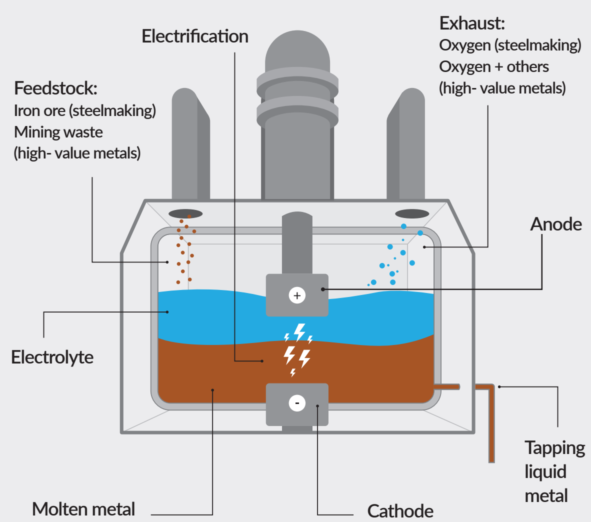
03

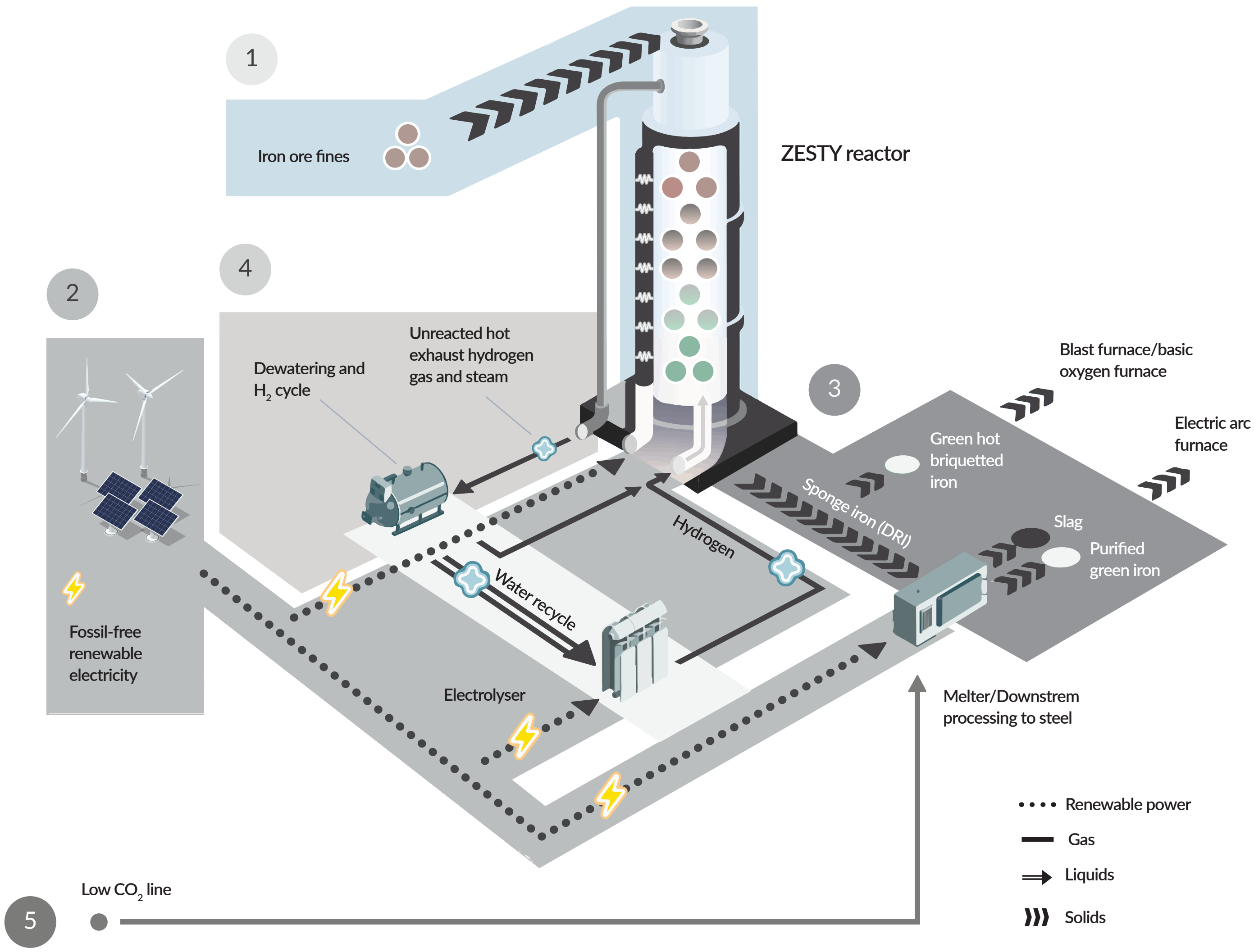
Molten oxide electolysis (MOE)

This approach uses no hydrogen or carbon-based reducing agents. Originally developed by Boston Metal, it uses heat from renewable electricity to convert iron ore to liquid metal. MOE does not require iron ore sintering or pelletising and removes several steps in the steelmaking process.

In the MOE cell, an inert anode (chromium-based alloys are most effective) is immersed in an electrolyte containing iron ore and subjected to an electric current. When the cell heats to 1600°C, the electrons split the bonds in the iron oxide in the ore, producing pure liquid metal directly from the oxide feedstock. Oxygen is the only byproduct, with no need for hazardous chemicals or expensive catalysts.

The process produces a high-purity liquid metal that can be sent directly to ladle metallurgy without the need for reheating. The process is also cost-effective, scalable, and capable of converting various grades of iron ore.





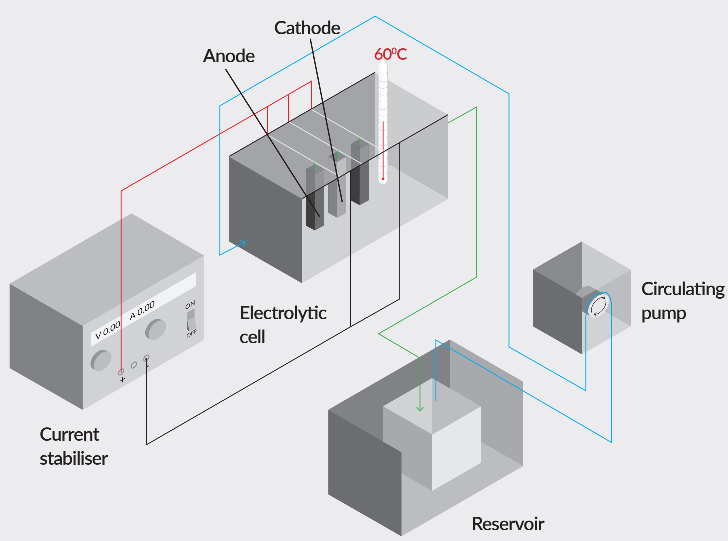
04

Electrowinning

Originally developed by US startup Electra, electrowinning involves battery-like systems that use acid solution and clean electricity to pull pure iron out of low-grade ores. Operating at just 60°C, this innovative approach requires no fossil fuels or hydrogen.

The ore is dissolved in an aqueous solution, typically containing iron sulphate, then electricity is passed through the solution to separate and collect pure iron molecules at the cathode. The process can be optimised by adjusting the pH and adding salts like sodium or ammonium sulphate to improve conductivity and current yield.

The battery cells can be laid out in modular fashion at many different sites, avoiding the need for a single, large capital outlay. It can produce high-purity iron with relatively modest power consumption.



INNOVATIVE **'LOW STRESS'** DESIGN

With its innovative design and patented 'post/fuse' system, DOLRE 'Regular' barrier delivers MASH TL4-rated protection while limiting the maximum transverse force transmitted to the bridge deck to less than 44 kN/post (22 kN/metre), which equates to only 14% of the ultimate outward transverse design load as per AS 5100.2:2017.

What's more, at around 80 kg/m installed, DOLRE bridge traffic barriers are significantly lighter than many AS 5100 'Regular' / MASH TL4-rated barrier alternatives.

SEAMLESS **PROTECTION** WITH **DOLRE TL4** TRANSITIONS

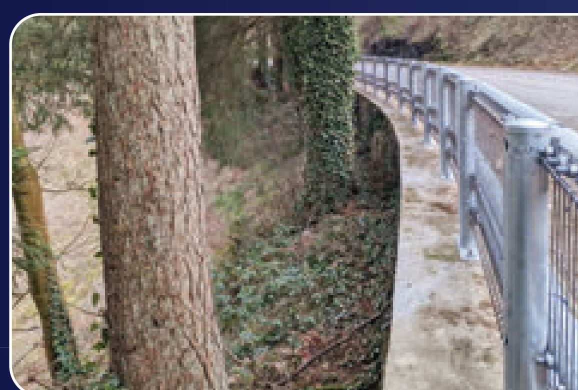
DOLRE transitions have been designed and tested to provide full longitudinal load transfer between the bridge traffic barrier and connecting roadside barriers.

The DOLRE 'Regular' barrier, together with the DOLRE transitions and Thrie-Beam barriers create an engineered continuum of MASH TL4 protection – delivering maximum safety for road users onto and across the bridge structure.

WHERE **PERFORMANCE** AND **AESTHETICS** MEET

DOLRE's clean, uncluttered lines and aesthetically pleasing design make it an ideal match for a wide variety of bridge designs and locations. The design allows for rapid installation, as well as rapid repair and reinstatement of the barrier following an impact. DOLRE is also easy to dismantle and remove in times of flood, thereby helping to significantly reduce the risk of damage to valuable bridge assets caused by flood-borne debris.

DOLRE is also available with an extensive range of standard or custom fascia designs and integrated lighting options.



CHOICE OF PERFORMANCE LEVELS

Available in a range of AS 5100:2017 performance levels, including DOLRE Low (MASH TL2 | EN1317 N2), DOLRE Regular (MASH TL4 | EN1317 H2) and DOLRE Medium (MASH TL5+ | EN1317 H4b), there is a DOLRE barrier to suit virtually any bridge, culvert or road embankment application.

All DOLRE systems feature three rails - two rails for the initial vehicle impact and one rail to resist rollover – and one post design per system type, suitable for both sides of the bridge.

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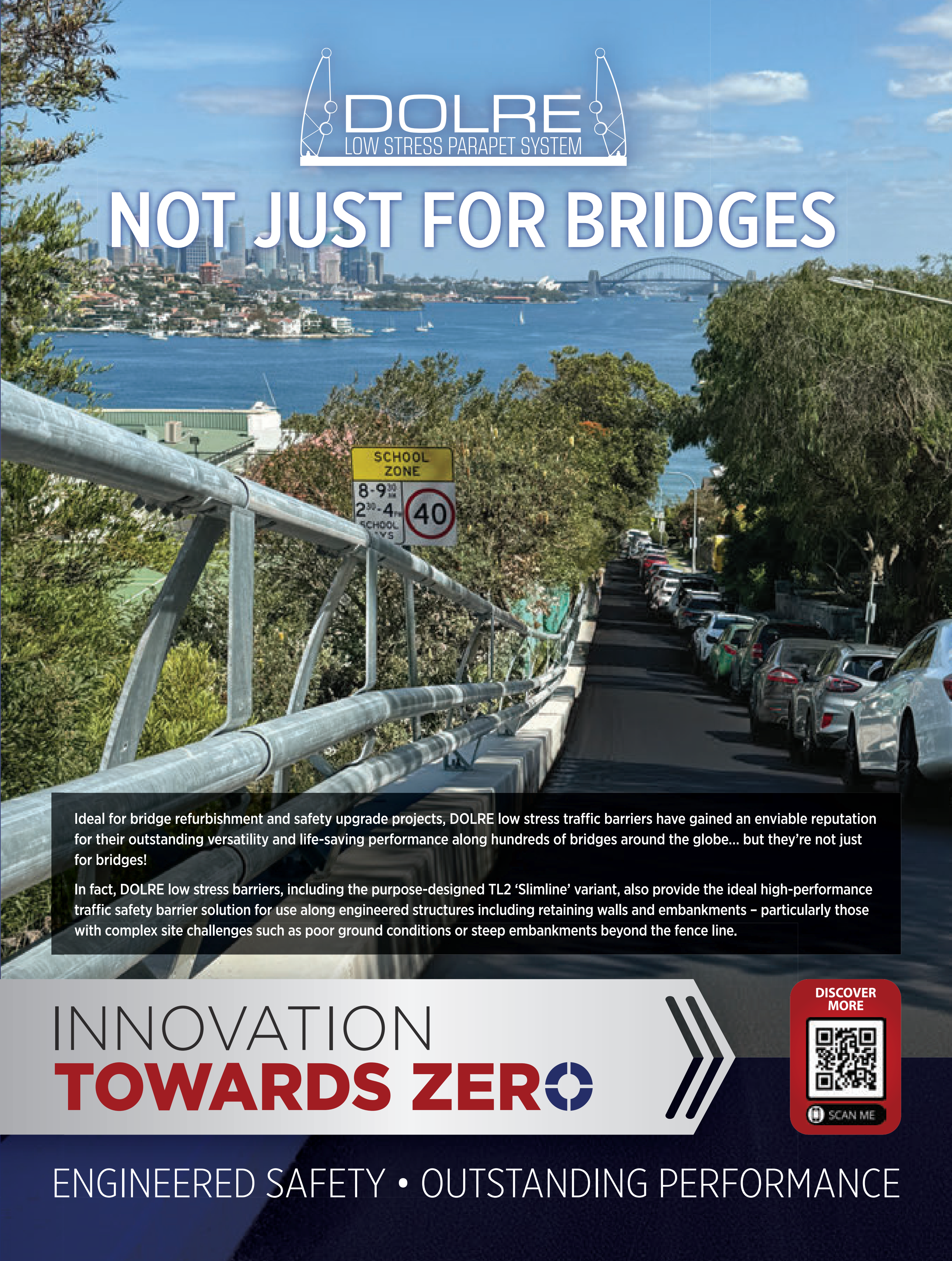

DOLRE
LOW STRESS PARAPET SYSTEM
NOT JUST FOR BRIDGES
SCHOOL ZONE
40
Ideal for bridge refurbishment and safety upgrade projects, DOLRE low stress traffic barriers have gained an enviable reputation for their outstanding versatility and life-saving performance along hundreds of bridges around the globe... but they're not just for bridges!
In fact, DOLRE low stress barriers, including the purpose-designed TL2 'Slimline' variant, also provide the ideal high-performance traffic safety barrier solution for use along engineered structures including retaining walls and embankments – particularly those with complex site challenges such as poor ground conditions or steep embankments beyond the fence line.
INNOVATION
TOWARDS ZERO
DISCOVER MORE
SCAN ME
ENGINEERED SAFETY • OUTSTANDING PERFORMANCE

The future is electrifying

WORDS BY CHRIS SHEEDY

Until recently, net zero mining was considered an impossibility. What a difference innovative engineering makes.

BY THE NUMBERS

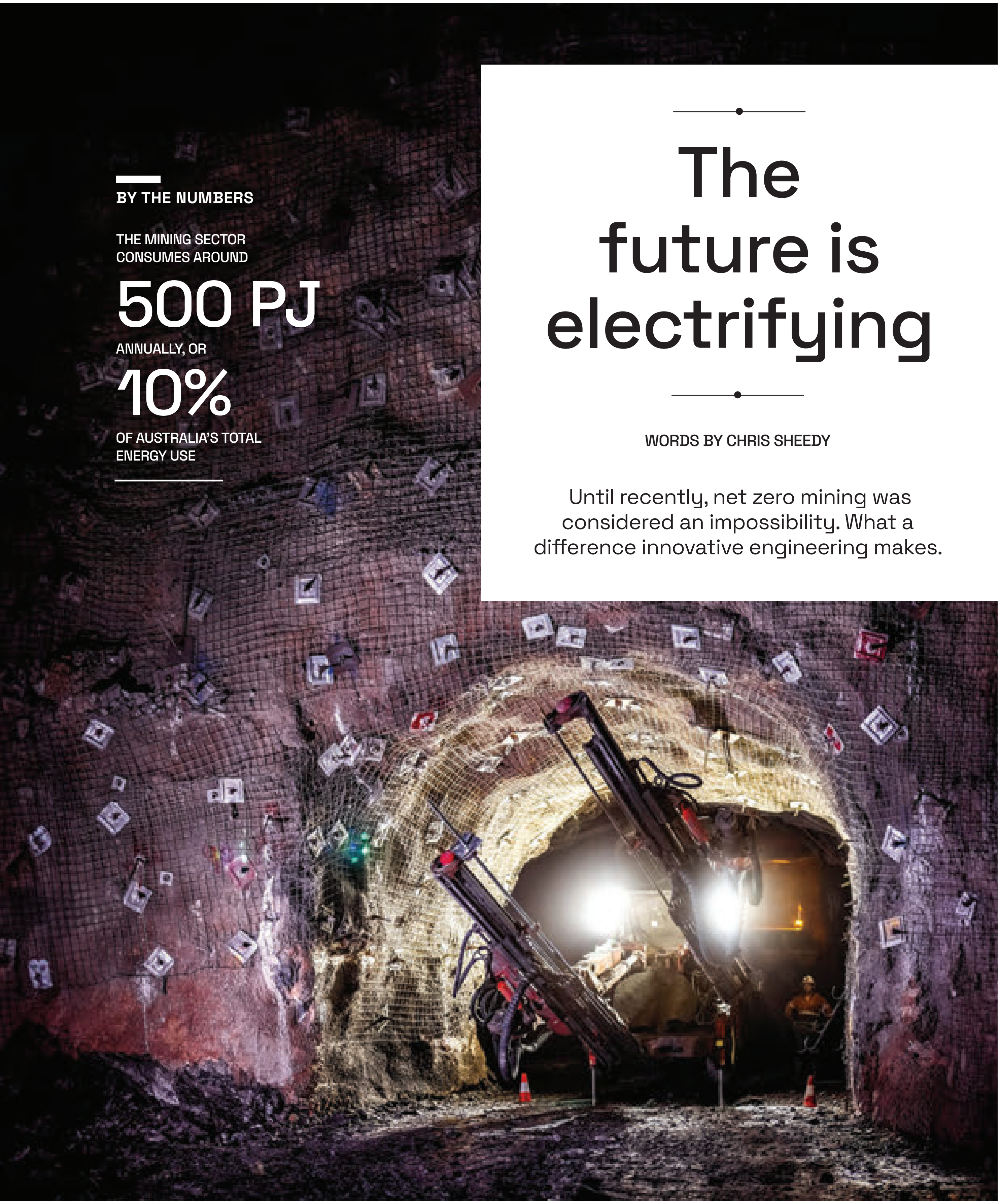
THE MINING SECTOR CONSUMES AROUND

500 PJ

ANNUALLY, OR

10%

OF AUSTRALIA'S TOTAL ENERGY USE



The challenges of decarbonising the mining sector, currently responsible for four to seven per cent of the world's carbon footprint, have long been considered too technically difficult to solve.

But as engineers have thrown themselves at the task, solutions have started to appear. Some are now being implemented, others are in testing and more are in design. Most experts now agree that net zero mining is not just possible but inevitable.

Some in the industry are leading the way with bold claims. Bellevue Gold, with a mine powered by wind, solar and thermal and firmed up with battery storage, is looking to produce net zero gold by 2026. Fortescue is targeting net zero emissions by 2030.

Mining engineer Clare Larkin-Sykes, Managing Director of Forelight Advisory, said while green mining is ambitious and costly, it is the future.

ABOVE: Clare Larkin-Sykes, Forelight Advisory

"From a purely commercial perspective, a current existing mining operation already has capital sunk into it," Sykes said. "So, what is required is a rethink about how those structures already in operation can be repurposed to accommodate a net zero future."

That involves better understanding the ore body in the ground, so miners only extract what they need to, minimising waste. It also requires renewable energy to power mining processes.

Mineral processing practices and technologies will need to change, and diesel use in machinery must be phased out through electrifying equipment and vehicles.

And that's all before the sector develops ways to help mitigate scope 3 emissions, previously considered outside its control.

"What is required is a rethink about how those structures already in operation can be repurposed to accommodate a net zero future."

Mining in Australia, according to the Renewable Energy in the Mining Sector paper from the Australian Renewable Energy Agency (ARENA), consumes around 500 PJ annually, or 10 per cent of Australia's total energy use.

THAT ENERGY COMES FROM:

41%
DIESEL

33%
NATURAL GAS

22%
GRID ELECTRICITY

In coal mines, the most energy-intensive processes are comminution, or crushing and grinding, as well as vehicles and machinery. Mine ventilation also requires a significant energy feed.

This energy will continue to be required, renewable or not. To meet Paris Agreement deadlines, copper alone must be mined at a previously unimagined rate. According to Professor Michael Goodsite CPEng EngExec, that decarbonisation goal will only be achieved if we mine more copper in the next 25 years than has been mined in the history of mankind.

Other environmentally critical minerals, including lithium, cobalt, manganese, nickel and graphite, are also required in greater volumes than ever by green technology manufacturers.

The greening of mining will require what was once considered an engineering miracle and, with leading miners already making bold claims about their net zero goals, that's just what engineers are set to deliver. >

ABOVE: Fortescue infinity train

RIGHT: DRIFTEX vehicle

ABOVE: Murray Timpson, Slam Engineering; Ben McGarry, Aurecon

Electric vehicles

Numerous EV options are being tested in mines across Australia for everything from people movers to mining trains.

Fortescue's iron ore hauler, the Infinity Train, is famously being designed to charge its batteries via regenerative braking on the way downhill and under heavy load, to the port. It will then return empty, powering itself back uphill and never requiring external power.

This all requires research, investment and innovative engineering. For example, battery-electric vehicles (BEVs) set to work underground have faced extra challenges around safety, according to engineer Murray Timpson, Director of Slam Engineering.

"It's about making sure the battery doesn't create a spark or a fire, or heat that can result in a fire," Timpson told *create*.

Timpson references the Ampcontrol Intrinsically Safe battery management system used by DRIFTEX, the world's first IECEx (International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres) Group I-certified electric vehicle. The DRIFTEX vehicle boasts a methane monitor shutdown system, data logging, lower sound levels, and battery charging flat-to-full in 10 minutes, and will run in conditions from -35°C to more than 50°C.

"Diesel engines that operate underground are explosive-protected and flameproofed, and have been designed over decades," Timpson said. "Batteries are a new technology and unknowns cause concern."

Engineer Ben McGarry, Principal Decarbonisation at Aurecon, said the technical challenge around getting energy on board is enormous.

"One of the ways you can deliver energy to a moving vehicle is via an overhead powerline system," he said. "One solution is to blanket an entire mine with fixed overhead infrastructure."

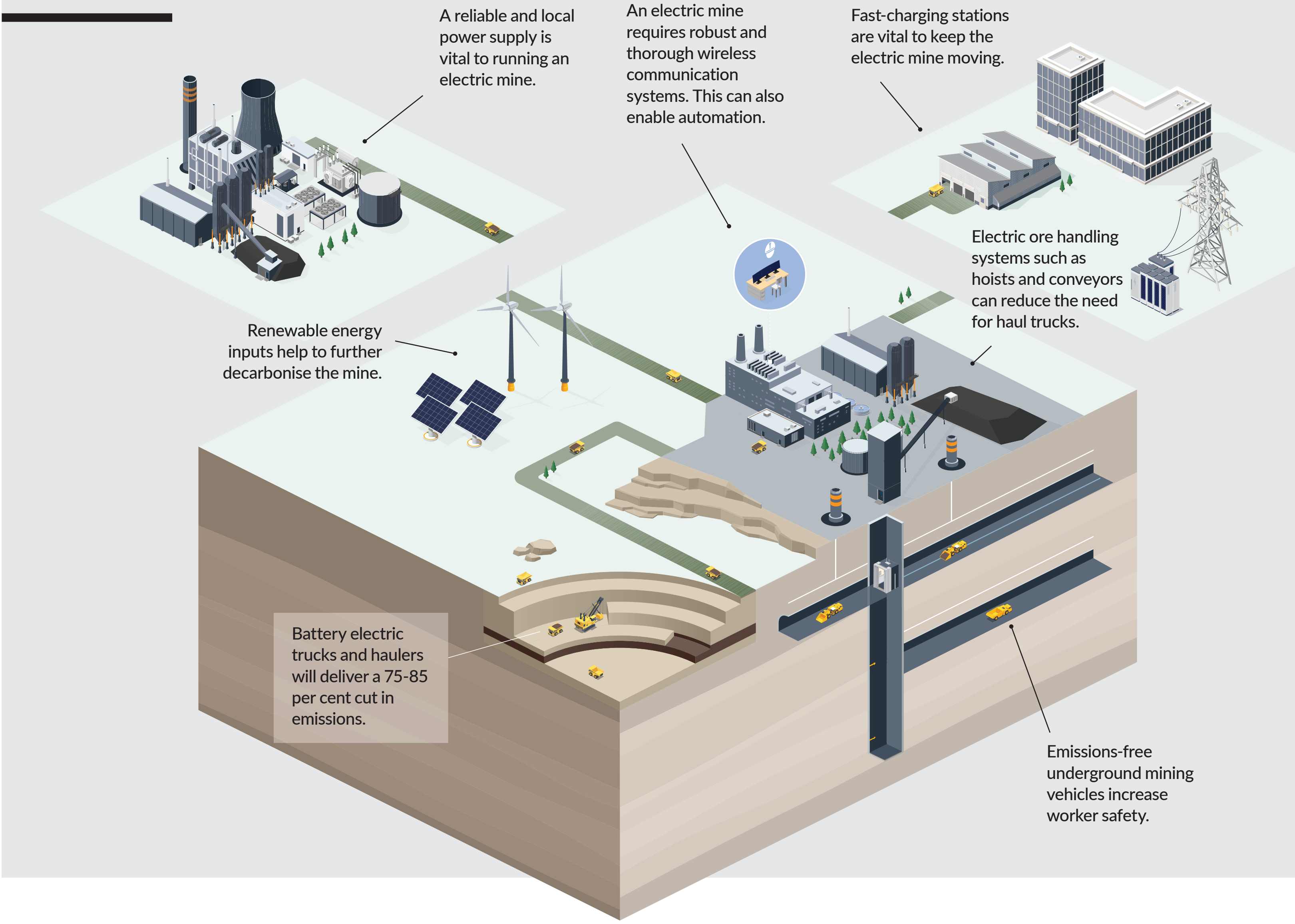
In the Pilbara, Rio Tinto and BHP are collaborating on the testing of large, battery-electric haul trucks using various static and dynamic charging systems.

Some mines are utilising vehicles with batteries that last a full eight-hour shift, such as Komatsu's first-generation lithium iron phosphate hauler battery, a 240 V, 160 kWh, 7500 kg system that operates for eight hours on a single, two-hour charge.

Others are opting for a "mosquito fleet" of more nimble trucks that are simpler to maintain and require less road infrastructure. There are also EVs that utilise battery swapping stations, which enable instant refuelling but require greater external infrastructure.

> "Batteries are a new technology, and unknowns cause concern."

The electric mine



A study by Perenti, IGO and ABB confirmed the technical feasibility, at non-prohibitive CAPEX and OPEX, of an all-electric underground mine fleet on the Cosmos Nickel Project in Western Australia.

It also found that "a BEV fleet would enable a significant reduction in cooling and ventilation demands, which would offset the additional power required by BEVs".

Energy solution

Within the next couple of months, Bellevue Gold will have the ability to run its entire operation on renewables alone. In doing so, it will become the first Australian mine to boast true engines-off capacity, according to Darren Stralow, Bellevue Gold's Managing Director and CEO.

As well as striving to have the lowest total scope 1 emissions of any major Australian mine, the goal for Bellevue is to be able to sell its green gold for a significant price premium.

Stralow faced a choice of a high-thermal solution, which has

ABOVE: Darren Stralow, Bellevue Gold

lower capital costs but higher operating costs over the life of the mine, or an energy solution that costs more up front but provides lower operating costs.

"With our long mine life, we have gone for the second option and built a high-renewable energy power station," he said. "It's going to be over 80 per cent renewable energy penetration into the mine grid when measured over a 12-month period. That's solar, wind, thermal and batteries."

This has been achieved through a power purchase agreement with >

Zenith Energy Operations, which has constructed the power station.

Larkin-Sykes said such a partnership is usually essential for the success of net zero mining.

"Most mines don't have the luxury of access to grid power," she said. "At the same time, miners typically are not in the business of power generation. Collaboration and partnership are key.

"Then, the challenge for miners is to explore different models of operation where those power demands can be managed more effectively to match renewable energy supply."

Bellevue Gold is doing just that – adjusting its operations to maximise electrification by matching renewable energy generation periods. This includes conducting regular maintenance on their oversized crusher during shoulder periods – dawn and dusk – when there is less wind and solar.

McGarry said this operational flexibility will become increasingly relevant as more renewable generation is introduced to mining.

"When the wind is blowing and the sun is shining, you can get away with extremely low energy costs," he explained. "Conversely, when it's still and dark, energy could be eye-wateringly expensive.

"So, whoever decides to simply not have to use energy for those 10 hours a year when it's expensive, and who therefore doesn't need to build the infrastructure to serve that peak 10 hours, can save material amounts of money."

Ventilation

The Perenti/IGO/ABB study, *Making electrified underground mining a reality*, analysed the ventilation design changes enabled by an underground electric fleet as opposed to a diesel fleet at IGO's brownfield Cosmos nickel mine.

"Cosmos is unique in the Australian underground mining scene because it actually has a shaft," Darren Kwok, Perenti's Head of Mining Electrification and Technology, said. "The number of trucks was a lot lower at Cosmos than at another decline mine."

The mine's total power consumption with a fully electrified fleet was less than that of the equivalent diesel operation due to the substantial power savings in cooling and ventilation.

"The health and safety benefits of an electric mine also shouldn't be undersold," Kwok said. "We are seeing vast benefits when it comes to electrification underground related to vibration, heat and tailpipe emissions as a health and safety consideration."

Interoperability

Electrification is also set to deliver further sustainability by enabling new control and automation systems that optimise operations in ways never before possible.

Since 2019, the University of Western Australia's ERDi I4.0 Testlab has been coordinating efforts by more than 20 miners, technology partners, government entities and training organisations to help validate open-process control systems using international standards. The effort has already been instrumental in major

ABOVE: Bellevue Mine, Bellevue Gold

ABOVE: Darren Kwok, Perenti

KEY FINDINGS FROM THE *MAKING ELECTRIFIED UNDERGROUND MINING A REALITY* STUDY

- Significant cooling requirement reductions, with bulk-air cooling plant capacity reduced from six MW to 4.5 MW
- Cooling required over two months annually, instead of five
- Smaller 45 kW auxiliary fans could be used for secondary ventilation, compared to 55 kW fans, increasing blast fume clearance times by just two to five minutes.
- For a greenfield mine, the implementation of an underground electric fleet represented CAPEX and OPEX savings, including savings to primary airflow volume.

"When the wind is blowing and the sun is shining, you can get away with extremely low energy costs."

ABOVE: Prominent Hill Mine, South Australia

LEFT: A Perenti electric vehicle

advances, such as helping Gold Fields' Granny Smith mine become one of the most digitally connected mines in the world. The Western Australia gold mine's new ISA-95-aligned operations management system allows real-time connectivity between workers, fleet and plant, significantly boosting efficiency.

Hoists and conveyers

ABB Global Head of Mining Max Luedtke said their daily focus is on electrification and automation.

Vehicles are the low-hanging fruit, he said, as is the other machinery required to move things, particularly hoists and conveyers.

"There are now more energy-efficient motors and ways to design a mine," Luedtke said. "A lot of mines in the past were over-designed because miners were not looking at electrification."

But the electric mine won't just make deep ore extraction more sustainable, it will also enable automation, optimisation and remote management of machinery.

Remote management capabilities, in turn, help to solve the talent challenge being faced by the mining sector globally.

"We developed a plant in Chile, at nearly 5000 m altitude and 1000 km from Santiago," Luedtke said. "But they manage much of it from an office building in the city, where engineers are happier to work and, in this office, 50 per cent of the engineers are female.

"That sustainability and diversity is only possible if you design the mine the right way." □

ABOVE: Aaron Trueman, ABB

CASE STUDY

BHP's Prominent Hill mine

From trucking to electric hoisting

Cost of operation at the Prominent Hill copper, gold and silver mine was rising fast as trucks hauled ore from deeper underground. The mine was set to become uneconomical by 2033.

A major part of the solution is a powerful electric hoist capable of lifting almost 40 t up a 1300 m shaft in just 90 seconds. Expected to be operational by late 2025, the hoist is the largest and most powerful in the country, and will enable double-digit increases in productivity and similar decreases in operating costs and emissions.

Large sections of the plant are also being engineered and fabricated in Australia.

The savings come not only from the efficiency of electric motors compared to diesel engines (>90 per cent compared to 35 per cent), but also the fact that, while haul trucks must generally traverse at least seven horizontal metres for every vertical metre climbed, hoists pull straight up.

Hoists can also operate autonomously, according to Aaron Trueman, ABB's Business Line Manager for Hoisting in Australia. When powered by renewable sources, they emit zero emissions, and can provide a dual purpose as a ventilation shaft. Adding to their sustainability CV, hoists are also the safest and most efficient way to transport people, equipment and materials underground.

The engineering has not been without challenges, chiefly the sinking of the shaft. That shaft provides access to new areas of mineral reserves unserved by the current trucking plan, boosting production by 30 per cent, to 6.5 million t a year.

Ready for take-off?

The energy-to-weight ratio that makes for efficient air travel means aviation is one of the hardest-to-abate sectors. How do we reduce our reliance on jet fuel?

WORDS BY ROSALYN PAGE

Perched on its own continent, half composed of first- or second-generation migrants, Australia is hugely dependent on aviation, both economically and socially.

With Australians among the world's most frequent long-haul fliers, we have a large stake in the success or otherwise of rapidly decarbonising aviation, one of the hardest industries to abate. The challenges are many, but so there are many engineering attempts to overcome them.

Already, aviation acoounts for about four per cent of global warming. But that share is expected to swell rapidly as other sectors decarbonise. In fact, given projected growth in air travel, by 2050 aviation could represent up to 22 per cent of global emissions, according to Deloitte.

BY THE NUMBERS

AVIATION COULD REPRESENT UP TO

22%

OF GLOBAL EMISSIONS BY 2050

SUSTAINABLE AVIATION FUEL WILL CONTRIBUTE UP TO

65%

TOWARDS DECARBONISATION

While the rise of battery-electric aircraft means the pathway to zero-emission short-haul commercial flights is visible, the unforgiving energy-to-weight ratios that long-haul passenger flight demands mean major engineering ingenuity is needed.

Global aviation decarbonisation efforts are guided by the International Air Transport Association (IATA) net zero roadmap, which lays out the critical actions needed across aircraft technology, energy infrastructure, operations, finance and policy.

Their current modelling suggests sustainable aviation fuel (SAF) will account for the lion's share – two thirds – of the emissions cut. Offsets and carbon capture are predicted to account for a further 19 per cent, and new electric and hydrogen technologies 13 per cent, with savings from infrastructure and operational efficiencies.

The role of design

While it's technically challenging, we'll likely see engineers innovating in this space with new and inventive forms of transport such as electric vertical take-off and landing aircraft (eVOTLs), said Damian Ogden, pilot and Group Executive of Policy and Public Affairs at Engineers Australia, which this year made a submission to the Australian government's Aviation White Paper.

"We can't underestimate the importance of innovation in aircraft design, such as using lighter materials like composites and improving aerodynamics, to reduce fuel burn and support sustainable aviation goals," Ogden explained.

Decarbonising aviation will require significant innovation and retooling of fuel sources, engine technology and aircraft, particularly when it comes to long-haul flights and freight aviation where weight, fuel volume and engine power are critical factors. >

"It will take a multi-faceted approach that needs policy advocacy, government, technological advancements and collaboration between industry leaders, government agencies and the community."

Non-petroleum fuels

SAF is a non-petroleum fuel derived from alternative feedstock such as cooking oil, plant oils, municipal waste, waste gases and agricultural residues. To be sustainable, it needs to use raw materials to avoid depleting natural resources, although not all of the relevant feedstock sources are available in abundance.

SAF offers enormous economic potential to Australian industry, given the country's agricultural strengths and proximity to major transport hubs. However, it is still prohibitively expensive compared to fossil fuels and consensus is needed on global sustainability standards for feedstocks.

It is produced through a number of different pathways such as converting woody biomass using gasification, hydroprocessing fatty acids in oil-based material or fermented sugars in cellulosic biomass, and processing other biomass or fats and oils.

SAF has lower CO_2 emissions across its lifespan than conventional jet fuel because the emissions produced when the fuel is burned in a combustion engine are offset by the CO_2 absorbed by plants during the growth of biomass. Although there are emissions from producing SAF, depending on feedstock and production, CO_2 emissions can be up to 94 per cent lower overall using this alternative fuel source. However, there is a range of challenges involved in scaling SAF production.

The cost to stand up each new production facility is prohibitively high and SAF is currently two to five times more expensive than jet fuel. Worldwide production needs to scale and requires a greater diversity of feedstock to meet future demand.

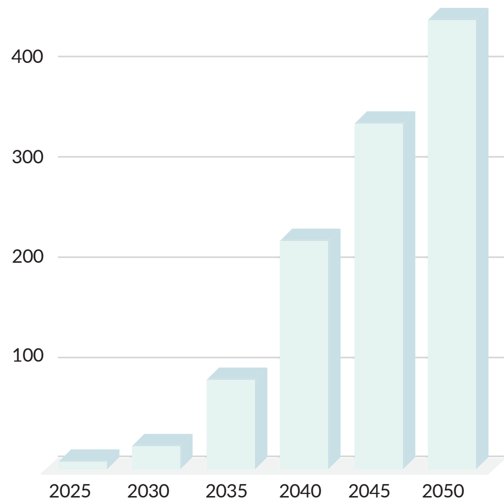
"There is a limit to how much can be produced from used cooking oil and tallow, so more research is needed into sustainable oil crops," said Heidi Hauf, Chair of GreenSkies and former Asia-Pacific Sustainability Lead at Boeing.

While each production pathway needs to be certified under the International Fuel Standard, it opens up more avenues for feedstock options, and this is where Australia is looking to join the global efforts to ramp up SAF production.

New pathways allow regionally specific feedstocks to be converted to SAF, which would benefit Australian production as it can account for our unique conditions, according to Hauf.

"International alignment on sustainability standards is important, but Australian conditions need consideration due to our different farming practises," she said. "We have had to work on our water consumption more than other parts of the world so

Expected SAF required for net zero 2050 goals, in billions of litres



Source: International Air Travel Association net zero roadmap

BELOW:
A Virgin Atlantic jet refuelling with SAF

IMAGE: Virgin Atlantic

ABOVE: Andrew Moore and Siobhan Lyndon, AMSL Aero

we often have crops that are much lower in water usage."

Australia also needs to consider the available bioresources, and weigh up the potential of synthetic fuels and how these resources are allocated to other industries. Bioresources are used to create renewable energy, but there are alternatives to make renewable energy, and we don't have alternatives to make renewable liquid fuels, Hauf noted.

"We can't meet all our jet fuel needs this way, but feedstocks should be prioritised for highest-need applications such as liquid fuels over uses like energy generation," she said.

The bigger challenge might be the scale of current jet fuel appetites. SAF consumption rose from approximately 19 million L in 2021 to 93 million L in 2023, according to the Environmental Protection Agency.

To reach net zero by 2050, the IATA estimates the aviation industry would need 449 billion L of SAF – meaning production needs to scale more than 4800-fold within 25 years.

A report earlier this year from the UK's Royal Society estimated that fuelling all UK-based airliners with SAF derived from locally grown rapeseed, for example, would require more than two-thirds of the country's agricultural land to be converted into feedstock production.

> "There is a limit to how much can be produced from used cooking oil and tallow, so more research is needed into sustainable oil crops."

Battery-electric

Battery-electric aircraft are operating today thanks to advancements in battery technology and electric propulsion, making them viable for short flights. There are fixed-wing planes and eVTOL aircraft, which are suited to flights within and between cities because they can operate in confined spaces such as rooftops or dedicated vertiports.

But there are significant challenges, with energy density and weight limitations for long-haul passenger aviation because a suitable battery to power aircraft across those distances would be prohibitively heavy. Battery technology enabling high-energy density and fast recharging suitable for long flights is still some way off.

"Incremental improvements are needed to balance energy density, fast-recharging capability and lifespan," said Andrew Moore, co-founder and Chief Engineering Officer of AMSL Aero, an Australian company pioneering hydrogen-powered electric aircraft.

ABOVE: Damian Ogden, Engineers Australia; Heidi Hauf, GreenSkies

There's also the problem of preventing issues such as dendrite growth that degrade battery performance over time, and of optimising for aviation needs.

"A battery must combine high-energy density with high-power density to meet the power demands of take-off while also providing sufficient energy for long flights," Moore said.

Hydrogen-powered

From the Wright brothers onwards, aviation has faced the challenge of delivering maximum energy from the least weight. To this end, hydrogen's energy-per-unit mass – three times higher than traditional jet fuel – makes it an attractive alternative for decarbonising long-haul aviation.

It can be combusted through modified gas-turbine engines or converted into electrical power to complement the gas turbine via fuel cells. The two approaches can also be combined. >

"We can't underestimate the importance of innovation in aircraft design."

To be usable, the hydrogen must be compressed and stored in suitable high-pressure vessels, with compatible refuelling trucks handling the high-pressure refuelling of the aircraft.

"With gas hydrogen, it can be compressed to a high volume, however the mass of the tanks is very high and requires aircraft to be redesigned as it's much harder to retrofit existing aircraft," Moore said.

By contrast, liquid hydrogen has less volume and is lighter because it's stored at lower pressures, but it requires very low temperatures and isn't in abundance locally.

"In Australia, access to liquid hydrogen is one of the biggest challenges as there are only two hydrogen production plants in the country."

Hydrogen fuel cells offer a viable technology for medium-range aircraft applications up to around 2000-3000 km in the near term. Progress has been made clearing some of the hurdles in bringing them to reality.

"There are still challenges with cryogenic storage of liquid hydrogen on aircraft and integration with fuel cells, but these issues are close to being solved," Moore said.

As well as AMSL Aero, there are several local groups working on hydrogen-powered aircraft, such as Aviation H2, and Stralis Aircraft in partnership with the Queensland University of Technology and iMOVE CRC.

Watching the skies

The reality is that there will be no single solution for abating emissions from long-haul flights.

Instead, progress will come not just from breakthroughs and advances in engineering fields as diverse as aeronautical, chemical, electrical and agricultural, but from the ability of these fields to work together to craft new systems for long-haul aviation. □

BELOW: The AMSL Aero Vertiia (render)

AROUND THE WORLD

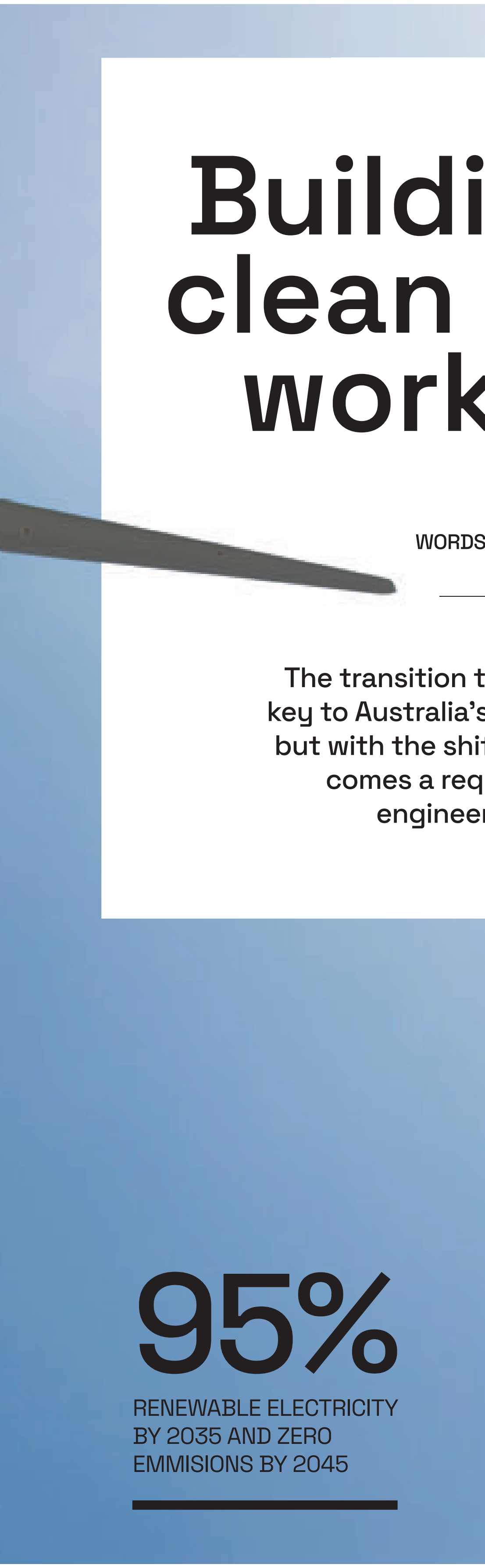
European giant Airbus is exploring hydrogen combustion (H2C). It has developed a system that takes the hydrogen, which must be stored at -253°C, and "conditions" it to reach both a suitable temperature and the right pressure for combustion.

It's also working on hydrogen (H2) fuel cells that run at full power of 1.2 MW, to create a power "chain" that couples 12 fuel cells, which is what is needed to reach suitable output for commercial flight.

Rolls-Royce is working on hydrogen-burning gas turbine engines for short-range flights and collaborating with EasyJet on a hydrogen combustion engine, compressing hydrogen from 20 bar to 200 bar to maximise capacity.

Startup ZeroAvia is developing hydrogen-electric powertrains, tackling the powertrain weight challenge and higher volume fuel tanks for aircraft.

H2FLY is working on hydrogen storage and fuel cell power systems for a range of aircraft, alongside safe and reliable high-flow liquid hydrogen (LH2) for aircraft ground operations at airports and, eventually, large commercial aircraft.



Building the clean energy workforce

WORDS BY ELLE HARDY

The transition to renewable energy is key to Australia's decarbonised future – but with the shift to renewable energy comes a requirement for a new engineering workforce.

95%

RENEWABLE ELECTRICITY BY 2035 AND ZERO EMMISIONS BY 2045

Australia is in the middle of a global race for the capital, resources, materials, equipment and workforce needed to build a new energy system. Being reliant on skilled migrant engineers to fill the skills gap might have worked in the past, but it won't be enough to help Australia meet ambitious decarbonisation targets.

"More than half of Australia's electrical engineering workforce is born overseas and we currently have one of the lowest rates of engineers in our graduating cohort of any OECD nation," Kane Thornton, CEO of the Clean Energy Council (CEC), told *create*.

"It is imperative that we increase our domestic engineering capacity because of increased global competition for the future clean energy workforce."

Australia needs almost two million workers in engineering, building and energy trades between now and 2050. Analysis by Engineers Australia has also found that 70 per cent of the engineers added to Australia's labour force between 2016 and 2021 were born overseas. Despite a national increase in university enrolments, enrolment rates in engineering degrees have fallen since 2015, contributing to an estimated shortfall of 12,500 engineers in a population of 224,500 required by 2026 – that's a little over five per cent.

Victoria's State Electricity Commission (SEC) is already grappling with this issue. The state aims to achieve 95 per cent renewable electricity by 2035 and net zero emissions by 2045. The workforce implications of these targets are significant, with interim CEO of SEC Victoria, Chris Miller, telling *create* that the commission estimates that 59,000 jobs will be created by 2035 to deliver on Victoria's transition targets.

Having the appropriately qualified professionals in those roles is a more complex issue. Given that an 18-year-old entering university today will be a recent graduate in 2030, it is clear that a broad strategic plan is required to build the necessary workforce.

"We need to develop new models for training and upskilling new and existing workers," Miller said. "This includes flexible training offerings to specialise and build on base qualifications, like engineering, and to support mid-career transition, such as through recognised micro-credentials.

"Our investment portfolio is a major lever to create job opportunities, get industry involved in addressing workforce challenges, raise standards and make the workforce more inclusive." >

Industry is also looking at innovative training models, Miller said, such as an electrical dual qualification which combines an electrotechnology apprenticeship with a Bachelor of Electrical Engineering – a development led by the AI Group partnering with industry and the Victorian government.

"Earn-and-learn models can also provide an effective way to combine structured on-the-job training, mentoring and supervision with degree-level study for engineers," Miller said.

Turning targets into action

Thornton pointed to the Federal Budget released in May 2024 as being a landmark commitment to education.

"[We saw] several commitments aimed at unlocking tens of thousands of clean energy jobs, including $91 million over five years to fund relevant education and training programs," Miller said.

But attracting students to these industries is not as easy as just investing in education programs; it requires building awareness. This is where the Careers for Net Zero program comes in. A joint initiative between the CEC and the Energy Efficiency Council (EEC), it aims to highlight the diverse and exciting opportunities available in the clean economy, no matter their skillset or passions, Thornton said.

The SEC has found that it can be difficult to attract STEM workers to renewables compared with more established sectors, largely due to uncertainty about the job and investment pipeline on long-term career prospects. Demand peaks and the stop-start nature of projects also present labour supply issues, especially as multiple large-scale projects are delivered along similar timeframes.

"Additionally, demand for essential roles – like hydropower technicians, grid engineers and blade technicians – hasn't yet reached a critical mass, which means it's not yet economically viable for training providers to offer such niche courses," Miller said.

ABOVE:
Chris Miller, SEC Victoria; Kane Thornton, Clean Energy Council

Engaging with industry, government and the education sectors, the SEC is aiming to complement the existing work being done and streamline entry pathways.

"Firstly, we'll be engaging students to boost the profile of renewable careers," Miller said, adding that this includes improving visibility of courses and pathways into the sector and encouraging girls and other diverse student groups to participate.

"We'll also be expanding earn-and-learn pathways."

Building on established apprenticeship networks and training organisations, the SEC plans to "deliver bespoke programs for the renewable energy sector, including tailored programs that support women to enter the industry". Finally, the Centre of Training Excellence will collaborate with industry to deliver industry-led training.

"The SEC can help bring industry to the table and get better alignment on skills needs, and work with the training sector to help bridge gaps in industry-specific training," Miller said.

Building the talent pipeline

A 2022 Engineers Australia white paper on strengthening the engineering workforce sounded a number of alarms about strengthening and building the required talent pipeline in Australia. In addition to attracting young students to the profession, improving engineering study completion rates is critical.

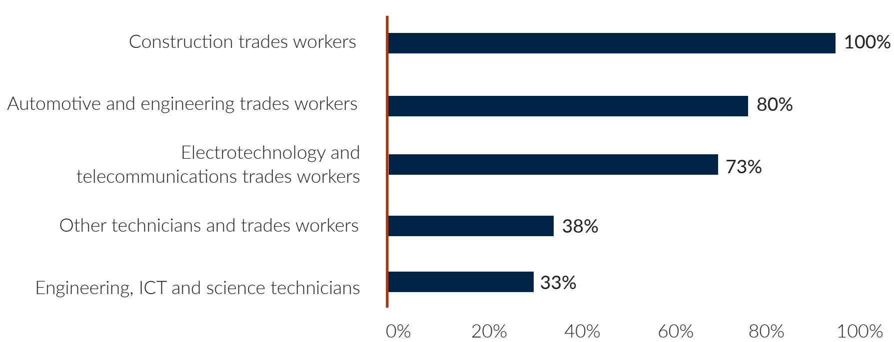
Around 25 per cent of four-year engineering qualification students complete their degree in the minimum time, and only half of all engineering students graduate with an engineering degree. Added to that, only 60 per cent of qualified engineers in Australia work in an engineering role.

Engineers Australia is currently conducting further research into transferable skills.

Top engineering-related occupations in national shortage

Occupation ANZSCO 4-digit description	Years in shortage 2021-23	Total employed 2021 census
Electricians (general)	3	128,300
Motor mechanic (general)	3	79,300
Fitter (general)	3	68,500
Construction and project manager	3	64,900
Software engineer	3	54,300
Project builder	3	47,800

Proportion of occupations in shortage, by Technicians and Trades Workers occupation sub-group



Engineers Australia Acting Chief Engineer Bernadette Foley FIEAust CPEng EngExec said that the construction and operation phases of the energy transition each present their own challenges.

"The regional and dispersed nature of the workforce is going to be one of the challenges alongside the geographical spread," she said.

National coordination is important, she added, because individual approaches from different states won't work without it.

"Many other countries have similar targets, which means that we're competing with them for talent," Foley said. "Therefore, we need to have a global perspective."

With the UK and US producing relatively low levels of engineers compared to other OECD countries, "skilled migration is important, but we also need to consider brain drain as engineers are lured overseas".

One advantage of engineering is that it has transferable skill sets.

"The technical similarities between fossil fuel and renewable engineering means that the transition may not be as difficult as it sounds, so the upskilling and reskilling of people willing to move sectors becomes very important."

Engineers Australia has been advocating for government funding for placements and program development, such as for more support for conversion master's programs to help reskill workers.

"Say there's someone who has a three-year bachelor's degree in science wants to do a master to specialise in renewable energy," Foley said. "The funding model for universities sees undergraduate programs largely funded through supported places, but few masters are supported from a Commonwealth perspective – and this places the burden of cost on the individual.

"We need to effectively demonstrate that renewable energy is a viable and ongoing career path, and that support will be provided to new and transitioning engineers to the sector." □

60%

ONLY 3 IN 5 AUSTRALIAN ENGINEERING GRADUATES ACTUALLY WORK IN AN ENGINEERING ROLE

ABOVE: Blair Linden, Alinta Energy

BELOW: Bernadette Foley, Engineers Australia

PROFILE

Blair Linden *Project Development Manager, Alinta Energy*

A gasworker's move to renewables

In 2021, I was working as a subsea engineer on an offshore gas project for Woodside. While exercising on the helideck of an offshore construction vessel, I listened to an interview with Alinta Energy CEO Jeff Dimery on the *Energy Insiders* podcast. He described the company's ambition to develop offshore wind projects in Australia to contribute to its decarbonisation goals.

I found Dimery's honesty and bold ambition refreshing, and I joined Alinta Energy as the company's first recruit with offshore expertise.

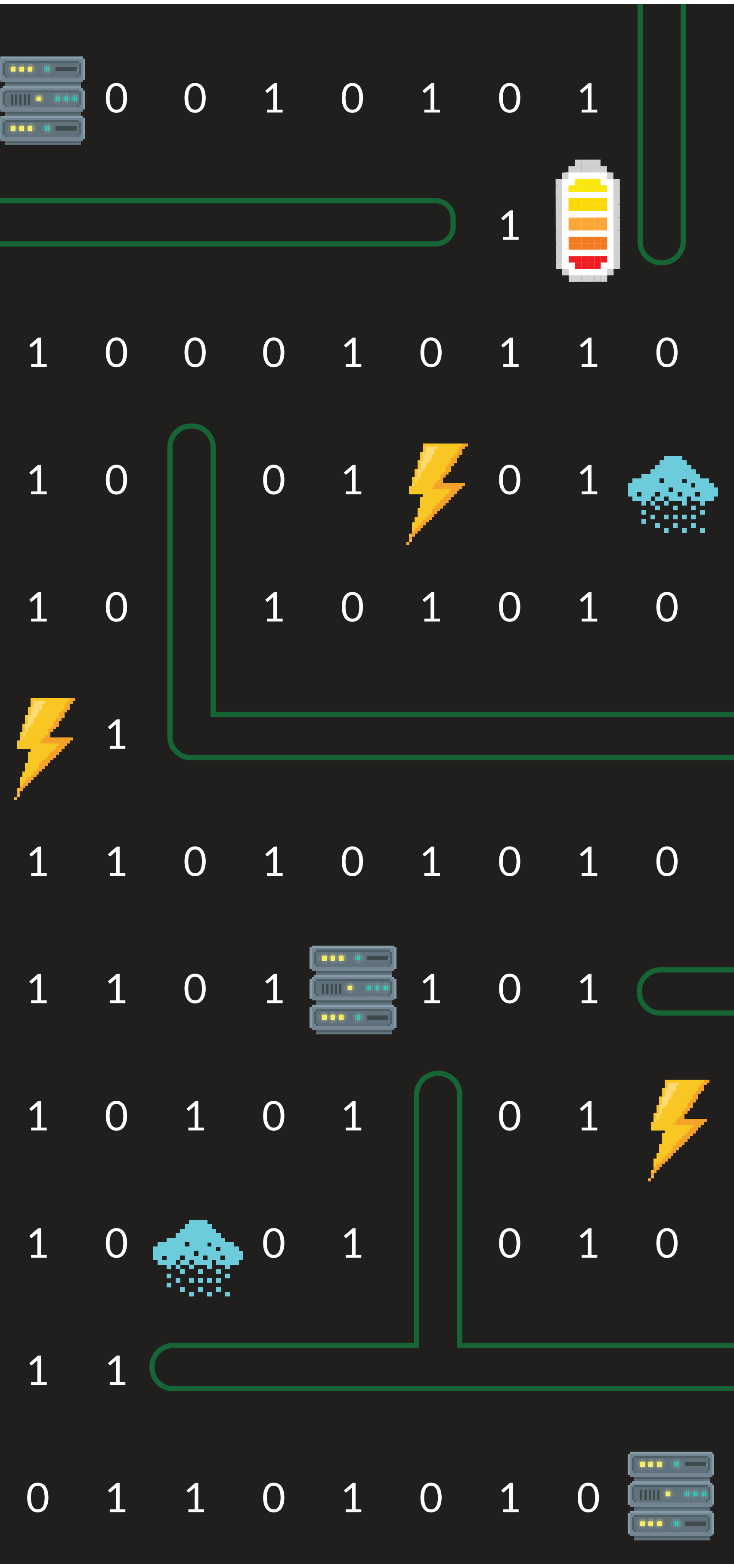
Many of the engineering fundamentals are common between offshore oil and gas and offshore renewables, such as the design of offshore structures, offshore geotechnical investigation and foundation design, metocean conditions and hydrodynamics, heavy lift engineering and remote operations. However, there were a few key gaps for me, including wind energy analysis and power systems engineering. I improved my knowledge in these areas by completing online micro-credentials before starting the new job.

A fundamental difference I have observed is that the offshore wind industry is more competitive and operates on lower rates of return than typical oil and gas projects. This means we need to run lean teams but still maintain the same high standards of safety, quality and reliability. As a result, every team member needs to have a broad knowledge base and manage a diverse range of responsibilities.

Data centres in the age of AI

WORDS BY KEVIN GOMEZ

Data centres are power-hungry, heat-generating beasts and the rise of AI is set to make them hungrier and hotter than ever. So how are engineers working to keep future energy demands in check?



Data centres have an outstanding history of efficiency gains. In the 10 years between 2010 and 2020, for example, internet traffic leapt 17-fold, and data-centre workloads soared 10-fold. And data centre energy use? It stayed flat.

But the industry's ability to keep energy demands in check will be intensely challenged by the rapid growth in complexity and use of the new generation of AI models. Already, the energy needed to train new large-language models is estimated to be doubling every 10 months.

Chips such as NVIDIA's H100 GPUs are the workhorses of training current AI models, and they are incredibly hungry. They have a peak power consumption of 700 W, using more energy than many Australian households and generating prodigious amounts of waste heat.

By the end of this year, more than 3.5 million of NVIDIA's H100s alone will be deployed, using more energy than entire nations like Georgia and Costa Rica for computation alone, not to mention cooling.

On top of that, the integration of AI tools in ever more digital interactions is pushing data centre workloads significantly higher. For instance, an AI-assisted Google search is estimated to consume 10 times the energy of >

AI CURRENTLY REPRESENTS

4.5GW

OF GLOBAL POWER CONSUMPTION

a standard search. Clearly, meeting the energy demands of the AI future requires major engineering achievements. With cooling accounting for an average of 40 per cent of a data centre's energy consumption, major advances are needed.

The power crunch

AI currently represents 4.5 GW of global power consumption and, according to Schneider Electric, this is set to grow annually by 25 to 33 per cent. Schneider predicts total consumption to reach between 14 GW and 18.7 GW by 2028. This growth is three times that of overall data centre power demand.

"AI applications have a higher load per rack, so we're trying to get the same amount of power into a smaller footprint," said Stefan Sadokierski, Principal at Arup, which is constructing data centres across the world. "With cloud computing, we're fairly close to the limit. To go much further, you need a different way of cooling the IT equipment within the space. And there's really two ways; one is direct to chip and the other is immersion cooling, where the equipment is all immersed in a bath of dielectric non-conductive fluid."

Variations in load are another issue. "Most current data centres have a fairly constant load but with AI, they have very big loads turning on and off very quickly," Sadokierski said.

These step changes can affect the equipment and the grid.

ABOVE: Equinix LD7 Data Center in Slough England. Image: Epaillard + Machado; design by Arup

RIGHT: NEXTDC S1 in Sydney. Image: Greenbox and Fretwell Photography; design by Arup

"With cloud computing, we're fairly close to the limit. To go much further, you need a different way of cooling the IT equipment within the space."

ABOVE: Stefan Sadokierski, Arup

Cooling solutions

Given this power consumption, the pressure is on data centres to boost their green credentials.

"There is a tendency to jump straight to offsetting carbon and importing green electricity and not looking for the opportunities on the ground," Sadokierski said. "There are foreseeable changes in the data centre industry, such as increasing load density and the transition to liquid cooling. We need to, at some point, get away from fossil fuels, stop using diesel for standby generators, and look for an alternative."

While engineers work out ways to deal with the heat, this could also present an opportunity. John Vollugi CPEng, Director at ADP Consulting, is working on a large 300 MW data centre in NSW. At this size, the data centre generates a fair amount of waste heat.

"It's a bit depressing to think of all that wasted energy, especially when it is not far from residential areas," Vollugi said. "That prompted us to learn more about emerging technology and we assisted two

ABOVE: Swiss National Supercomputing Centre. Design by Arup

IMAGE: CSCS

pioneers, Submer and ResetData, in a pilot project in Sydney in the basement of the 151 Clarence Street commercial tower.

"We've got immersion pods down there that feed into the building's condenser water loop, We look forward to reviewing this data as the year goes on, as this should improve the National Australian Built Environment Rating System (NABERS) energy rating as the waste heat from the immersion racks pre-heats the hot water system in the building. So there's a reciprocal relationship here."

Australian-owned ResetData is an Infrastructure-as-a-Service provider that has pioneered a cooling system that not only reduces carbon footprints by 45 per cent but also eliminates water waste entirely. In Submer's system, servers or other IT components are submerged in a thermally conductive dielectric liquid or coolant. The coolant always remains in a liquid form and gets pumped to a heat exchanger where heat is transferred to a cooler water circuit.

Vollugi and his team have published a white paper, entitled *Think … Liquid Cities*, where he proposes that data centres be connected by a network of underground pipes that transport heated water across the city.

"Imagine pools and surf parks, office end-of-trip facilities and manufacturing plants all sourcing low-cost, zero-emissions heating >

ABOVE: John Vollugi, ADP Consulting

How data centres keep cool

Immersion cooling

Hardware sits in a tub of non-conductive, non-flammable dielectric liquid. Dielectric fluid absorbs heat more efficiently than air.

Direct-to-chip cooling

Pipes deliver liquid coolant directly into a cold plate which sits atop a motherboard's chips to draw off heat.

Free cooling

In regions with cold climates, facilities vent hot air and then draw cool outside air into the facility. China Telecom has built a hyperscale data centre in a Mongolian region with an average temperature of 0.2°C.

Hot and cold aisles

Cabinets and racks are arranged in a line format, with each rack facing the opposing direction. This layout causes the cold and hot air vents to turn towards each other, creating alternate aisles of hot and cold air.

BY THE NUMBERS

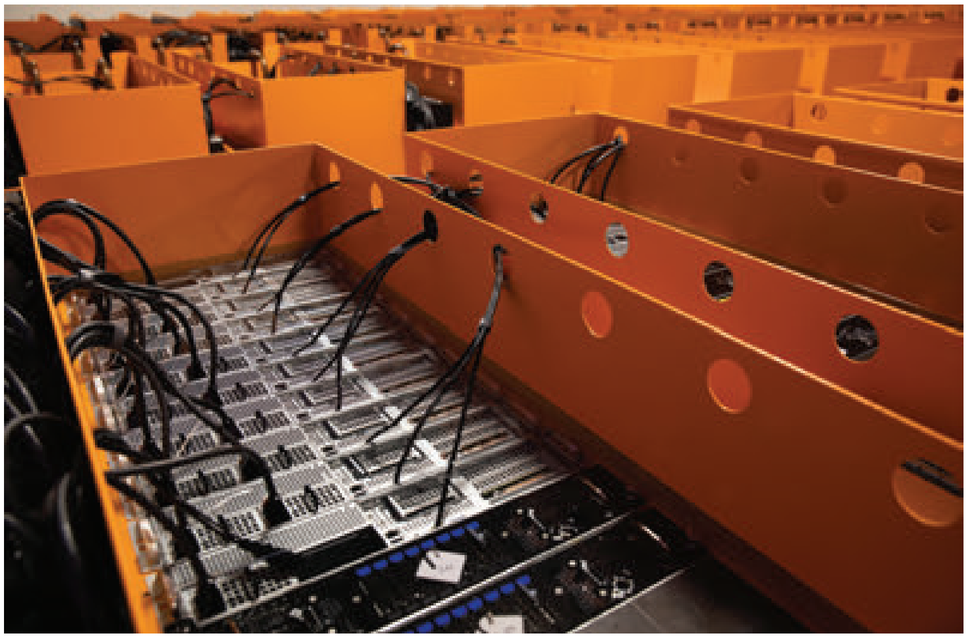
AI'S POWER CONSUMPTION WILL RISE FROM

8%

TOTAL DATA CENTRE POWER IN 2023 TO

15-20%

TOTAL DATA CENTRE POWER IN 2028



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and water," Vollugi said. He believes it's possible to turn today's high-energy consumer data centres into truly circular energy sources.

Australia as a data centre hub

According to Brisbane's Cloudscene, Australia had 306 data centres at the start of 2024, with Sydney home to the most intensive concentration of facilities. Numbers are growing rapidly too, with Microsoft alone investing $5 billion in hyperscale data centres in Australia in the next two years.

Environmental concerns are shaping the next generation of data centres. GreenSquareDC has positioned its WAi1, currently under construction in Perth, as the country's greenest data centre. WAi1 will source energy from 100 per cent renewable sources and run its backup generators on hydrotreated vegetable oil. It will also be water-positive by using aquifer-free cooling.

Mark Lommers FIEAust CPEng, Managing Director at Nequinn Consulting, is something of a pioneer in this area, having been granted a patent in 2018 for his innovative liquid cooling system for computers.

ABOVE: One of the world's fastest supercomputers is about half the size of a football stadium and situated on an eight-hectare site in Katy, Texas. Designed and built by Perth-based DUG Technology.

RIGHT: Cooling towers and infrastructure behind the data centre keep the supercomputer's temperature cool.

ABOVE: Mark Lommers, Nequinn Consulting

"My claim to fame was an immersion cooling system that I designed and is now rolled out to data centres around the world," Lommers said.

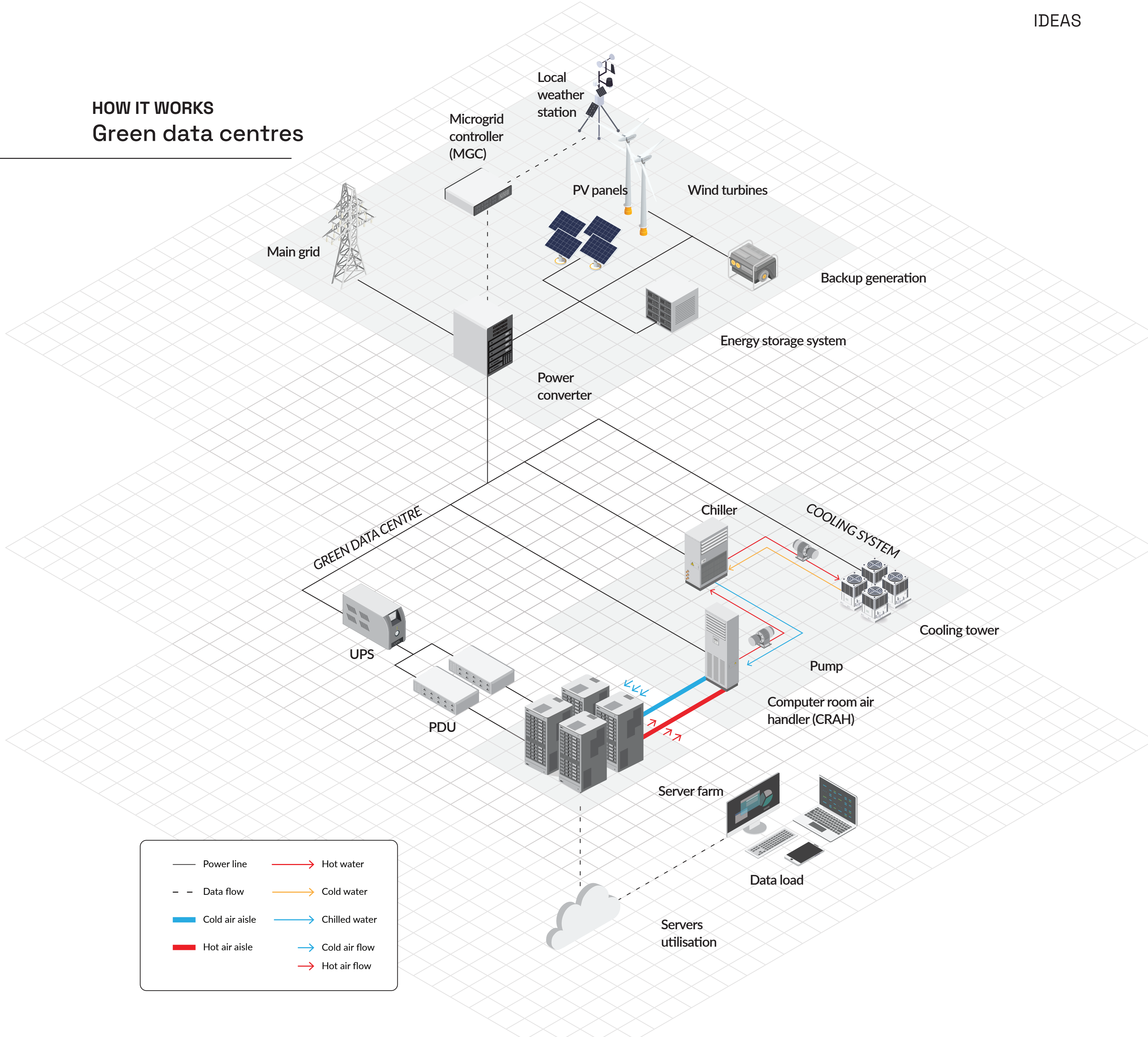
In 2019, he won *DCD Magazine*'s Enterprise Data Centre Design Award. Designed in-house, the DUG 15 MW High Performance Cluster is entirely cooled by complete liquid immersion and is used for seismic processing.

"WAi1 does not have any legacy constraints and has been built with this 'green' philosophy from the ground up," Lommers said. "The lowest common denominator of an air-cooled system determines all the systems that go into a data centre.

"WAi1 is designed for subsets of equipment, so 20 to 30 per cent is designed for air cooling and 70 to 80 per cent is designed for direct cooling methods."

IMAGES: Epaillard + Machado; Greenbox and Fretwell Photography

HOW IT WORKS
Green data centres



Using your footprint effectively

As the national subject matter expert for three Ph power systems at Schneider Electric, Jason Deane has been involved with data centre design, particularly in uninterruptible power supply (UPS) design.

In terms of heat management, he sees it as a race between direct-to-chip and immersion cooling, and is betting on the former winning in the short term.

"When I was a teenager, people were overclocking their PCs for gaming and developing bespoke heat exchangers for the CPUs in computers," Deane said. "So, the concept is not new. But I think direct-to-chip will take off because it's probably a lower-cost implementation. In a data centre every square metre might be worth about $90,000. If you've got to build immersion bathtubs you can't make use of the traditional 48RU >

ABOVE: Jason Deane, Schneider Electric

"Imagine swimming pools and surf parks, office end-of-trip facilities and manufacturing plants all sourcing low-cost, zero-emissions heating and water."

[rack unit] height. You can only have them half that high – like 24RU – and you're already losing half your IT footprint."

Deane also sees benefit in the Chilldyne negative pressure technology; Schneider Electric has a new partnership with the company. The Chilldyne solution creates a vacuum to pull water through the cooling ecosystem.

"The system won't leak even if the hose is cut since both sides will be negative with respect to normal atmospheric pressure and will suck up the liquid," Deane said.

Vollugi noted that Meta is gradually shifting to a water-cooled AI infrastructure while Microsoft is investigating liquid immersion for high-performance computing applications such as AI, showing that liquid cooling is increasingly seen as a viable solution.

Bespoke solutions

Donna Bridgman, FEng, Chartered Engineer, Global Board member of iMWomen (Infrastructure Masons

THE POWER DEMAND BY DATA CENTRES WILL BOOST TOTAL DEMAND TO

4250 MW

BY 2028 – 212 TIMES MORE THAN THE CONSUMPTION ORIGINALLY FORECAST

ABOVE: Met Office Exeter Data Centre. Design by Arup

ABOVE: Donna Bridgman, iMWomen

Women) and Trainer at DCD Academy in the EMEA and APAC regions, sees a heightened consideration around designing more bespoke solutions to suit the technology available.

The adoption of modularised solutions to accelerate speed to market, and better match end customer and client equipment technical requirements, as well as to optimise capex financing and deployment are becoming much more business-as-usual.

"Smart companies are adopting modular designs that are pre-manufactured to suit a variety of technology and engineering specifications," Bridgman said. "These can be leveraged at speed and scale with precision quality control, and optimised for price at the onset, with supplier agreements and long-term manufacturing slots secured to also provide a competitive edge."

Hardware shortage

Currently though, energy and cooling demands might not be the main limiting factor to the growth of AI – it might be a shortage of GPU chips. There is a "huge sucking sound" coming from businesses representing the unrivalled demand for AI, Raj Joshi told CNN recently. Joshi is a Senior Vice President at Moody's Investors Service and tracks the chips industry.

"Nobody could've modelled how fast or how much this demand is going to increase," he said. "I don't think the industry was ready for this kind of surge in demand." □

IMAGE: Michael Whitestone Photography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Projects

No laughing matter

WORDS BY PETRA STOCK

New technology installed at Orica's Kooragang Island facility in Newcastle has nearly halved the site's greenhouse gas emissions, far exceeding expectations.

In an Australian first, tertiary abatement technology installed in June 2023 has been reducing nitrous oxide emissions from Kooragang Island's three nitric acid plants – used in the production of ammonium nitrate – by at least 95 per cent.

"When we make nitric acid, one of the by-products is nitrous oxide (N_2O), or laughing gas," Paul Hastie, Orica's Sustainability and Development General Manager, told *create*. "It's a serious greenhouse gas pollutant.

"This project aimed to put a catalyst on the exhaust pipe of all three nitric acid plants to break down that nitrous oxide into nitrogen and water."

The technology, called EnviNOx, was developed by industrial company thyssenkrupp Uhde. It consists of large reactor vessels – giant cylinders measuring up to 14 m tall and 3.6 m wide, containing an iron zeolite catalyst – able to be retrofitted onto nitric acid plants.

Ammonium nitrate reactions

Orica manufactures a range of products at Kooragang Island, primarily ammonium nitrate (NH_4NO_3).

The site operates 24 hours a day, seven days a week, producing about 400,000 t of ammonium nitrate a year. Most is sent to mining operations in the nearby Hunter Valley, where the compound is used to make explosives for breaking up overburden.

Producing ammonium nitrate requires a complex set of chemical reactions. The 24 ha facility includes an ammonia plant, three nitric acid plants, two ammonium nitrate plants and a dispatch area.

Natural gas (methane, piped from Sydney to Newcastle) is first used to generate ammonia (NH_3). That ammonia becomes an input for producing nitric acid (HNO_3), which is later reacted with ammonia, producing ammonium nitrate.

Dr Gabriel da Silva, Associate Professor of chemical engineering at the University of Melbourne, told *create* that Australia is an extensive producer – and user – of ammonium nitrate.

"A lot of that is because of its use in agriculture as a fertiliser, and also as a mining explosive," he said.

"The ammonium nitrate process inherently deals with a number of gases that are potentially harmful to the environment, so there is an imperative to control those, both for human health and the climate."

Serious concern

Inside the nitric acid plants, vapourised ammonia is mixed with air in the presence of a catalyst, which generates NOx gases at temperatures of 800-900°C. These gases are then absorbed into water to produce nitric acid, with nitrous oxide as a byproduct.

ABOVE: The Kooragang Island facility. Image: thyssenkrupp Uhde and Orica

"When you do nothing, the N_2O gas is emitted into the atmosphere," chemical engineer Jarrad Bird, Orica's Production Superintendent at the Kooragang Island facility, said.

Belying its nickname "laughing gas", nitrous oxide is a serious concern when it comes to climate change. >

BY THE NUMBERS

1 kg

OF N_2O IS EQUAL TO

273 kg

OF CO_2E

500,000 t

OF CO_2E ABATED EQUALS

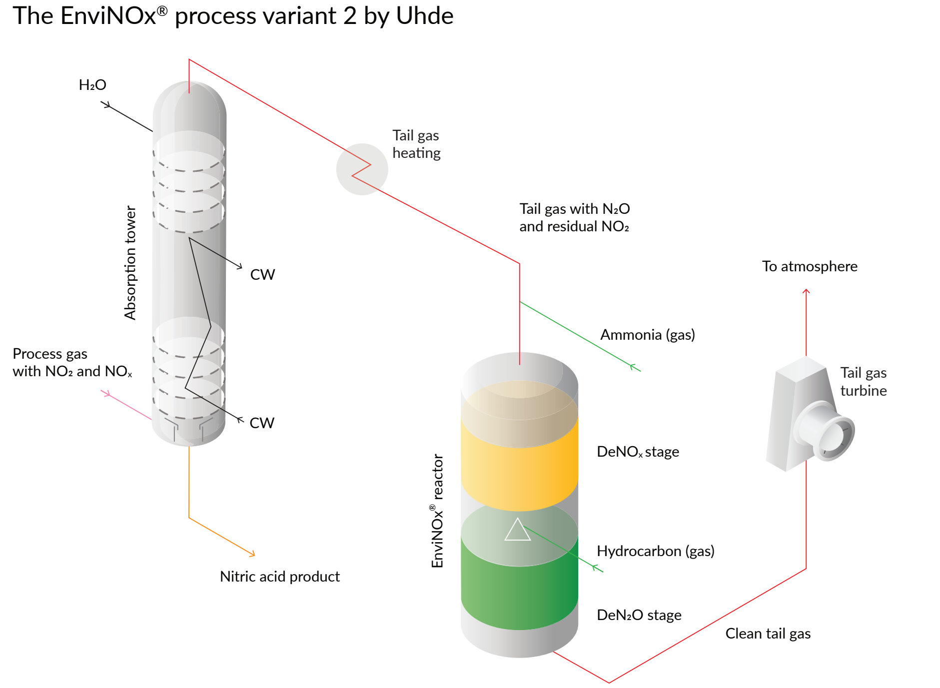
11%

OF AUSTRALIA'S CHEMICAL INDUSTRY PROCESS EMISSIONS

48%

OF THE SITE'S OVERALL EMISSIONS ABATED

HOW IT WORKS



ABOVE: The EnviN0x process by Uhde.

The colourless and odourless gas, commonly used as pain relief in medical procedures and childbirth, proves potent and long-lived when released into the atmosphere.

According to the CSIRO, N_2O has a global warming potential 273 times that of carbon dioxide over a 100-year timescale (though Australia's greenhouse reporting scheme applies a global warming potential of 265). The gas is the third largest emissions source after carbon dioxide and methane.

Concentrations of N_2O in the atmosphere are now the highest in 800,000 years, a situation unequivocally the result of human activities, according to the IPCC.

Da Silva said these factors make removing N_2O "low-hanging fruit" for companies looking to reduce their greenhouse gas emissions.

"For every kilogram of nitrous oxide you remove, that's the equivalent of almost 300 kg of CO_2," he said.

While nitrogen fertilisers used in agriculture are the main global source, industry also contributes about 14 per cent of human-caused emissions, according to the Global Carbon Project.

Abatement technology

From design to operation, Bird was involved in all aspects of installing the tertiary abatement technology.

Over the previous decade, Orica had trialled approaches to reduce nitrous oxide emissions. None came close to the effectiveness of EnviNOx, where nitrous oxide emissions are removed from the tail gas after the absorption stage. Bird said that each of the three new reactor vessels – one for each nitric acid plant – are filled with catalyst in a pelletised form.

"It's arranged in a way that the flow path through the reactor is quite tortuous so that you're encouraging mixing and contact with as much gas and catalyst as possible," he said.

"The tail gas comes in the top. We add ammonia, which reacts with the catalyst to reduce any residual NOx gases. We also add methane, which reacts with the N_2O."

While the system is extremely effective at removing nitrous oxide, Bird said an "added bonus" is the removal of residual NOx gases, a known air pollutant.

"It's not something that we could do with our previous technology, where we still had a small amount of NOx gases … this technology has enabled us to reduce that to zero."

Da Silva said that processes that work on multiple air pollutants – if implemented and operated correctly – can have the benefit of improving local air quality at the same time as reducing greenhouse gas emissions.

Learning through doing

Years of careful planning, data collection and technical design preceded the onsite installation, which began in October 2022 and was completed in June 2023.

"It was a brownfield installation, so we had to retrofit new pipework and control logic, and design all our safety trip systems," Bird said.

The new technology had to be integrated into every aspect of the plant's operation, from training procedures to asset maintenance.

Each nitric acid plant was done sequentially, with the added challenge of installing the plant, with minimal disruption, at a facility that operates around the clock.

"For the first plant, we built the whole analyser room and frame," Hastie said. "We built it adjacent to where it was going to be put in. So as soon as we shut down, we took out a vessel and lifted the prefabricated room into place. That saved a huge amount of time."

While Kooragang Island marked the first use of tertiary abatement technology in Australia, for Orica it was the second time globally. The team benefited from previous experience at a site in Canada.

"I was fortunate enough to go over to our Canadian site," Bird said. "I identified areas they found challenging. We had to dot our Is and cross our Ts when commissioning analysers, as it was completely new technology for us."

LEFT: One of the three EnviNOx reactors at Kooragang Island.

He added it was also crucial to leverage the knowledge and support of the thyssenkrupp Uhde engineers.

Orica is so pleased with the results in Newcastle that plans for installing the same technology at Orica's Gladstone site are already underway. And everything learned through the experience at Kooragang Island will be applied to assist the next installation.

Meredith Read, Orica's Acting Head Sustainability, said the company completed a net-zero study to identify further decarbonisation opportunities.

Four pathways were identified: renewable hydrogen; feed and fuel switching to biomethane; carbon capture and utilisation/storage; and alternative methods for producing ammonia.

Support included $25 million from the Clean Energy Finance Corporation in the form of debt finance and $13.06 million from the NSW Government Net Zero Industry and Innovation Program.

For the CEFC, this was the green bank's first major direct investment into the manufacturing sector. CEFC Head of Wind Joe Harber said the potency of nitrous oxide together with the immediate effectiveness of the technology made it a high-impact investment.

"It was an incredibly large abatement project," Harber said. "[It was] one we were keen to make sure happened, because for a relatively modest amount of upfront capital, you had a sustained impact and high abatement level."

The savings from the technology are already enormous, approximately equivalent to 11 per cent of Australia's chemical industry process emissions.

Read said given nitrous oxide emissions from producing nitric acid make up 51 per cent of Orica's direct emissions (scope 1) globally, secondary and tertiary abatement technology will be "a key lever in Orica's decarbonisation pathway and ambition to achieve net zero emissions by 2050".

For those involved, the benefits extend beyond just numbers.

Hastie said it has changed how the site and industry are perceived within the organisation and the wider community.

"We're really proud that Orica was a leader in this, especially in Australia, that we're not waiting for others to do it." □

ABOVE: Newcastle Lord Mayor Nuatali Nelmes, Minister for Climate Change, Energy, Environment and Heritage Penny Sharpe, Orica President AusPac and Sustainability German Morales and Newcastle Deputy Lord Mayor Declan Clausen

"We're really proud that Orica was a leader in this, especially in Australia, that we're not waiting for others to do it."

Electricity megastorage

WORDS BY LARISSA FOSTER

Built on the site of a decommissioned coal-fired power station, this modular big battery is the first stage in decarbonising Western Australia's electricity grid.

RIGHT:
Kwinana Battery Energy Storage System 1 (KBESS1)

It's unsurprising that residents in Australia's sunniest state have enthusiastically adopted rooftop solar. An average of almost nine hours of sunshine a day in Perth explains why more than 460,000 Western Australian households – or around 30 per cent of homes – had installed solar units as of last year.

Their combined output adds up to the largest power station on the South West Interconnected System (SWIS) grid, the state's main electricity network which has more than 1.1 million customers and serves most of the state's population.

Commissioned in September 2023, the Kwinana Battery Energy Storage System Stage 1 – more commonly known as KBESS1 – represents an important step for the WA government's decarbonisation efforts as the electricity system moves from fossil fuels to renewable sources.

Developed and delivered by state-owned electricity provider Synergy, with funding provided by the state and federal governments, it is the first lithium-ion, large-scale utility battery energy storage system in the SWIS. The 100-200 MWh facility can power up to 160,000 average homes in WA for approximately two hours.

A firming power source

Dominic Watson, Synergy's Renewable Development Lead for the project, said that since the containerised battery became operational it has closely followed the predicted modelling.

"It does one cycle per day, serving the evening peak, and charges by soaking up excess solar in the middle of the day then discharging energy to

"KBESS1 has been built on the bulk fuel oil storage area ... it's a really positive story about a steam-powered site being repurposed into a modern new-age battery storage facility."

BY THE NUMBERS

THE
100-200 MWh
FACILITY CAN POWER UP TO
160,000
WESTERN AUSTRALIAN HOMES

reduce the evening peak," he said. "I have seen sometimes that the battery has performed close to two cycles per day, which means it serves morning and evening peaks."

As a back-up "firming" source of power, large-scale batteries help the grid cope with the uneven household demand for power. While rooftop solar generation provides up to 64 per cent of WA's electricity needs in the middle of the day, the overwhelming uptake of rooftop solar has put pressures on the grid. In the absence of large-scale storage, they force the "spill" of excess power generated during the day for no benefit while adding to maintenance and generation costs.

Helping the grid cope with the massive shift to solar, battery storage is proving its efficacy at stabilising renewable energy sources, which not only helps households but also supports the widescale energy transition of industry.

South Australia in 2017 became home to Australia's (and the globe's) >

first big battery, the Hornsdale Power Reserve, but WA is making up for lost time by fast-tracking its Kwinana project, announced in 2019 in the pressing face of minimum demand constraints.

"Our really strong uptake of rooftop solar in the West depresses midday demand and the most efficient fix for that is energy storage that can soak that up," Watson said.

"That was one of the reasons KBESS1 got off the ground. Coupled with things like Covid causing major supply challenges with the battery and inverter, there were a number of other challenges put in front of the project – but it was a good outcome, all things considered."

Repurposing existing infrastructure

Located at the existing Kwinana Power Station site around 30 km southwest of central Perth, KBESS1's vital statistics include a size that is the equivalent of 14 tennis courts. At 103 m in length, 123 m wide and consisting of a number of discrete, modularised batteries and its own specially-constructed substation, it is "a very small battery considering how much rooftop penetration we had".

One of the most innovative aspects of KBESS1, Watson explained, lies not in the size but in how it has led to the repurposing of the outmoded Kwinana Power Station, a facility that was commissioned in 1970 as a traditional steam turbine site fuelled by coal, gas and oil.

"We retired the last units in 2015, and Synergy has been going through a process of rehabbing the site. KBESS1 has been built on the bulk fuel oil storage area. We've repurposed the network connection assets down there, so it's a positive story about a steam-powered site being repurposed into a modern, new-age battery storage facility."

Small yet significant, KBESS1 represents the vanguard of large-scale battery adoption on WA's road to decarbonisation.

Stage two underway

Construction began on its follow-up, Kwinana Battery Energy Storage System Stage Two (KBESS2), in June last year. On the same site, yet its own separate facility, when completed at the end of this year

"It's going to be a very interesting decade watching these storage assets come in and seeing the WA market transition. It's going to have a profound impact."

BELOW: Kwinana Battery Energy Storage System 2 (KBESS2)

KBESS2 will be state's biggest grid-connected battery, providing 200 MW of power with 800 MWh of energy storage – four times that of KBESS1's ability."

In effect, KBESS2 will be able to power 370,000 average WA homes for approximately four hours. And in another positive example of repurposing, it is being constructed on the former coal stockpile of the Kwinana Power Station.

"They will operate completely independently of each other and can support the market in multiple ways," Watson said.

The operational aspects of KBESS1 and its much-anticipated sibling are particularly pertinent to the WA government's announcement it will retire all state-owned coal-fired power plants by 2030, a move that will leave just one coal generator in the state grid. The downstream effects of large-scale solar storage will manifest in a few short years, Watson anticipated.

"KBESS1 was just the first step for Synergy and the Wholesale Electricity Market (WEM), and now KBESS2 will be four times the capacity," he said.

Watson also noted installation of the Kwinana batteries comes as Synergy gears up to replace the Collie coal-fired power station with what will become one of Australia's biggest lithium-based batteries. Once built, that battery will provide 500 MW of power with 2000 MWh of energy storage, or eight times the capacity of KBESS1.

"We're significantly increasing the amount of battery energy storage in the WEM, and we'll soon see the effect this has on our market once they become operational," he said.

Battery storage will be integral to keeping systems secure over the long term, and as the leap from KBESS1 to KBESS2 shows, the technical capabilities of batteries are improving so rapidly that the technology promises to scale up to meet more of the needs of the grid.

Commercially competitive

A storage system with a four-hour capacity was unheard of only several years ago, whereas now it is on the road to being considered a baseline requirement for battery storage. As the CSIRO noted in its Renewable Energy Storage Roadmap, released in March last year, lithium-ion batteries have reached competitive commercial deployment overall, with short-duration, grid-scale storage applications of up to four hours' storage reaching maturity. However, medium-duration grid-scale storage applications of more than four hours remain in the supported commercial deployment stage.

"As we get more capacity into the market, particularly four-hour capacity, which is what AEMO [the Australian Energy Market Operator] has estimated is a direct comparison for synchronous or fossil generation in the market, that will allow us to firm up those renewables and stabilise generation throughout the day, which will then allow greater renewable penetration," Watson said.

"We need to pair the renewable generation with the energy storage and allow further penetration of large-scale renewable assets as well as rooftop solar."

Getting to net zero

WA remains the only Australian state with no specific 2030 emissions reduction target, although it has announced it will legislate to achieve net zero by 2050. Part of Synergy's role in that process is forecasting what that energy mix will look like.

ABOVE: Overview of KBESS1 and 2

"It's really hard to say because once you get to that last 10 to 20 per cent of synchronous generation it's a really hard problem to solve," Watson said. "We're still working through those details like everyone else. I can certainly say there will be a lot more renewables and a lot more large-scale batteries, although the jury is still out on what the technological mix seems right to solve those last few per cent."

Synergy's own decarbonisation plan has set out to deliver 410 MW of large-scale renewables by 2030 and 1100 MW of four-hour battery storage.

"We've modelled that to have an 80 per cent reduction on Synergy's emissions from 2021 levels, and that equates to around a 40 per cent reduction on the SWIS," Watson said. "It's going to be a very interesting decade watching these storage assets come in and seeing the WA market transition. It's going to have a profound impact." □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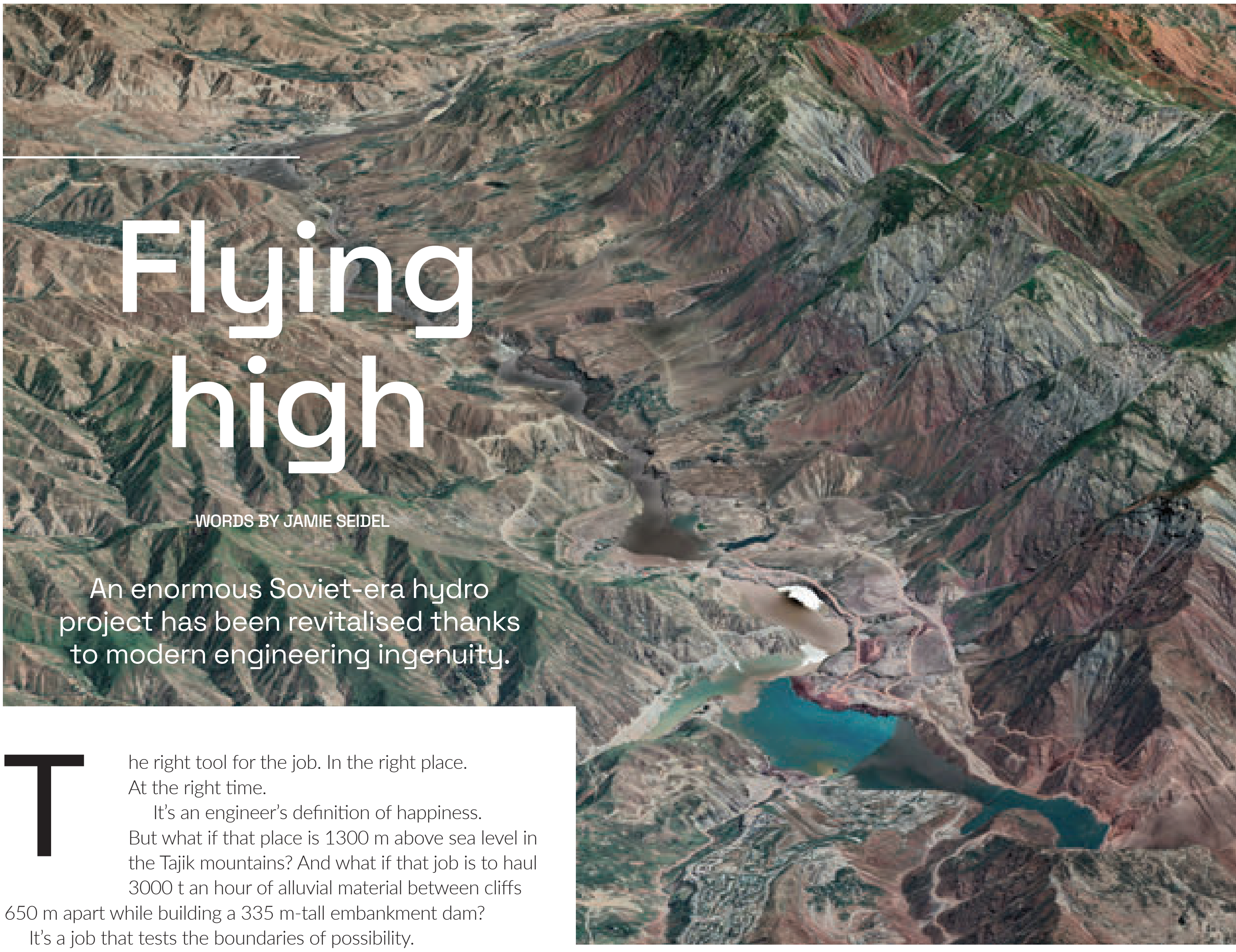


Flying high

WORDS BY JAMIE SEIDEL

An enormous Soviet-era hydro project has been revitalised thanks to modern engineering ingenuity.

The right tool for the job. In the right place. At the right time.

It's an engineer's definition of happiness. But what if that place is 1300 m above sea level in the Tajik mountains? And what if that job is to haul 3000 t an hour of alluvial material between cliffs 650 m apart while building a 335 m-tall embankment dam?

It's a job that tests the boundaries of possibility.

And that's the fun part, according to the engineers behind the Flyingbelt conveyor.

"All the tools and materials were already there to be found," Project Director Fabio Guerino told *create*. "They just needed to be processed and matched in ways that would work best."

The Rogun Hydropower Project is enormous. The Central Asian mountain range is remote, and the high-altitude terrain is as rugged as it gets. But the multibillion-dollar project promises to transform lives across the entire nation.

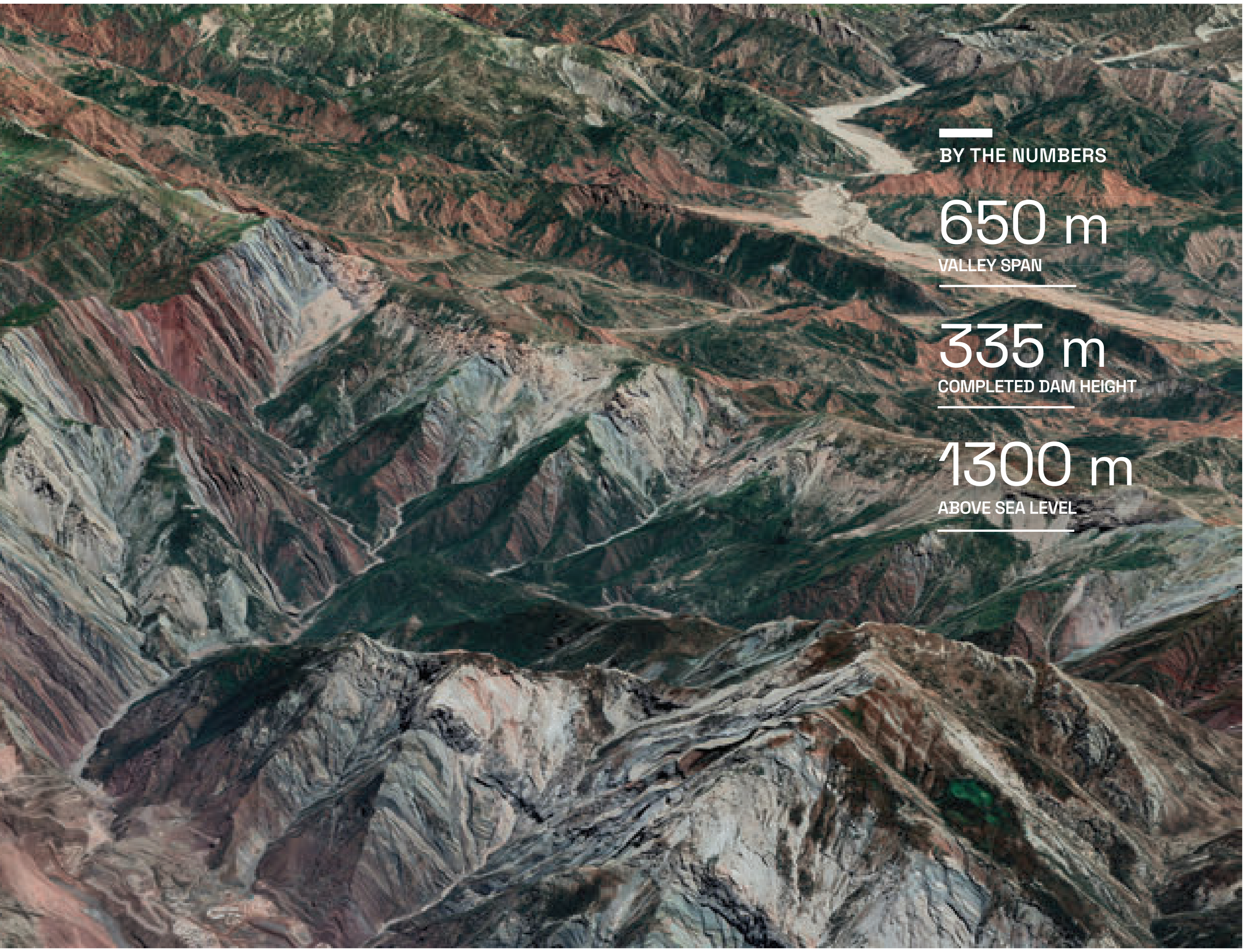
Two of the six planned 600 MW hydroelectric turbines are already operational. Once completed, the 3600 MW project promises to double Tajikistan's overall energy production.

It's an outcome worthy of the effort and inspiration needed to get the megaproject off the ground, Guerino said. But getting things off the ground proved one of many challenges for the principal contractor.

How do you move all that material and infill into place in a fast, reliable, efficient and safe manner at such a challenging site?

The answer comes down to how strong you can make a piece of string.

A belt's-eye view
The 650 m-long single-span conveyor belt, suspended by four track ropes, is designed to withstand an overall tension of about 8000 kN. This dramatic overview of the belt shows both the scale of the project and the terrain the Rogun Dam team must contend with.



The challenge

The Rogun Dam sits in the Vakhsh River valley, some 110 km from Tajikistan's capital, Dushanbe.

When completed, it will be the tallest embankment rockfill dam in the world – overtaking the current holder of that title, the Nurek Dam, also in Tajikistan, and also taking the overall title for world's tallest dam from China's Jinping-I dam by 30 m.

Work on the megaproject began in 1976 under the former Soviet Union. Progress was curtailed in 1993 – as the Soviet Union dissolved – before restarting in 2016 under the Tajik government. Italian civil infrastructure group Webuild was brought in to complete the project.

With the plant slated to achieve full operational capacity in the 2030s, solving the materials transportation challenges to fill around 80 million m^3 of dam structure plays a critical role in meeting that deadline.

It's about linking supply to demand. Different grades of infill material must be transferred from one side of the valley to the construction site on the other.

"The complexity of the geomorphology and geological conditions in the project area makes the usual method of building roads and hauling with heavy trucks a very slow, costly and unsustainable prospect," Guerino said.

A suitable road would have to be hacked out of the steep, rugged landscape over several kilometres. And the fuel consumption of the haulage trucks is daunting.

A long line of conveyor belts is already in use to bypass the boulders, cliffs and switchbacks that dominate the landscape. It carries embankment material between stockpiles and to the dam location.

But extending this to the final 650 m span across the neighbouring Obishur valley needed extra thought.

The Flyingbelt

Webuild foresaw the use of a conveyor system for the advanced phases of construction from the start. >

Production rates were set and the necessary haulage capacities were calculated. These calculations pointed to a possible solution: a 650 m-long single-span suspended conveyor belt.

"The Flyingbelt itself is an extension of the conveyor system currently operating at the site," Deputy Technical Manager Francesco Celeste said. "But its use will be of paramount importance to raise the dam up to its final configurations."

Conveyor belts have a well-established role on construction sites; these traditionally run along supports placed on the ground.

Suspended conveyor technology is nothing new, but is usually found in mining operations and cement production facilities – and none of these inhabit locations as extreme as the Vakhsh Valley.

"Only one other example of a suspended conveyor exists, on a construction site in Italy," Celeste said. "But this is a much lower scale of system in capacity and length."

It first had to be determined if a suitably large suspended conveyor was even possible. A site survey confirmed the original alignment of the system and the final location of the loading and unloading stations.

The physical nature of the site had to be understood.

A geotechnical and geophysical investigation was carried out to assess the existing geomechanical conditions of the abutments beneath the foundations. Then came an exploration of the physical possibilities of such a single-span conveyor system itself.

Under pressure

Designed by Italian company Agudio, the Flyingbelt is a conveyor kept suspended by four track ropes designed to withstand an overall tension of about 8000 kN.

The success of the idea depends on the strength and resilience of its lock-coil steel wire ropes.

BY THE NUMBERS

THE FLYINGBELT CAN WITHSTAND
8000 kN
OF FORCE

OPERATING TEMPERATURES OF
-20 TO 30°C

AND WIND GUSTS OF
160 km/h

IT CAN ALSO CARRY
3000 t
OF MATERIAL PER HOUR

BELOW: The Flyingbelt conveyor running above the Rogun Dam project.

LEFT: The conveyor belt's support cables and slings prior to the belt itself being inserted.

BELOW LEFT: The loading station in a more advanced stage of construction, with the conveyor slung into place.

"The concept of the system is that the ropes are built to last; no replacement is planned as it implies a substantial stop of production," Celeste said.

"Those types chosen have three layers of Z-shaped wire [with a] height of 5.2 mm, for an external diameter of about 65 mm. That kind of wire rope is typically used for the track ropes of aerial tramways".

The setup has been designed to avoid the need for regular re-tensioning to minimise maintenance. But doing so is feasible if necessary.

"The wire ropes are able to ensure a very low elongation, which allowed us to consider a reduced range of tensions at the design stage of the system."

The ropes are anchored around drums at both the loading and unloading stations' large reinforced concrete structures.

Once strung up and tensioned, three months was allowed for the anticipated permanent stretching to take place. A close eye was kept out for any difference in elongation between the four lines; only then was the conveyor system attached.

Tense situations

The necessary 8000 kN tension isn't just about accommodating the weight of the steel rope, conveyor and rubble. Thermal effects on the steel and weave of the cable itself had to be considered due to the location's extreme temperature variations; Tajikistan's mountains can be more than 30°C in summer and below -20°C in winter. Then there's the intermittent additional load of snowfall and ice.

"The ropes are built to last; no replacement is planned as it implies a substantial stop of production."

Above all, there is a need to cope with dynamic load scenarios associated with heavy structures in seismically active areas.

"It may sound surprising, but the rope suspension system itself does not require any sensor," Celeste said. "The monitoring of the rope inclination is performed manually using an inclinometer, as commonly done for aerial tramways."

But the suspension bridge is vertically and laterally flexible.

"Its location naturally leads to a high exposure to wind that may trigger significant effects."

The kind of movements the 650 m-long system would be subject to had to be carefully modelled.

To prevent rotations of the suspension along its axis, the line has been fitted with a series of hung counterweights.

Hauling alluvial material

With the suspension bridge established, its conveyor works like any other, Celeste said. A sensor network closely monitors its performance, but this is no different to any "classic" ground setup. Its performance is determined by the needs of the dam.

It can transport embankment materials up to 400 mm in size at a speed of four metres per second. This delivers about 3000 t per hour from a transfer chute on loading to a discharge pulley.

Celeste said the Flyingbelt can sustain this full-load performance at wind speeds of about 70 km/h. And it can avoid damage from gusts of about 160 km/h if emptied and deactivated.

"Considering both the scenarios mentioned above, the span tends to sag horizontally by about three metres in operation and by more than 20 m out of operation.

"Although the latter values are important displacements, the system is designed to cope with them and the conveyor belt smoothly follows the suspended structure."

The Flyingbelt will remain operational for the remainder of the dam's construction, carrying materials in different directions according to need. □

Experience

DISASTER

An avoidable disaster

WORDS BY LACHLAN HAYCOCK

The collapse of the Florida International University Bridge was a clarion call for enhancing safety procedures in construction.

On 15 March 2018, the 53 m-long main span of a pedestrian bridge at Florida International University collapsed, falling 5.6 m onto the road below in less than half a second.

Eight vehicles were crushed by the bridge, which was still under construction and not being used by pedestrians at the time. Six people were killed and 10 injured.

Flawed design

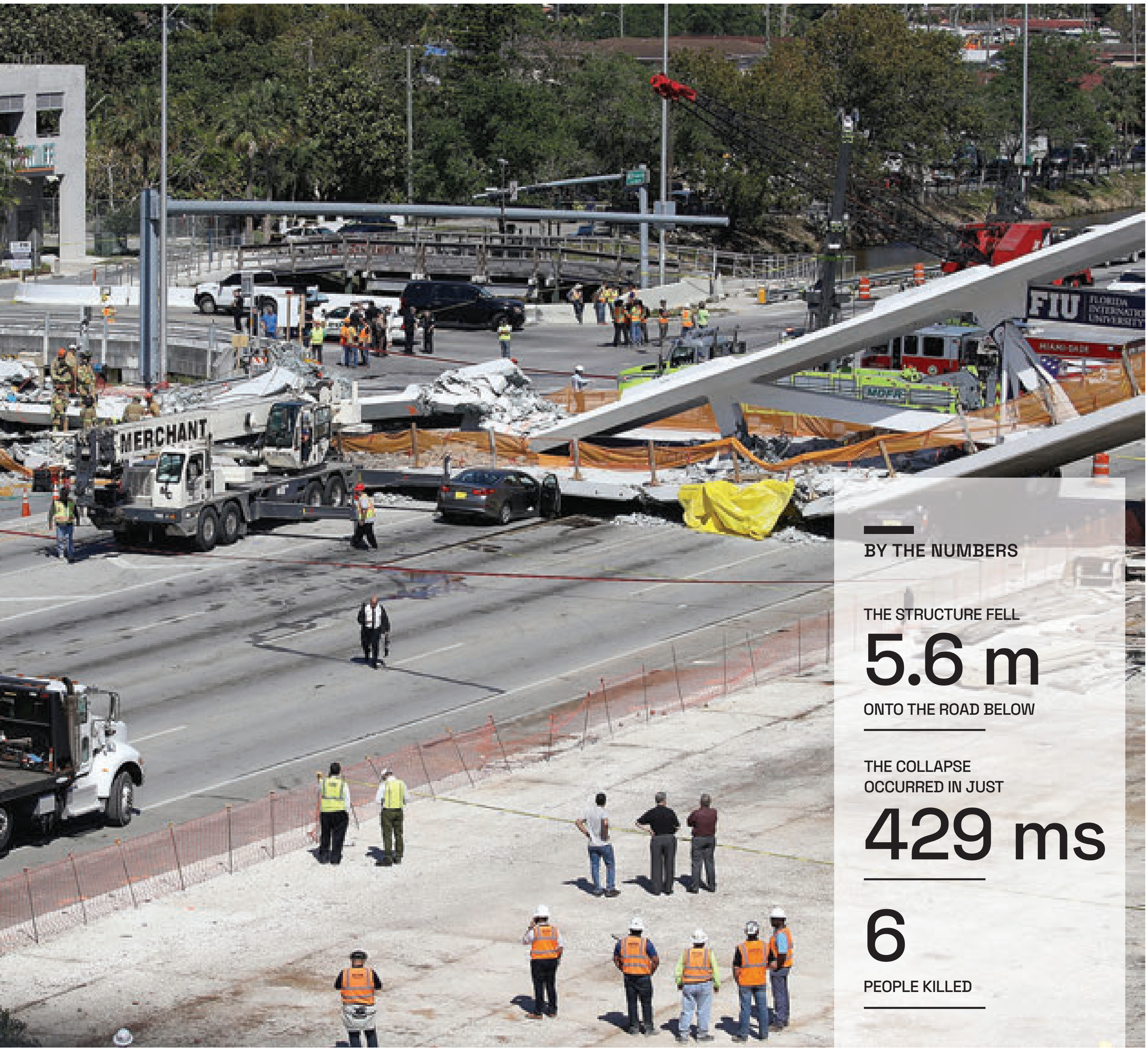
The simply supported bridge's unusual design played a "massive" role in its eventual failure, according to Dr Sean Brady FIEAust CPEng, who spoke on the topic at a webinar hosted by Engineers Australia's College of Leadership and Management.

"[It's] incredibly rare to have a concrete truss bridge," Brady said. "It's certainly incredibly rare to have a bridge with only one line of truss members.

"This makes them [vulnerable]. If you break one of those members, the bridge is almost certainly going to collapse because there's nowhere for the load to go."

The node points where members met the canopy and deck were cold joints; the concrete of the canopy and deck had been cast separately to that of the members. This introduced an

"In many ways, the more you learn about this failure, the harder it is to understand why it actually happened."



BY THE NUMBERS

THE STRUCTURE FELL

5.6 m

ONTO THE ROAD BELOW

THE COLLAPSE OCCURRED IN JUST

429 ms

6

PEOPLE KILLED

inherent weakness into the design, according to Brady.

This weakness was compounded when a design note to "roughen" the cold joint between the 11th and 12th members – left on the planning document for the contractors, with the aim of enhancing the interlocking between new and old concrete pours, and reducing sliding – was inadvertently omitted in the construction drawings.

The joint in question "snuck" through the peer review process, Brady said, and the flawed design ended up on site in a clear organisational failure.

ABOVE: The aftermath of the bridge collapse.

Failure to act

The main span was cast offsite and moved into position by a self-propelled modular transporter (SPMT), a 2020 safety alert by the Collaborative Reporting for Safer Structures UK (CROSS-UK) said.

"During lifting, the end diagonals cantilevered from the >

> "If you break one of those members, the bridge is almost certainly going to collapse because there's nowhere for the load to go."

inboard SPMT supports in tension, so they were post-stressed to bring them back into compression during the temporary condition.

"When the main span rested onto the supports, the end diagonals returned to compression in the permanent condition, with the tension rods de-stressed."

The bridge collapsed 19 days after the structure had been lifted into place. That morning, onsite engineers had conducted an inspection of the structure, identifying significant cracking at the node point between the 11th and 12th truss members.

Despite this, the road was not closed, nor the truss supported to reduce the load. Instead, the team elected to re-tension the bars in the distressed diagonal under compression, which added to the overall compression.

The main span collapsed during this re-tensioning operation. Following the failure of the node, the canopy and deck immediately fractured in separate locations, introducing a catastrophic flaw in the structure.

An investigation by the National Transportation Safety Board (NTSB) in 2019 identified "a complete lack of oversight by every single party that had responsibility to either identify the design errors or stop work and call for a safety stand-down, once it was clear that there was a massive internal failure".

The NTSB concluded that:

- The design team "underestimated the demand ... that would be acting on the nodal area".
- The designers "overestimated the capacity of the node to resist shear (horizontal force) where the nodal region (11/12) was connected to the bridge deck".
- Together, these mistakes "resulted in a node that lacked the capacity to resist the shear force pushing the node to the end of the bridge".

Further to this, the CROSS-UK report found that "it is highly likely that the location of service voids, placed so close to the node which failed, was a contributory factor, as it appears this [was] not accounted for in the design".

Aftermath

The event has become the subject of numerous studies. The collapse was described as an "avoidable tragedy" that should be carefully

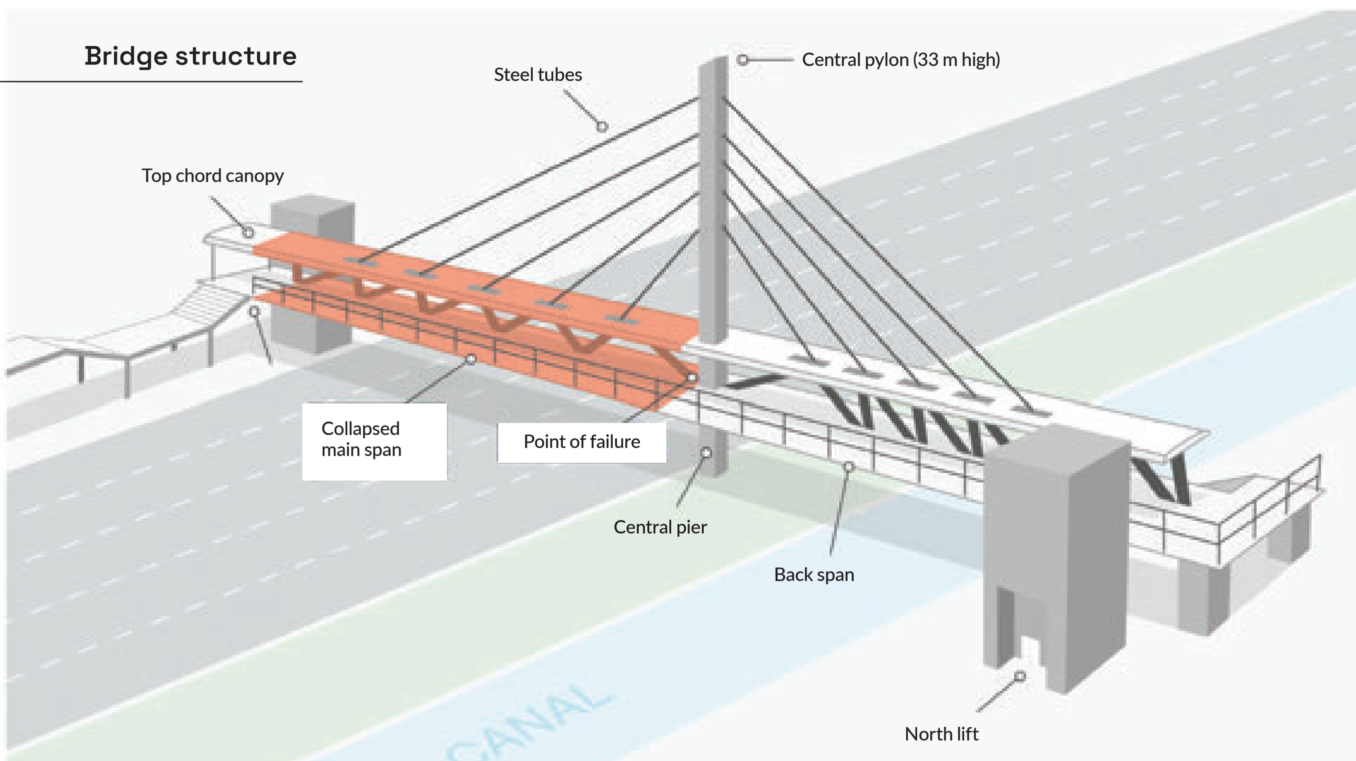
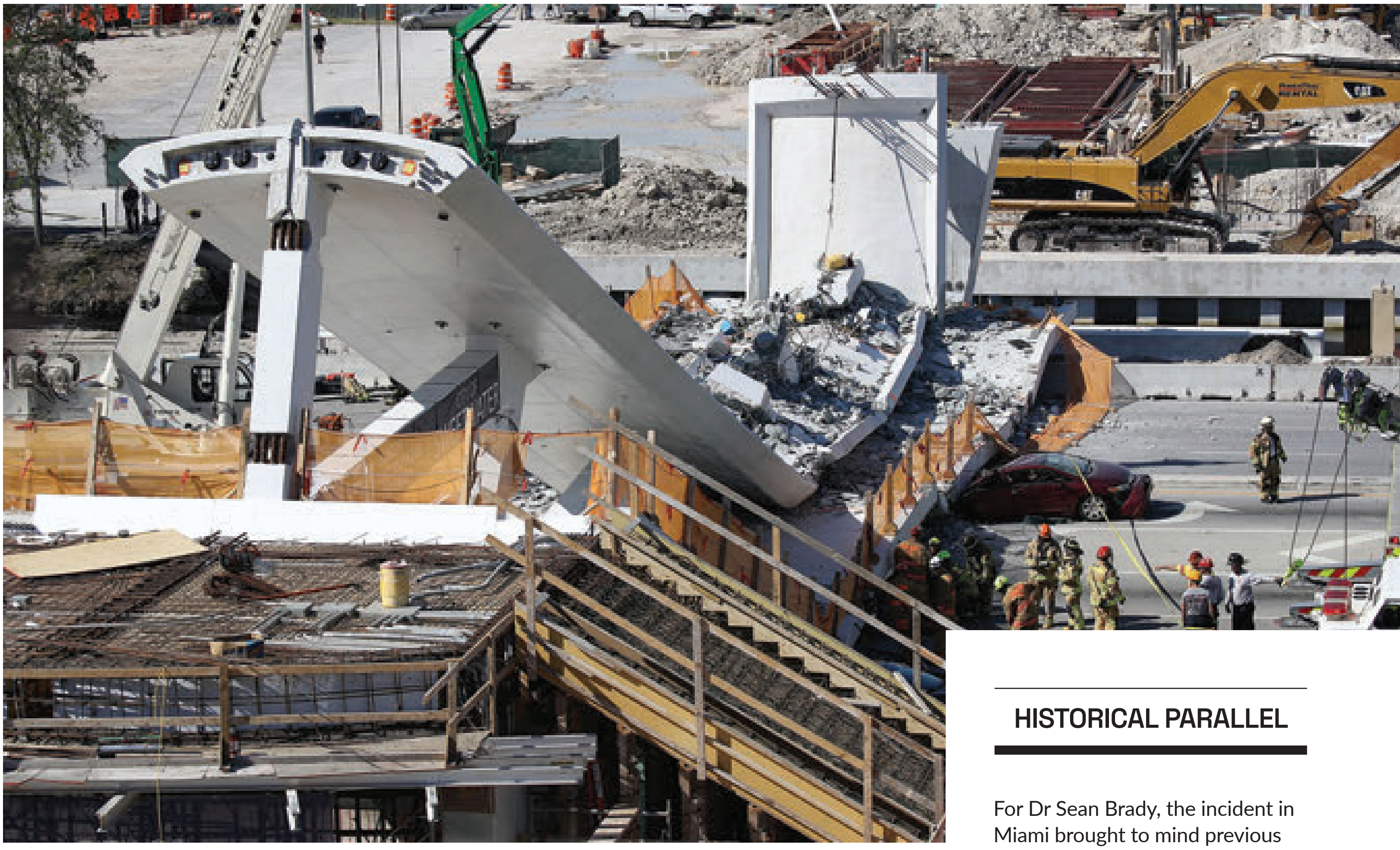


IMAGE: CROSS-UK



studied by organisations in the construction industry.

The recommendations outlined by CROSS-UK included:

- Cracks should be immediately addressed by an expert, especially if they appear without warning.
- Engineering decisions should be made by, or in direct consultation with, trained engineers.
- A project's procurement strategy and contracts must be checked against the project's complexity and the competence of its workers.

In addition, the NTSB stated that changes to bridge construction oversight procedures were necessary to emphasise "bridge and road closures [that] protect public safety when structural cracking (beyond what sound engineering judgment [sic] considers acceptable) occurs and to increase state oversight of complex bridge construction".

A replacement bridge, in the same location and with a more conventional design, has been announced with construction expected to begin before the end of 2024. ◻

To view the EA OnDemand webinar, scan the QR code.

HISTORICAL PARALLEL

For Dr Sean Brady, the incident in Miami brought to mind previous disasters such as the collapse of a pair of walkways at the Hyatt Regency Hotel in Kansas City, Missouri, in March 1981.

The collapse, which killed 114 people and injured 216 gathered in the packed hotel lobby, was caused by the failure of a single steel tension rod.

"That bolt ... was meant to be held in place by ... double channels; [instead] it actually tore through the double channels," Brady said. "And it tore through ... because that joint wasn't strong enough to hold the weight of the two walkways."

By contrast, the story of the Florida International University bridge collapse is far from linear.

"There [were] many, many things that [went] wrong," he continued. "In many ways, the more you learn about this failure, the harder it is to understand why it actually happened."

THE LOOK BACK

Rammed earth

The modern desire for low-carbon materials means this paleolithic technology is enjoying a resurgence in popularity.

WORDS BY JAMES CHALMERS

RIGHT: Alhambra, Granada

With a known history dating back around 10,000 years, rammed earth is perhaps a surprising contender to be an on-trend building material.

But architects and engineers across the globe are rediscovering and reworking the ancient technique, driven in large part by its promise of ultra-low embodied emissions.

Deep foundations

Rammed earth is a durable – and enduring – construction technique.

Landmarks such as Alhambra palace in Spain and sections of the Great Wall of China, constructed centuries ago, are testament to its impressive longevity.

Even today, an estimated 30 per cent of people globally live in earthen buildings, particularly in the Middle East and North Africa, where an unbroken architectural tradition has produced rammed earth buildings up to 10 storeys tall.

In much of the western world, however, concrete has mostly supplanted rammed earth construction, particularly on scales larger than single-family homes.

ABOVE: Aaron Hazelton, Indesco; Professor Jianfeng Xue CPE, UNSW Canberra

Low-carbon opportunity

Today, strong sustainability credentials are spurring renewed interest in rammed earth.

Its chief advantage is its abundant availability. Ideally, rammed earth uses soil from the construction site, minimising the amount of material needing to be transported to the site, as well as the amount of spoil needing to be trucked away. These benefits are particularly marked for remote projects.

If unstabilised – that is, not using cement or lime as a stabilising agent – it is infinitely recyclable too.

However, many projects built as part of the recent rammed earth renaissance have used stabilisers.

This is partially for the superior performance characteristics – cement-stabilised rammed earth can have up to 10 times the strength of unstabilised – but crucially for the predictability such stabilisers can deliver. However, using cement and, to a lesser extent, lime can largely negate rammed earth's low-carbon benefits.

Australian research has found cement-stabilised rammed earth is just 15 per cent less carbon-intensive than traditional brick veneer construction.

In fact, using cement as a stabiliser in rammed earth construction can lead to higher embodied emissions compared to concrete, says Aaron Hazelton, Managing Director of engineering consultancy Indesco, as the greater thickness of rammed earth walls can mean more cement is used.

Australian ambition

Indesco is the engineering partner for the Dairy Road mixed-use precinct under development in Canberra. The project is designed to make use of rammed-earth walls and columns in residential buildings of up to six storeys. The 14 ha site was actually the dumping ground for waste from the construction of Parliament House and the National Gallery of Australia, and this soil will form the substrate.

A strong intention to maximise the precinct's sustainability means avoiding cement and lime stabilisers, which has demanded an advanced engineering approach, UNSW Canberra Associate Professor Jianfeng Xue said.

Xue is leading a research project, funded by the Australian Research Council's Industrial Transformation Training Centre, to develop a testing method for determining the strength of rammed earth structures, as well as developing models for calculating bearing capacities for unstabilised rammed earth structures made with different aggregate mixes.

"For rammed earth, you need the right type of soil, a bit of clay and a bit of everything," he said. "But in Canberra, the soil doesn't have enough clay to stick together. It will work for a single-storey house, but if you want to use it for multiple storeys like Dairy Road, you have to improve it."

For this project, the engineers have been investigating using geo-polymers and recycled waste from steel mills as stabilisers.

Setting standards

Hazelton said determining the right design parameters for unstabilised rammed earth is both the biggest challenge for the project as well as its biggest opportunity for impact.

"We don't want rammed earth to be a standardised product, because so many of its advantages come from how the approach can be modified for site-specific conditions," he said.

Xue's research project has so far analysed more than 500 rammed earth samples made using soil from the site. He said suitable design parameters should ensure this level of testing is unnecessary for future projects.

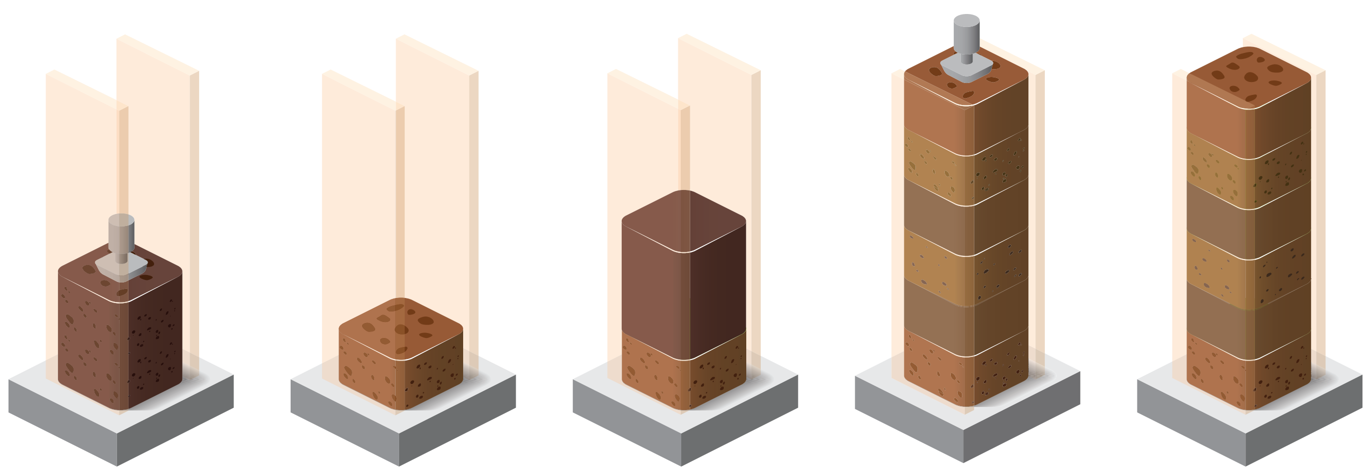
Given the certification hurdles that unstabilised rammed earth can present in Australia, some research efforts have focused on creating a low-carbon standardised rammed earth.

Research from the University of Western Australia, led by Dr Alexandra Meek in 2020, investigated a range of potential rammed earth mixtures made from recycled construction waste (crushed brick and concrete) and industrial byproducts (blast furnace slag, fly ash and silica fume), stabilised with sodium hydroxide or hydrated lime.

Meek found that these methods could reduce the carbon intensity of Australian house construction by up to three quarters. □

LEARN MORE
Get references at createdigital.org.au

The basics of rammed earth



STEP 1
Concrete or stone foundations are often used, given rammed earth's susceptibility to moisture.

Built with temporary formwork, walls are generally 300 mm to 800 mm thick.

STEP 2
Subsoils excavated from at least one metre below the surface are the most suitable substrates, with clay the most common binder.

A layer of damp earth is added and manually or mechanically tamped down to about half its original volume, usually to a final layer height of 80-150 mm.

STEP 3
The next layer is added and the process repeated until reaching the top of the formwork.

STEP 4
Unstabilised walls – those without cement or lime – can achieve strengths of up to four N/mm^2, strong enough for multistorey buildings.

Strength is gained by sorting and sifting the aggregate to ensure well-mixed particles and minimising voids.

STEP 5
Once dry, the formwork is struck to reveal the completed wall.

Events

September 2024 to August 2025

SEPTEMBER

12-19
SEP 2024
Engineers Australia Excellence Awards local events

Location: *Various*
Website: *engaus.org/excellenceawards*
Local event celebrations will include the announcement of Engineers Australia's national finalists for each division in the project and people categories, plus unveil the winners of the achievement awards.
Register now

22-25
SEP 2024
Systems Engineering Test and Evaluation Conference 2024 (SETE 2024)

Location: *Melbourne*
Website: *sete-24.w.tas.currinda.com*
With optional workshops on day one in addition to a comprehensive three-day program, you can network and learn from leading experts as we advance in an emergent digital world.
Register now

OCTOBER

24-25
OCT 2024
Australasian Engineering Heritage Conference (AEHC 2024)

Location: *Adelaide*
Website: *engineersaustralia.org.au/aehc*
Immerse yourself in two whole days of knowledge-sharing and debate while exploring the preservation and advancement of heritage engineering in Australia.
Register now

30-31
OCT 2024
Australasian Structural Engineering Conference (ASEC) 2024

Location: *Melbourne*
Website: *engineersaustralia.org.au/asec*
Join the exchange of ingenious ideas in structural engineering among global colleagues at ASEC 2024, serving as a nexus for practitioners, professionals, academics and students.
Register now

NOVEMBER

17-20
NOV 2024
Engineering and Physical Sciences in Medicine (EPSM) Conference & Australian Biomedical Engineering Conference (ABEC) 2024

Location: *Melbourne*
Website: *epsm.org.au*
Delve into cutting-edge biomedical engineering and physical sciences research, fostering interdisciplinary collaboration and advancing medical innovation.
Register now

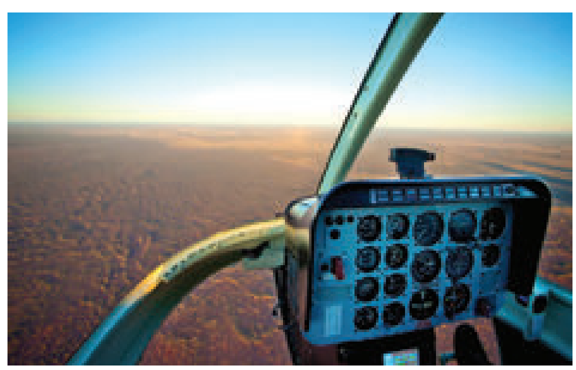
18-21
NOV 2024
Hydrology and Water Resources Symposium (HWRS)

Location: *Melbourne*
Website: *engineersaustralia.org.au/hwrs*
Shape tomorrow's water solutions at HWRS, a four-day exploration of innovative water management and flood estimation solutions, featuring the latest in hydrology, hydraulics and beyond.
Register now

MARCH

24-26
MAR 2025
Australian International Aerospace Congress (AIAC21)

Location: *Melbourne and Avalon*
Website: *engineersaustralia.org.au/aiac21*
The congress will explore advances in aerospace and aviation through technical, industry, government, sustainability and diversity lenses.
Register now



21 NOV 2024

Engineers Australia Excellence Awards national gala dinner

Location: *Brisbane*
Website: engaus.org/excellenceawards
This prestigious black-tie gala event is a special opportunity to recognise the engineers and projects at the forefront of innovation in Australia.
Registrations open in September

27-28 AUG 2025

Climate Smart Engineering Conference (CSE25)

Location: *Adelaide*
Website: *engineersaustralia.org.au/cse*
Returning in 2025 with a two-day technical conference, this is your opportunity to contribute to critical climate change conversations by submitting an abstract.
Abstracts open

RESOURCE RECOMMENDATIONS

Measuring up

Carbon Measurement Fundamentals for Engineers is a new resource developed to enable all engineering disciplines to gain an understanding of emissions accounting and the associated tools and techniques. ***bit.ly/3zUT95H***

Build your brand

Enhance your engineering career and professional profile with Engineers Australia's Build Your Brand toolkit. Explore tailored resources designed to help you unlock skills, advance your career and gain greater recognition.
https://bit.ly/4cV4QIf

Engineering Reimagined

This podcast series reimagines the world and our place in it. With guests from the engineering world and broader society, it looks at how we can rethink and rebuild our world by looking at the problems of our times from a multitude of angles.
aurecongroup.com/podcast

Back to the future

Low-tech Magazine underscores the potential of past and often forgotten technologies and how they can inform sustainable energy practices.
solar.lowtechmagazine.com

THE LESSON LEARNED

David Cruickshanks-Boyd HonFIEAust

When the former Engineers Australia National President was young, he avoided conflict. Little did he know that this character trait could lead to a mistake that would endanger a $400 million project.

As told to Joe Ennis

It was the early 1980s. I was working as a project manager at a large engineering firm. I was running several large projects, including a $400 million mineral sands project for a key client.

Like most people, I don't like conflict. When something is going wrong, my tendency is to try to either avoid it or not confront it head-on. With this project we were working as the client's partner in delivering a mining project that was, at the time, our biggest project ever.

I was the principal in charge of our team and we had a real issue around availability of people. One of our key personnel was being torn between two clients and I allowed that to go on for too long – until it became evident to our major client that he wasn't doing what he was supposed to be doing.

But I let it go on because, as a stereotypical engineer, I avoided the people side of the job. I didn't have the courage to have an honest conversation with a client about the challenge and the problem of the people that were being supplied to the project.

Of course, the client realised the issue wasn't being addressed and raised the issue with me – which meant the difficult conversation had to happen. There was no avoiding it anymore.

I really had to summon my courage to address this. I apologised and openly admitted my failings as the leader of the team, and discussed how to address the issue. The client accepted this and over a period of time we were able to rebuild the trust that was lost. The relationship grew stronger and eventually we delivered the project ahead of time and under budget, earning the company a bonus in the process.

If I'd had the courage to be honest earlier and address the personnel issue, it wouldn't have reached a relationship-damaging level. When I eventually had this conversation and revealed my authentic self, acknowledged mistakes and took responsibility for rectifying them, the response was life-changing. I became aware of my own behaviours and though it is difficult to change innate personality traits, being aware of them allows me to make better decisions and become a better leader.

Courage and authenticity are the qualities that I believe enable engineers to be great leaders.

David Cruickshanks-Boyd recently retired after a long career in materials and biomaterials engineering. He continues to serve the profession as a board member of the Engineers Australia College of Leadership and Management. □

KEY LESSONS

01
Take every opportunity to learn about yourself and act on your insights.

02
Criticism is a good tool; don't reject it, reflect on it.

03
Don't avoid tough decisions. They will need to be made eventually.

"If I'd had the courage to be honest earlier, it wouldn't have reached a relationship-damaging level."