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FUTURE OF MINE SITES
Replacing high-risk brownfields with sustainable landforms
34

IMAGING INNOVATION
How digital twins are assisting with reef restoration and research
68

ROBOTS ON THE RANGE
An automated alternative to heavy farming machinery
84



Taking the plunge

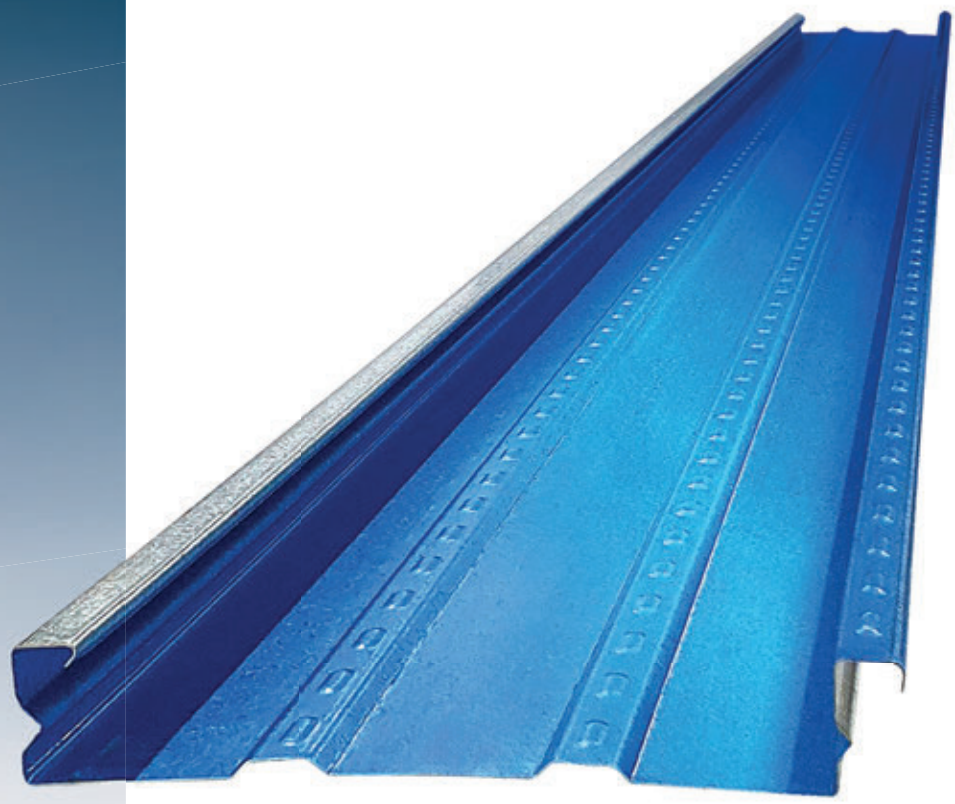
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Contents

LEADERSHIP

09
News
The nation's engineering benchmarks have been overhauled.

13
President and CEO
Learning from natural systems is key to engineering's evolution.

14
The big picture
Inside the building that's successfully integrated natural systems into its design.

16
Decision-maker
Infrastructure projects show an increasing realisation that nature has intrinsic value.

22
Career path
Nanotechnology is expanding its presence in decarbonisation, human health monitoring and more.

28
Essay
There is a critical need to investigate the transfer of toxic compounds released by micro and nanoplastics.

IDEAS

34
Mine remediation
The engineering design of a post-mining landform requires input from many disciplines.

42
Swimmable cities ▾
From Melbourne to Paris, making waterways swimmable again has natural and economic benefits.

52
Swarm robotics
Nature is inspiring engineers to harness collective intelligence in artificial systems.

58
Petropolymer problems
Meet the Australian companies turning bio-based polymers into durable structural materials.

68
Digital twins ▸
From weather forecasting to reef restoration, these tools are improving engineers' predictions.





PROJECTS

76

Record breaker
The world's tallest hybrid timber commercial building is right here in Australia.

80

Dirty business
Contaminated soil is being repurposed as construction material.



84

Advancing agriculture ▲
SwarmFarm's line-up of automated farming robots is expanding quickly.

EXPERIENCE

90

Off the rails ▼
The response to a 2013 high-speed rail disaster missed the chance to ensure deeper preventative changes.



94

Ground-effect vehicles
The Cold War-era novelty has returned with new commercial investment.

96

Events
Upcoming events for your calendar.

97

Resources
What you should be reading and watching.

98

The lesson learned
Past success on one project doesn't guarantee success on the next.

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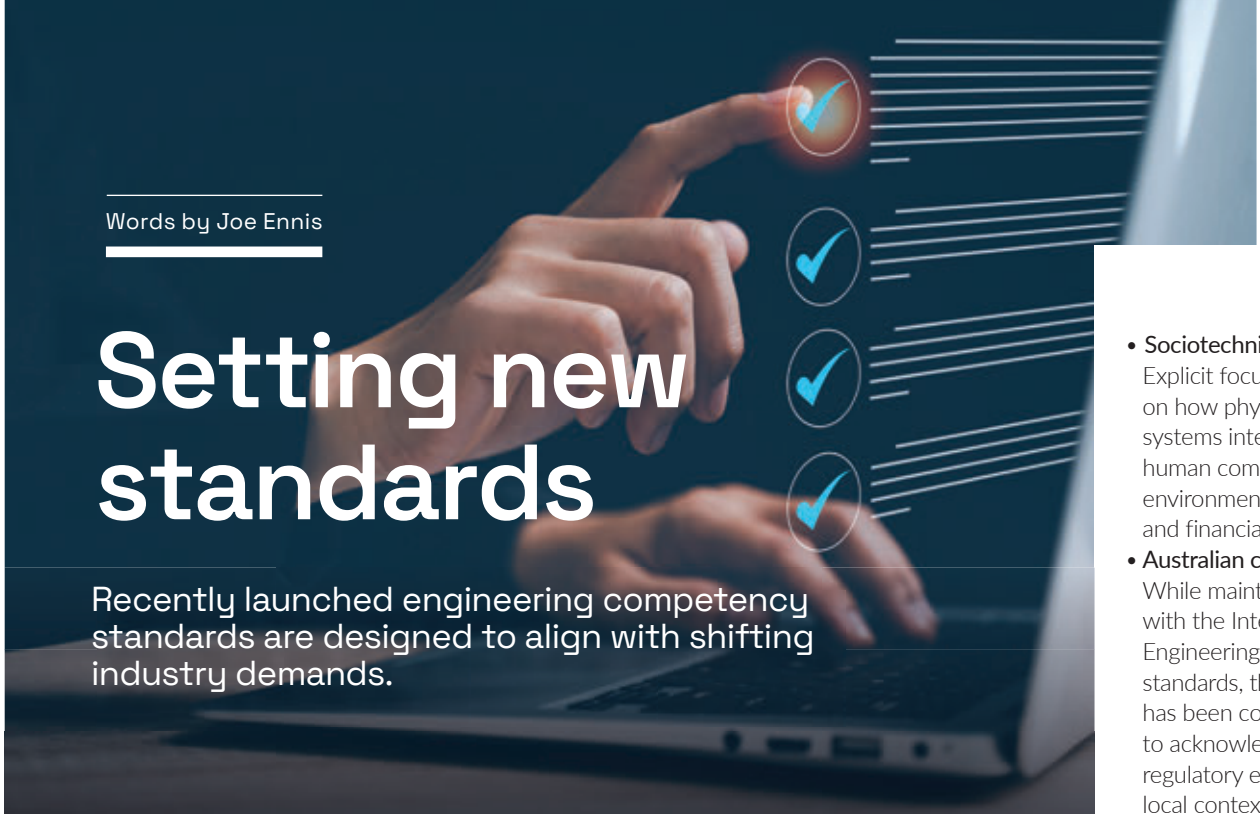
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Words by Joe Ennis

Setting new standards

Recently launched engineering competency standards are designed to align with shifting industry demands.

Engineers Australia has formally released the new National Competency Standard for Engineering (NCSE) 2026, marking the most significant structural overhaul to the nation's engineering benchmarks in more than a decade.

The new framework collapses six separate legacy competency documents from 2012 into a single, integrated national standard establishing a unified benchmark that covers all three recognised engineering occupational categories: Professional Engineer, Engineering Technologist and Engineering Associate.

"Engineers Australia established one of the world's very first engineering competency frameworks back in the early 1990s," Bernadette Foley FIEAust CPEng EngExec said. "Every iteration since has evolved to serve the profession. With the launch of the NCSE 2026, we're directly expanding on that once again, evolving to ensure Australia's engineering standards remain internationally benchmarked, proactive and fit for a digital and rapidly changing profession."

The transition represents a shift in how professional competency is evaluated in Australia. The NCSE 2026 prioritises the real-world application of professional engineering judgement within complex settings over checking off isolated technical tasks.

"The core competencies from the 2012 baseline are still valid. These revised standards change the narrative to ensure engineers are proactive rather than reactive, focusing on how they reflect on knowledge to create contemporary, sociotechnical solutions."

Key changes

The updated standard introduces several distinct features designed to align with shifting industry demands:

- **Embedded engineering mindsets.** The standard introduces six definitive orientations. Rather than being assessed in isolation, these mindsets are woven directly into the competency profile requirements:
  - Systems approach
  - Sustainability
  - Risk-based
  - Curiosity and inquisitiveness
  - Inclusive and culturally responsive
  - Human-centred
- **Sociotechnical integration.** Explicit focus is now placed on how physical engineering systems interact with diverse human communities, environmental frameworks, and financial constraints.
- **Australian contextualisation.** While maintaining alignment with the International Engineering Alliance standards, the framework has been contextualised to acknowledge Australian regulatory environments, local contexts and local cultural awareness.
- **Digital tool authentication.** New profile criteria place a higher emphasis on navigating modern tools, predictive modelling, and critically verifying the reliability and authenticity of data in an algorithmic workforce environment.



ABOVE: Bernadette Foley FIEAust CPEng EngExec, Engineers Australia.

These updates won't affect current credential holders. Practitioners already Chartered, registered or successfully assessed under the 2012 rules will not require reassessments or immediate continuing professional development structural additions.

The implementation follows a strict, phased roadmap:

- July 2026: formal standard document approval
- Early 2027: framework becomes active
- Mid-2027: progressive transition of individual migration skills assessments and Chartered credentials

The full suite of companion resources, including User Guides for Independent Practice Assessment, Entry to Practice Individual Assessment, and Education Providers, the NCSE document and the companion resources are now accessible via the Engineers Australia website. □

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13
President and CEO
Welcome to the latest edition of *create*.

14
The big picture
How a research centre in Wollongong has achieved Full Living Certification.

16
Decision-maker
For engineers, environmental performance is now a risk management principle.

28
Essay
How to regulate, monitor and educate about the impact of dangerous microplastics.

22
Career path
For Noushin Nasiri, engineering belongs in every classroom in this country.

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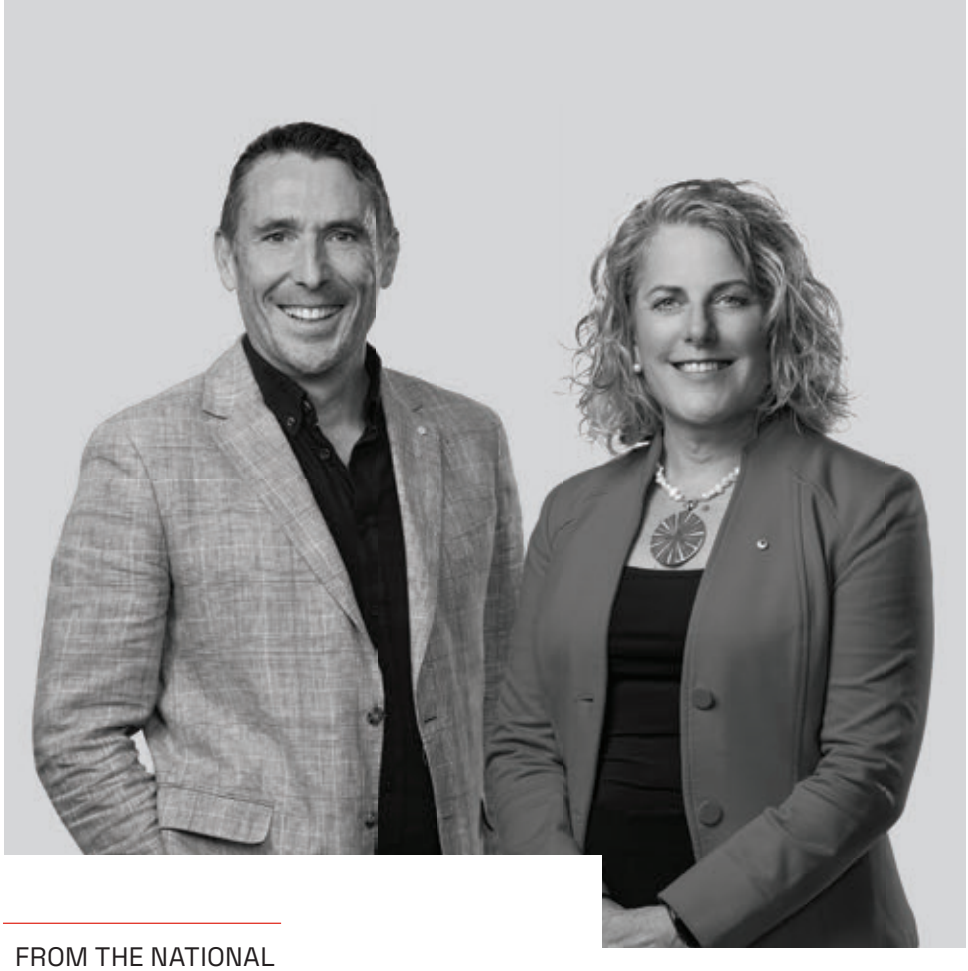
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FROM THE NATIONAL PRESIDENT AND CEO

Harnessing nature

From nature-inspired robotics to green infrastructure, Australia's engineers are looking to the natural world for its next wave of innovation.

Australia's prosperity and security depend on the strength of our engineering workforce.

In this issue of *create*, we explore how engineers are harnessing natural systems to deliver lasting economic, social and environmental benefits. Their work demonstrates that the natural environment is not only something to protect, but also a powerful source of engineering inspiration and innovation.

Engineering has always been about asking the big questions and solving complex problems.

This edition examines how integrating with and learning from natural systems is becoming an increasingly important capability across our profession. Whether in the resources sector, energy systems, large-scale infrastructure, AI or robotics, engineers are applying nature's principles to create smarter, more resilient and more sustainable solutions.

We also highlight how forward-thinking engineers are developing innovative approaches to mine remediation that create self-sustaining landforms designed for the future. With around 240 Australian mines projected to close by 2040, the need for practical, cost-effective solutions has never been greater.

Australia is home to world-class engineering and innovation, and in this edition we also broaden our perspective to explore how Australian engineers are contributing on the global stage.

A compelling example is the growing field of swarm intelligence, where robotics and computer systems engineers are drawing inspiration from nature to develop artificial systems capable of remarkable collective decision-making. It's another reminder that some of our most advanced technologies are informed by the natural world.

Our nation is home to outstanding examples of green building design that successfully integrate the natural environment into the built environment. One Central Park in Sydney demonstrates how modern engineering can work in harmony with nature while delivering safe, sustainable and commercially successful infrastructure.

Continuing this theme, *create* also speaks with the engineers behind a record-breaking 186 m commercial tower in one of Australia's busiest cities. Their work highlights the innovation, creativity and collaboration required to overcome complex challenges in logistics, sustainability and construction.

To engineer with nature requires a broad range of competencies, from technical expertise and problem-solving to creativity, systems thinking and project management. It demands a willingness to continually learn, adapt and embrace new opportunities.

Over the next decade, Australia must deliver net zero, strengthen sovereign capability, build more housing, revitalise manufacturing and keep pace with rapid advances in AI. Engineering will play a central role in meeting each of these national challenges.

Harnessing our natural environment, and learning from the systems it provides, will be an important part of that journey. □

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The big picture

How do engineers working in the built environment ensure they act in partnership with rather than against nature?

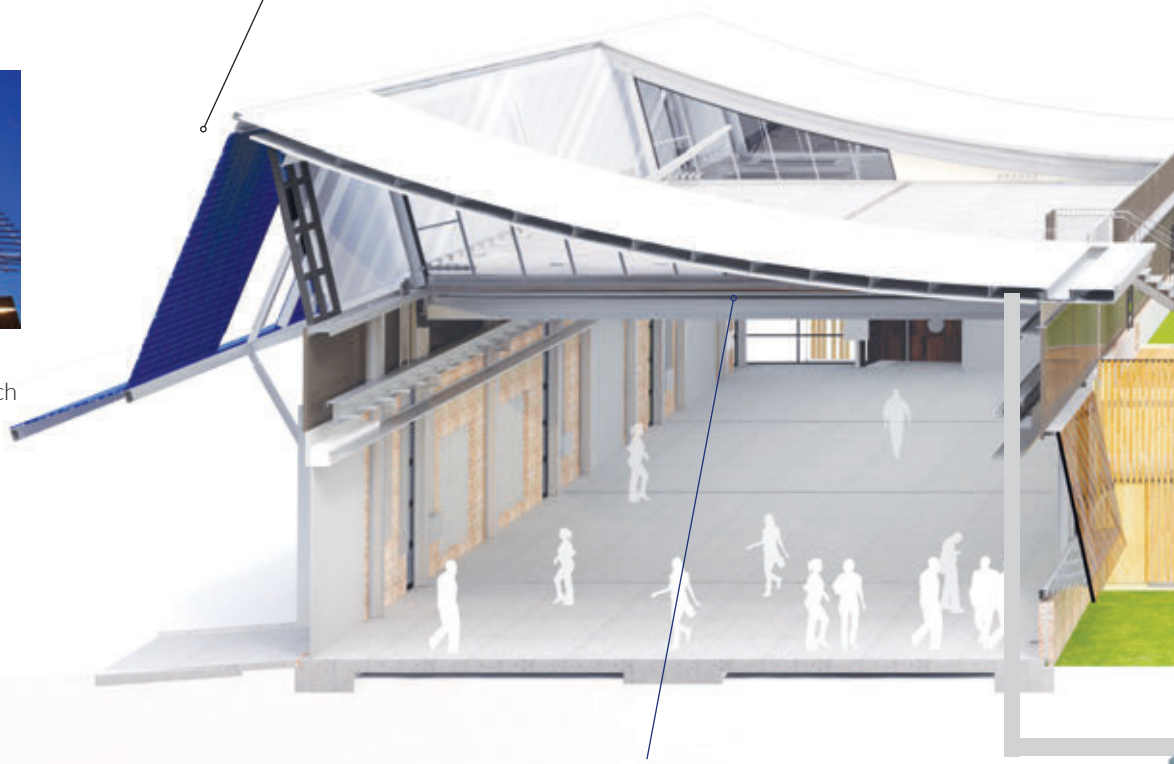




The Sustainable Buildings Research Centre (SBRC) at the University of Wollongong showcases how engineers are successfully integrating natural systems into construction.

It's the only building in the country to achieve Full Living Certification (FLC) as part of the Living Building Challenge.

FLC is a sustainable building certification and design framework that aims to create regenerative, self-sufficient buildings that positively impact both human health and the natural environment.



BEAUTY

Forked Y-column roof supports at either end of the building emulate tree branches in an example of biomimicry.

Certain services, including electrical wiring, and heating and cooling systems, have been made visible to users to promote greater understanding of its inner workings.

Petal goal: Celebrate design that uplifts the human spirit

MATERIALS

No lead, PVC or formaldehyde was used anywhere in the structure, including in bathroom fixtures, cables and conduits, and insulation.

A spray-applied paper pulp product was used as soffit insulation on the underside of the thermally activated floor slab that formed the ceiling of the main exhibition space.

Petal goal: Endorse products that are safe for all species through time



The seven petals of certification

How does the SBRC meet the FLC's goals to become certified?

IMAGE: University of Wollongong and COX.



EQUITY

The building doesn't block access to sunlight or any natural waterways for adjacent developments.

No noxious or red-list chemicals are emitted by the structure or its services.

Petal goal: Support a just and equitable world

ENERGY

The building's extensive solar array boasts nearly 600 panels separated into three clusters, including a 122 kW array for the main office.

A single transformer connects the SBRC and neighbouring accommodation to the grid, a sharing arrangement that improves the return on investment of the array.

Petal goal: Rely only on current solar income



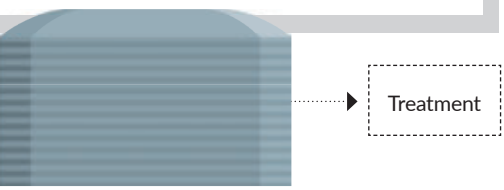
PLACE

The extensive range of plants is almost entirely indigenous to the neighbouring reserve.

Garden spaces include five raised garden beds built using recycled brick and five using corrugated iron barrels.

Petal goal: Restore a healthy interrelationship with nature





WATER

A 65 kL sub-surface tank on the western perimeter collects rainwater for use throughout the building, treated without the use of chemicals by filtration and ultraviolet sterilisation.

All water used within the building is treated in a black water treatment plant before being used in the surrounding landscape via subsurface irrigation.

Petal goal: Create developments that operate within the water balance of a given place and climate

HEALTH

The design maximises natural daylight and uses minimal artificial lighting during daytime hours.

Natural ventilation is available in 95 per cent of habitable areas, with ventilation rates designed in accordance with AS 1668.2.

Petal goal: Create environments that optimise physical and psychological health and wellbeing

Seeing the good for the trees

Modern engineering has moved past the idea of conquering nature to working in tandem with it. Ken Lunty believes that begins by learning how to value the natural world within an expanded set of success criteria.

Words by Karen Jamal

The meeting had dragged on for almost an hour as engineers debated the relocation of an electrical pole. Every option was carefully weighed before a choice was made. Then the conversation turned to a mature street tree.

"The decision to remove it came surprisingly quickly," recalls Ken Lunty, APAC Discipline Lead for Sustainability with Arcadis. "I thought, 'Hang on. The tree has value too. If we could put a dollar value on that tree, would it change the decision?'"

Research has quantified the role of trees in cooling cities, storing carbon, managing stormwater, improving air quality and supporting biodiversity. Economists have linked tree-lined streets with higher surrounding property values, and the City of Melbourne has developed a methodology that assigns financial value to trees by accounting for their amenity, ecological services, replacement cost and establishment cost.

"When we can show that a tree isn't worth zero dollars, then everyone at the table can talk the same language," Lunty said. Engineering has always weighed competing priorities, "nature needs a place on the scales".

Lunty's anecdote illustrates a mindset that has shaped more than $150 billion of infrastructure projects, helped refine the Infrastructure Sustainability (IS) Rating Scheme, trained more >

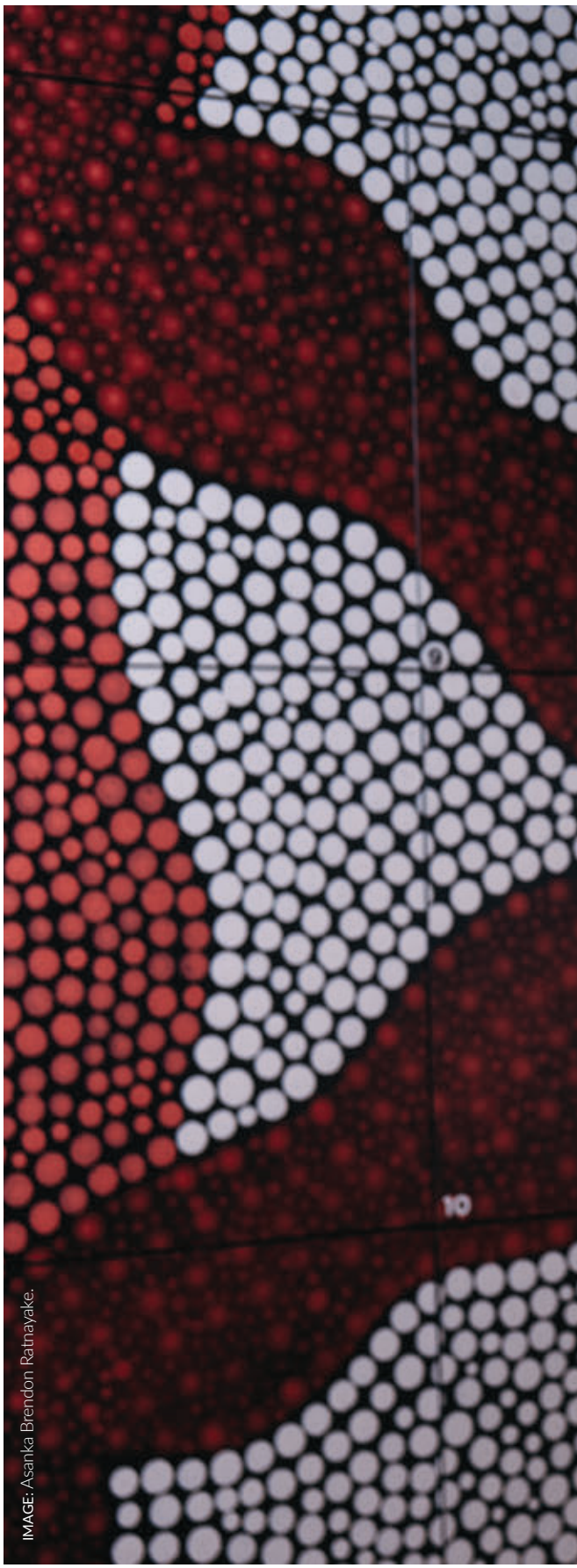


IMAGE: Asanka Brendon Ratnayake.

RIGHT: Ken Lunty, Arcadis.



"We need sustainability metrics to sit alongside engineering drawings, not in a report delivered at the end of a project."



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than 500 practitioners and recently earned him the IS Council's Enduring Impact Award.

It also reflects a growing realisation that nature has intrinsic value. Around half of Australia's gross domestic product depends on nature.

Uniqueness and extinction

Australia supports up to 700,000 native species, many of them found nowhere else on the planet. But the natural world is retreating as rapid urban development, overconsumption, pollution and climate change alter our ecosystems. The 2021 State of the Environment Report found Australia has lost more mammal species to extinction than any other continent. These numbers can't be ignored.

Growing up in Hong Kong, Lunty was fascinated by the relationship between cities and the natural world.

"On the surface, Hong Kong is very metropolitan. But there's actually a lot of nature among the city, and I wanted to do something to protect it."

After studying marine science in Canada, Lunty moved to Australia to complete a Master's degree in environmental management. Along the way, he realised that understanding ecosystems was only half of his challenge.

"If you really want to change a system, you have to understand people," he said.

Lunty spent 15 years developing his technical skills and building one of Australia's first sustainability consultancies before taking up his role with Arcadis five years ago.

"I didn't want to see sustainability sitting on the sidelines."

His goal wasn't to change engineers, but to change the information they have when they make decisions.

"Most people do the right thing," he said. "They have nice gardens, compost and don't waste water. But when engineers go to work, they are laser-focused on cost, risk and program. Is it cost-effective? Is it safe? Is it constructible? These are the classic engineering success criteria.

ABOVE:
Arcadis, in a JV with Worley as Technical Advisor, is supporting the delivery of Westport, Western Australia's new container port. The project's nature-led, future-focused approach demonstrates how major infrastructure. can be developed while supporting environmental outcomes.

"It's not that engineers don't value nature. It's that engineering has struggled to value nature in the same way it values cost, risk and program."

Biodiversity framework

New frameworks and regulations now require engineers to account for how projects depend on and impact the natural environment.

Globally, the Kunming-Montreal Global Biodiversity Framework, adopted by almost 200 countries in 2022, sets the world's biodiversity agenda for this decade. Alongside halting species extinction, it commits nations to restore at least 30 per cent of ecosystems by 2030.

The implication is profound. Infrastructure design can't just minimise environmental harm; it must leave places better than it found them.

In the financial sector, the Taskforce on Nature-related Financial Disclosures (TNFD) is placing biodiversity alongside more traditional business risks. TNFD sector guidance issued in January 2025 for engineering, construction and real estate underscores the importance of analysing nature-related dependencies and impacts during the design stage.

At a national level, Australia's first National Environmental Protection Agency, launched on 1 July, signals stronger regulatory focus on nature.

For engineers, environmental performance is no longer a planning approval issue, but a core design, delivery and risk management consideration.

And at the project level, industry frameworks such as the Infrastructure Sustainability Rating Scheme and Green Star are translating expectations into design and delivery decisions. The latest update to Green Star Buildings, launched in October 2025, establishes a "Nature Positive Pathway" which will require all buildings to achieve a 10 per cent biodiversity net gain by 2030. >

Changing decisions

Understanding how voluntary frameworks and regulation fit together can be "overly complicated", Lunty admits.

"But they are all saying the same thing. Nature has a value. Everything is interconnected. We can't stick to the traditional constraints or success criteria anymore."

Ideas only matter if they change decisions. One example is Arcadis's pavement footprinting metric, which compares the sustainability impact of different pavement designs over their lifecycle, from raw materials and construction through to maintenance and replacement.

Rather than handing the client a sustainability report after the design is complete, the metric adds "the equivalent of a nutritional label" to every pavement option.

"We can show our clients alternative pavements that cost the same over their design life, have a 40 per cent lower carbon footprint, are aligned to government targets, won't cost more, and will still be durable and safe." The metric can be extended to nature, he adds.

Another Arcadis innovation is a framework which measures biodiversity net gain on every project. This allows project teams to reduce harm and increase their positive impact on nature in real time, as well as report on their achievements.

Over his career, Lunty has chaired technical working groups, helped shape sustainability rating tools and amassed dozens of IS ratings. Yet he believes the hardest part of sustainable engineering isn't technical.

"Technical output holds so much value in engineering that it is easy to forget to communicate the value of that technical output. At Arcadis we bring our clients and our peers on the journey instead of just saying, 'Here's the answer.'" Sustainable engineering succeeds when it appeals to the purse strings and the heart strings.

Change in infrastructure is measured in decades, not months. Yet incremental change is evident. Just one proof point: the 29 projects the IS Council certified in the 2025 financial year avoided almost 3.5 million t of carbon emissions and generated more than $1.27 billion in avoided costs.

"If I look back on the last 20 years, we have made progress. Sometimes it feels slow. But I do have optimism that we are going to get to a point where we're designing-nature positive."



"I want people to see that sustainability can be business-minded and engineering-led, but that we can broaden our success criteria to create new and better outcomes."

The next generation

At a recent Women in STEM event, a Year 9 student pulled out her phone to show him a photograph of a wildlife bridge in the United States.

"She said, 'This is what I want to design when I'm older.' I told her we already have those in Australia, and her eyes lit up."

For Lunty, this was another source of optimism. The next generation cares about safety, cost and constructability. But they also expect infrastructure to restore habitats, strengthen communities and leave places better than they found them.

Perhaps that's what seeing the forest for the trees really means. The better we understand the value of each tree, the better decisions we make about the forest. □

IMAGE: Asanka Brendon Ratnayake.



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Find a way, or build a way



"[My father] taught the power of engineering and showed me how engineers are the hidden heroes of the planet."

Her nanosensors can detect a single molecule hidden among a million. They may one day tell us when to get out of the sun, whether we have diabetes, or detect cancer. For Professor Noushin Nasiri MIEAust, nanotechnology was always the future. Now, she says, it's the present.

As told to Joe Ennis

Life, for me, is governed by one question: "What if?" It was planted in my mind by my father, an engineer himself, who grew up on a farm in northern Iran. He worked in a hybrid field between environmental and agricultural engineering, a discipline that doesn't quite exist here in Australia.

He never sat me down and said, "Noushin, you are going to be an engineer." That was never how he operated. What he did instead was refuse to let me accept the world at face value.

I was in grade four when he posed the question that broke me for two weeks. He told me there was a seven-hour time difference between Iran and Canada, where my uncle was studying. And then he said: "Why would anyone buy an airline ticket and spend 18 hours travelling? Why not just hire a helicopter, rise above the earth, hold still while the planet spins beneath you, and land in Canada in seven hours?" He was completely serious. He even offered a business proposition – we could sell the farm and open a helicopter company.

Of course I had no answer. I was nine years old.

But he didn't let it go. Eventually, he taught me about the atmosphere and how you can't cheat physics. The lesson was the push to think. I can still remember how much I wrestled with it.

He is the reason I see the world as a series of unsolved problems waiting for someone curious enough to ask, "Why?"

Engineers' creed

When I finally decided, in my second year of high school, that engineering was my path, the decision crystallised around something my father used to say. He would look at a problem – something broken on the farm, something that wasn't working – and he would say, "I either find a way, or I build a way." That's what engineers do.

He taught me the power of engineering and showed me how engineers are the hidden heroes of the planet. In an operating room, the outcome is in the hands of the surgeon. But without engineers, he would say, the whole world collapses in a matter of minutes. The monitors, the instruments, the building itself. All of it is engineering.

The biology class that finally closed the door on medicine probably helped too. My school presented us with a live frog dissection. I grew up on a farm – we always had animals, injured ones rescued from the paddocks, wild ones living alongside each other in unlikely peace – and I couldn't reconcile what I was being asked to do with what I believed. I decided that day I was going to fix things instead. And engineering was how I was going to do that.

IMAGE: Ross Coffey.

LEFT: Nanotechnology found Noushin Nasiri "almost by accident".

I did my undergraduate and Master's degrees in materials engineering at the University of Tehran, one of the top-ranked universities in the region. I went to work for engineering companies after graduating – one installing electron microscopes at universities, another building extraction systems for oil wells. Both were genuinely exciting.

I came to realise I'm driven by discovery. I need new problems. The same solution applied again and again, no matter how elegantly, is not something I can sustain. That recognition sent me back to academia and a PhD scholarship.

True to form, my father helped me choose among offers from universities in Australia, Canada and Switzerland. At the time, the Australian National University (ANU) was ranked 16th in the world, which made choosing Australia an easy decision.

Nanotechnology found me almost by accident. I had seen the word on the cover of a magazine at a careers consultancy back in Tehran – "The future is nano" – but no Iranian university was teaching it yet. When I arrived at ANU and spent those first exploratory months going between laboratories, seeing what people were actually doing at atomic and molecular scales, it clicked. Here was materials engineering taken to its logical extreme: If you can control matter at the level of individual atoms, you can design structures to do precisely what you need them to do.

My PhD project became a UV nanosensor – the foundational work behind what we now call the SunWatch. Australia has one of the highest rates of skin cancer in the world, and more than 90 per cent of it is caused by overexposure to UV. The problem isn't that Australians don't know sunscreen >



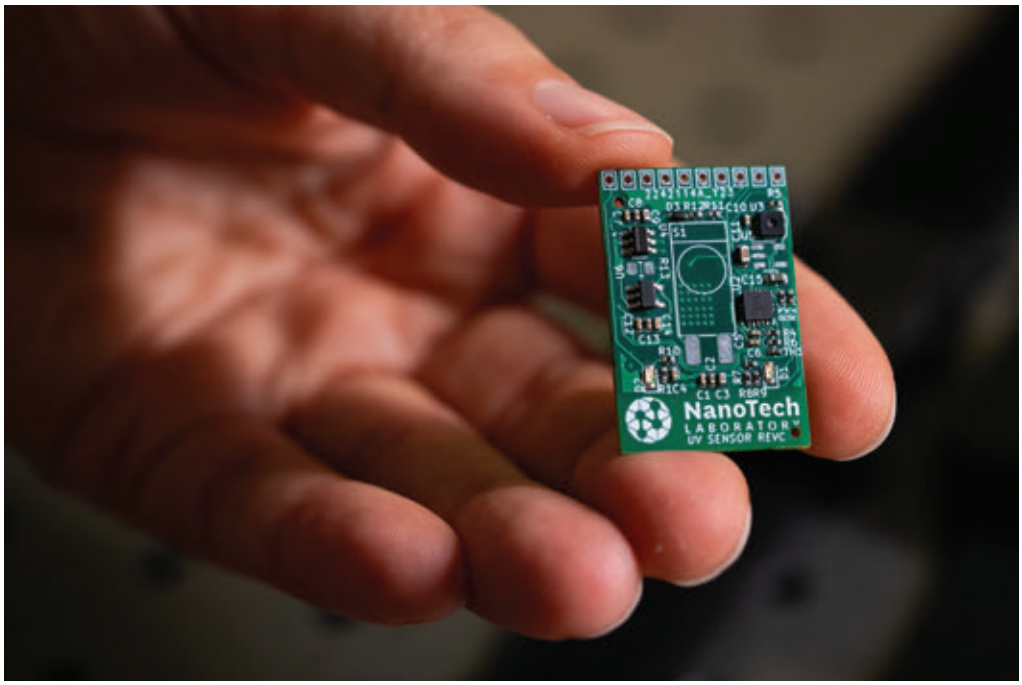
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"A chemical engineer, an electronics engineer, a materials engineer – all of them can operate from a nano perspective."

exists. The problem is that the damage happens silently, over time, and we have no feedback loop. You don't feel UV. The redness of sunburn can take more than 12 hours to appear after overexposure.

A sensor small enough to wear, sensitive enough to measure UV index in real time, and smart enough to give personalised advice based on your skin type – that felt like something worth devoting years to.

ABOVE: Nasiri's SunWatch prototype.

Eureka Prize

My lab is called the NanoTech Lab at Macquarie University, and the work that brought us the most recognition – winning the 2025 Eureka Prize, which some call the Oscar of Australian science – grew from a simple realisation about nanoparticles and vinegar.

The challenge with nanosensors is connectivity. A sensing film is made of billions of individual nanoparticles. Each one interacts with a target molecule.

But if those particles aren't talking to each other – if they're not electrically connected – the signal from each individual interaction never reaches the electrode. You're losing billions of data points.

Traditionally, we joined the particles by putting them in a high-temperature oven: enough to make them melt slightly at the edges and fuse together without losing their nanoscale size. It worked, but it was energy-intensive, time-consuming and hard to scale. We started looking for alternatives and landed on acetic acid, diluted so far that it was safer than kitchen vinegar.

We discovered that zinc oxide, the sensing material we were using, has a slight solubility in acetic acid. Fifteen minutes of vapour exposure dissolved just enough of the particle edges to create conductive bridges between them without collapsing the structure.

I remember the moment we thought the water in the acetic acid solution might be doing the work. My student and I ran to the kitchen in the engineering building, held the sensor over a boiling kettle and waited.

Nothing.

It wasn't the water. It was the acid. And once we understood that, the fine-tuning followed. The result was a 128,000-fold improvement in sensor performance. That improvement matters because sensitivity is everything in this field. We now detect acetone in human breath at one part per million – one molecule hidden among a million others. That's the concentration differential that separates a healthy person from someone with uncontrolled diabetes.



Developed from Professor Nasiri's PhD research into UV nanosensors, the SunWatch is a wearable device that measures real-time UV exposure and alerts the wearer based on their skin type. Sixty prototypes have been trialled with community volunteers. A commercial partner is being sought.

Nano is now

There is a tendency in public conversation to talk about nanotechnology as something that is futuristic; it's coming soon. I want to correct that. It's already here, embedded in things you use every day without knowing it.

The tyres on high-performance vehicles contain carbon nanoparticles that make them stronger and more efficient. The quantum dot displays on premium televisions use nanoscale particles to generate colour >

more precisely than LEDs. Paints incorporating titanium dioxide nanoparticles can interact with and capture pollutants on building surfaces, so that when it rains, those pollutants wash away. Decarbonisation, urban heat, air quality – nanotechnology has a role in all of it.

What makes this field genuinely extraordinary is its breadth. A chemical, electronics or materials engineer can operate from a nano perspective. That multidisciplinary character means the applications are effectively unlimited. Our laboratory works simultaneously on UV sensing for skin cancer prevention, breath analysis for disease monitoring, gas sensors for agricultural applications including pregnancy detection in cattle, and environmental monitoring inside beehives. The thread connecting all of it is the same: nanoscale materials with engineered surfaces, sensitive to the specific molecules we want to find.

The SunWatch is already at prototype stage with 60 units built. It's currently being trialled with community volunteers and tested in real sunlight as part of a Cancer Institute NSW fellowship.

But it also has huge potential to integrate into existing wearable technology designs. One of my students is investigating how to embed the sensor into sunglasses so that UV monitoring becomes effortless, the battery hidden in the frame. If a manufacturer wanted to add this capability to a smartwatch, they would need only to integrate the sensor — everything else they already have.

Gender visibility

When Engineers Australia named me Sydney Professional Engineer of the Year in 2025, I said in my interview for that award something I genuinely believe: engineering is being diluted inside STEM.

We are good at encouraging young women into biology, chemistry and medicine. But not nearly as good for engineering. And I think I understand why, because I've lived both sides of it.

Growing up in Iran, I never once felt engineering was unusual for a girl. My cohort at the University of Tehran was 17 women out of 57 students in materials engineering. Chemical engineering was 70 per cent female. The toys my brother and I bought from the same shop came in boxes showing hands, not boys or girls. We watched the same television programs about how things work and how to fix them.

When I arrived in Australia for my PhD, I assumed the gender gap would be smaller in a Western country. Instead, I walked into a tutorial and the girls had disappeared. A class of 400 engineering students at Macquarie today will contain 30 women.

The difference, I've come to believe, begins much earlier than university. When a three-year-old's birthday present is selected based on whether the child is a boy or girl, something is already being decided. When the school timetable includes science but never engineering, a door is being quietly closed. We ask why girls don't choose engineering at 18, but we never look back far enough for the answer.

As Global Chair of IEEE Women in Nanotechnology, and in every classroom I teach, I carry this belief: you cannot be what you cannot see. The Eureka Prize, the Engineers Australia recognition – these matter to me primarily because they let me walk into a room and be visible as a successful engineer who is also a woman. That matters for the students watching.

If I could change one thing, I would put engineering into every primary school in Australia. Not robotics as a novelty. Not coding as a standalone subject. But the genuine practice of identifying a problem, forming a hypothesis and finding or building a way through it. That is the mindset my father gave me at the kitchen table in rural Iran. It belongs in every classroom in this country.

Find a way or build a way. My father was right. That is what engineers do – and we need every curious mind we can find to keep doing it. □



BELOW: Nasiri "never once" felt that engineering was unusual for her.

IMAGE: Ross Coffey.

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Microplastics, major problems

Words by Dr Kala Senathirajah FIEAust CPEng

With mounting evidence that micro and nanoplastics have breached biological barriers, the engineering profession must pivot towards a precautionary, science-led approach to material transparency and regulatory standards.

The history of engineering is, in many ways, the history of materials. From the Bronze Age to the Information Age, our ability to manipulate matter has defined human progress.

The 20th century belonged to synthetic polymers. These long-chain polymers are now globally ubiquitous and integrated into almost every facet of modern society: infrastructure, telecommunications, agriculture and health care.[1]

But as we advance through the 21st century, we are discovering that our reliance on these materials has created an unforeseen and pervasive biological challenge.

Recent scientific evidence suggests a startling reality: the human body has become a repository for plastic waste. Humans are ingesting microplastics every single day through various exposure pathways, including water, food and air.[2] For engineers, this represents an urgent call to action.

Balancing the undeniable utility of synthetic polymers with the growing body of evidence regarding risks to human and ecosystem health is perhaps one of the most pressing engineering challenges of our time.[3] While the impacts of macro-plastics – large, visible debris – are well-documented, the behaviour of microscopic and nanoscopic plastics within biological systems requires significantly more research and engineering-led assessment.

The challenge is no longer simply detecting microplastics. Increasingly, it is about how institutions, regulators, industry and engineers respond under conditions of evolving evidence and uncertainty. Monitoring capability is advancing rapidly, and decision-making capability must evolve alongside it.



ABOVE: Dr Kala Senathirajah FIEAust CPEng, Engineers Australia.

I have previously provided evidence regarding plastic pollution to the House of Representatives Standing Committee,[4] included in the final report *Drowning in Waste*, released in May 2024.[4,5] Furthermore, I have explicitly called for life-cycle controls via international forums such as the Intergovernmental Negotiating Committee on Plastics Pollution.[6] The challenge facing engineers is not choosing between plastics and progress. It is ensuring that future progress is designed with a fuller understanding of risk.

Reproductive presence

The risk profile of micro and nanoplastics (MNPs) is more complex than simple ingestion and excretion.

Detection studies continue to expand, animal studies provide evidence of potential biological effects, and questions regarding causation and long-term human health outcomes remain areas of active research.[17] While causal relationships with disease outcomes remain under investigation and uncertainties remain regarding exposure, dose-response relationships, and long-term health



effects, there is enough evidence to warrant precautionary action, source reduction and continued investigations.[17] There is a critical need to investigate the transfer of toxic compounds released either from the plastic itself or from pollutants that the plastic has concentrated from the surrounding environment. These microscopic particles can act as vectors for pathogenic species, creating a multifaceted threat to human health.

Nowhere is this threat more visible than in reproductive health. Emerging evidence indicates a widespread presence of MNPs within human reproductive systems, with sightings in placental tissue, ovarian follicular fluid and reproductive organs reported at recent international conferences.[7,13-19]

Mechanistic studies have shown that these particles interact directly with mitochondria and endoplasmic reticulum structures, even causing the deformation of intracellular components in placental tissue.

Observational studies have identified correlations between higher MNP burdens in the placenta and reduced fetal growth metrics, such as smaller head circumference and an elevated risk of prematurity. In males, MNP presence has been detected in testes and reproductive fluids, with animal models demonstrating impaired spermatogenesis.

Cardiovascular and endocrine

The heart and vascular systems are also on the front lines. International research has recently detected microplastic particles within arterial plaque, reporting an association between the presence of microplastics in plaque and an increased incidence of cardiovascular events, including myocardial infarction and stroke.[8]

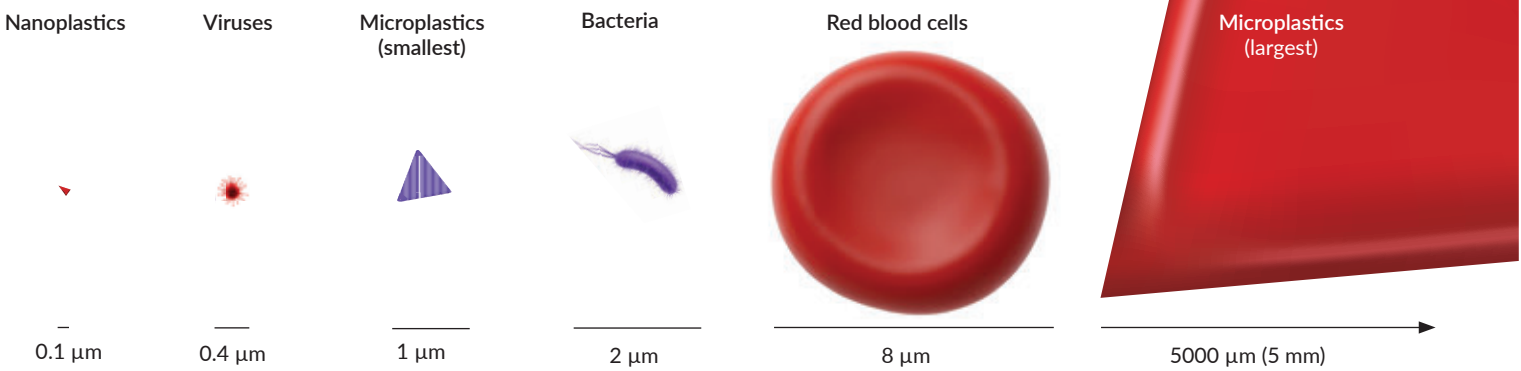
Although causality has not yet been established, these findings reinforce the need for continued research and precautionary risk assessment.

The ability of these particles to cross biological barriers suggests they can distribute systemically throughout the body, challenging previous assumptions regarding biological compartmentalisation.

Microplastics should not be viewed solely as particles. They represent a combination of physical particles, associated chemicals and biological interactions whose cumulative impacts are still being investigated. >

Microplastics to scale

Nanoplastics can be as small as 0.001 µm – the size of a few atoms – while microplastics can range from 1-5000 µm.



Beyond physical particles, chemical additives pose a major threat. Many polymers contain additives such as plasticisers and flame retardants that exhibit endocrine-disrupting properties.[9] With more than 16,000 chemicals currently used in plastics – many without full toxicological profiling – the engineering profession must advocate for a risk-based, life-cycle approach to avoid regrettable substitution.[10]

This shifts the discussion beyond waste management alone. Long-term risk reduction may depend as much on influencing material selection, product design and supply chains as on managing particles and plastic associated chemicals after release. [16] Product stewardship, source control, monitoring and treatment all have important roles to play.

Medical device safety

For engineers working in the biomedical sector, the findings are particularly pertinent.

Stents, catheters and other implantable materials represent a direct exposure pathway. These materials may cause foreign-body-associated infections or degrade and shed micro-fragments over time. Engineers Australia recommends engineering-led reviews of polymer-based medical devices to assess chemical interactions, shedding risks and the feasibility of safer alternatives.

Recommendations

The response required cannot be undertaken by any single organisation or profession. It requires collaboration across the full life-cycle of the plastic value chain, from material selection and product design through to use, recovery and end-of-life management. However, engineers are uniquely positioned to influence outcomes through the systems they design, the materials they specify and the standards they help shape. Engineers Australia has therefore proposed six recommendations that can strengthen prevention, transparency, monitoring and informed decision-making.[20]

FOCUS AREA	RECOMMENDATION HIGHLIGHTS
Prevention and stewardship	Promote product stewardship, material transparency and source reduction approaches that prevent microplastic generation before release into the environment.
Regulation and disclosure	Apply the precautionary principle at all stages. Strengthen regulation for additives and monomers.
Standards	Work with industry to develop a national standard for consumer products to reduce emissions.[11]
Monitoring	Establish a coordinated national monitoring network and a publicly accessible database. Conduct engineering-led reviews of polymers, particularly polymeric-based medical devices.
Research and capability	Fund targeted toxicity studies and build analytical capability for particles <10 µm.
Education	Develop an evidence-based risk communication program to raise awareness.[12]

International alignment

Encouragingly, jurisdictions around the world are already moving from awareness to action. The European Union has already advanced restrictions on intentionally added microplastics and is progressing frameworks for materials transparency.[11] Adapting these elements to the Australian context would reduce regulatory ambiguity and promote industry compliance.

A national standard could set clear specifications for design, composition, shedding and durability. While standards, monitoring and treatment remain critical, international experience increasingly points towards prevention. Product stewardship, material transparency, safer-by-design approaches and source reduction are often more effective than attempting to remove contamination once it has entered environmental systems.

As we look to the future, the engineering profession must champion the precautionary principle. We must move beyond managing waste at the end of its life and start managing risk at the beginning of the design process. Through consistent standards, robust monitoring and a commitment to safer-by-design principles, we can help ensure that the materials of the future do not compromise environmental or human health.

Every era of engineering is ultimately judged by how well it balances innovation with responsibility. Plastics transformed modern society and will continue to play a role in our future. Yet the emergence of microplastics within environmental and human systems reminds us that every material carries consequences beyond its intended use.

Insights gained through my 2026 Churchill Fellowship examining leading approaches across Europe, North America and Asia demonstrate that effective responses require more than monitoring alone. They require fit-for-purpose analytical methods, transparent governance, precautionary decision-making and a commitment to prevention at source.

Engineers have faced large-scale challenges before. We have improved drinking water systems, improved air quality, strengthened chemical safety and redesigned infrastructure in response to emerging evidence. Microplastics represent the next chapter in that vein. The challenge is not to wait for complete certainty, it is to apply the best available evidence, embrace transparency and design systems capable of reducing risk while enabling innovation. Through safer-by-design approaches, better standards, robust monitoring and informed material choices, engineers can help shape a more sustainable future where technological progress, environmental and human health advance together. The question is not whether we can respond. It is whether we choose to lead.

Dr Kala Senathirajah FIEAust CPEng is the Chair of Engineers Australia's College of Environmental Engineering Board.

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[Ideas]



34
Mine closure

It's not about ending all mining, but leaving behind landforms with a self-sustaining future.

42
Floating a solution

The concept of a swimmable city involves reimagining the value of stormwater.

58
Plastic powers

Replacing plastics isn't as simple as a material swap – there's an entire system to consider.

68
More than a model

How digital twins are helping engineers ask sharper questions and make better decisions.

52
Central control

Swarm intelligence is beginning to make headway in defence, warehousing and agriculture.



Mining's second act

Australia's resources sector is racing to replace high-risk brownfields with self-sustaining landforms engineered for the future.

WORDS BY JEN WALKER

For decades, mine closure was often treated as an afterthought. Fill the hole, cap the waste, plant some vegetation and move on. The problem is that natural systems are dynamic: slopes erode, drainage lines migrate, vegetation communities change and water reshapes land over time.

But with almost 240 Australian mines projected to close by 2040, demand is growing for innovative and cost-effective mine remediation methods that mitigate environmental, social and economic risks.

In Australia, the shift is visible in both practice and regulation. For example, Queensland now requires operators to submit final landform designs linked to proposed post-mining land use, supported by modelling of long-term stability.



ABOVE: Irene Chan FIEAust CPEng, PSM.

Irene Chan FIEAust CPEng, Principal Geotechnical Engineer at PSM, stresses that closure engineering is multidisciplinary.

"The engineering design of a post-mining landform is often complex and requires input from a broad range of disciplines to address aspects such as geotechnical stability and settlements, surface water, groundwater, geochemistry,

BY THE NUMBERS

NUMBER OF AUSTRLIAN MINES PROJECTED TO CLOSE BY 2040

240

erosional stability, soil science and revegetation," she told *create*.

She notes that these technical questions are inseparable from broader design considerations, and that it is important to understand how the different elements interact in order to achieve the optimal closure design outcome that satisfies the design intent.

Landform design

The major change in mine remediation in the last decade or so has been around intent. Regulators are no longer asking whether a site looks neat at the point of closure; they are asking whether it can perform without ongoing intervention long after the operator has left, and for a myriad of proof-points starting before ground is broken.

Walter Weinig, Discipline Leader of Hydrology and Mine Closure at Stantec, described the earlier approach to mine closure as one that was often treated as the final step rather than planned for from the outset.

"Until more recently, the idea of mine closure was very much 'the last person out locks the gate'," he said. "In some cases, particularly historically and among smaller operators, sites ceased operating without a clearly defined long-term closure strategy. Responsibility for the land could then revert to the Crown or the state, depending on the original tenure, leaving a legacy of unresolved issues.



ABOVE: Walter Weinig, Stantec.

"But it's been really nice to see in the last 10-15 years that we're being more intentional about mine closure and thinking about what that end game really is, instead of leaving that to the next people."

Weinig said post-mining land use is now part of feasibility planning and operational procedures, a shift prompted by the "recognition of the magnitude of the liabilities" as well an increasing acceptance that more planning up front makes a significant difference to costs at the back end.

Natural lessons

Geomorphic landform design starts from a simple premise: no natural slope is perfectly static, so a successful post-mining landform should not be designed as if it will never change.

Weinig believes there has been a lot of progress in geomorphic landform design and models in the last five years, using them to guide activities during operations to help reshape the landscape to blend into the surroundings.

"It doesn't necessarily restore the exact shape as it was before mining, but it blends in, and we use the natural landforms and natural areas as good analogues because they're stable, so maybe we can make this stable also – learning from what nature is giving us."

A key consideration is what is meant by the term "stable". >

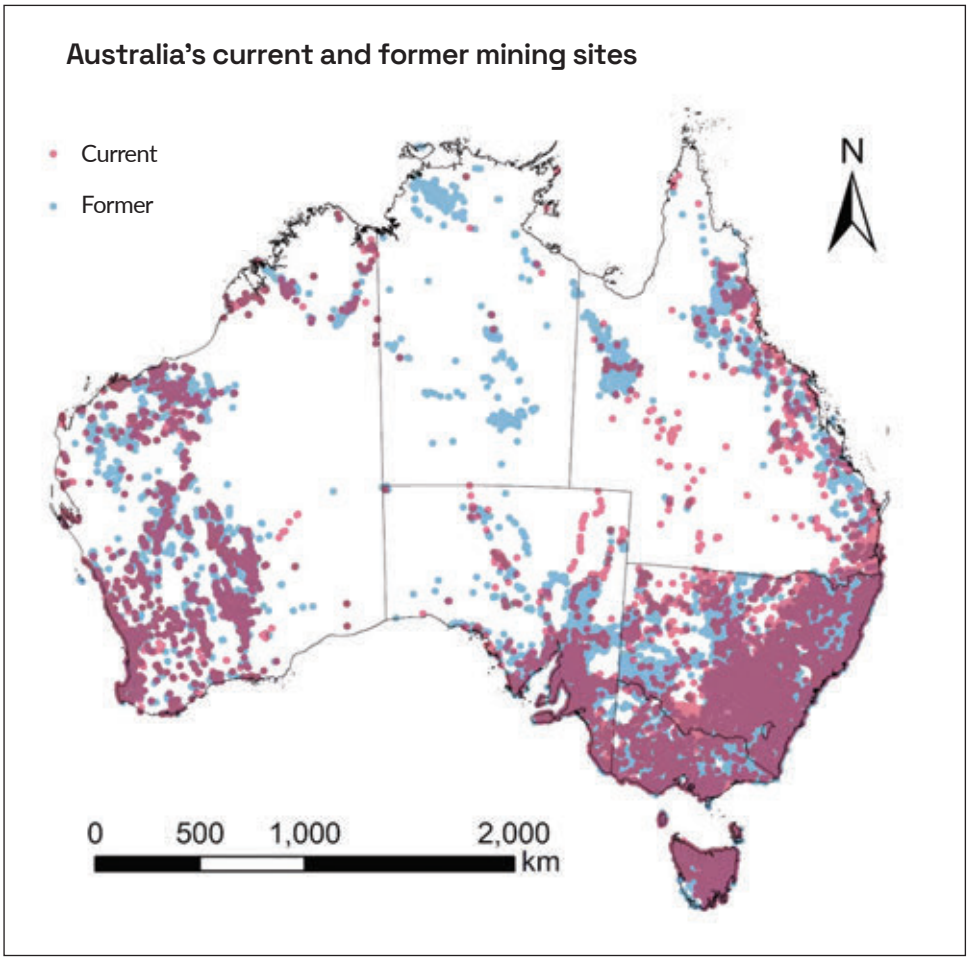


IMAGE: Mohan Yellishetty and Peter Marcus Bach, CC BY 4.0, creativecommons.org/licenses/by/4.0.





LEFT: Capping and spillway landforms.

"In a strict geomorphic sense, no natural slope is truly static," Chan said. "All landscapes evolve over time as they respond to weathering, erosion, vegetation changes and gravity processes. Even undisturbed natural slopes undergo gradual change over time.

"For this reason, geomorphic landform design is not about creating a landform that never changes, but to create a landform that can evolve in a manner similar to the surrounding natural landscape."

She said that, in practical terms, geomorphic design tries to replicate the geometry, drainage patterns and surface processes of natural catchments so the landform responds to rainfall and runoff in a way that is consistent with the surrounding environment.

"Although soil and rock properties are important, water is usually the dominant control on long-term performance, both with respect to erosional impacts and the potential influences on slope pore pressures. Rainfall intensity, runoff concentration, catchment hydrology, groundwater conditions and vegetation establishment are often the key factors that determine whether a landform remains resilient over time."

"Geomorphic landform design is not about creating a landform that never changes, but to create a landform that can evolve in a manner similar to the surrounding natural landscape."

Weinig reaches the same conclusion, saying that "a lot of the hurdles revolve around water", especially where climate change adds uncertainty to extreme events, water quality and downstream impacts.

Overall, the practical challenge is that closure design must respond to local materials and climate rather than force a standard template onto every site.





ABOVE: Harley Lacy, Mine Closure Management Services; Craig Francis, Genex.

Negative legacies

Mine Closure Management Services' Harley Lacy said most mine landforms lack integration with the natural ecosystem and landscape they inhabit, and impact as negative legacies.

"If some of the current landform design practices continue, many of these landforms will be prone to failure, bringing ongoing problems for the resources industry. In parallel, social outrage against mining will continue unabated as society will rightly feel vindicated in calling for greater regulation."

IMAGE: Genex.

It would be ideal to have zero impact, but Weinig said it is more realistic to think about what that post-mining land use is going to be and work towards that.

"It's not necessarily restoration of the land to exactly as it was, but to what may be a beneficial use in the future, recognising the impacts that the mine is potentially going to have."

Lacy believes that in Australia's arid lands and marginal farmlands, we rarely see a use for final voids because there is no human population at a scale to attract the capital required for conversion, so they remain brownfields and, in many cases, abandoned.

However, one remote project has become the poster child for repurposing mine sites.

Genex's Kidston Pumped Storage Hydro Project in Northern Queensland was a world-first when the former gold mine was transformed into a natural energy hub. CEO Craig Francis described Kidston as a case where an old gold mine's liabilities became the basis of a new industrial asset providing sustainable energy generation and storage.

"There were two giant open pits," he said. "One was about 300 m deep and full of water already, and the other one was shallower and surrounded by revegetated waste rock dumps. They were very close to each other, which meant that you could have short waterways connecting, so it's lower-cost there."

Just as important, he said, was the inherited infrastructure: "There was construction power supply, a dedicated water supply, accommodations for workers, an airstrip – it ticked a lot of boxes in that regard."

The concept of the scheme is to construct a dam on top of the shallower pit using existing waste rock dumps for the upper reservoir and connect this to the deeper pit as the lower reservoir >

IMAGE: Phibion.

Ground-breaking innovations



ABOVE: Dr Guy Boggs, CRC TiME.

Algal biomass to address contaminated mine site water

Research by CSIRO and CRC TiME has discovered that various micro and macro algae found in mine waters can remove pollutants and sequester carbon dioxide. Algal biomass could also be used to suppress dust and improve plant growth as a fertiliser and biostimulant.

Dr Guy Boggs, CEO of CRC TiME, said water treatment and management of acid mine drainage remains a significant hurdle to successful transitioning to next land uses.

"If industry can capitalise on new technologies like algae and algal biomass to improve water conditions, this could help both risk reduction and value creation – key factors in transforming regions after mining."



RIGHT: Acid mine drainage.

Tailings dewatering

The MudMaster – Phibion's patented twin-screw amphibious machine – operates directly on soft tailings, mechanically removing interstitial water and increasing material strength. While improving density and shear strength, it also accelerates water recovery without the need for filtration or chemical treatment by leaving it on the surface to be pumped away and reused.

Phibion said these outcomes support safer storage, smaller footprints and preparation of land for life after mining.



BELOW, TOP RIGHT: Phibion's MudMaster machine.



Electrokinetic dewatering

Electrokinetic dewatering involves direct current voltage using two or more electrodes. Water flows towards the negatively charged electrode, the cathode, separating it from the sludge.

Although the technology is not new, its usefulness in mine tailings has been limited due to issues such as rapid corrosion of the anode, difficulties with collecting the water flowing to the cathode and loss of contact with the electrodes as the tailings dry.

Recently, forming conductive polymers into tubular wells around which a filter cloth is wrapped has solved the problem of water collection, and contact is improved with a greater surface area of the polymer electrodes. The lack of exposed metal also negated the corrosion issue.

Various research projects are underway to see how electro-osmosis dewatering can be used to enhance the strength of the tailings and support mine closure and reclamation processes.

via an underground power station and waterways.

The significant difference in water levels of the two reservoirs enables the generation of power when water flows from the higher pit to the lower pit via underground turbines and generators.

The system then operates in reverse to store water (or energy) by pumping from the lower reservoir to the upper reservoir in times of low electricity demand.

The project also combines solar (a 50 MW solar farm has been operating at the site since 2017) and wind energy with a battery energy storage system to optimise dispatchable power supply.

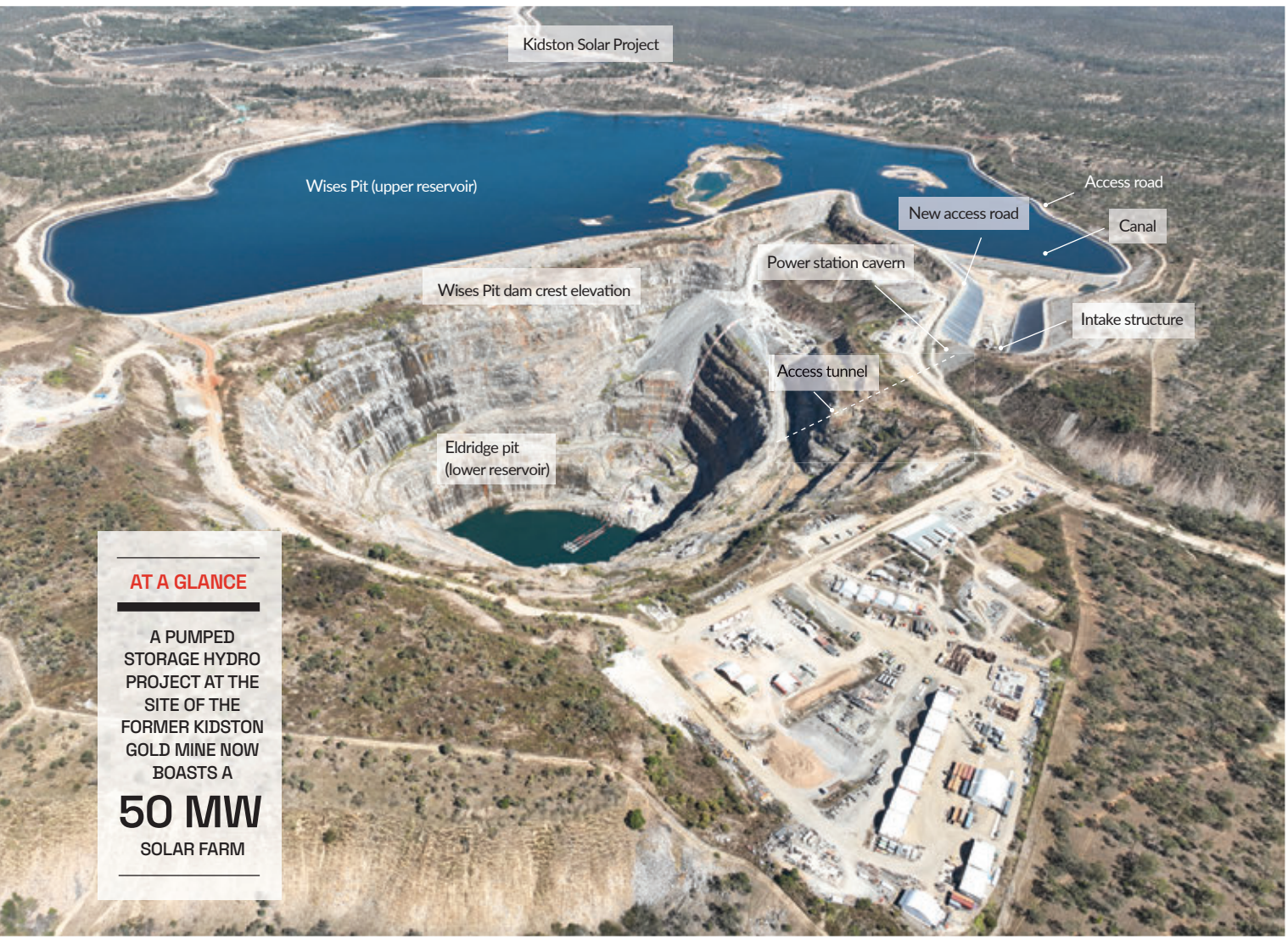
"The tailings area had already been capped, it was flat, elevated, so there's no shading from any trees, and it was homogeneous material too, because of the rehabilitation," Francis said. "That made it suitable for a 50 MW solar farm.

"We bought the mine having been rehabilitated, with the long-term obligations to essentially retain water run-off within the site. We are in the process of moving into a different legislative regime, away from mining legislation to contaminated lands because >

BELOW:
An aerial view of the Kidston remediation.



Genex's flagship project



AT A GLANCE

A PUMPED STORAGE HYDRO PROJECT AT THE SITE OF THE FORMER KIDSTON GOLD MINE NOW BOASTS A

50 MW

SOLAR FARM

IMAGE: Genex.



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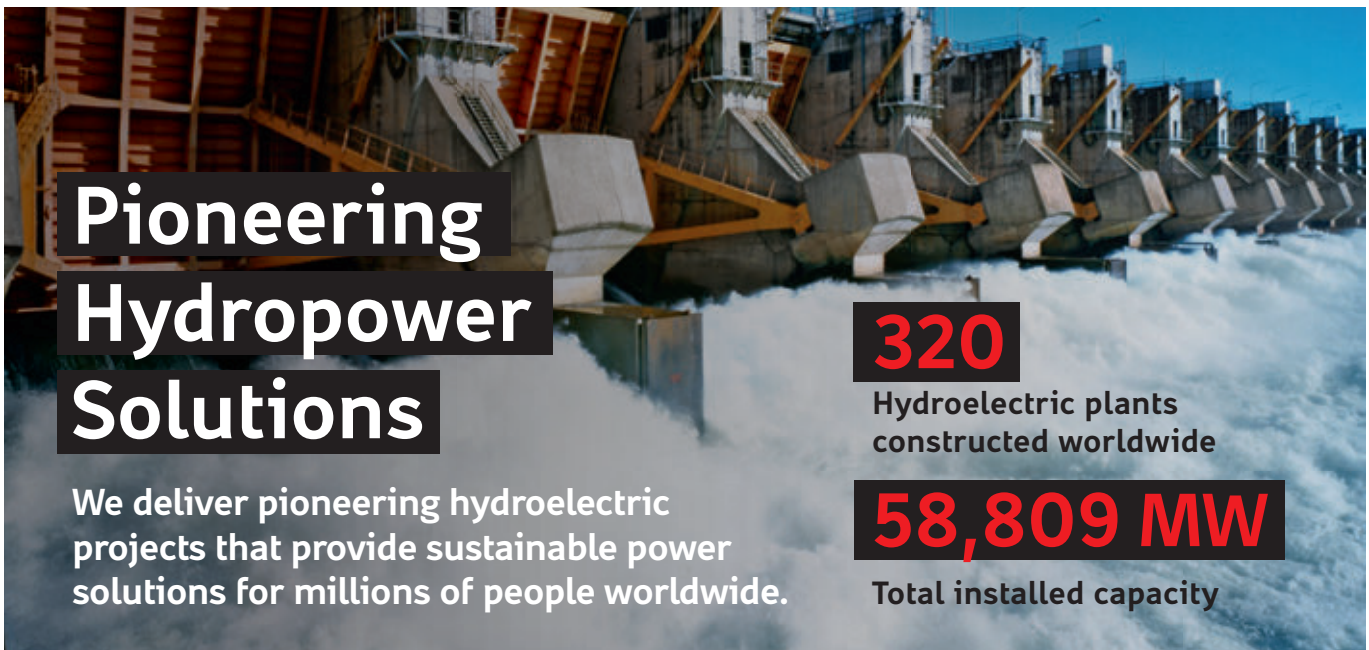
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of the long-term use with the pumped storage hydro project.

"Given the long-term industrial use, and that the water is being retained onsite centrally, we think it's an appropriate juncture to do that."

Accelerating closure

Mine closure still depends heavily on earthworks, water management and vegetation establishment, but technology is changing the speed at which those tasks can be completed and verified.

Lacy noted that over the last couple of decades, geomorphic restoration/geomorphic landform design tools, such as GeoFluv, and landform erosion models such as SIBERIA, have been proven as the most likely pathways to engineer and construct mine landforms to leave a positive legacy.

In a study of coalfields in the Hunter Valley by the University of Newcastle, GeoFluv design using SIBERIA modelling reduced erosion by half while being able to store 7 per cent more mine waste volume than contour banks. Additionally, the gullying pattern was predicted by the landscape evolution model, and 77 per cent of the eroded material was predicted to be deposited within the first-order subcatchments, significantly further reducing sediment yield.

GeoFluv is a design tool that recreates the drainage patterns and slopes of stable natural landscapes adjoining the potential remediation site, so it can perform more like mature terrain over the long term and promote the growth of flora and fauna.

It involves measuring slope gradients, channel dimensions and catchment forms, with the data fed into 3D design software to generate a network of ridges, valleys, swales and stream channels scaled to the site's conditions and variable flows.

The final digital surface can be tested for cut-and-fill balance and then uploaded to GPS-guided earthmoving equipment for construction.

Meeting standards

If there is a single phrase that defines modern closure, it is the regulator's expectation that the post-mining landscape be safe, stable and sustainable. But proving that is not straightforward.

Chan said the requirements are evolving and many of the state regulatory policies have been updated within the past five years, including creation of specific mine closure bodies, such as the Queensland Mine Rehabilitation Commissioner.

"Often in regulatory policy there is reference to the post-mining landscape being safe, stable and sustainable," she said.

"While guidance on interpretation of this requirement does exist, it is still often subject to interpretation and alignment between a mine and the regulatory body depending on what is feasible for a particular site considering its unique conditions. This highlights the importance of establishing acceptability criteria for different aspects at the outset of mine closure planning.

"This is complicated by the fact that each site is unique and there isn't a tick-box list of requirements to allow relinquishment of a mining lease upon closure – and

> "It's not necessarily restoration of the land to exactly as it was, but to what may be a beneficial use in the future, recognising the impacts that the mine is potentially going to have."



RIGHT: The remediated La Plata mine in Mexico.







RIGHT: The Jabiluka mine site in 2006, 2015 and 2022.

IMAGES: Google Earth.



the outcome requirements, monitoring approaches and establishing a proof of performance are all subject to interactions with the applicable state regulator."

Australia's standards are still largely state-based, but several interviewees describe clear progress. Weinig said parts of Australia are now "as good as anywhere else around the globe" in how proactively they think about post-mining land use and closure metrics.

Lacy is more cautious, arguing that standards have improved, but commercial pressures, fragmented bonding regimes and inconsistent enforcement still create gaps between best practice and what actually gets built.

However, he noted regulators are pointing the way. In 2021 the NSW Resources Regulator published a guide "identifying and adopting geomorphic design principles to achieve a natural and stable landform outcome".

Creating environments

The broader lesson is that mine closure is not separate from mine design. It is an extension of it, and a long-term extension at that. Rather than being about whether the environment is acceptable at handover, engineers are being asked to use natural analogues as design references to create environments that are likely to keep functioning for centuries as climate, runoff and ecological communities change.

The most advanced Australian closure projects are not trying to erase mining. They are trying to leave behind landforms with a credible future – self-sustaining, lower-risk and increasingly capable of supporting new ecological and social value. □

Legislation as the driving force

Mine remediation in the 21st century has evolved from fill-and-cap to a more holistic approach. This evolution has been driven by evolving state and federal laws that have transformed Australian mine remediation from a cosmetic afterthought into a legally enforceable obligation.

- 2000 (QLD Environmental Oversight): Shifted environmental regulation to independent EPAs, ending discretionary internal approvals.
- 2012 (WA Mining Rehabilitation Fund): Introduced a pooled, industry-funded levy to address historically abandoned legacy sites.
- 2018 (QLD PRCP Framework): Legally mandated final landform designs tied directly to approved post-mining land uses.
- 2021 (NSW Lease Conditions): Codified geomorphic design principles, establishing guidelines to achieve natural, stable landform outcomes.
- 2026 (Federal NEPA): Created a centralised national regulator enforcing uniform environmental standards and multi-million-dollar non-compliance penalties.





A city worth swimming in

As Australia rethinks its relationship with urban rivers, engineers are no longer simply stopping pollution from entering waterways. They're redesigning entire catchments so cities become healthier, cooler and ultimately swimmable.

WORDS BY CHRIS SHEEDY



During last year's European summer, Charity Mosienyane MIEAust, Regen Melbourne's Lead Convenor of the Swimmable Birrarung project, cooled off by swimming with locals in Denmark's Copenhagen Harbour, taking a dip in Rotterdam's Nieuwe Maas River in the Netherlands, and diving into the Seine in the centre of Paris.

Several years ago, each of these experiences was unthinkable, such was the condition of the water in each location. But having focused on engineering swimmability back into their cities, each has discovered entirely new benefits for their people as well as their natural and economic ecosystems.

The same engineer-led discussions are now being had in Sydney and Melbourne. If the Seine is now swimmable, why not the Nepean/Hawkesbury, Parramatta, Georges and Yarra (Birrarung) rivers?

Tracking river pollution

A study by Arup, a signatory to the global Swimmable Cities movement, found a number of contributors to pollution in the Yarra River which limit swimmability. It begins far upstream from Melbourne, where fertiliser chemicals and manure wash into the river.

As the river flows closer to the city, more faecal matter from domestic and native animals washes in during rainstorms. Some rural treated wastewater and emergency overflows also enter the system. Household septic tank discharges and industrial contaminants pollute the water and, more significantly, urban stormwater runoff adds to the problem.

Each year, said Celeste Morgan, Arup's Integrated Water Management Lead, the equivalent of 76 Melbourne Cricket Grounds filled with polluted urban stormwater enters the river.

Much of the problem comes during the first 30 minutes of a rainstorm. Slowing or preventing stormwater runoff is vital for quality of river water, said Matt Gijselman, Principal of Public Square Advisory and a member of the Western Sydney Rivers Taskforce.

Gijselman described "first flush" stormwater as a far greater challenge than wastewater and industrial outflows, both of which can be managed at a central point.

As rain washes across roads, roofs, car parks and footpaths, it collects *E. coli*, oil, heavy metals from vehicle brakes, pesticides, fertilisers, plastics and other litter, carrying it all into rivers.

Melbourne Water said more than 90 per cent of litter that washes up on Port Phillip Bay >

BY THE NUMBERS

VOLUME OF POLLUTED URBAN STORMWATER ENTERING THE YARRA RIVER EACH YEAR IS EQUAL TO

76

MELBOURNE CRICKET GROUNDS FILLED TO THE BRIM

beaches comes from stormwater, some of it dropped more than 10 km away.

Engineers have plenty in their toolkits to negate the effects of storm surge run-off, including utilising natural systems alongside river systems, said Tony Wong, Professor of Sustainable Development at Monash University and former CEO of the CRC for Water Sensitive Cities.

One example of what is more broadly known as water-sensitive urban design is the utilisation of sports fields and golf courses alongside or near rivers. Water-sensitive collaboration would result in a design for the fields to intentionally flood during storm events, similar to the way wetlands do. They would be engineered to hold and filter water, rather than dumping it as quickly as possible into the river.

"Wetlands throughout our cities act as kidneys do in a body," Wong said. "They ensure water is cleaned before it gets to the river, which is a very long-term gain."

Engineers need to have more conversations about the natural environment as part of the infrastructure, Mosienyane said.

"When people talk about capital works, they're typically thinking about concrete or stormwater pipes," she said. "They're not thinking about the marshes and the potential natural filtration systems.

"These things are often not assigned funding or recognised as essential infrastructure. However, they are often even more efficient than what we can build, because it's the system working how it is meant to work."







ABOVE: Charity Mosienyane MIEAust, Swimmable Birrarung; Celeste Morgan, Arup; Matt Gijselman, Public Square Advisory.

Sponge cities

Morgan said engineers already have all the solutions they require at their disposal.

"We just need to deliver them more purposefully and at scale. It's about water-sensitive design elements like rain gardens within the street, which capture and filter run-off before it enters the river."

"One focus is stormwater harvesting, avoiding the large amounts of urban runoff in the first place, keeping rain where it falls rather than rushing into the drainage system and bringing everything with it."

Morgan discussed the idea of "sponge cities" that are naturally designed to slow down the rush of water during a storm. Houses

Engineering the world's cool swim spots

SOAKING UP THE SEINE

In Paris, creating a swimmable Seine involved the construction of a massive piece of infrastructure at enormous cost: a $2.3 billion underground stormwater and wastewater storage and treatment system equivalent in volume to 20 Olympic swimming pools.

By intercepting storm flows, it prevents untreated wastewater from flowing into the Seine.



RIGHT: East River, New York City.

BELOW LEFT: The Seine is now swimmable.

FAR RIGHT: A vision for a swimmable Rotterdam.



LAPS IN NEW YORK'S EAST RIVER

Planned for delivery and testing this year, with a public launch in 2027, the +POOL is four pools in one. There's a kids' pool, one for sports such as water polo, one for relaxation and one for swimming laps.

Delivered by Arup, it's a floating, self-filtering pool. Instead of chemical treatment of the water, the patented walls of the pool will draw river water through a layered membrane filtration system that removes all contaminants. The system, driven by pumps and hydraulic gradients, will filter more than two million litres of water per day.



REJUVENATING AN INDUSTRIAL HARBOUR

Making Rotterdam's Nieuwe Mass River swimmable was more about redesigning an industrial harbour precinct than fixing the water in the river itself. Engineers delivered floating pontoons and floating parks as well as a continuous, real-time water quality monitoring system, driving further investment and engagement in river health and stormwater management.

IMAGES: + POOL rendering designed by Family New York & Playlab, Inc. Image Family New York; The Outdoor Swimming Society.

BY THE NUMBERS

SUNSHINE COAST FLOATING WETLANDS IN A STORM-WATER POND ACHIEVE

81%

REMOVAL OF TOTAL SUSPENDED SOLIDS AND

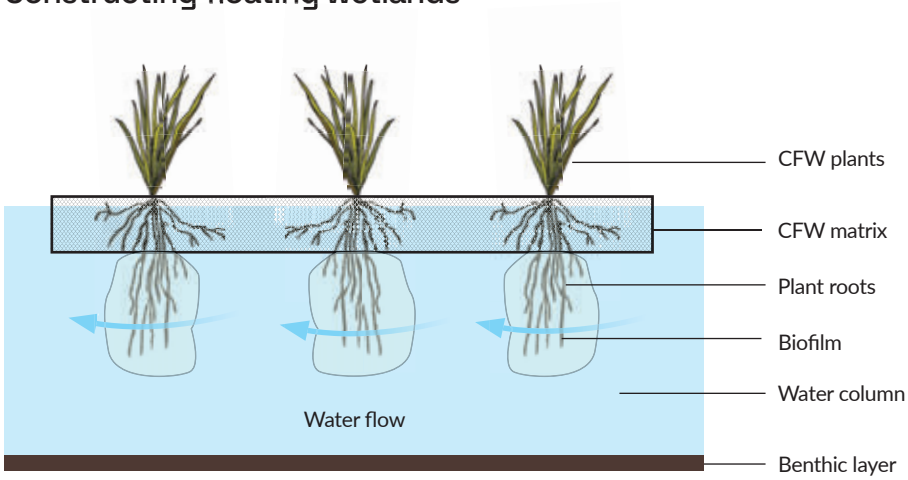
52%

REMOVAL OF TOTAL PHOSPHORUS

BUT WERE LESS EFFECTIVE AT REMOVING NITROGEN AT

17%

Constructing floating wetlands



might have smart rainwater tanks, for example, with sensors that know when a storm is coming, emptying themselves gradually before the rain arrives, then capturing the mass of the downpour and holding it.

"Once the water is in our drainage system underground, we've lost most of the opportunity," she said.

In sponge cities, tree planters on city streets should have stormwater funnelled into them, where it can be filtered through the soil. Such natural systems can even be bumped out intentionally into streets, to double as a traffic-calming device.

"Buildings are prime for green roofs, to absorb rainwater, filtering it into a tank that householders can use to flush their toilets or water the garden," Morgan said.

Floating wetlands are another, lesser ingredient in the recipe for swimmability success. According to a 2017 study at the University of the Sunshine Coast, constructed floating wetlands in a stormwater pond, as opposed to a river, achieved 81 per cent removal of total suspended solids and 52 per cent removal of total phosphorus. Floating gardens were less effective in removing nitrogen, at 17 per cent.

"Buildings are prime for green roofs, to absorb rainwater, filtering it into a tank that householders can use to flush their toilets or water the garden."

Simpler fixes

Then there are more basic solutions that can have an oversized effect, Gijselman said.



ABOVE: Tony Wong, Monash University.

BELOW: Sydney Water stormwater management.



IMAGE: Sydney Water.

"Sydney Water pulled out 200 m^3 of litter in one year via a single gross pollutant trap in Marrickville," he said. "We can do digital twins and all the high-end things, but the direct engagement engineering approach of something like a gross pollutant trap can get you a long way."

In fact, Sydney Water manages more than 80 gross pollutant traps, also known as stormwater quality improvement devices (SQIDs), that catch litter and sediment more than five millimetres in width. The SQIDs collectively remove more than 1200 m^3 of sediment and litter that would otherwise enter waterways, meaning other systems further downstream, such as treatment plants or wetlands, can work more efficiently.

Wetlands are typically designed into three zones. First is a sediment basin known as the inlet zone, that further removes coarse sediment.

Next is a shallower, densely planted area known as a macrophyte zone, which takes out finer particles larger than 125 µm, or 125 millionths of a metre. Slimy biofilms that naturally occur on the surface of aquatic plants absorb dissolved pollutants, and >



the slowing and settling of water in this zone also enables UV disinfection of the water.

Finally, a high-flow bypass channel is typically built in, to allow excess water to flow around the wetland, preventing overflow damage.

Such engineered wetlands, according to Melbourne Water, can remove 95 per cent of sediment down to 125 µm for a one-year annual recurrence interval rain or flood event.

Divided responsibility

The issue of non-point pollution, or pollution that enters rivers via diverse entry points, is a challenging one for other reasons, said Dr Therese Flapper CPEng.

Flapper, an ex-President of Engineers Australia's Canberra division, a consultant at TG Factor and a tutor and guest lecturer at ANU, said the real problem is that while water treatment plant discharge is highly engineered, scientifically monitored and tightly regulated, run-off after the first 30 minutes of a rainstorm is not. The challenge of non-point pollution comes down to governance and regulation.



ABOVE:
A Sydney wetland.

TOP:
An artist's vision for making the Yarra swimmer-friendly.

"With non-point sources, you've got everyone from the person walking their dog, the householder, the local council, the catchment management authorities, Sydney Water, Sydney Catchment Authority and WaterNSW," she explained. "Nobody is fully responsible or accountable."

The solution will come from both social science and engineering. Modern wastewater treatment plants provide chemical and biological protection at the point of treatment, but cleaning up a river is about cleaning up its entire catchment.

"In a way, engineering solutions are easy. We've been able to remove pollutants from

IMAGE: Studio Octopi; Sydney Water.

water for a long time and make it swimmable and drinkable. It's the rest of it that's a challenge."

Technological systems will play a leading role in the management and maintenance of urban waterways.

"We can now implement a range of sensors that, through an AI-driven analysis approach, offers real-time outcomes and information not just to water managers but also to the public," Gijselman said. "People can use an app to find out if it's safe to swim."

Such technology doesn't just democratise access to the water. It also helps water managers learn where the pollution is coming from and therefore what might be done about it.

"It increases engagement with the river and also the quality of the decisions made around the river."

Natural inconsistency

However, it's important to accept that a focus on cleaning an entire river, from top to bottom, is potentially misguided, Mosienyane said.

"As humans, we tend to want things very homogeneous. So in a river, we want swimming-pool clarity and cleanliness from the surface to the riverbed along the entire length," she said.

"But nature is inconsistent, dynamic and constantly changing. The Yarra River is 242 km long and travels through alpine, rural, agricultural and urban environments, and its quality naturally changes along that route.



ABOVE: Dr Therese Flapper CPEng, TG Factor.

"Throughout much of the city of Melbourne, and up as high as Dights Falls, the bottom level of the Yarra is saline water. There's essentially a salt wedge below the surface. Salt water, or saline water, has a better disinfection process than fresh water."

"Our focus at Swimmable Birrarung is deliberately at the city end, the last 20 km of the river, not just because of the way water flows but also because of the way money flows, because of how we govern, and because that section of the river alone travels through eight local government areas that all have different strategies and teams and priorities."

As long ago as 2016, a proposal was put forward for the construction of a swimming pool in the Yarra, in central Melbourne.

"In the Yarra, you find that the top level of the river is stormwater or fresh water," Wong said. "However, throughout much of the city of Melbourne and up as high as Dights Falls, the bottom level of the Yarra is saline water.

"There's essentially a salt wedge below the surface. Salt water, or saline water, has a better disinfection process than fresh water."

The Yarra Pool concept was developed by Professor David McCarthy, at Monash University at the time, who proved an idea around cutting into that salt wedge, then pumping saline water upwards.

The proposal involved a floating marine infrastructure that kept the top edge of the pool just above the waterline. An outlet port and relatively simple pump system at the surface level would remove water from the pool's interior, drawing saline water in via an inlet below the pool's floor. Sensors in the pool would enable constant, real-time monitoring of water quality.

McCarthy's testing of the system indicated concentrations of *E. coli* and *enterococci* were reduced by more than 92 per cent in the pool, as compared to the surrounding river water.

From four different locations in the Yarra where the pool >

The Yarra Pool concept

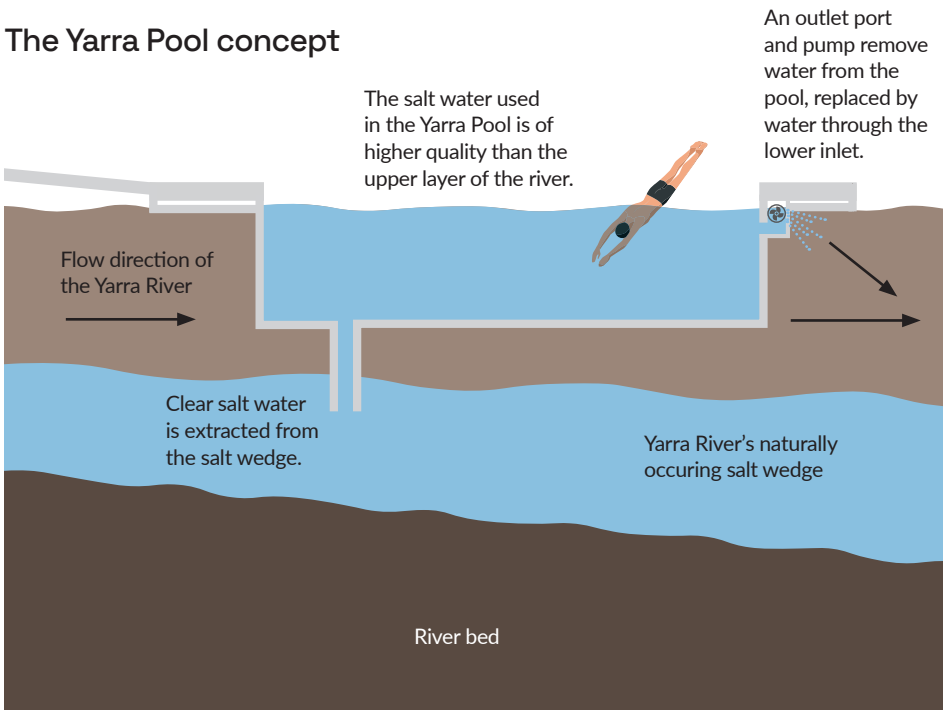


ILLUSTRATION: Adapted from Yarra Swim Co.

concept was tested, three resulted in swimming-quality water. This meant the water was significantly cleaner than most Port Philip Bay beaches.

It was a brilliantly simple engineered solution, but was a workaround rather than a fix of the root causes of the pollution problem.

Its benefit, Wong said, would be in the engagement of Melburnians in the concept of a swimmable city.

That engagement is causing waves across Europe, where former ports and industrial areas of major cities are discovering a new, refreshed purpose as high-end residential and leisure areas centring around urban beaches and pools.

In Paris, the solution required billions of dollars for the construction of a massive wastewater and stormwater storage and treatment system. In Australian cities, it needn't be that dramatic. Engineers know the fix. >



ABOVE: Professor David McCarthy, Monash University.

BELOW: Charity Mosienyane, Regen Melbourne.



Making the Yarra (Birrarung) swimmable again

Water quality aspects influencing swimmability

Pathogens
E. coli and *enterococci* mainly come from faecal contamination from animals, including pets, wild animals and farm livestock, but can also come from waste-water overflow.

Nutrients
Nitrates and phosphates wash into the river from fertilisers, soils and animal waste, while treated waste-water from rural treatment plants can increase nutrient loads. High nutrient levels cause algal growth, which can harm aquatic life and make people sick.

Sediments
The Yarra's brown colour is due to clay soils. Although this isn't harmful, it makes the water look muddy and reduces clarity for swimmers. In some areas, sediments can contain heavy metals, chemicals and microbials that can pose health risks.

Tidal flows
In the CBD section of the Yarra, twice-daily tides push and pull water back and forth, diluting pollution. However, tidal flows also create dangerous currents.

For Melbourne, the journey towards swimmability requires a rethink of how to absorb, reuse and filter the rain that falls on the city.





BY THE NUMBERS

2 million
PEOPLE CALL THE YARRA CATCHMENT HOME

29%
OF THE TIME IT IS UNSAFE FOR SWIMMING*

21%
OF THE CATCHMENT IS URBAN, BUT IT GENERATES

58%
OF NUTRIENTS IN THE RIVER

*Tested in Kew, Melbourne

ILLUSTRATION: Sourced from Arup.

More than swimming

The concept of a swimmable city involves more than a population's change in its perception of its relationship with a river or harbour. It should also lead to a reimagining of the value of stormwater, Mosienyane said.

"We start diverting stormwater to new wetlands after we get more funding for natural biofiltration of the run-off," she said. "But can we also start changing our guidelines and policies so when we build massive roads and railway tracks, we have a percentage of funding going towards making sure we're reducing stormwater run-off into urban waterways?

"I say this because stormwater is so valuable. Yes, it's water that has fallen onto greasy roads, but it's still water. So how do we change that relationship and revalue it as water?"

Can run-off be diverted, then used for watering urban gardens, or for play, or to cool parts of cities? Part of the solution will involve a better understanding of the water along the entire length of the river.

"We don't have enough accessible water-quality data points along the river to understand its overall health."

Part of Mosienyane's work is to find out what data is out there, to see what's available and what it tells us.

"Are parts of the river swimmable right now? They could be. But we must remember that swimmability is just a door opener – it's not the end of the line. Engineering with nature unlocks so much opportunity. It has economic, social, cultural and ecological benefits. It's not just for itself." □



ABOVE: Research is underway on gathering river health data in Melbourne.

Melbourne's Action Plan

Regen Melbourne's Swimmable Birrarung program outlines a pathway to swimmability success.

1 Get swimming

Where swimming is currently safe, promote greater engagement with local communities through efforts such as the proposed Yarra Pool. The more people see and experience it, the more they will engage with the idea.

2 Measure and keep watch

Gather robust, real-time water data around river health and swimmability to inform plans and interventions. This data is likely now available, but fragmented. The Swimmable Birrarung program has a funded research project focusing on bringing this data together.

3 Clean up the river

After developing a better idea of the health and biodiversity of the river, accelerate innovation around stormwater and run-off management, including engineered intervention such as gross pollutant traps, wetlands and rain gardens.

4 Connect hearts and minds

A swimmable Yarra will never be the responsibility of one organisation or body. Success, particularly around the storm surge run-off challenge, will be found through the collective efforts of the entire city.

5 Unlock capital

Develop greater investment in the long-term health of the river by understanding the mechanisms, markets and funds required to achieve swimmability, and educating those markets around economic benefits of a swimmable city.

6 Work with a living river

Focus on the development of policy, legal, political and governance systems that work in partnership with a living, healthy, swimmable river.

7 Return to nature

Develop a balance between ecological and human needs by protecting the river's natural systems and respecting the fact that some sections will not be swimmable every day.



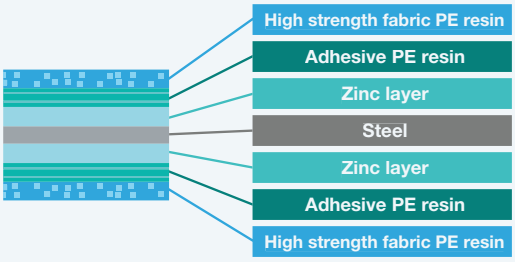


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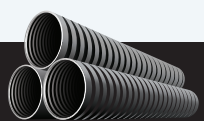
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All for one

In nature, swarm intelligence is the result of many actors that produce a collective intent greater than any individual part. Can distributed decision-making show robotics engineers how to work with nature rather than against it?

WORDS BY JONATHAN BRADLEY



The brain of an ant weighs 0.1 mg, with about 250,000 neurons packed into that space. It's not a lot – a honey bee or cockroach brain packs four times the computational power – and, accordingly, individual ants are not the most sophisticated of thinkers.

Colonies of ants, however, can overcome their species' intellectual shortfall to perform ingenious acts of problem-solving and coordination. They do this with no form of central control. There are no formic engineers or project directors sketching blueprints or designing CAD drawings for the colony to follow.

"Ant colonies work through a network of very simple local interactions; most ants can't see and they operate by smell," is how Stanford University's Professor Deborah Gordon explained the process in a podcast produced by the university. "An ant colony is like a [human] brain in that there's no central control. So just as no neuron tells the other neurons what to do, so no ant tells the other ants what to do."

Traditionally, robotics has followed neither the path of human nor ant intelligence. Roboticists program systems to adhere to centralised controls and carefully coordinated interactions.

Roboticist and computer systems engineer Dr Kirstin Hagelskjaer Petersen, however, prefers to draw her ideas from termites – along with other swarms in the natural world, such as bees and social amoebae. Sometimes, she admits, she and her Cornell University team will watch nature documentaries for inspiration, wondering what might happen if they applied a wondrous biological technique to their own field.



ABOVE: Dr Kirstin Hagelskjaer Petersen, Cornell University.

Swarm robotics, the often biologically inspired effort to harness collective intelligence in artificial systems, is the focus of Petersen's research. She draws a distinction between her efforts to produce advanced autonomy in groups of independent robots and the more commonly found instances of multi-agent systems, consisting of centrally controlled robotic teams acting in parallel.

"When we say swarm robotics, it has a very different feel," she said. "We're talking about emergent complexity. They're all locally interacting, so you can't predict exactly what will emerge. Instead, you rely on statistical guarantees about a swarm's behaviour. The benefit is that the system is far more versatile."

> "You can cover larger spaces. You can manipulate things that you wouldn't be able to do with just a single point of contact. And if you're smart about the way you write your algorithms, it's much more scalable."



That adaptability is part of the appeal of swarm robotics. Another is cost: one expensive robot is useless if it breaks, but it matters less if a swarm loses a few of its many machines.

"To support deployment of many robots, every single one has to be cheaper and less capable, but on the bright side, you have a tonne of redundancy," Petersen said. "You have graceful degradation. You can adapt to circumstances, cover larger spaces and manipulate things that you wouldn't be able to do with just a single point of contact. If you're smart about the way you write your algorithms, it's much more scalable."

Robots that do less

In their purest form, the machines produced by swarm roboticists look markedly different to traditional robots. Petersen's most recent research involves a system she calls a "cross-link collective", which comprises dozens of 200 mm winged modules consisting of little more than a motor, some sensors and a printed circuit board.

The modules form one of just two shapes: an I or a U. Alone, each is useless, but operating together – weak Velcro patches at the end of each wing allow them to connect and disconnect from one another – the robots form a mass that moves around obstacles like a fluid.

"Normally in modular robotic systems. or any robotic system, you carefully engineer everything," Petersen said. "You decide how everything is fitted together, where the sensors and actuators go, and what signals flow between them.

"Here, we throw a bunch of these robots out there, and they continuously self-organise into reasonably functional units."

Each module performs just one motion, inspired by the Purcell swimmer, a physics model describing locomotion at microscopic scales.

"These chains form which are inherently optimised for speed and low torque, so they use very little energy. These properties emerged on their own because >



we gave up one of engineering's most fundamental disciplines: designing exactly how everything fits together.

"The result is a powerful example of embodied intelligence: complex behaviour emerging not from sophisticated software but from the physical interaction of many simple components."

Watching Petersen's cross-link collective navigate a maze is an awe-inspiring and unsettling experience – the individual modules look both alive and unnatural, helpless and determined – but they don't seem to have any immediate practical application.

Petersen sees swarm robotics as an exercise in engineering minimalism: finding the simplest combination of robots, behaviours and interactions that can accomplish a task.

"Yes, termites achieve more as a colony, but each individual termite is already an extraordinarily capable system," she said. "Similarly, we can always build out our systems with more computation and control. The question is how much we can achieve before we need to."

Robotic agriculture

There are domains in which swarm robotics is beginning to find headway, Petersen said, pointing to war, entertainment and warehouses. She also highlights the potential for swarm robotics to be deployed in agriculture as a way of addressing labour shortages.

"That's an obvious place where robotics can contribute. There are excellent researchers and engineers in agricultural robotics in Australia."

Queensland-based company SwarmFarm is at the forefront of this effort. Tom Holcombe, the company's portfolio manager for Western Australia, said the company aims not to automate current processes, but to use technology to grow better crops.

"We use smaller, lighter, more precise machines going slower through the paddock, if we have to, to ultimately make the best decision for what's required on the ground," he said. "If it has to come down to making a decision on a plant-by-plant basis, then we can potentially do that."

Rather than spraying an entire field, one of the robots deployed might be used to target pesticides at a precise location, for instance, or to pull out a specific weed.

"Eventually we'll use multiple smaller, lighter-weight machines to be able to achieve what we're doing currently with one big machine," Holcombe said.

The actual level of autonomy delivered by SwarmFarm's technology varies. Holcombe notes that some farmers want greater control than others. And while they might trust a robot fleet to spray pesticide in the correct location, then return to restock with more chemicals before going back to the field, major events such as seeding could require more oversight.

"I think it comes back to who you ask and what they're trying to achieve with autonomy," he said. "Ultimately, you can go and throw sensors at something, but at the same time, you've got to make sure it's reliable and make sure it actually works and can deliver the result that people are after."

Introducing that autonomy to its machines and building trust with customers is the first step SwarmFarm is taking to eventually implementing genuine distributed decision-making.

"We know that to be successful with smaller machines, a change in the farming system is required," Holcombe said.

> "Sometimes we have robots with different types of sensors and they complement each other. That's where it makes sense, because you can choose which sensor goes to which place and they can coordinate."



ABOVE: Tom Holcombe, SwarmFarm; a SwarmFarm robot in action – learn more on page 84.



Control centre

Practical application of swarm principles, then, demands a trade-off between the simplicity of each individual robot and its capacity to actually perform its desired task.

Another trade-off, according to CSIRO senior research scientist Dr Nicholas Lawrance, is in the level of centralised control an operator retains over a swarm.

"When you have a really large number of robots, it gets

very hard to have centralised control," he said. "If you only have a handful of robots, you can often just have one computer that's making all the decisions, and it acts like one robot. It just decides and then it sends them to wherever they need to go. If you've got thousands, that becomes much harder."

The compromise is to allow each robot in the swarm to have its own limited intelligence so it can make small decisions related to its immediate environment.

"They're making their own decisions, and they have to agree locally on some kind of consensus," he said. "It shares information maybe with its neighbours, and then you get the team to do what you want without a centralised controller saying, 'You do this, you do that.'"

Doing the careful work of deploying robots to gather data in complex and uncertain



ABOVE: Dr Nicholas Lawrance, CSIRO.

BELOW: An autonomous robot during CSIRO's DARPA Challenge.



environments means Lawrance is not willing to give control of his machines completely over to a decentralised swarm. Nevertheless, he understands the advantage of having a larger number of robots able to act autonomously.

"It's about having the scale to collect data in a way that you either couldn't before because it was inaccessible, or at a time rate or a spatial rate that you couldn't [before]," he said. "Sometimes we have robots with different types of sensors and they complement each other. That's where it makes sense, because you can choose which sensor goes to which place and they can coordinate."

Lawrance's robotic teams have the potential to work with marine scientists to collect data to monitor such phenomena as algal blooms. Since it's expensive to take environmental DNA samples that can detect specific species, his robots could coordinate between devices that look for areas of potential interest and more specialised machines that gather precise measurements.

The uncertainty of the environment the robotic teams are entering is a key challenge that requires surrendering some decision-making authority to the squad.

"Getting the robot out into this environment is often a significant challenge," Lawrance said. "They have limited range and some amount of autonomy, but they can't deal with every single case. So you are trying to put them in places where you know roughly what to expect."

Clemson University Professor >

IMAGE: CSIRO.

Drones down



Sydney's Vivid Festival this year planned a wondrous addition to the spectacle of lights: a thousand-strong swarm of colourful drones that would fill the sky with spectacular choreographed patterns. But after 83 of the drones unexpectedly plunged from the sky into Sydney Harbour, the remaining shows were cancelled.

This is not the first time an Australian aerial light display has ended in such disastrous fashion. A July 2023 show in Melbourne, preceding a World Cup game played by the Australian women's soccer team, saw 427 of the swarm's 500 drones fall into the Yarra River.

It's a stark example of how collective intelligence can lead to collective failure, and prompted an inquiry by the Australian Transport Safety Bureau (ATSB).

It found that excessive windspeed caused the failure, with a unique combination of human, technical and design errors at play.

Michael Dawes, who led the ATSB investigation, told *create* a number of factors were involved:

- The pilot was operating in a high-pressure environment.
- The copilot had limited experience.



- The crew did not launch a weather drone before the show to check conditions.
- While the drone software did measure windspeed, it didn't clearly communicate to the pilot that conditions were unsuitable for flying.

Since the light show failure, the manufacturer has updated the software to improve the pilot interface.

"You end up with these things building on each other," Dawes said. "We have the heightened workload that was created through a number of different things, and we have the addition of the operational pressure, and so the way those two compound one another [affects] the launch decision."



Fatemeh Afghah also uses swarm robots – in her case, drones – for disaster management, including for firefighting. She highlights communication as one of the most significant challenges when working with multiple agents.

"When the swarm lead is down for any reason – if the communication is intermittent or if the agent is physically damaged – then who's going to take over that task, or how are we going to redistribute the task between the agents?" she asked. "We can program the drones to operate independently, but the reason we have these drones on the fleet is actually to collect real-time data for the mission planner and the emergency control system.

"We don't want these drones to just collect data and save it on an SD card. We want that data to be communicated in real time to a human to have a better understanding of what's going on in the field."

The trust factor

There remains a distinct gap between pure swarm intelligence, such as Petersen's experimental cross-link collective, and the practical, on-the-ground applications being explored by engineers such as Lawrance and Afghah. Indeed, Lawrance has observed that too much autonomy can make the operators he works with nervous.

"We always assume that of course you want the most autonomy, because that's what we do and that's what we think people want," he said.

"When you talk to stakeholders, they're usually coming at it from a different angle. They're already doing some part of this job, and they want to do it better or faster. Usually, they're not interested in changing everything completely because they don't trust it yet."

Nonetheless, Afghah sees other domains where the technology can prove valuable.

"Disaster management, traffic management in urban areas, military applications," she said. "Any complex system with critical restrictions in terms of timing – swarm intelligence could be a good player there."

Petersen adds that the biomedical industry is one domain hoping to make use of swarm robots, creating microscopic devices that can be injected into the body to gather data or deliver drugs.

"It works really well because every robot is just so tiny and limited in power and sensors and compute, so you really do need a swarm to be able to do anything," she said. "It hasn't happened yet, but it's certainly an area a lot of people are working on, and it's hopefully imminent." □

"Disaster management, traffic management in urban areas, military applications. Any complex system with critical restrictions in terms of timing – swarm intelligence could be a good player there."



ABOVE: Professor Fatemeh Afghah, Clemson University.



Swarm intelligence in nature

For many species in the natural world, swarm intelligence is a deeply ingrained survival strategy that goes beyond simple herding behaviour. Operating collaboratively enables creatures to behave with a sophistication and purpose beyond any individual member of the collective.

Here are some of nature's most impressive swarm accomplishments:

FISH DEFENCE

Small fish such as sardines defend against predators by packing themselves into a tightly constructed "bait ball", which makes it difficult for individual fish to be identified and picked off. If necessary, the ball can disband, sending fish in all directions, before coming back together again.

ANT PROBLEM-SOLVING

One study, from the Weizmann Institute of Science, found that ants, working collaboratively to manoeuvre an object through a tight gap, can outperform humans under certain conditions.

HONEY BEE ARCHITECTURE

Bees can adjust the angle, size and shape of individual honeycomb components to construct a hive that adapts to constrained spaces and obstacles.

TERMITE CONSTRUCTION

Interaction between individual termites and their environment allows them to create mental maps of their mounds, allowing them to undertake repairs where needed.

SHEEP AND SHEEPDOGS

Sheep might not seem the most sophisticated of thinkers, alone or en masse, but swarm roboticists are using them as models for systems that see simple agents governed by a handful of smarter "sheepdogs".



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The plastics pivot

Recycling the rigid petrochemical polymers in dashboards, pipes and uPVC window frames remains limited, fragmented and economically challenging. Looking to solve this issue are some innovation-seeking engineers.

WORDS BY JULIA ABBONDANZA



ABOVE: Dr Kala Senathirajah FIEAust CPEng, Engineers Australia.

For Dr Kala Senathirajah FIEAust CPEng, plastics are legion. When discussing alternatives to conventional plastics, the terminology quickly becomes confusing.

"There's bioplastics, there's biodegradable, there's compostable, there's biopolymers, there's bio-derived polymers, there's bio-based plastics," she said. "Plastics can mean different things to different people, and I don't think there's any clear definition yet."

Senathirajah, who is Chair of the Engineers Australia College of Environmental Engineering, said her reaction to the prospect of structural bioplastics is one of cautious optimism.

The radical idea is engineering petrochemical polymers into redundancy, designing rigid plastics out of renewable and biodegradable feedstocks while developing enzymes that digest the plastic already in circulation.

Before any of that excites an engineer, she wants a word about language, because the ambiguity in those terms is not pedantry.

The categories carry different consequences. According to Senathirajah, some of these materials are genuinely excellent, while others merely defer the problem. A few deepen it, where the additives used to give a material its properties are themselves hazardous, or where a polymer marketed as greener fragments into microplastics earlier than the conventional plastic it replaced.

She warns that no single material should be sold as the ultimate solution.

Held against that caution, the engineering that follows reads not as a cure but as a set of uneven, fast-advancing options.

Senathirajah also distinguishes between plastics used primarily for short-lived consumer applications and those embedded in long-life engineered assets. While many packaging and convenience plastics can often tolerate some changes in material >

performance or design, plastics used in infrastructure, buildings, vehicles and industrial systems are typically specified against stringent safety, durability and performance requirements, making them significantly harder to replace.

A dashboard, a length of PVC pressure pipe or a uPVC window frame is specified against a simultaneous envelope of requirements rather than a single duty.

It has to hold its load-bearing capacity and stiffness, retain dimensional stability across its service temperature range, tolerate UV exposure and remain manufacturable at volume. A petrochemical grade arrives with decades of design data against every one of those axes, and a bio-based candidate doesn't.

Replacing these more structural plastics can't just be a material swap," Senathirajah said. "Because it's embedded into systems engineering. Some convenience applications may be redesigned, reduced or replaced through changes in product design and consumer behaviour, whereas infrastructure materials must continue to meet strict engineering specifications throughout their service life."

What that looks like in practice sits alongside a South Australian power line, in a post-and-rail fence that appears entirely unremarkable. What makes it worth a second look is what it's made from; half recycled timber, half high-density polyethylene from a kerbside recycling bin, with no metal fixings to risk arcing on the high-voltage line. It's made by APR Composites, an Adelaide manufacturer, and it points to a change that runs deeper than a single product.

> "If it wasn't a challenge, it would be too easy, and therefore we'd have a market that was already saturated."



ABOVE: Simon Modra, APR Composites.

For decades the Australian conversation about plastic has centred on the soft, visible, single-use kind, which has left the harder half of the problem almost untouched.

Five years on from the 2021 National Plastics Plan, around 84 per cent of Australia's plastic still ends up in landfill, and the figure for plastic packaging recycling sits at roughly 18-20 per cent against a 70 per cent target. Those numbers describe the plastics we can see, while the rigid and structural materials built into our cars, our homes and our infrastructure barely feature.

Simon Modra, Research Lead at APR Composites and a



research contact at the University of South Australia, frames the standards barrier bluntly.

"The first to write the standard wins," he said, pointing to AS/NZS 4766, the polyethylene standard for rotational moulding, which requires an impact test at minus 40 degrees, a benchmark that suits a tank bound for Norway, but tests his material against a cold Australia's climate will never deliver.

He doesn't dismiss the standards wholesale, since the benchmarks for an Australian house build, written around pine timber grades, strike him as a fair target. Working in an unconventional material still guarantees friction, which he reframes as the point.

"If it wasn't a challenge, it would be too easy, and therefore we'd have a market that was already saturated."

The more radical response is not to source a greener drop-in but to design the polymer from the backbone outward.

Senathirajah frames it as moving past like-for-like replacement towards specifying the architecture itself – the backbone chemistry and molecular weight distribution, tuned so the resin hits a defined mechanical profile and pathway to degradation.

Molecular designs

The engineering payoff is the avoidance of regrettable substitutions, where a regulated hazard is swapped for an unregulated analogue that shares the same liability: bisphenol flagged as an endocrine disruptor, then replaced by BPS and BPF analogues with comparable activity behind a BPA-free label, or long-chain PFAS giving way to short-chain homologues that are just as persistent.

"These regrettable substitutions can be avoided with molecular engineering, because it lets us design materials at the molecular level," she said.

It's the engineering expression of the caution she opened with, since designing a polymer deliberately is how you avoid recreating the hazard you set out to remove.

The polymer family in this context is the polyhydroxyalkanoates (PHAs), microbially synthesised polyesters that bacteria accumulate intracellularly as carbon reserves and recover by fermentation rather than petrochemical synthesis.

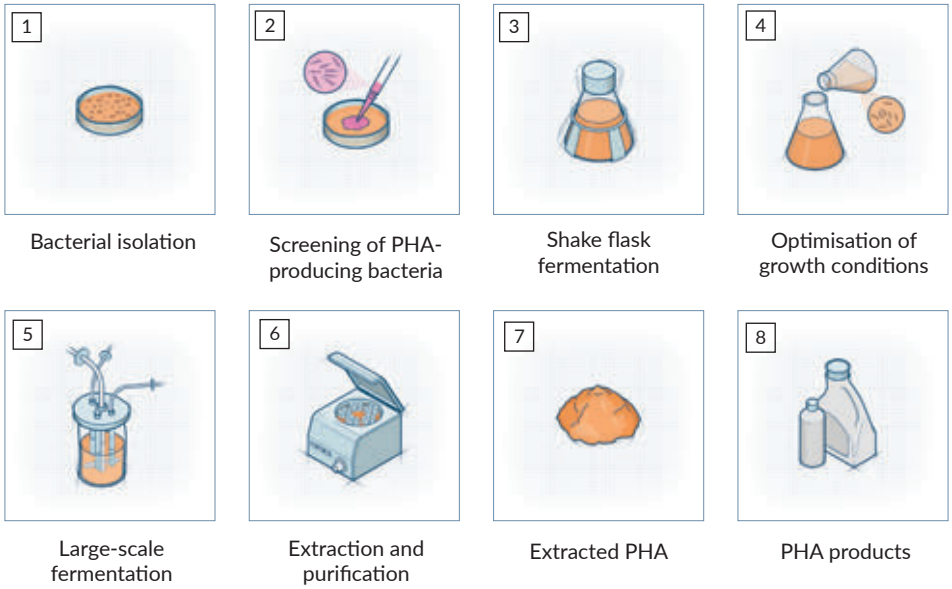
The mechanical envelope splits along chain length. Short chain-length grades, three to five carbons in the repeat unit, are highly crystalline, stiff and brittle. Medium chain-length grades run low in crystallinity with a depressed glass transition and high elongation, behaving as elastomers. That compositional control is why no single number describes a PHA, though all are biodegradable, non-toxic and water-insoluble.

The canonical-grade, poly-3-hydroxybutyrate or P3HB, sits close to commodity polypropylene on the headline numbers, with a tensile strength near 40 MPa and a Young's modulus around 3.5 GPa, yet it fails an engineer on the properties that do not make the datasheet headline.

Its elongation at break sits near 6 per cent and the brittleness is time-dependent. P3HB crystallises above 50 per cent, its glass transition sits near room temperature and low nucleation density produces large spherulites that crack between themselves – while secondary crystallisation and physical ageing over days to weeks embrittle a part that tested adequately when moulded. A narrow processing window adds chain-scission risk near the melt temperature.

Each failure mode has a lever, copolymerising with 3-hydroxyvalerate depresses melting point and crystallinity, trading tensile strength toward 20 MPa for elongation near 50 per cent; nucleating agents suppress cracking; plasticisers slow ageing; sub-150-degree annealing restores ductility. >

Polyhydroxyalkanoate production



The published range runs from under 1 MPa to roughly 190 MPa, and documented modifications have raised tensile strength by 330 per cent – so the unsolved work is process control and economics, not feasibility.

Australian effort

The clearest Australian demonstration that PHA chemistry can scale is Uluu, a Perth company that grows its polymer from farmed seaweed rather than food waste.

Red Gracilaria seaweed is hydrolysed with enzymes into sugars, which saltwater microbes ferment and store internally as PHA, harvested as white pellets. The grade is PHBV, the copolymer that tempers P3HB's brittleness. It drops into existing injection-moulding and extrusion equipment, removing the capital barrier that kills most material substitutions.



ABOVE: Michael Kingsbury and Dr Julia Reisser, Uluu.

The marine-biodegradable, microplastic-free pellets have already been prototyped with Audi and Quiksilver, and funding is moving from a 100 kg-per-year pilot to a 10 t demonstration plant.

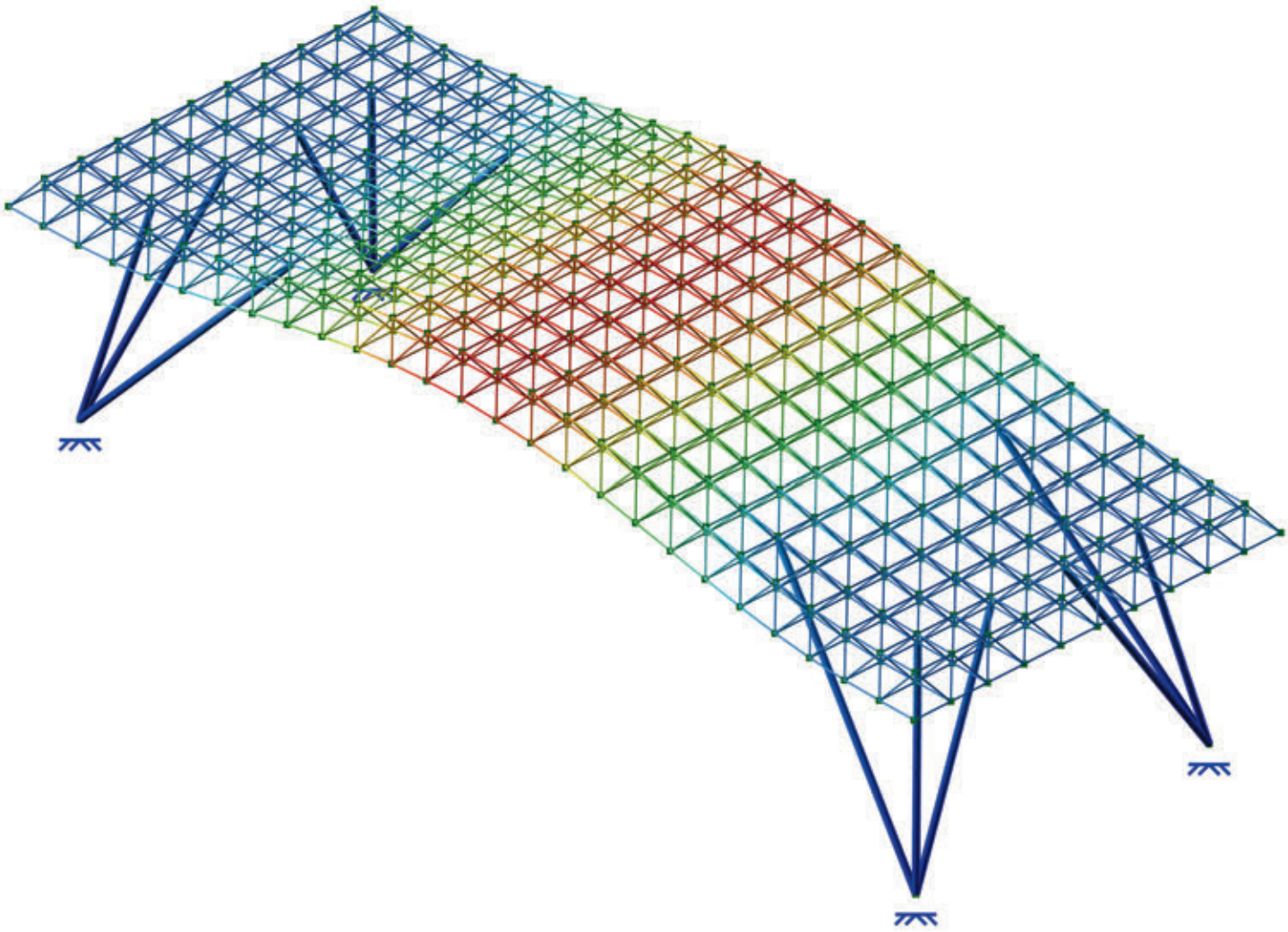
Much of the national effort to carry that capability towards production runs through the Bioplastics Innovation Hub, a collaboration between CSIRO and Murdoch University that couples microbiology, synthetic biology and biochemical engineering to advanced manufacturing, aiming to move PHA work from pilot scale to full production.

Its lead industry partnership is a co-investment with Ecopha Biotech, that has completed its R&D stage and filed several patents on PHA production, fermenting sugars and lipids recovered from food-industry waste into polymer, the upstream feedstock economics any rigid-grade product depends on.

Australia has excellent research, but it tends not to translate into application as readily as other regions, such as Europe.

"Currently we put the burden >

IMAGE: Uluu.



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on 'Prove to me that it's not safe,'" Senathirajah said. "We need to shift that mindset. The burden should be on demonstrating safety and sustainability up front, rather than managing unintended consequences after deployment."

The proof that this chemistry survives a real structural specification comes from BARBARA, a Horizon 2020 project coordinated by the Aragonese technology centre Aitiip.

It targeted engineering-grade feedstock for fused filament fabrication, extracting polysaccharide fractions from corn by-products, starch from broken corn and arabinoxylan from corn fibre, and compatibilising them with engineered polyamide and polyester resins, with reinforcing additives recovered from agro-food waste including almond shells and pomegranate.

The project produced eight qualified materials and validated them in prototypes including door handles and a dashboard fascia produced with Centro Ricerche Fiat, alongside a starch-and-polyamide matrix upscaled for a load-bearing construction mould.

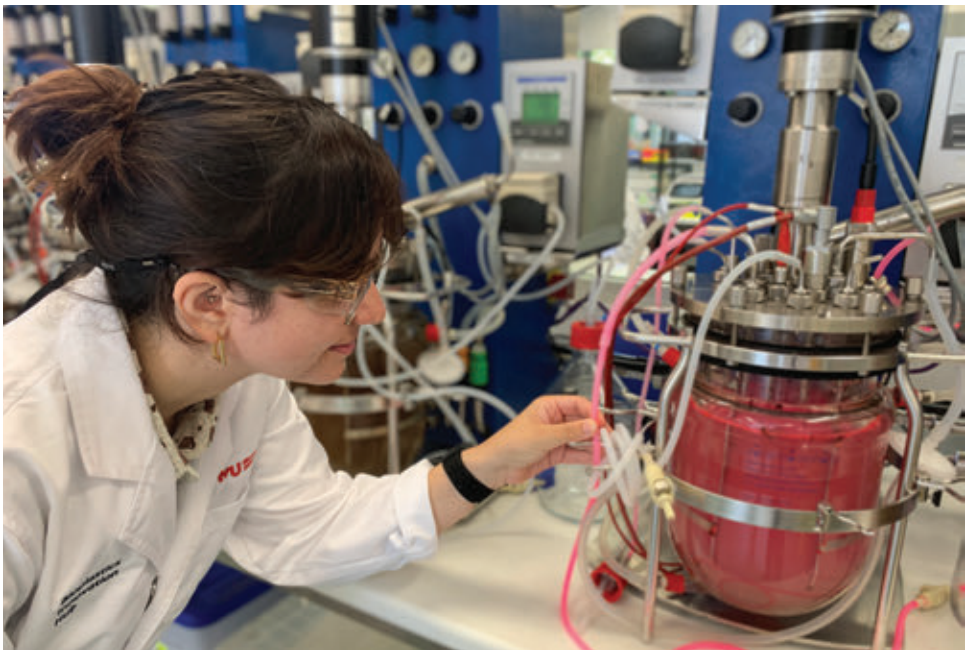
"It shows that structural bioplastics are not just a hypothetical wishlist," Senathirajah said.

While it doesn't resolve the local problems of scale and standards, it removes the open question of whether bio-based resins can meet automotive and construction performance, which lets the Australian conversation move from "whether" to "how soon".



BELOW: Bioplastics can be used in straws and packaging; bioroplastics research at CSIRO.

"Currently we put the burden on 'Prove to me that it's not safe.' We need to shift that mindset to 'Prove to me it's safe, and then I'll use it.'"



Designing new polymers is only half of the redundancy argument, since the other half is digesting the petrochemical plastic already in circulation. Engineered PET hydrolases now achieve at least 90 per cent depolymerisation in 10 hours, and a 2025 closed-loop process from the University of Portsmouth has put recycled PET at $2.19 dollars a kilogram against $2.71 for virgin – the first signal that enzymatic recycling can compete on cost.

Filling the consumer and precision-parts gap, much of it imported, is Biolastics, a Western Australian materials and design firm that distributes the Tecnaro lignin-based family, whose three grades map onto a property ladder.

Arboform, the original liquid wood, combines lignin with natural fibres and injection-moulds at 150-170 degrees with thermal stability to around 95 degrees, below the 140-degree automotive bar. Arbofill lifts impact strength and thermal resistance into ABS territory and is visually indistinguishable from petrochemical plastic.

Arboblend, the most capable, is formulated from blends that can include PHA, PLA and bio-polyamides, engineered for high impact strength, flame retardancy and full biodegradability, and its PHA content makes it the direct commercial bridge to the resin chemistry the Perth researchers are scaling.

APR Composites, meanwhile, is working on the structural edge.

Its wood-plastic composite runs roughly 50 per cent recycled high-density polyethylene against 50 per cent recycled timber, with a UV stabiliser, masterbatch and lubricant making up the balance. It performs strongly in compression, which suits retaining-wall and post-and-rail duty, and turns up in coastal and park infrastructure, in

IMAGES: CSIRO, Pixabay.

Plastic powers

A snapshot of the Australian and international players turning bio-based polymers into rigid, structural and durable materials.

Company / Hub	Primary material	Form	Target application	Progress
APR Composites (SA)	Wood-polymer composite (recycled HDPE and timber)	Solid boards	Decking, boardwalks, civil and power infrastructure	Already supplies structural and civil markets at scale.
Biolastics (WA)	Lignin (Arboform), plus Arbofill and Arboblend	Injection moulded	Furniture, technical profiles, consumer goods, precision parts	Distributes a lignin-based material family spanning consumer goods to higher-impact technical profiles.
Ecopha Biotech (WA)	Polyhydroxyalkanoates (PHA)	Rigid resins	Bottles, durable goods, food-waste-derived products	Ecopha and the CSIRO-Murdoch Hub are scaling PHA production from packaging towards durable solids.
Bioplastics Innovation Hub, CSIRO and Murdoch University (WA)	PHA resins and bio-additives	Resins	Compostable packaging, durable moulded solids	
Project BARBARA (EU)	Bio-based polyamides and polyesters with bio-reinforcement	3D-printed solids	Car dashboards, door handles, structural moulds	Project BARBARA, in Europe, has already proven the category can meet automotive and structural standards, the benchmark Australian researchers now work towards.

the dunnage that cushions the curved precast concrete segments of Melbourne's Metro Tunnel, in vehicle crossing pads over rail lines, and in the non-conductive post-and-rail systems supplied to SA Power Networks.

Modra, of APR Composites, is proud of that last product, the VAB, which carries no metal fixings and so removes the arcing and work-health-and-safety exposure metal hardware introduces. His framing of the feedstock is the sharpest line in the argument.

"Plastic is eminently recyclable. It's the waste part of plastic that's a problem, until we treat it as precious, which it is, because it's a petrochemical," he said.



ABOVE: APR Composites' products blend wood with plastic.

The trade-off in the composite is real, because adding a hydrophilic timber fibre to a hydrophobic polyolefin raises stiffness but opens a moisture-uptake pathway the neat polymer would not have.

APR's answer is a hemp-plastic composite, developed with the University of Melbourne to improve impact performance and crystallinity while making the matrix markedly more hydrophobic, with an explicit target: match MGP10 and MGP12, the machine-graded pine that frames most Australian houses. Clear that bar, Modra said, and APR has early state-government interest in mandating 20 per cent recycled content in structural components of new builds.

"The structure would be using up plastic, and that is a good thing," he said.

The path there is less a breakthrough than a grind of externally ratified weathering, span and bend testing. Automotive dashboards and electronics casings fall outside >



“Rather than seeking direct substitutes, we can design polymer structures for both function and fate from the outset. This creates a pathway to avoid regrettable substitutions of the kind seen with BPA and PFAS.”

APR's focus, and while the technology is transferable, the company is staying with architectural and water infrastructure, leaving the rigid consumer and automotive frontier to the materials that will claim it.

Part of what keeps that frontier open is economics.

APR's own costs rose by around a third on oil price volatility, a reminder that petrochemical plastic remains hostage to a market the bio-based alternatives can in principle escape, while bioplastics, still dearer today, track down a double-digit growth curve as oil extraction grows more expensive.

The two cost curves are converging, and a full substitution of fossil-based plastics would represent a market turnover of roughly 250 million tonnes a year.

With the foundational science proven and macroeconomic tides turning, the challenge now shifts from the laboratory to the unglamorous mechanics of industrial adoption.

Factors like rewriting conservative regulatory codes, generating long-term performance data and scaling production lines.

This pivot won’t happen overnight, and as Senathirajah said, it can’t be treated as a singular silver bullet.

But on the factory floors where Australia’s new material architecture is actively being developed, the future has already begun. □

THE SYSTEMIC CHALLENGES OF THE BIO-PLASTIC TRANSITION

Words by Dr Kala Senathirajah FIEAust CPEng

Australia's plastic problem is more complex than it looks.

Material selection sits at the heart of sustainability outcomes, and the shift towards bio-based plastics reflects this growing recognition. Replacing rigid petrochemical plastics with renewable alternatives can reduce lifecycle emissions, diversify feedstocks and create new regional value chains. For engineers, however, this is not a straightforward substitution. It demands a systems view that accounts for performance, durability, supply chains and end-of-life pathways.

Bio-based doesn't automatically mean biodegradable or environmentally benign. Many bio-derived polymers are designed to match conventional performance and will persist unless effectively recovered. Conversely, biodegradable and compostable materials only deliver benefits within waste systems that remain limited in Australia. Without alignment between material choice, infrastructure and standards, there is a risk of shifting impacts rather than resolving them. This challenge is most evident in structural applications. Standards and specifications remain largely built around petrochemical materials, and updating them requires broad consensus over time. Engineers and asset owners understandably favour materials with decades of performance data, because failure in these contexts carries significant consequences.

International experience reinforces that the limiting factor is rarely the material itself, but the alignment of standards, infrastructure and risk frameworks needed to support it.

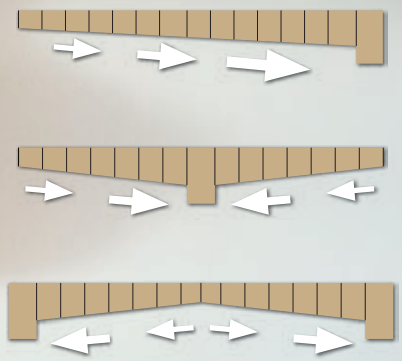
What is encouraging is the shift towards molecular engineering. Rather than seeking direct substitutes, we can design polymer structures for both function and fate from the outset. This creates a pathway to avoid regrettable substitutions of the kind seen with BPA and PFAS.

Progress will rely on aligned policy, modernised standards, trusted certification and de-risked pathways for early adopters, alongside a clearer burden of proof, where materials must demonstrate safety before widespread adoption.

The real opportunity is to treat hard plastics not simply as a waste issue, but as a design challenge. Delivering on this will require coordinated action now across standards bodies, industry and government to validate new materials, update specifications and support early deployment at scale. With that shift, we can reshape how materials are specified, validated and used across the built environment, moving towards a more circular and resilient system.







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WORDS BY GEMMA CHILTON



PICTURED: An AIMS researcher maps a Great Barrier Reef site.

IMAGE: AIMS / Ian McLeod.

On the Great Barrier Reef, change can be hard to see clearly, even when it is happening quickly. After bleaching events, cyclones or marine heatwaves, researchers need to know more than how much coral remains. They need to understand which colonies survived, where new corals are recruiting, which parts of the reef are growing and how the structure of the habitat is shifting over time.

To capture that detail, engineers are turning sections of reef into digital models. Divers, boat-towed cameras and underwater robots photograph coral from multiple angles, while scale markers fix the measurements. Software then stitches thousands of overlapping images into a 3D reconstruction.

That reconstruction shows the reef at one point in time, but a digital twin goes further. By adding new observations and connecting them with data and modelling systems, it becomes a living model that can help researchers ask what might happen next.

"The defining feature of a digital twin is its dynamic nature," said Dr Renata Ferrari, Senior Research Scientist at the Australian Institute of Marine Science (AIMS), where she leads research into coral demographics and spatial ecology.

"While traditional 3D models and maps offer only a single snapshot in time, a digital twin continuously evolves."

For many engineers, digital twins are already part of the language of infrastructure, manufacturing and the built >

environment. A digital twin of a bridge, building or machine can help monitor performance, simulate stress and test changes before they are made in the real world.

Nature is less obliging. Reefs, catchments, oceans, farms and cities are shaped by climate, weather, water, biology, genetics, land use, human behaviour and chance. They can't be fully instrumented or neatly controlled. Yet as climate pressure grows, researchers and land managers need better ways to see what is changing, update their understanding and make decisions under uncertainty.

In the Netherlands, Professor Femke Vossepoel works on the problem of bringing models and observations together in ways people can use. As Professor of Earth System Simulation at Delft University of Technology, her expertise is data assimilation: combining numerical models with observations. This is a familiar idea in weather forecasting, where models are continually updated with new data to improve predictions. The challenge now is applying that logic to other systems, from cities and farms to reefs and catchments.

"A digital twin is not just a model," Vossepoel said. "It's a tool that helps a decision-maker evaluate different criteria, run what-if scenarios and decide what to do."

A dashboard can tell users what has been measured, a map can show where change is happening, and a model can simulate how a system behaves.



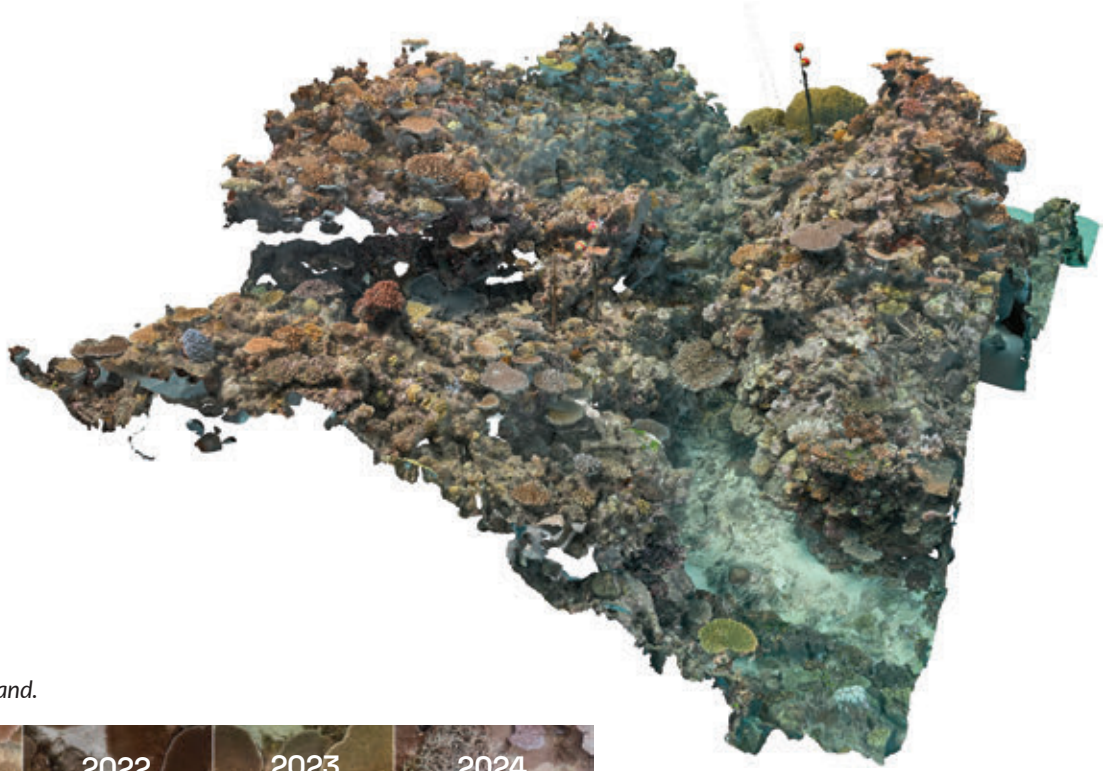
ABOVE: Dr Renata Ferrari, AIMS.

BELOW: A digital twin of the Davies Reef.

A digital twin, at its strongest, brings those functions together, combining observations and models so users can test interventions, compare risks and understand uncertainty before acting.

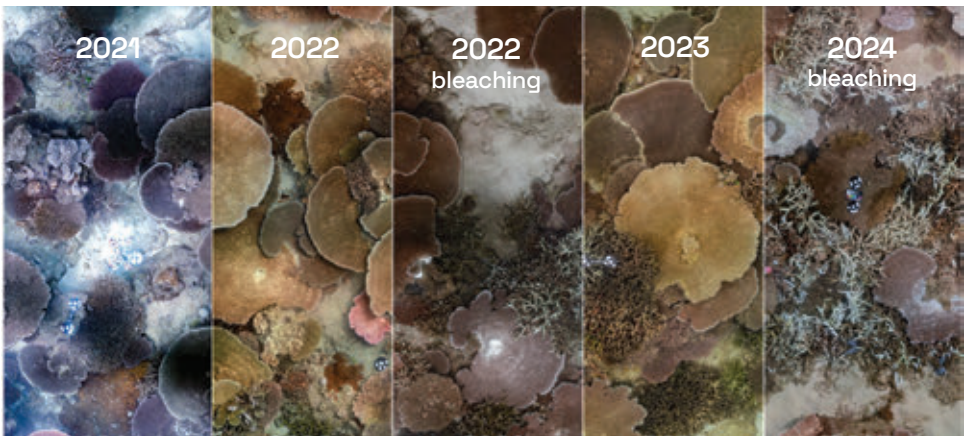
Image to intervention

At AIMS, reef digital twins are being used across restoration, monitoring and ecological research. Ferrari describes the workflow in five broad stages: data collection, processing, extraction, integration and analysis.



(Un)natural evolution

Bleaching of the reef near Orpheus Island.



"A digital twin is not just a model. It's a tool that helps a decision-maker evaluate different criteria, run what-if scenarios and decide what to do."

IMAGE: AIMS / Marine Lechene; AIMS / EcoRRAP.



IMAGE: AIMS / Marie Roman.

High-performance computing can help scale the work, but Ferrari said accessibility matters just as much as technical power. Her team focuses on off-the-shelf tools and regularly updated standard operating procedures so the methods can be adopted beyond specialist research environments.

"Global impact requires accessibility," she said.

Through the Ecological Intelligence for Reef Restoration and Adaptation Program, known as EcoRRAP, AIMS and its partners use digital twins to track coral recruitment, growth and survival across the Great Barrier Reef and Torres Strait. The aim is not simply to make reefs visible in 3D, but to turn repeated observations into evidence that can feed models, guide restoration and test where heat-tolerant corals may have the best chance of thriving.

Ferrari said the technology allows researchers to follow tens of thousands of individual corals at once. The same models can show how reef structure influences fish diversity and abundance, with insights feeding into engineered habitat design, including "fish-smart" seawalls designed to support biodiversity or attract target species.

AI is helping AIMS researchers extract useful information from the large image sets behind digital twins. RapidBenthos, an automated tool developed by AIMS, analyses reef imagery to help quantify what is living on the seafloor. AIMS has also worked with La Trobe University to test 3D Gaussian Splatting, a visualisation method that can create highly realistic reef representations.

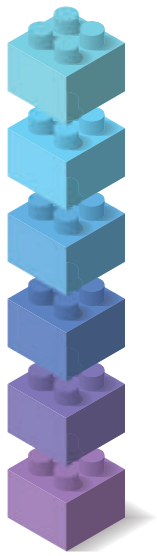
Ferrari said traditional photogrammetry remains stronger for precise measurement, while newer 3D approaches can help people see and understand the reef more easily. For digital twins, both functions matter: the system needs reliable measurements to feed models, and clear visualisations to help decision-makers understand what those models are showing.

Beyond past data

Vossepoel is currently working on UrbanAIR, a $23.6 million Horizon Europe project developing urban digital twins for air quality and heat resilience. Horizon Europe is the European Union's main research and innovation funding program, and UrbanAIR brings together 18 partners across 11 countries.

The stack behind ecosystem twins

From sensors to simulation, ecosystem digital twins rely on several layers working together.



ABOVE: Ferrari processes the imagery captured during a dive.

An ecosystem digital twin is not a single technology. It is a chain of tools and processes that turns observations into usable insight.

It starts with observation. Depending on the ecosystem, that might mean satellite imagery, drones, underwater cameras, photogrammetry, environmental sensors, field surveys, climate records or farm-level data.

Next comes processing. Raw images, sensor readings and spatial datasets need to be cleaned, quality checked, aligned and made usable. In reef work, that might mean turning thousands of overlapping underwater images into a scaled 3D reconstruction. In agriculture, it can involve combining satellite imagery with soils, weather and crop data.

Then information needs to be extracted. AI and machine learning can help classify features such as reef composition, crop type or land use. For more complex systems, extracting reliable information from 3D models remains difficult and needs careful validation.

The next step is integration. A useful twin does not simply store information. It connects observations with physical, ecological, hydrological, climate or crop models, so the system can be updated and used to explore change over time.

Simulation adds the "what if?" layer. Users might test what happens if a heatwave hits, a restoration site is chosen, a crop input changes or a land use shifts.

The final piece is the interface. This might be a map, dashboard, visualisation, virtual environment or decision tool. Its job is to make the system usable by the people who need to interpret it.

The stack only works if those layers serve a clear purpose. Before engineers choose the sensors, models or interface, they need to know what question the twin is being built to answer.

to help cities plan for heat, air pollution and climate risk.

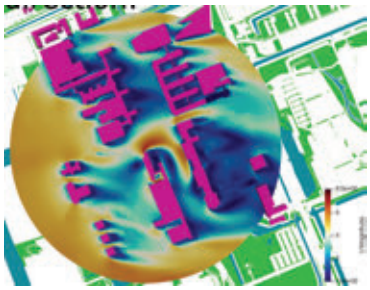
The project connects to Destination Earth, a European Commission initiative to build a highly detailed digital model of the planet. UrbanAIR draws on that larger infrastructure, then zooms down from climate-scale modelling to the street-level questions cities need to answer: where heat will build, how air pollution will move and what might change if trees, buildings or evacuation plans are altered. It shows how the digital twin concept can connect large-scale climate modelling with the local decisions made by councils and city managers.

Vossepoel said one newer challenge is integrating human behaviour with physics-based models. Another is computational cost – fine-scale probabilistic modelling can require thousands of simulations, and the observations needed at street scale are not always available.

AI can help digital twins process large datasets, but Vossepoel said it can't replace physical modelling. A model trained only on past data may struggle when climate change pushes natural systems into conditions not previously observed.

"If you stick to the physical equations, then you know that whatever your model or twin is going to predict is something that is physically consistent and sensible," she said.

The same issue applies to reefs, catchments and farms. A system under repeated bleaching, altered rainfall or hotter and drier conditions may not behave as it did in the past. Digital twins need data, but they also need models that can work when history is no longer a reliable template for the future.



LEFT, BELOW: Digital visualisation of wind flow at the Delft University of Technology.

> "While traditional 3D models and maps offer only a single snapshot in time, a digital twin continuously evolves."

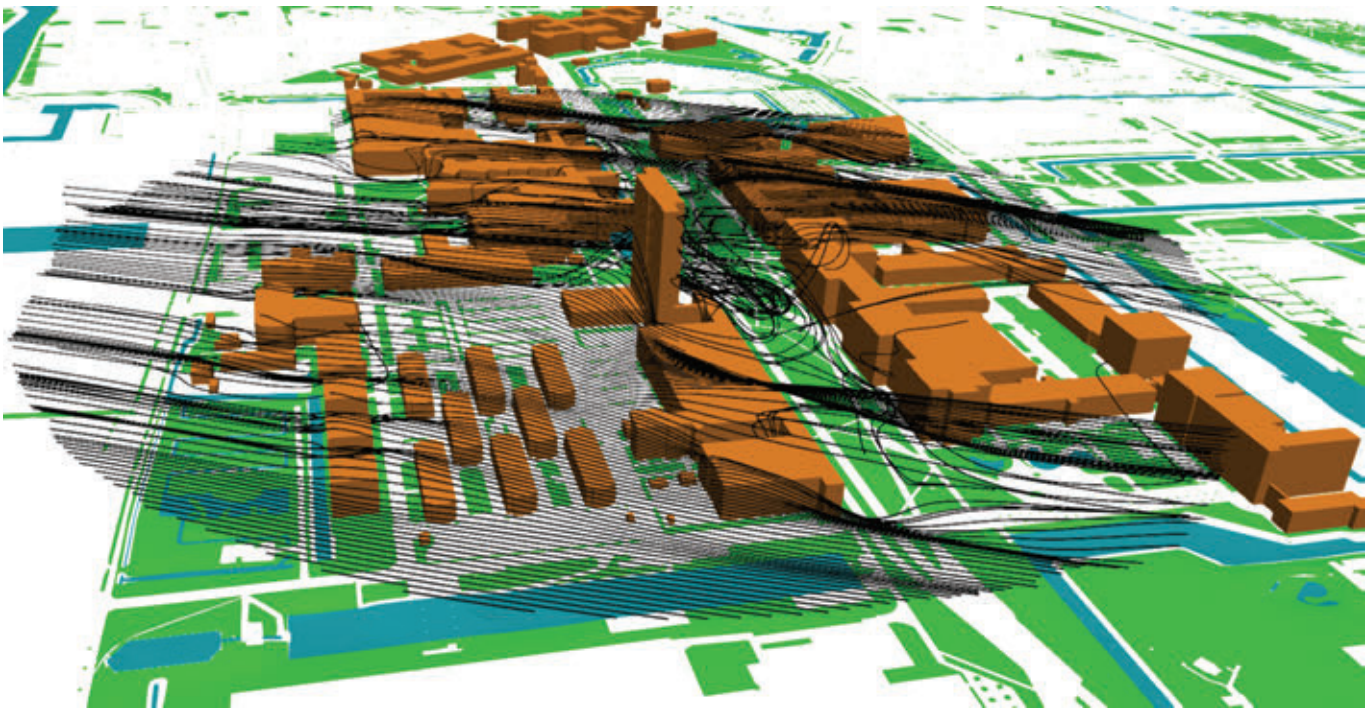


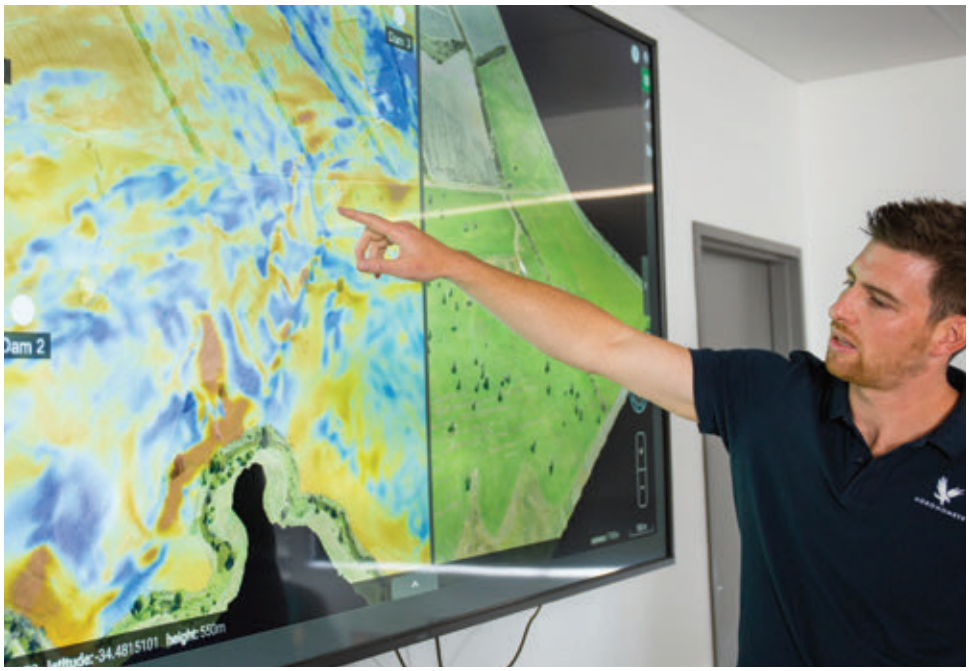
ABOVE: Professor Femke Vossepoel, Delft University of Technology.

Start with a decision

In agriculture, the same principle applies at landscape scale. Dr Roger Lawes leads CSIRO's Spatial Temporal Decisions Team, which operates from Canberra and Floreat in Western Australia, developing digital agriculture technologies that draw on satellites, crop models, climate data, soils data, Australian Bureau of Statistics data, remote sensing and machine learning.

The team works across climate response, land-use change, resilience, nitrogen fertiliser decisions, genetics, crop rotations and farm economics.





The questions vary, but Lawes said the starting point should always be the same: who is using the tool, and what decision do they need to make?

"You have to focus on understanding the end user and how they will engage with the platform, not how you as a scientist or a software engineer might interact or design it," Lawes said.

According to Lawes, CSIRO has built an internal proof-of-concept agricultural digital twin for Australia, bringing together datasets on wheat, cotton, land use, soils, climate and other agricultural variables. Through a web-based interface, users can explore questions about farming systems and landscapes without needing to assemble the data themselves.

A farmer-facing question may sound simple: should a land use change, an input be adjusted, or a crop decision be made differently? Behind the interface, the answer may depend on crop, pasture or livestock data, soils, satellite imagery, farm boundaries, cadastral data, climate records, machine learning, and in some cases logistics or transport networks. The user doesn't need to see every layer, but the tool still has to turn those layers into something usable.

For Lawes, that is what separates a digital twin from a dashboard: A digital twin should be able to perform complex analysis, replicate a real-world system and inform a decision. A dashboard, he said, "throws a suite of numbers at you in pretty graphs" but doesn't necessarily help someone decide what to do.

Central test

For all their promise, ecosystem digital twins are still at different stages of maturity. Some are already helping researchers measure change, validate models and guide restoration planning. Others remain closer to prototypes, research infrastructure or sophisticated visualisations.

The central test is whether they can move beyond representing a living system to helping people decide what to do.

In reef restoration, Ferrari said the next hurdles are user-friendly simulation platforms, automated 3D data extraction and broader accessibility. AI is streamlining some two-dimensional data extraction, but pulling reliable information from 3D digital twins remains difficult. New tools also need rigorous validation to ensure they produce data that are reliable and reproducible.

Ferrari imagines a future in which practitioners could use an intuitive virtual-reality environment to run virtual experiments and predict restoration outcomes at their own sites. For now, she said, accessible simulation platforms remain an aspiration.

Vossepoel sees the same gap between technical capability and practical use. "At the moment I see that as the biggest risk: that we develop a computational engine that is very heavy, but may never be used in practice," she said.

Uncertainty is also part of the decision-making process that digital twins will inform. Vossepoel's work uses uncertainty quantification to explore likelihoods, probabilities, and best-case and worst-case outcomes. Lawes said the challenge is not only to produce those measures, but to communicate what they mean for the person making the decision.

"The point is just trying to inform that decision," Lawes said. "You can't make it for them."

That may be the clearest test for ecosystem digital twins. The technology can make reefs, cities and farms more visible, but visibility alone is not enough. The useful twin is the one that helps people ask a sharper question, understand the limits of the answer and make a better decision in the real world. □



ABOVE: Roger Lawes, CSIRO.

IMAGES: CSIRO.

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[Projects]



80
Powerful against PFAS
EarthSure's thermal plant allows it to treat contaminated soil onsite.

84
Farming frenzy
A Queensland business's robotic inventory is driving productivity.

76
Tall timber
Atlassian Central, Sydney's most challenging development site, boasts several novel engineering features.

A detour for gravity

The world's tallest hybrid timber commercial building is challenging high-rise convention and encouraging engineers to rethink how towers carry load.

WORDS BY CHRIS SHEEDY

With its suspended floor plates, shifted structural loads, 50 MN of force channelled through two locations at the building's base, giant steel nodes, cantilevered upper floors and the world's tallest, self-climbing screens, the Atlassian Central tower seems an engineering fantasy.

Under construction next to Sydney's Central Station, it has already become the world's tallest hybrid timber commercial building. Beneath its striking diagrid facade is a complex series of engineering challenges stacked one on top of another, all above Australia's busiest live transport hub and within arguably the nation's most constrained construction site.

The unconventional, 186 m commercial tower is designed for 50 per cent less upfront embodied carbon and to operate on 100 per cent renewables. Its scale and ambition is as grand and daring as the business that has given the building its name.

Rising above the rails

Atlassian Central is located on the edge of Central Station, directly above the historic Parcels Shed, itself currently being carefully dismantled, refurbished and reinstated.



ABOVE: Jahaan Rowdah, Built.



IMAGE: Dexus/Atlassian/BOJV.



BY THE NUMBERS

THE LOAD PASSING THROUGH A SINGLE INCLINED COLUMN INTO THE CORE EXCEEDS

50 MN

SELF-CLIMBING SCREENS STAND UP TO

34 M

TALL AND EACH WEIGHS AROUND

12 T

A 137-room youth hostel will take up the first five levels, with 59,000 m^2 of lettable commercial office space beginning above that.

Its diagrid exterior, coming together to a narrow base that creates a popsicle-like silhouette, will bring numerous benefits to the finished building and its occupants. These include an integrated facade photovoltaic system that simultaneously provides shading, plus an automated operable facade for natural ventilation of landscaped areas and adjacent offices.

For engineers delivering the build, this translates to fascinating challenges. Perhaps the greatest is the site itself.

"We are building on top of Australia's largest railway station in Australia's biggest city," Jahaan Rowdah, Construction Manager at Built, told *create*.

The tightly constrained land parcel next to Central Station is bordered by live rail infrastructure and existing development.

Project Director Peter Morley, of Dexus, described it as "Sydney's most challenging development site".

These complex constraints have left their mark on every aspect of the project's design and construction methodology, beginning with a 20 m turntable for trucks.

Following that was an extraordinarily collaborative design process that brought 17 companies together across three continents and involved, according to official documentation, more than 1800 Zoom meetings, 160 cost planning drafts, 55 embodied carbon studies and more than 50 design submissions.

After all of that, the final design remained true to the original concept. "I think that's a reflection of a very strong vision as to what we were looking to achieve," Morley said.

Unique and dynamic

"When compared with other structures in the world, we do not believe there's anything that compares to this building," Rowdah said.

That is for several reasons, including the visual signature of the structure, characterised by a lattice of diagonal steel tubes that wrap the exterior.

This type of diagrid assembly is not new. What is unique is what happens to the forces carried by these structures on this building.

"The Atlassian Central's building structure is very unique and dynamic for a series of reasons," Rowdah said. "What is unusual on this project is that the load does not go down to the ground.

"At level seven, it transfers through diagonal columns into two locations, the concrete core and two mega columns. The load that is going through one of these inclined columns into the core exceeds 50 MN of load, which is an extreme amount of force." >

"The structure between level seven and level 11 was without a doubt the most complex activity logistically – and from an engineering perspective – that I think I'll ever come across again in my career."



To safely manage those forces, engineers developed one of the build's most remarkable structural elements: the level-seven tie floor.

At the base of the tower's visible diagrid but seven floors up, this post-tensioned structure is heavily reinforced and performs numerous roles. It redistributes loads from the tower above into the mega columns and concrete core below and, at the same time, becomes a suspension point for the six levels below.

This design affected construction sequencing as 12 temporary perimeter columns were erected to support the lower floors until level seven was built and fully stressed. Only then could the temporary columns be removed.

"Once level seven is poured, with a huge, multi-strand, concrete tie floor, then level one to level six is hung and suspended off the level seven floor plate," Rowdah said. "Above level seven is the commencement of the diagrid, resulting in a very dramatic cantilever across the perimeter of level one."

Creating balance

Above level seven, Rowdah said, "the concept of the building is that there are seven mega-floors, one every 15.5 m, supported by a series of diagrid steel tubes and a structural steel floor plate with a composite concrete slab on top".

Between levels seven and 11 there is also a six-metre cantilever on two of the four elevations, resulting in extreme, out-of-balance loads.

"On level seven, there is greater load on the eastern nodes ahead of the cantilever occurring," Rowdah said. "And then on level 11, that shifts over to the western elevation."

The nodes are large, steel transfer points that connect the diagonal members of the diagrid. They gather forces from above and redistribute them downward.

"The diagrid on the cantilevered elevation was a 65-mm thick plate, which took us about nine days of constant welding to complete," he said.

The largest nodes, weighing more than 28 t, required dual-crane lifts to manoeuvre into place.

"The structure between level seven and level 11 was without a doubt the most complex activity logistically – and from an engineering perspective – that I think I'll ever come across again in my career."

Timber challenge

Timber has been used across the build to achieve a lofty sustainability goal.

The team decided early on to shoot for a 50 per cent reduction in embodied carbon as compared to a conventional commercial tower build. Part of the solution was a habitat concept.





ABOVE: The inclusion of timber demanded changes in construction methodology.

"The hybrid structure essentially breaks the building up into a series of what we call habitats, but which are essentially four-storey buildings stacked on top of each other," Morley said, adding that each is anchored by

IMAGES: Dexus/Atlassian/BOJV.

a structural steel and concrete floor, with three timber office floors suspended between. As a result, about 75 per cent of the commercial floors are timber, enabling a significant reduction in embodied carbon.

Extensive fire testing was carried out, as was performance modelling and peer reviews.

The inclusion of timber demanded changes in construction methodology, particularly as those elements needed protection from the weather. This led to the timber being installed behind the facade.

"The work that's gone into the finalisation of the screens, the mobilisation of the screens, the climbing of the screens and the subsequent dismantling of the screens at the end of the project is phenomenal," Rowdah said.

"This complex and remarkable project would never have been possible without the vision of the co-owners, Dexus and Atlassian, and the delivery partner Built in joint venture with Obayashi Corporation. Thank you to all the subcontractors, consultants and everyone else who's played a part in getting us to where we are now on the project."

The self-climbing screens, which stand up to 34 m tall and weigh around 12 t each, have enclosed the building perimeter as it rises. They don't just protect the timber, but also provide greater comfort and safety for workers.

Custom-made to suit the geometry of the tower, the screens are a reminder, for Rowdah at least, that much of the most challenging engineering is invisible.

"I've spoken about the permanent structure of the building being difficult, but there is a large amount of temporary works required for this building to perform, and for us to be able to construct it," he said.

"While you won't see it, the work associated with finalising that temporary work is arguably as difficult as the work that goes into the permanent part of the building."

Future vision

Morley said Atlassian Central's greatest achievement is not related to its engineering at all, but to the fact "the vision for the building has been delivered from concept to construction".

That has required innovation and creativity around approaches to engineering, logistics, sustainability and construction methodology that will continue to have their own effects long after the building is delivered.

"I'm extremely proud," Morley said. "It's going to make a really meaningful difference as to how office buildings are imagined and developed in the future." □



ABOVE: Peter Morley, Dexus.

BELOW: The final building design stayed close to the original concept.

"The hybrid structure essentially breaks the building up into a series of what we call habitats, but which are essentially four-storey buildings stacked on top of each other."







Down in the dirt

A Melbourne area facility is producing useful construction material by processing soil polluted with a range of dangerous contaminants – including so-called forever chemicals.

WORDS BY JONATHAN BRADLEY



In 2023, the Victorian government laid out its predictions for how the coming decades years would shape a state very much on the grow. The resulting report, Victoria in Future 2023, anticipated a boom in the state's population from 6.8 million to 10.3 million. Metropolitan Melbourne is to grow to eight million residents, and the state as a whole will need 1.6 million additional dwellings.

To accommodate the growth, Infrastructure Victoria recommends 45 projects and policies to ensure the state delivers access to housing, jobs, services and opportunities, at a cost of $65-75 billion.

That means a lot of construction activity, and part of that activity involves breaking ground – literally. The problem with that is digging up the dirt, and getting these projects on track often means disturbing earth that has absorbed a host of pollutants harmful to humans and the broader environment.

Each year, Victoria disinters hundreds of thousands of tonnes of contaminated soil: dirt rendered toxic and seemingly useless thanks to the presence of lead and other heavy metals, hydrocarbons, historic mining waste, asbestos, old pesticides and per- and polyfluoroalkyl substances (PFAS), among other unpleasant substances.

"Historically, contaminated soils of this type would be sent to landfill," explained Mark Globan, General Manager for Resource Recovery at Veolia Australia and New Zealand.

ABOVE: Exterior of Veolia's EarthSure facility.

LEFT: EarthSure combines desorption and soil-washing in the one facility.

The problem for the organisations handling contaminated soil is that the Environment Protection Authority (EPA) Victoria imposes duties for managing, transporting, depositing and receiving this waste material.

Depending on landfill sites to take the contaminated soil produced by a project can add significantly to its cost. Any budget-minded business should be hoping for a better way.

"We've been able to extract resources out of that material to then go back out to market: sand that would usually be mined has been recovered and has gone into concrete manufacturing."

Washing and baking

Enter the EarthSure facility. A joint venture between Veolia, which has operational control, and the remediation services of Ventia, EarthSure can process 160,000 t of contaminated soil annually – a quantity that comprises, according to Globan's estimate, 25-30 per cent of all contaminated soils generated in Victoria each year.

Located at Dandenong South, the EarthSure facility combines a thermal desorption plant, which has operated since 2018, with a brand-new soil-washing facility, which opened in 2025.

The $15 million soil-washing component, in particular, is an important part of EarthSure's circular economy contribution, taking in polluted material and treating it to produce EPA-approved coarse and fine soil suitable for reuse. >

"With the [EPA] levy being where it is, it became a commercial decision and an opportunity to still play in the market, by looking at recovering the material rather than just disposing of the landfill," Globan said.

"We've been able to extract resources out of that material to then go back out to market: sand that would usually be mined has been recovered and has gone into concrete manufacturing. We also receive railway ballasts from rail jobs; we recover that, and then that gets reused in road base."

By combining the desorption plant and the soil-washing facility into one site, EarthSure functions as a one-stop shop for operators looking to dispose of contaminated soil as well as collect a sustainable source of new construction material.

The desorption plant is designed to handle category A and B waste, the most polluted class, which can't be sent to landfill. The desorption process cooks the contaminated material to more than 750 degrees Celsius, converting the contaminants to gas, allowing them to be separated, and leaving behind a thermally treated material suitable for being placed in pavements and road base as a subgrade.

"We have the ability to thermally treat contaminated soils, but also stabilise them through our thermal plant," Globan said. "Customers can come in, drop soil off, and pick up recovered sand and go back to the same project."

Powerful against PFAS

EarthSure's thermal desorption plant is particularly notable for its ability to produce useful products from some quite toxic soil.

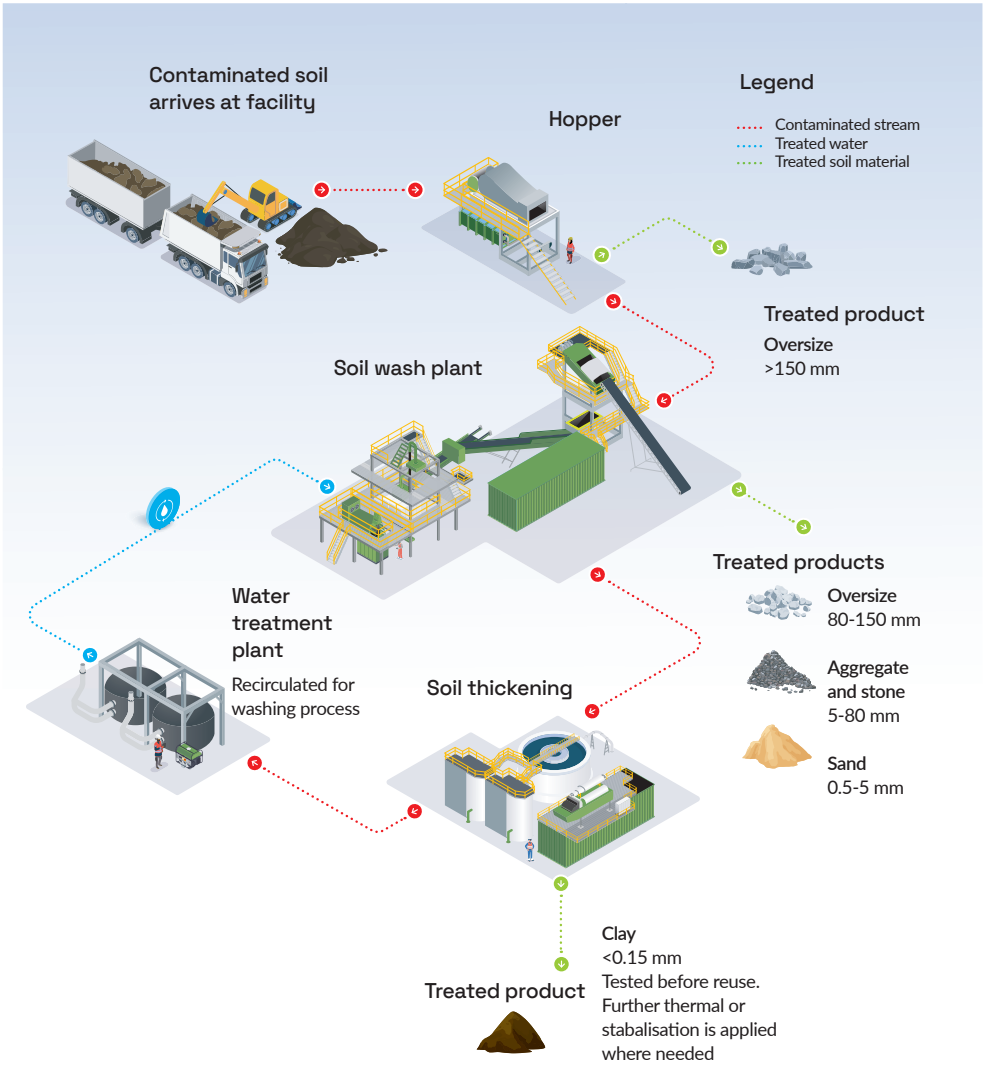
Soil contaminated with PFAS, for instance, is classed as category A or B. PFAS are also known as forever chemicals due to the difficulty of removing them from an environment – including the human body, where they can have carcinogenic effects, as well as causing other health issues.

PFAS are particularly associated with fire-fighting foam, and areas such as airports and military bases, where this foam has been deployed, can be seriously polluted by any PFAS that has leached into the soil. However, because PFAS are found in a wide variety of products, they are commonly found in groundwater, wastewater and soil across many locations.

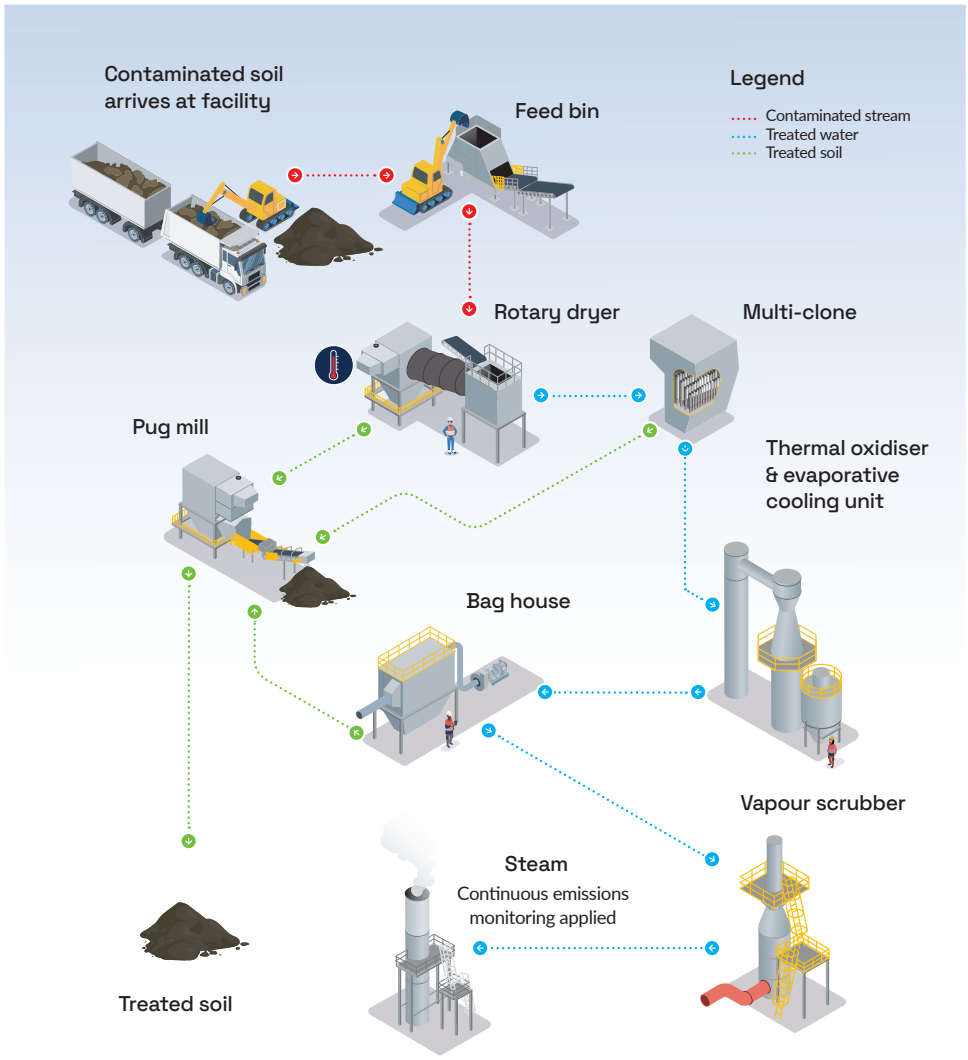
"PFAS is a contaminant of concern, and we have proven that we're able to destroy PFAS from the soil," Globan said.

"There are gasworks projects that are remediating those sites across the state, through to commercial developers who have purchased brownfield sites and need to remove contamination."

EarthSure soil washing process



EarthSure thermal desorption process



BY THE NUMBERS

EARTHSURE CAN PROCESS

160,000 T

OF CONTAMINATED SOIL ANNUALLY, COMPRISING

25-30%

OF ALL CONTAMINATED SOILS GENERATED IN VICTORIA EACH YEAR

"Where we're different is that we can actually capture the PFAS, and the benefit of having the thermal plant is we can then treat it onsite. But compared to other players in the market, we're able to capture the PFAS through our water treatment phase."

Since the PFAS is treated at EarthSure, the facility is able to reuse the water that's used to extract the material, rather than continually drawing on a new supply. That's another way the facility is greener than comparable services, Globan said.

"PFAS isn't soluble; it transfers in water," he explained. "It becomes suspended in the water, and goes through a series of filters – like a pool filter. It is caught up through GAC, or granulated activated carbon."

Once sufficient quantities of PFAS have been absorbed by the GAC, the material is removed to the thermal plant for destruction.

"We're comfortable that the material that we're recovering – rocks, aggregates, sands – do not contain any of those contaminants," Globan said. "That's all done by third-party testing."



ABOVE: Mark Globan, Veolia.

Circular systems

Much of the material managed at EarthSure is produced by the series of major rail and road projects that form Victoria's Big Build infrastructure program, but Globan adds that the facility also draws customers that handle other work.

"There are gasworks projects that are remediating those sites across the state, through to commercial developers who have purchased brownfield sites and need to remove contamination," he said.

Many Big Build projects are also required to use a particular percentage of recovered material, which encourages them to return to EarthSure to buy back the processed sand and soil, rather than to purchase it new directly from quarries.

In future, Globan said, EarthSure hopes to get approval to treat biosolids. That would have the benefit of providing the thermal desorption plant – which is currently powered by natural gas – with a greener source of energy.

"Biosolids have PFAS in them, but also have a high calorific value just by the nature of them," he said. "What that means is that, when they get heated, you're creating more energy, so you don't have to use as much gas." □

Bots in field

WORDS BY JONATHAN BRADLEY



The agricultural industry has long looked to technology as a way of solving labour shortages. One Australian company is replacing massive soil-compacting machinery with lightweight, intelligent robotics.

Farmers Jocie and Andrew Bate, in the central Queensland town of Emerald, had to compete with the local coal mining industry for workers, while maintaining their reputation for producing a high-quality crop.

It was 2012, after working too late into the evening atop an enormous and expensive tractor, when Andrew decided there had to be a better solution than larger and ever-more-complicated machines. Together, the Bates founded SwarmFarm, an agricultural robotics company that delivered its first commercial system in 2018 and has since accumulated 220,000 hours of operation across 2.1 million ha, saving 5.2 million t of chemicals.

But while labour shortages formed part of the company's inspiration, Tom Holcombe, the company's portfolio manager for Western Australia, said its ambitions extend far beyond that.

IMAGE: SwarmFarm.



BY THE NUMBERS

SWARMFARM DELIVERED ITS FIRST COMMERCIAL SYSTEM IN

2018

SINCE THEN, IT HAS ACCUMULATED

220,000

HOURS OF OPERATION ACROSS

2.1 MILLION HA

SAVING

5.2 MILLION T

OF CHEMICALS

“Rather than using potentially 20-30 t machinery, we’re down at a fraction of that. We have a lot less impact on the soil with compaction, which means that more of the area out in the paddock can be productive.”



ABOVE: Tom Holcombe, SwamFarm.

LEFT: A blanket pesticide operation in action.

BELOW: A SwarmFarm robot planting seeds.



“They were getting bigger, faster, wider, heavier machines, but they were compromising on the crop that they were growing,” he said.

“They were doing a blanket application, for example, of a specific pesticide across the whole paddock, when it might have only needed to be applied to 2-3 per cent of the paddock.”

The idea behind SwarmFarm was to use technology to grow better crops rather than simply automating current processes. SwarmFarm’s machines allow farmers to use less pesticide and rotate the ones they do use, meaning weeds don’t build up resistance.

SwarmFarm has added seed planting and mowing tasks to its robots’ repertoire, and SwarmConnect ecosystem permits partners to design further attachments, such as a slasher or spreader.

And this equipment does less damage to the soil than a traditional tractor. Rather than spraying an entire field, one of the robots deployed might be used to target pesticides only at a precise location, for instance, or to pull out a specific weed.

“Eventually we’ll use multiple smaller, lighter weight machines >

to be able to achieve what we're doing currently with one big machine," Holcombe said.

"Smaller, lighter machines mean less impact on the soil, so rather than using potentially 20-30 t machinery, we're down at a fraction of that.

"We have a lot less impact on the soil with compaction, which means that more of the area out in the paddock can be productive."

Meeting expectations

SwarmFarm began operations by producing eight metre-wide, 25 hp robots (its first prototype was electrically driven), but since then its inventory has grown to include hydraulic-drive robots up to 70 hp, which are able to pull a trailer 27 m wide while carrying 3000 L of chemicals.

Much of this evolution came through adjusting to farmers' expectations.

"For people to adopt this technology and take it into their farming practices, we needed to fit within current systems to a degree," Holcombe said.

"A lot of people have controlled traffic farming systems – you're looking at three-metre wheel centres – so your tractors, harvesters, sprayers and everything driving through the paddock is essentially driving along the same lines."

Responding to customer demand has also shaped the level of autonomy delivered by SwarmFarm's technology. Holcombe notes that some farmers want greater control than others.

He recalls discussing the process of seeding with two brothers who were customers.

"One brother was saying that it's such an important task to go and carry out, and it's cheap to put someone in there," he said. "The other brother was saying, 'Well, if we can automate it, then why not? Why not automate everything? It means we potentially have higher accuracy. If we have enough sensors on there, we can monitor everything that's going on.'"

"For people to adopt this technology and take it into their farming practices, we needed to fit within current systems to a degree."

For an activity such as crop spraying, however, many more customers are comfortable with starting the robot and allowing it to do its work.

"It's going to stop when the weather conditions aren't quite right and it's going to get to the end of the paddock having done what it said it has done," Holcombe said.

"Ultimately, you can throw sensors at something, but at the same time, you've got to make



BELOW: The robots can be assigned tasks in specific, geofenced areas.

IMAGES: SwarmFarm.





sure it's reliable, it actually works and can deliver the result people are after."

SwarmFarm's system combines its line-up of SwarmBots, which can be assigned to operate together on a task such as spraying or chipping; the AutoFill station, to which the robots can return to replenish supplies; and the SwarmView app, which sends data to the farmer.

SwarmBot is required to be connected to a network to be able to complete autonomous abilities. With full connectivity, the robot can be assigned tasks and restricted to a geofenced area for safety purposes.

"The software developers can put a new bit of software on a robot straight away," said Will McCarthy, SwarmFarm's Chief Product Officer, in a video produced by the company. "Within an hour of completing that software package, it can be out on a robot in a field in real-life conditions."

Path planning

That kind of operation requires a lot of planning.

"We've got to preload all of that information, so path planning is a massive part of that," Holcombe said.

"Planning a path for the machine to follow through the paddock before it goes out there and trying to set it up for success is a pretty big part."

As SwarmFarm works to build greater autonomy into its machines, it becomes increasingly important for Holcombe to build trust with customers and understand how they use the technology.

"Being able to share information between each of the machines and where they're up to is essential as well," he said. "Knowing what [another robot] has done to be able to share things like section control as applied data, so we're not doubling up out in the field – or if we do need to double up, we know that we need to double up."

ABOVE: The SwarmView app sends data to the farmer.

New markets

With SwarmFarm announcing $30 million in new funding late last year, it's turning its attention to expanding locally, as well as exploring the North American market.

"There are a lot of obstacles we need to solve along the way, like having machines autonomously running in a field where there are many variables," Holcombe said. "Whether it's different soil conditions at different times, weather conditions or an object that comes into a field, there are lots of obstacles we come up against both physically and mentally."

Ultimately, he said, the company measures success by its ability to help farmers grow crops more effectively and more efficiently.

"Australian agriculture has always had to innovate to compete on the global market." □

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[Experience]



90
Deadly crash
Why the Santiago de Compostela derailment was an avoidable disaster.

97
Resources round-up
Technical journals, blogs and podcasts that might interest you.

96
Calendar of events
What's happening in your city in months to come?

98
"I was riding high"
Paul Collier's big mistake forced everyone to step back and rethink.

94
Skimming the surface
Innovators are taking the ground-effect principle to defence, transportation and cargo shipping.

IMAGE: ST Engineering.



DISASTER

Derailed

The deadly derailment of a Spanish high-speed train in 2013 was put down to driver error. Authorities' response to the incident revealed a misunderstanding of the complexities that can trigger such an incident.

Words by Lachlan Haycock

On the evening of 24 July 2013, citizens of the Spanish city of Santiago de Compostela witnessed the derailment and destruction of all 13 carriages of a high-speed passenger train, in what became the second deadliest train disaster ever.

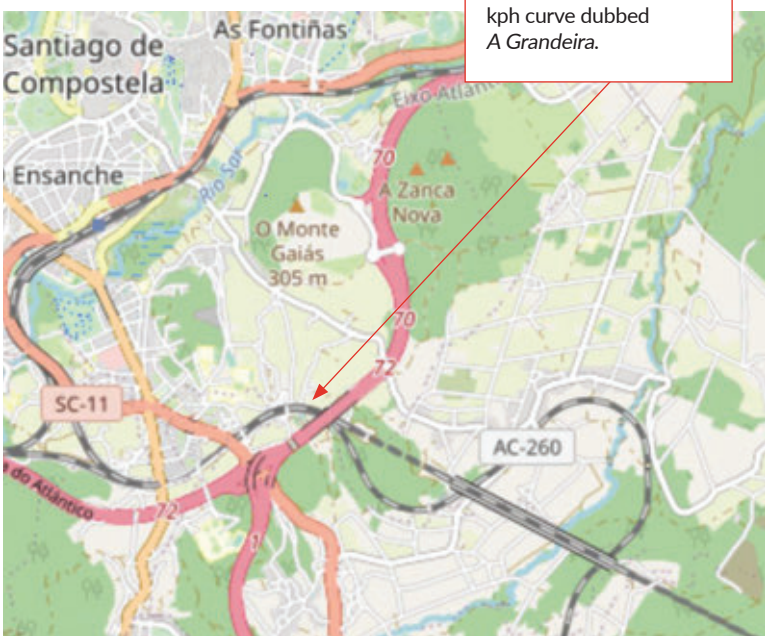
The incident happened extremely fast – friction brought the train to a standstill in under eight seconds – on a section of track infamous for its tight bend.

Spain's extensive high-speed rail network, which uses standard gauge, unlike the broad gauge



ABOVE: Carnage in Santiago de Compostela.

Figure 1:
The infamous *A Grandeira* curve



> "Rather than championing the creation of multiple layers of prevention, redundant safety systems and a proactive safety culture, the solutions tend[ed] to focus on driver behaviour."

evident throughout the rest of the Iberian train network, totals almost 4000 km and is surpassed only by that of China (at a mind-boggling 50,000 km).

The hybrid vehicle, a Renfe Class S130H/S730 boasting both electrical and diesel power, could travel on high-speed and regular stretches of the nation's network alike.

A pair of generator carriages, one located near the front of the train and one towards the rear, gave its electric traction motors the ability to work on non-electrified lines.

On the day of the crash, the train was packed with 218 passengers travelling on the eve of a national holiday and bound for the coastal city of Ferrol.

As it approaches the city of Santiago de Compostela from the southeast, the high-speed rail section merges with another, older railway line about three kilometres outside the station (Figure 1). This half-kilometre-long semicircle of track, dubbed *A Grandeira*, has a recommended speed of 80 kph.

The train's driver, Francisco José Garzón Amo, "failed to heed three separate alerts indicating that the train was traveling at excessive speed", according to Shultz et. al in a 2016 journal article.

Realising at the last moment that the train was about to enter the *A Grandeira* curve, Amo tried but failed to slow or halt the vehicle. It was too late. >

IMAGES: OpenStreetMap contributors, ODbL, via Wikimedia Commons.

The train entered the curve and flew off the tracks at almost 180 kph (Figure 2).

"Multiple cars fell over onto their right sides, skidding with forward momentum as their roofs scraped against an imposing concrete wall erected along the curved tracks," Shultz et. al said. "Several passenger coaches went airborne and both a generator car and a passenger coach caught fire."

The collision killed at least 78 passengers (some sources quote 80) and injured the rest. It became the second deadliest train accident, after the derailment of a train in Eschede, Germany, in 1998, which killed 101.

Shultz et. al observed that the 100 per cent rate of death or injury stemming from the incident "represents a 'true anomaly' in the history of rail crashes".

Sequence of failure

Both media coverage immediately following the incident and the 286-page official report from the Railway Accident Investigation Commission (CIAF) branded the disaster as entirely preventable and attributed the blame to the driver of the speeding train, who was charged with homicide by professional recklessness.

The CIAF report "opens with a terse [distillation] of the event: the crash was due to excessive speed that caused the train to derail on a sharp curve", Shultz et. al said.

"The driver was engaged in a conversation with the track agent using the company's mobile phone and he failed to attend to his driving duties as the train sped toward Santiago de Compostela, several minutes behind schedule. The driver was cited for breaches of protocol for failing to brake the train safely."

The October 2015 judicial ruling that formally charged the driver reiterated that his negligence caused the derailment.

But although human error was the primary cause, Shultz et. al pointed to the absence of automated safety engineering controls that could have slowed the speeding train. Applying a systems thinking perspective, the issue was not as simple as a case of a distracted driver equalling excessive speed causing derailment, but the result of a sequence of failed controls.

The *A Grandeira* curve lacked an activated European Rail Traffic Management System (ERTMS) system that could have overridden human error on the part of a driver. This kind of automated accident prevention system is present elsewhere in the Spanish train network.

"As noted by the victims' advocacy organisation, APAFAS, perhaps if railway personnel had not distracted the driver's attention with multiple cellular calls during a critical part of the journey, the driver would have reacted to the speed alerts and averted the crash," Shultz et. al said. "Furthermore, even under the circumstance where the driver was not paying attention, an activated ERTMS system would have decelerated the train to a safe speed, and again, the tragedy would have been avoided."

BY THE NUMBERS:

THE TRAIN EXITED THE TRACKS AT

180 KPH

KILLING AT LEAST

78

AND INJURING AS MANY AS

140

Figure 2:
Santiago de Compostela derailment as it happened

A trackside CCTV camera captured the moment the speeding train flew off the tracks.



At 8:41pm, the 13-carriage train enters the curve at a speed of 195 kph.



The front generator carriage, located immediately behind the front power carriage, is the first to leave the tracks.



Leading passenger carriages and the front power carriage soon follow, slamming into the adjacent retaining wall.



The rear generator and rear power carriages are the last to leave the tracks, while the front of the train takes out power cable supports.



Train parts and other debris are strewn across the tracks.

IMAGES: ADIF, Public domain, via Wikimedia Commons.

Authorities outlined the following measures in response to the disaster:

1. Mandate the posting of speed limit signs.
2. Reinforce established safety management system procedures.
3. Extend safety procedures to all railway companies via the National Railway Safety Authority.
4. Reestablish a traffic committee with representatives of all railway companies to analyse risks involving the lines, vehicles and roadways.
5. Analyse route-specific risks when developing new rail lines.
6. Develop secure communication systems for train personnel that diminish risks of distraction.
7. Implement audio/video recording and surveillance of the driver's cabin.
8. Integrate digital systems to allow for rapid reduction of train speed.

Shultz et. al called this list a "relatively limited set of remedies" that propagated a critical misunderstanding of what would need to change to minimise the risk of a similar event occurring again.

"Rather than championing the creation of multiple layers of prevention, redundant safety systems and a proactive safety culture, the solutions tend[ed] to focus on driver behaviour," they said. "Missing from consideration are recommendations for improving safety features of the passenger compartments (e.g. installation of passenger restraint systems, better securement of luggage, etc.) and considering how to cushion potential impact points such as the concrete retaining wall along the *A Grandeira* curve that contributed significantly to the severity of the injuries.

"Missing also are opportunities for public education on passenger safety precautions and how to survive a crash."



ABOVE: Rescue operations at the site of the 2026 derailment.

Did anything change?

Twelve years later, another deadly derailment occurred in Spain, this time in the south of the country. In addition to resurfacing memories of the Santiago de Compostela crash, the incident raised questions about whether the lessons of the past were learnt.

On 18 January 2026, a high-speed train derailed near the city of Córdoba before another train collided with it and also derailed. The crash killed 46 and injured 292.

Negligent driving was ruled out. The disaster was attributed to the tracks breaking almost 24 hours before the incident. The Spanish newspaper *Sur* wrote that "a flaw in the configuration of the safety systems at infrastructure firm Adif prevented an automatic alert from being triggered".

A 40 cm break in the track had caused a drop in the track circuit voltage from 2 to 1.5 V, which was detected by track monitoring systems. Despite this, no warning was provided to traffic control personnel as "the signalling system was not configured to automatically alert to such a drop due to the unreliability of the method on this railway infrastructure", according to the police report.

A warning is generated only when the voltage drops below 0.78 V. With the voltage sitting at almost twice this value, the system interpreted the track as safe.

The Adamuz derailment shows that the response to deadly disasters doesn't always preclude similarly deadly incidents from occurring in the future. □

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Spanish police report: Adamuz rail tracks broke day before fatal crash, *Sur in English*, 8 April 2026, www.surinenglish.com/andalucia/spanish-police-report-adamuz-rail-tracks-broke-20260408134501-nt.html

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THE LOOK BACK

Plane sailing



New commercial activity has brought ground-effect vehicles, once a Cold War-era novelty, into the 21st century.

Words by Lachlan Haycock

In aerodynamics, the ground effect is the reduction of drag that results from an aircraft's wings being closer to the ground. A ground-effect vehicle (GEV) or a wing-in-ground-effect vehicle harnesses this reduction in induced drag to increase flight efficiency.

With a given section of wing area producing more lift near the ground than at a higher altitude, the same payload can be transported with a much smaller wing. This results in greater fuel efficiency and lighter aircraft. In a maritime context, a GEV is capable of skimming the water's surface rather than being partly submerged like a regular boat or ship, while also avoiding the comparatively extreme heights flown by conventional aircraft.

The most famous example of a GEV in action over water was the aptly named Caspian Sea Monster, a Russian prototype GEV designed by the Central Hydrofoil Design Bureau at the height of the Cold War.

The Korabl Maket, as it was officially known, featured 10 single-shaft axial-flow turbojet engines and a maximum speed of 500 kph. With a maximum takeoff weight of almost 550 t, it was also the world's heaviest aircraft until it was superseded by the Ukrainian Antonov An-225 Mriya in 1988.

In his 2009 book *Understanding Aerodynamics: Arguing from the Real Physics*, aeronautical engineer Doug McLean explained that when a when a wing flies close to the ground, "the no-through-flow condition at the ground forces the flow field around the wing to change in a way that reduces the downwash in which the wing is flying".





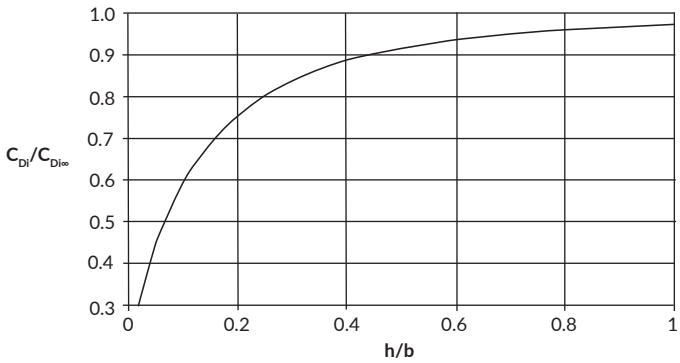
TOP TO BOTTOM: The Soviet Union's A-90 Orlyonok, the German Rhein-Flugzeugbau X-114, and the Soviets' Bartini Beriev VVA-14.

IMAGES: WikiMedia Commons.

"This has the general effect of increasing the lift at the given angle of attack … and reducing the induced drag for a given lift," he said. "It's clear … that the ground produces substantial percentage reductions in induced drag [which] can be important in many types of flight on minimal power, as, for example, in human-powered flight and the long-distance flight of some birds over water."

Despite the implicit aerodynamic efficiencies, McLean points to certain drawbacks of the technology that mean GEVs haven't been picked up for more extensive deployment.

"The operational disadvantages of flying very close to the surface (relatively low cruise speed, the possibility of conflicts with surface vessels, and sensitivity to weather) have discouraged widespread applications."



LEFT: The reduction in induced grad in ground effect at fixed lift. Results of a panel-method calculation for a planar wing with elliptic planform, AR = 10, no twist.

Another way of understanding the ground effect is to consider how it differs from the principle behind a hovercraft.

Whereas the former is "supported by a dynamic air cushion that forms under the lifting wings at large speeds … or/and by the wing-generated lift enhanced due to reduction of the down wash near the ground", the latter is borne aloft by a static air cushion, according to Kirill Rozhdestvensky in a 2006 journal article.

When the Caspian Sea Monster crashed in 1980, it ended Russian dreams of GEV development, if not a hoped-for Cold War victory. But it was far from the last time GEV principles would be embraced by engineers.

Modern fly-ability

The most advanced commercial program belongs to REGENT, whose fully electric Viceroy seaglider concept boasts a 12-passenger capacity and a range of 300 km. The craft uses hydrofoils for its takeoff run. The company commenced hardware and systems integration of its full-scale prototype in 2024, and investors include Hawaiian Airlines and Japan Airlines.

In Singapore, a 10-seat carbon-fibre composite GEV called AirFish 8, from ST Engineering, is powered by a pair of automotive V8 engines and fuelled by standard gasoline. A successful test flight in 2016 has since seen an order of up to 10 craft was made in 2024 by Eurasia Mobility Solutions in Türkiye.

Military applications have also been investigated, with the Liberty Lifter project from the American Defense Advanced Research Projects Agency developing a proposal for a defence-ready GEV. The project ended in 2025.

The first Australian-made GEV was assembled in Gladstone in 2009 by Sea Eagles International, who made plans to install a regular ferry service from Agnes Point to Yeppoon using craft that could travel at 150 kph. The company's Chris Holloway at the time described the potential to grow a market among police and customs authorities in archipelago countries such as Indonesia.

More recently, Woolgoolga-based Project Greenlift developed its own version of GEV with a green-coloured design inspired by cicadas. The hybrid cargo craft, which features a hemp-reinforced fuselage, is being positioned as addressing disaster relief and support logistics needs. □



IMAGE: REGENT; **DIAGRAM:** Adapted from McLean, D (2009).

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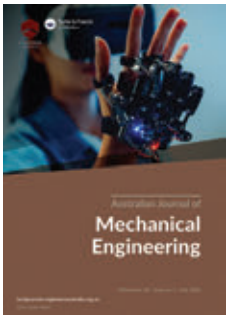
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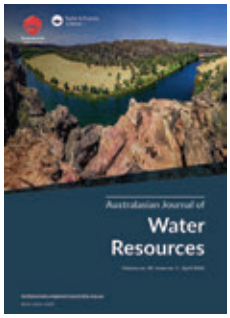
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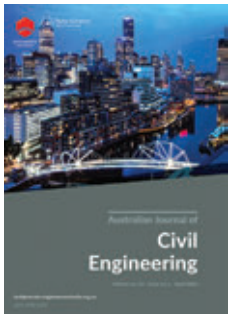
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RESOURCE RECOMMENDATIONS

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How much impact can a LEGO car absorb before the driver is no longer safe? Find out as YouTube's Brick Technology devises a sequence of safety upgrades for a LEGO crash dummy.
youtube.com/@BrickTechnology

Mechanical Pencil
Mechanical engineer Bryan Macomber creates interactive illustrated breakdowns of everyday items such as a mechanical pencil and a Zippo lighter.
mechanical-pencil.com

Support hub
The Overseas Qualified Engineers Career Support Hub is your go-to for credible, industry-specific guidance, supporting you to take the next step in your Australian engineering career.
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Engineers Australia members have access to a plethora of technical journals free of charge.

THE LESSON LEARNED

Paul Collier FIEAust CPEng EngExec

A chance holiday job in a New Zealand engineering office set Paul Collier on an unexpected path. Years later, a stinging loss at a planning hearing taught him that technical excellence alone is never enough.

As told to Joe Ennis

I didn't set out to be an engineer. I was planning to study chemistry at university. But in my final year of school I picked up a holiday job in an engineering office in Wellington, New Zealand. The structural and civil team took me under its wing, and I was hooked. I changed my enrolment and never looked back.

After graduating university, I spent a number of years travelling and working on projects in NZ, the United Kingdom, Africa and the Middle East. Civil engineering in those days was a beautifully transferable occupation. You could walk into an agency and have a job by the end of the day.

Eventually I returned to NZ and joined a major consultancy. After a few years in its Wellington office, I was asked to open a new regional office. It was a real buzz. But unlike the large anonymous jobs I'd been doing overseas, this was a tight community where people had opinions about everything that was happening on their patch.

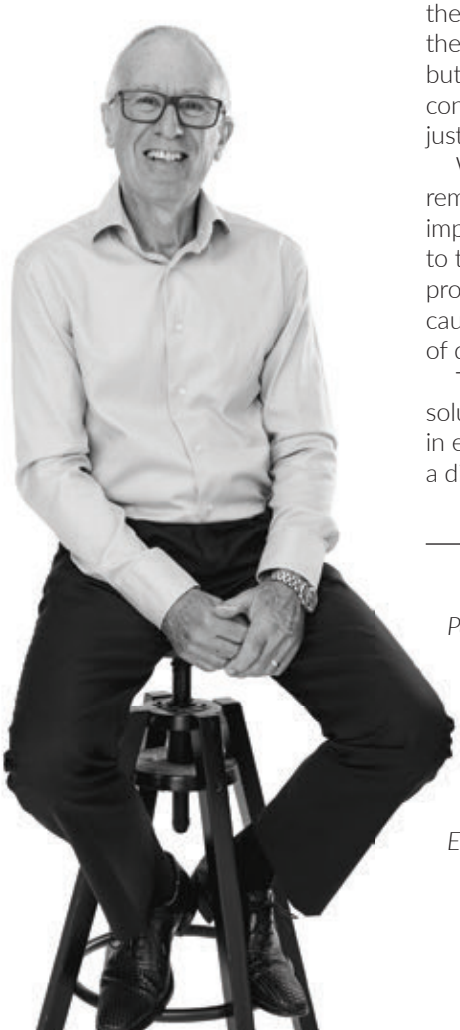
Early on, we were engaged to design a secure landfill to deal with a historical chemical disposal site that had started to leach potentially hazardous substances onto a foreshore. It attracted intense public scrutiny. The regulatory approvals process was rigorous.

We put a huge amount of effort into both the technical design and the community consultation. By the time we reached the planning hearing we had one objector, who only objected to indicate their support. The application sailed through.

I was riding high. And that is exactly where I went wrong.

Not long after, I was working on a low-cost waste collection and disposal scheme for a small council on a tight budget. We prepared the design, got the costings done and applied for a planning permit. Considering the scale of the job, I decided to front the public hearing myself rather than engage legal and planning advisors. The technical approach was sound, so I was very confident.

I was absolutely smashed by the lawyer for the objectors and the application was rejected out of hand.



Though we had met the client's brief, we had failed to meet community expectations. In hindsight, it was the right outcome. I'd gone straight to solution mode. I hadn't taken enough time to consider all the options or think seriously about all affected groups.

Because I hadn't developed options for comparison, I was out on a limb when it mattered. And I'd underestimated just how different this job was to the one before it. Every project is inherently different. Just because an approach works once does not mean it will work again.

The setback forced everyone to step back and rethink. The tone of the objections gave us a clearer picture of what the community actually expected. We developed a new approach and it was accepted.

When I'm asked to respond to a brief since then, the first thing I think about is the actual problem we're trying to solve and who the affected parties are. Not just the person paying for the work, but everyone who lives with the consequences. That approach is just good practice.

When I run workshops, I remind senior engineers of the importance of not going straight to the answer. Think about the problem and analyse its probable causes. Develop a list of questions first.

The instinct to leap to a solution is deeply ingrained in engineers. Resisting it is a discipline. □

KEY LESSONS

01
Past success on one project does not guarantee success on the next.

02
Take time to understand the full scope of affected parties and their expectations before you start designing anything.

03
Recognising when you are outside your expertise is a strength, not a weakness.

Paul Collier FIEAust CPEng EngExec is a member of the Engineers Australia College of Leadership and Management Board, and the People and Governance Committee of the Engineers Australia Board.



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26.	Detailing in Practice Workshop	24 November (ZOOM)	8 HRS CPD
27.	Reinforced Concrete Design Workshop: Module Two	25 + 26 November (ZOOM)	16 HRS CPD
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