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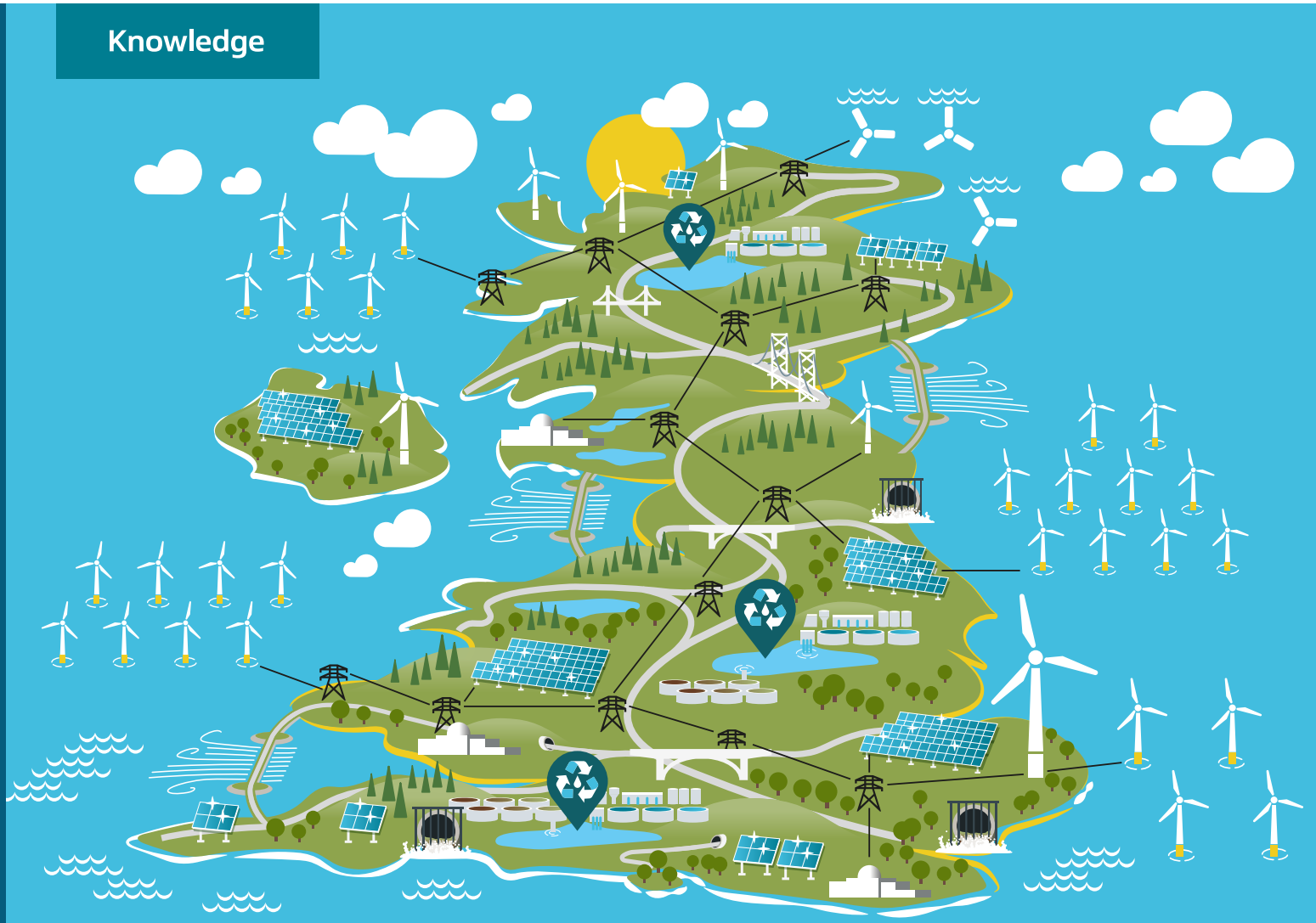
Knowledge



STATE OF THE NATION

Infrastructure in 2025

JANUARY 2025

ice.org.uk

Foreword

Professor Jim Hall
ICE President 2024-25

Globally, about £2.5tn is invested in infrastructure every year, yet even that vast sum still isn't delivering the advances the world needs. Our slow progress towards the UN Sustainable Development Goals tells us that.

Here in the UK, the National Infrastructure Commission's latest progress review has warned that the country is at risk of missing the government's targets for pursuing energy security and net zero, promoting economic growth across all regions, improving climate resilience and enhancing the environment.

The government we elected last summer has committed to providing a new national infrastructure strategy this spring. So now is the time to establish a clear vision of how infrastructure can contribute to a better future for all of us. Some real prioritisation is called for, not only of investments, but also of innovations that need to be exploited and emergent technical solutions that must be better deployed.

State of the Nation is the ICE's annual review of the pressing issues affecting the critical infrastructure sectors of transport, water and energy. It highlights developments in these fields that are both inspirational and practical.

This is not a report full of wild, uncosted, undeliverable ideas. It is the reasoned opinion of practitioners and researchers at the cutting edge of infrastructure.

This is the ICE's role: we qualify civil engineers and support their capability throughout their careers, so that they can surmount all of the professional challenges they will face. We're an organisation that shares knowledge and advances best practice. We're the home of infrastructure.

There's incredible expertise within our membership. We have drawn heavily on that, through a series of roundtable discussions and follow-up interviews, in creating this report.

It tackles several key concerns. These include: dealing with ageing transport infrastructure through honest reporting, digital technology and big data; unlocking new water resources through recycling; and addressing the net zero energy transition by exploring innovative sources of power and upgrading the grid. The solutions it proposes aren't simple fixes, but they are deliverable if the right long-term decisions are made.

The recommendations in this report will therefore form the bedrock of the institution's annual knowledge programme. You'll be able to find out more and engage in the discussion through our Prestige Debates, our knowledge podcasts and our Knowledge Hub.

Whatever the infrastructure challenge, the ICE is here to help.

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Find out more: ice.org.uk

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About State of the Nation

Based on extensive research and member engagement, State of the Nation has been the ICE's flagship report since 2002. This annual industry assessment aims to stimulate debate and highlight actions that the institution believes its members could take to improve UK infrastructure.

State of the Nation 2025 harnesses the expertise of the ICE's global membership in showing how the profession can help to deliver the UN Sustainable Development Goals by providing affordable and climate-resilient solutions in the transport, water and low-carbon energy sectors.

This publication follows a change of UK government in mid-2024. The new administration has a set of priorities for infrastructure that it has pledged to formalise in a national strategy this spring. These priorities, while new, will still need to respond to challenges set by the National Infrastructure Commission in its Second National Infrastructure Assessment, issued back in Q4 2023.

The report has been informed by three roundtable discussions involving experts in transport, low-carbon energy and water infrastructure, convened with the support of the institution's knowledge partners, Bluebeam and Wavin. It also draws on case studies provided by ICE subject-matter experts from around the world.

The institution is grateful to all of those listed on this page for their valuable contributions to this publication.
It extends particular thanks to Professor Jim Hall, ICE President 2024-25, and ICE Senior Vice President David Porter for their oversight and support.

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Introduction: a country dealing with challenges on many fronts

Vital parts of the transport network are ageing badly, the renewable energy revolution is putting the grid under strain and water scarcity is becoming ever more problematic in densely populated regions of the UK. These are just some of this country's key infrastructure problems for the coming year and beyond. But the institution is working tirelessly to help the whole sector solve them – both efficiently and effectively

Serious concerns are emerging about the condition of critical infrastructure – particularly ageing highways assets – in the UK, throughout Europe and around the world. That is the core theme of this year's State of the Nation report, which takes a sector-by-sector look at the main issues facing the industry and the engineering solutions to them.

The ICE's research, informed by three roundtable discussions involving technical experts from across the UK, revealed growing disquiet about the continued resilience of the nation's infrastructure network, with bridges causing the most worry. As our experts put it, parts of the network are perhaps not as safe as the public thinks, while some structures should have usage restrictions but don't. If such facts were more widely known, they said, the government would have to act.

Dealing with the nation's creaking transport infrastructure is therefore crucial. The ICE is tackling this task head-on. Specifically, we will build on the bridge near-miss reporting campaign that was piloted last year, as detailed in this report. We firmly believe that it's our members' ethical responsibility to act when serious problems arise. And Collaborative Reporting for Safer Structures UK (CROSS-UK) provides the mechanism by which individuals raise their safety concerns in confidence.

Early findings from this campaign will be debated at this year's Inspiring Engineering Excellence conference, which takes place in July and serves as the ICE's annual 'learning lessons' event.

And we will build on it significantly, because this spring we'll be issuing a call for papers for the ICE's first Transport Resilience conference. This event aims to bring together global expertise and the innovative ideas and best practice that will address these problems effectively, even where budgets are restrictive.

Where's the water (and power)?

Transport isn't the only sector where big issues need to be tackled. This year we also focus on the resource challenge in water: how do we make more of it available for supply in water-stressed areas

3.1C

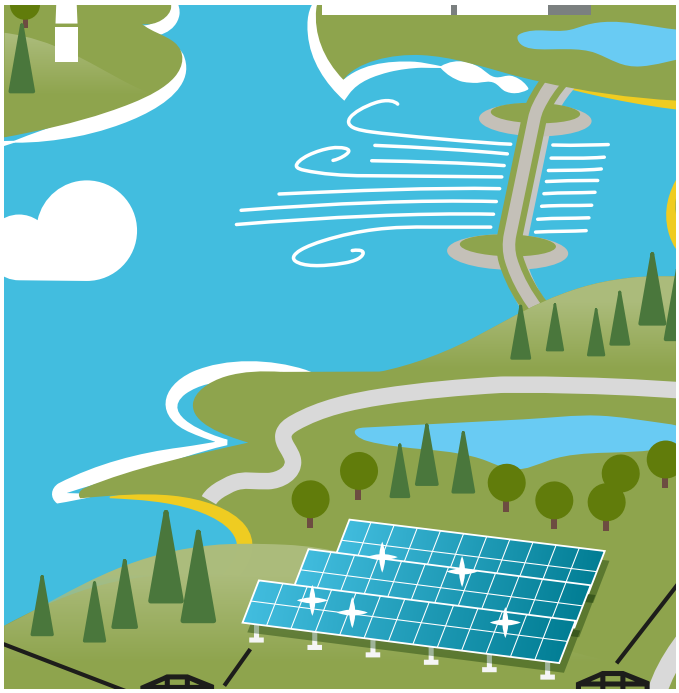
Potential global temperature increase above pre-industrial levels if current climate policies aren't strengthened worldwide

81%

The UK government's new targeted greenhouse gas reduction from 1990 levels

55,000

Estimated number of jobs that will be created by the Great Grid Upgrade and other National Grid initiatives



of the UK? The big push is towards re-use: treating wastewater and putting it through an acceptable process that renders it potable and adds it to the supply network. This report includes examples of where that's happening elsewhere in the world.

Wastewater recycling schemes, which can entail reservoir-building too, court controversy with the so-called yuck factor. Here again, the ICE is taking practical action, this time through its design champion work. The design champion is a key new board-level role that the government has mandated must be in place on every scheme deemed to be a nationally significant infrastructure project. By putting good design at the heart of projects, in line with the National Infrastructure Commission's design principles – climate, people, places and value – these potentially contentious initiatives should become more publicly acceptable.

The ICE is working with the National Infrastructure Commission and Anglian Water to shape the role of the design champion on the latter's major water resource projects. In doing so, the institution hopes to help make these vital plans a reality.

In the energy sector, too, more sources need to be tapped. The potential of tidal energy is back on the agenda – and there is strong support in Liverpool and the surrounding region for a proposed barrage-based power station on the Mersey estuary. This report showcases the Mersey plans and other related initiatives. The ICE will be working with managers of this project to help them with their market engagement.

It's also looking to partner with National Grid to help build a community of professionals that can meet the challenge of keeping the country's 90-year-old electricity transmission and distribution network fit for purpose. The Great Grid Upgrade project, also covered in this report, will better equip the network to handle the nation's shift from fossil fuels to renewables.

The continuing criticality of carbon

All of these challenges need to be tackled while adhering to the ICE's core principles and themes of delivering a decarbonised infrastructure system where projects productively deliver climate-resilient assets. It's therefore vital that the institution keeps promoting engagement with the PAS 2080 carbon management standard. Throughout this year it will put on regional roadshows designed to build members' competence and confidence in low-carbon solutions.

The profession cannot say that it lacks leadership here, with the new prime minister setting a bold example at the very top. Sir Keir Starmer announced a fresh set of climate targets at the

“As our experts put it, parts of the transport network are perhaps not as safe as the public thinks, while some structures should have usage restrictions but don’t”

UN’s COP29 summit in Baku in November 2024, declaring that he wanted the UK to lead the world in the reduction of greenhouse gas emissions. The nation is now aiming for an 81% cut in its emissions from 1990 levels by 2035, compared with the previous government’s pledge of 78%. Starmer has urged other countries to toughen their targets too, given the UN’s stark warning that Earth is set for a 3.1C increase in global mean temperatures without further timely and effective interventions.

Several important infrastructure clients have signed up to the Five Client Carbon Commitments published by the Construction Leadership Council (CLC). According to the council, these are “simple, practical steps that organisations can take to show how they are reducing their carbon emissions and by when”.

The ICE is helping the CLC’s Green Construction Board and the UK Lower Carbon Concrete Group to drive out the most carbon-intensive materials, specifically through its sponsorship of a new code of practice: BSI Flex 350 – Alternative Binder Systems for Lower Carbon Concrete. This will be a theme of the institution’s carbon competency roadshows in 2025, alongside continuing work to boost the sector’s adoption of PAS 2080.

Standards are the answer

The ICE will also be working throughout this year to develop two sister standards to PAS 2080: one on productivity and the other on climate adaptation pathways.

The PAS for climate adaptation pathways will support clients and their advisers on how to adapt their assets to the threats posed by climate change. The standard responds to the Third National Adaptation Programme (NAP3), published in 2023. In effect, NAP3 is a governmental pledge to maintain the UK’s climate resilience. It establishes a clear basis for action over the medium term – by, for instance, committing the Department for Environment, Food and Rural Affairs to £2.2bn of accelerated investment in improving water quality and supply resilience.

The productivity PAS will be a framework providing recommendations for developing and delivering projects in a way that maximises their productivity throughout the infrastructure development lifecycle. The ICE is working on the standard with the Infrastructure Client Group.

This PAS will help integrated project teams to maximise productivity in terms of delivering high-quality outcomes and wider social value while using fewer resources. To the ICE, this is crucial – productivity is about both efficiency and effectiveness. Maximising productivity is central to sustainable development and asset management. It enables procurement, design and delivery partners to effectively achieve economic, social and environmental benefits – all with the most efficient use of resources and with minimal environmental impact.

The three PAS standards will prove relevant to everyone delivering new assets and renewing extant ones. They’ll be applicable to construction projects of any type, from national infrastructure programmes down to the smallest local schemes.

Working to a relevant PAS will become crucial in overcoming the various sectoral challenges highlighted in this report. The ICE will strive to make that notion feel ever more tangible through its 2025 programme of regional roadshows, Prestige Debates and the CPD content in its Knowledge Hub.

01 Transport

"Infrastructure engineers have an ethical obligation to report issues and raise alarms; and to actively advocate for more sustainable, affordable alternatives"

ICE State of the Nation position statement

Across Europe, highway authorities have been expressing grave concerns about the state of their assets. On 16 April 2024, members of the Conference of European Directors of Roads (CEDR) issued a stark warning about the deterioration of key infrastructure they own and operate.

The so-called Dublin declaration, signed by national authorities collectively managing more than a million kilometres of highway, pulls no punches.

"The preservation of the pan-European road network requires close attention, as it is showing its age after decades of service," it states. "This particularly concerns the most critical parts of our networks: our bridges and tunnels."

The declaration not only conveys their anxiety about the amount of badly worn transport infrastructure. It also suggests that the combined challenges of providing resilience to climate change and meeting decarbonisation targets, while dealing with supply chain limitations and a skills shortage, are creating the conditions for a perfect storm.

The CEDR's key objective with the Dublin declaration is to spur pan-European cooperation in mapping the extent of the common challenges and planning a concerted response.

With the collapse of the Polcevera Viaduct in 2018 still fresh in Italy's memory, its national highway authority, Anas, fully supports the declaration. Although liability for the tragedy in Genoa, which killed 43 people, is still being determined in court, all reviews published to date have pointed to a lack of maintenance as a key contributor. Anas is investing €275m (£225m) in a structural health monitoring system for use on 1,000 of its most critical bridges.

Crossing the rubicon

The UK's highway authorities are treating the Dublin declaration as a watershed moment. They are determined to learn from other failures and, crucially, precursor events – near misses – and so prevent a British Polcevera.

Every time a major bridge collapses anywhere in the world, the institution's bridge experts are asked: "Is there a risk that this could happen in the UK?"

The perception challenge, they say, is that the public believes that civil engineers design such structures so that they won't fall down, whereas they're actually designing them to make the risk of a collapse acceptably low.

"How should professionals communicate when it's not the case that a structure is 'going to fall down tomorrow' but it has changed from being acceptably safe to unacceptably safe?"

So how should professionals communicate when it's not the case that a structure is "going to fall down tomorrow" but it has changed from being acceptably safe to unacceptably safe?

This concern has prompted a recent ICE-backed collaboration to prevent further bridge collapses by encouraging the reporting of so-called precursor events (see panel, next page).

The partnership, endorsed by the Infrastructure Client Group (ICG), will enable Collaborative Reporting for Safer Structures UK (CROSS-UK) to collate knowledge on this topic and encourage professionals to share safety concerns so that others can learn from them.

Crucially, it will also provide more evidence to highlight the parlous state of UK infrastructure and help the authorities to make the case for extra funds to tackle the problem.

66

Number of fatal bridge collapses reported around the world since the turn of the millennium

£225m

Investment by Italian highway authority Anas in structural health monitoring for 1,000 key bridges

50%+

Proportion of UK road workers who say they receive abuse on the highway every week

Sources: CROSS-UK, World Highways, Stamp it Out

An early-warning system to improve bridge safety

Bridges fall down with alarming regularity around the world. In this century alone, 66 reported fatal collapses have already claimed more than 1,200 lives.

Yet close calls and precursor events often go unreported. If the authorities can be made more aware of these warning signs, they'll be better able to anticipate more serious incidents and take timely preventive action.

With this concern in mind, the UK Bridges Board, the Bridge Owners Forum and the ICE have come together to highlight the importance of precursor events and encourage anyone working in the bridges sector who learns of these to disclose them to Collaborative Reporting for Safer Structures UK (CROSS-UK).

SHUTTERSTOCK/ROMAN023_PHOTOGRAPHY

Co-owned by the ICE and the Institution of Structural Engineers, CROSS-UK enables professionals to report such matters confidentially. Disclosures are anonymised, commented upon by experts and shared to disseminate the key lessons and thereby help to reduce the likelihood of a catastrophic failure.

For more about the new reporting system, see page 20.

The need for more money should come as no surprise to anyone. In its Second National Infrastructure Assessment, published in the autumn of 2023, the National Infrastructure Commission (NIC) observed that the maintenance and renewal of the UK's road and rail networks was likely to become more costly for all the reasons later cited in the CEDR's Dublin declaration. It argued that "historical levels of spend are unlikely to be sufficient to provide outcomes similar to today [sic]".

The NIC recommended that the government should prioritise maintenance and renewal over expansion. The new government is expected to formally respond via a new national infrastructure strategy this spring, but the early signs suggest that it's placing less emphasis on big and new transport infrastructure.

In a speech to Parliament on 29 July, the incoming chancellor, Rachel Reeves, wasted no time in axing several costly projects, including the Stonehenge tunnel and the Arundel bypass. The next day, the then secretary of state for transport, Louise Haigh, committed to a capital spending review to support the "long-term strategy for transport" that Labour had pledged in its manifesto.

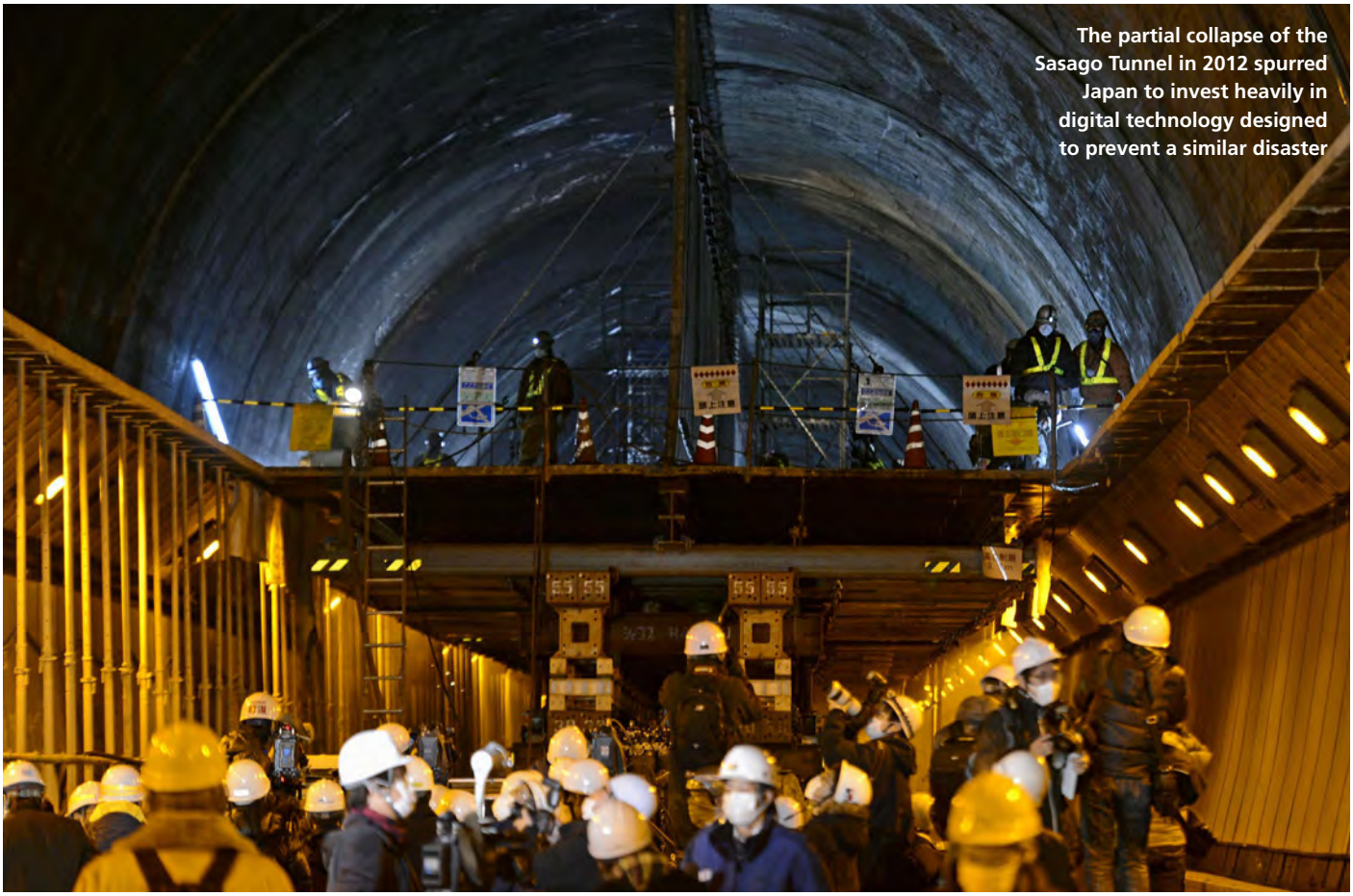
The ICE believes it's crucial that the government follows through with a national infrastructure strategy that sets out a vision that aligns with the NIC's latest recommendations.

Home truths

Addressing concerns about the nation's ageing transport infrastructure is crucial – and ICE members have a key role to play here. Members need to be honest about the risks such assets carry, which means helping non-technical decision-makers to understand the ramifications of choosing to invest elsewhere.

Parts of the network are perhaps not as safe as the public thinks, while some structures should have usage restrictions on them but don't. If such facts were more widely known, the government would have to act.

Engineers need to warn policy-makers about the risks. Politicians don't tend to grasp these until an asset fails. Even then, the attention that a problem receives in the media and political sphere tends to be fleeting – and promises can be clawed back.



The partial collapse of the Sasago Tunnel in 2012 spurred Japan to invest heavily in digital technology designed to prevent a similar disaster

ALAMY/NEWSCOM

Another difficult conversation is needed about the prevailing maintenance practice that can be described as changing the brake pads while driving. One-year funding windows, budget cuts and the advancing age of assets have been rendering this approach unfeasible. But, in any case, it's not fair on the front-line workers who must often make repairs in dangerous conditions while facing the ire of frustrated road users.

Last year, 2,307 people reported being verbally or physically abused while working on UK roads to Stamp it Out, an industry-led initiative aimed at ending this problem. The campaign, which has found that more than half of road workers receive abuse weekly but 80% of victims don't deem it worth reporting, has even heard of incidents involving guns and machetes.

The ICE would encourage all organisations responsible for highway teams to join it in supporting Stamp it Out.

Maintenance crews often perform small miracles – at a cost to themselves – on overnight carriageway repairs, for instance, but there's still a limit to what such an approach can achieve.

By contrast, National Highways' recent decision to close a stretch of the M25 for five full weekends for the A3 junction upgrade may have been disruptive to travellers, but it wasn't the end of the world. Honest communication with the public is again the key.

Big assets, big data

Both the Second National Infrastructure Assessment and the Dublin declaration recognise that advanced digital tools may enable infrastructure to be maintained and renewed in more productive, cost-effective and sustainable ways.

Since being jolted into action by the Sasago Tunnel disaster, which claimed nine lives in 2012, Japan has invested heavily in trialling new technologies. The government hopes that its advances in this field are applied globally.

In the UK, the Forth Road Bridge has become both a cause célèbre and an exemplar of how the smart use of digital systems and data can affordably extend the useful life of a large and complex structure (see case study, page 14).

Nonetheless, even if the government follows the NIC's recommendations and sets common standards for the condition of road and rail infrastructure, getting a complete nationwide picture will be a challenge. Obtaining this information will first involve capturing large amounts of data. Knowing what to capture will be crucial in establishing consistent national benchmarking for all assets. And, while it's undoubtedly useful, data isn't knowledge.

The ICE believes that data cannot fully replace the senses of an experienced engineer inspecting an asset in context. Some defects can look nightmarish to a layperson. You may be able to fit your whole hand into a void where material has crumbled away, for instance, yet this may only be a cosmetic problem. By contrast, an anomaly that looks innocuous to the untrained eye may in fact be deadly serious.

Concerns have also been raised by some that an overreliance on data can create a culture of box-ticking and micromanagement, disempowering skilled workers on the ground who may well be able to solve problems easily and cheaply, if given the autonomy to do so. And, if data isn't handled carefully, it can result in the duplication of work rather than improvements in efficiency.

"An overreliance on data can create a culture of box-ticking and micromanagement, disempowering skilled workers on the ground"

If used inconsistently, data may also provide only snapshots of an asset rather than describing how quickly it's degrading. Many structures may be entering periods of non-linear accelerated deterioration as the demands on them increase and climate change takes its toll.

The ICE therefore supports the Dublin declaration's proposal to shape the CEDR's vision for a "digital road manager" into a defined role. This is likely to be based at least partly on National Highways' Digital Roads initiative, which addresses digital design, construction and operations.

ALAMY/NICK HARRISON

A long-disused railway viaduct in Castlefield, Manchester, has been granted a new life as a public park managed by the National Trust

If a national picture of the state of our transport infrastructure can be established, that will enable a debate on whether the service levels provided by these assets are still affordable, feasible or even socially acceptable in a changing climate. Do we want to, say, extend the life of an ageing road bridge by closing it to motor vehicles and turning the structure into a nature-rich leisure space for pedestrians and cyclists?

Thinking outside the box girder

It's an old idea – New York City converted a disused elevated railway into a public park called the High Line in 2009, for instance. London is planning its own version in Camden Town, while Manchester has already transformed Castlefield Viaduct into a "sky garden".

It's notable that these projects have been driven by grass-roots campaigners rather than politicians. London's Hammersmith Bridge is a case in point: the borough council, City Hall and central government are all unwilling to fund repairs that would bring this historic Thames crossing back into service for road vehicles. Will it have another life as a green bridge?

The Covid pandemic showed that city dwellers all want more greenery and places to walk without choking on traffic fumes. Various local authorities across the UK have responded to their wishes by establishing a patchwork of low-traffic neighbourhoods (LTNs). Designed to restrict the flow of motor vehicles through residential areas, these tend to be divisive. They often prove popular among people living within the zones and deeply unpopular with anyone who must drive around them and/or live along their polluted perimeters.

Some people in the UK view the 15-minute city concept as a conspiracy to restrict free movement or a luxury for those with steady incomes and secure homes, even though it may well be a better approach than LTNs and seems at heart to be no more than a revival of solid town planning. Who *wouldn't* want a wealth of amenities within a 15-minute walk of their home? This would offer various benefits, including reducing the need for short car journeys, alleviating pressure on transport networks and building more exercise into residents' lives. This, combined with the improvement in air quality, would in turn cut the NHS's outlay on health problems such as cardiovascular disease, diabetes and asthma.

While the argument about 15-minute cities has dragged on in the UK, no fewer than 50 of them have been created in Paris. Such zones are being developed here, but no one dares call them 15-minute cities. This is where engineers need to speak up.

Related links

- **Applied Sciences: Causes of the collapse of the Polcevera viaduct in Genoa, Italy**
- **Bridge Owners Forum: Grand Challenges – Extending the Life of Existing Structures**
- **Fracture and Structural Integrity: Considerations over Italian road bridge infrastructure safety after the Polcevera viaduct collapse**
- **Highways: Extending the life of bridges with integrated solutions**
- **ICE: A review of latest trends in bridge health monitoring**
- **National Highways: Our Approach to Asset Management**
- **Masahiro Shirato: Investigation of tunnel ceiling collapse accident**

ICE Knowledge Hub: CPD content for members
knowledgehub.ice.org.uk/learn

- **Explainer: A systems approach to transport projects**
- **Explainer: What engineers need to learn from common failures**
- **Tech Talk podcast: How civil engineers can design for active travel**
- **Tech Talk podcast: How to put social value at the heart of infrastructure**
- **Tech Talk video: How to achieve a joined-up digital transformation**

The UN Sustainable Development Goals

Linking the ICE's work back to the UN Sustainable Development Goals (SDGs) is a core part of the institution's plan and mission. This chapter ties in with the following SDGs:

TRANSPORT CASE STUDY

Nursing the Forth Road Bridge into its seventh decade

The Forth Road Bridge lacks the designed-in accessibility offered by its newer neighbour, Queensferry Crossing, to in-person structural inspections

ALAMY/MACDONALD IMAGES

The crossing's unforeseen popularity during its 60 years in service has been punishing on its fabric, but engineers are prolonging this asset's useful life with the aid of structural health monitoring

Since it first opened to traffic in September 1964, Scotland's Forth Road Bridge (FRB) has spent most of its life being repaired and reinforced.

Significant increases in both traffic (from 4 million crossings every year to a peak of 24 million) and maximum lorry loads (from 24t to 44t), combined with the corrosive effects of the Firth of Forth's estuarine environment, have taken a heavy structural toll over the decades.

Not to be confused with the nearby Forth Bridge – the cantilever trussed rail crossing long famed for its ceaseless consumption of red paint – the FRB is a suspension bridge, designed with complex articulation. This is another reason why it has felt the rigours of time so acutely. From 1978 onwards, its tower and viaduct steelwork, suspension cables, hangers, bearings, bolts and truss end links have had to be treated, strengthened, repaired or replaced to keep the structure safe.

Signs of corrosion

Internal inspections of the FRB detected numerous rusted and broken wires, first in some vertical hanger cables in 1995 and then in some suspension cables in 2004, after rusting was reported in US suspension bridges of similar age.

It proved feasible to replace the corroded hangers in 2000 without shutting the bridge. A full closure for the duration of those works, which cost £7.8m, would have imposed a 56km diversion on road users and severe harm on Scotland's economy.

“At the heart of this solution is an acoustic monitoring system featuring tiny microphones that are sensitive enough to detect the sounds made by breakages in the suspension cables’ 5mm-diameter wires”

The suspension cables were a different matter. If these were to become so badly corroded as to need replacing – a far more expensive project in itself – these major works would entail a lengthy bridge closure and all of the extra indirect costs associated with such disruption.

In 2000, Breedon Northern, Eurovia and Jacobs formed a joint venture called Bear Scotland, which continues to operate and maintain the Forth Road Bridge on Transport Scotland’s behalf. The firm set about sourcing technologies that could detect structural warning signs early and help it to take targeted action before problems such as rusting suspension cables worsened and required major remedial works. The solution it found has been fundamental to the FRB’s ongoing longevity, enabling Bear Scotland to lead the way in suspension bridge maintenance.

Structural health monitoring

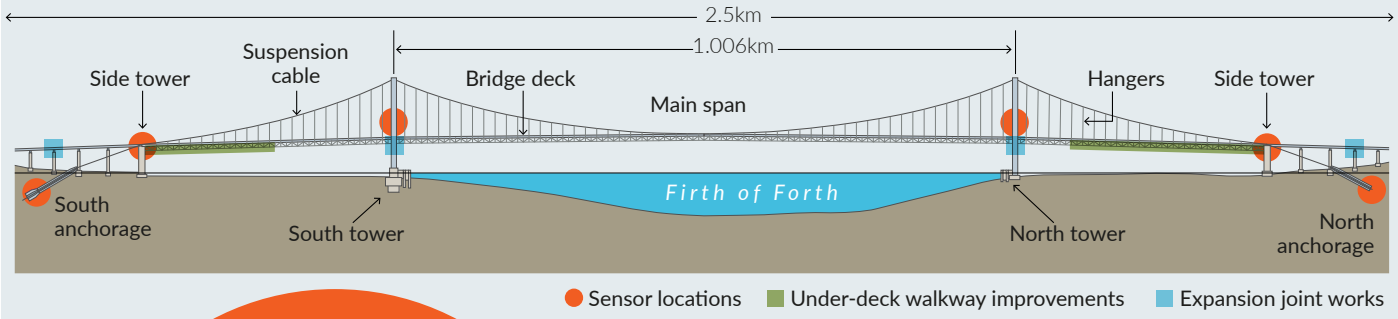
At the heart of this solution is an acoustic monitoring system, introduced in 2006. This features tiny microphones that are sensitive enough to detect the sounds made by breakages in the suspension cables’ 5mm-diameter wires.

This was the first piece of structural health monitoring (SHM) technology to be installed on the bridge. The system’s sensors transmit data continuously, producing graphical forms denoting the health of the parts under observation. Acoustic monitoring helped Bear Scotland to identify areas of the bridge where significant rusting was likely to have occurred and measure changes in the rate of deterioration. ▶ p17

ISTOCK/GEORGECLERK

The construction of Queensferry Crossing (originally known as the Forth Replacement Crossing) took six years and cost about £1.35bn

FORTH ROAD BRIDGE

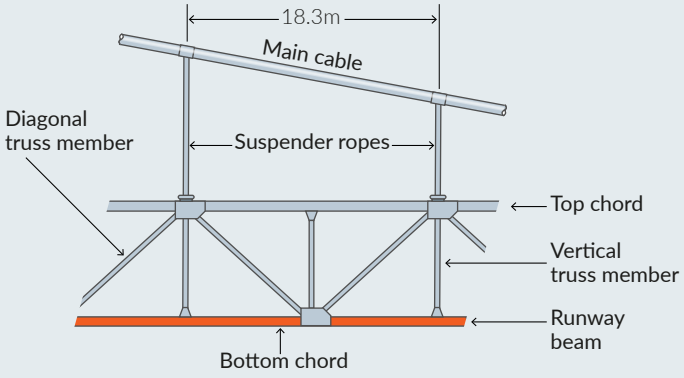


Sensor locations | Under-deck walkway improvements | Expansion joint works

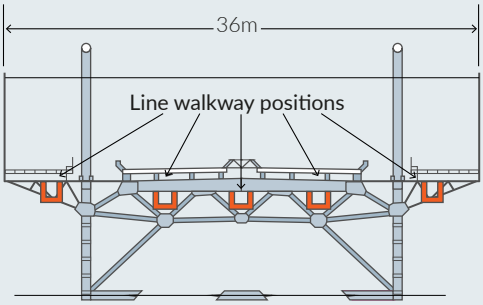
Elevation

Structural health monitoring (SHM)

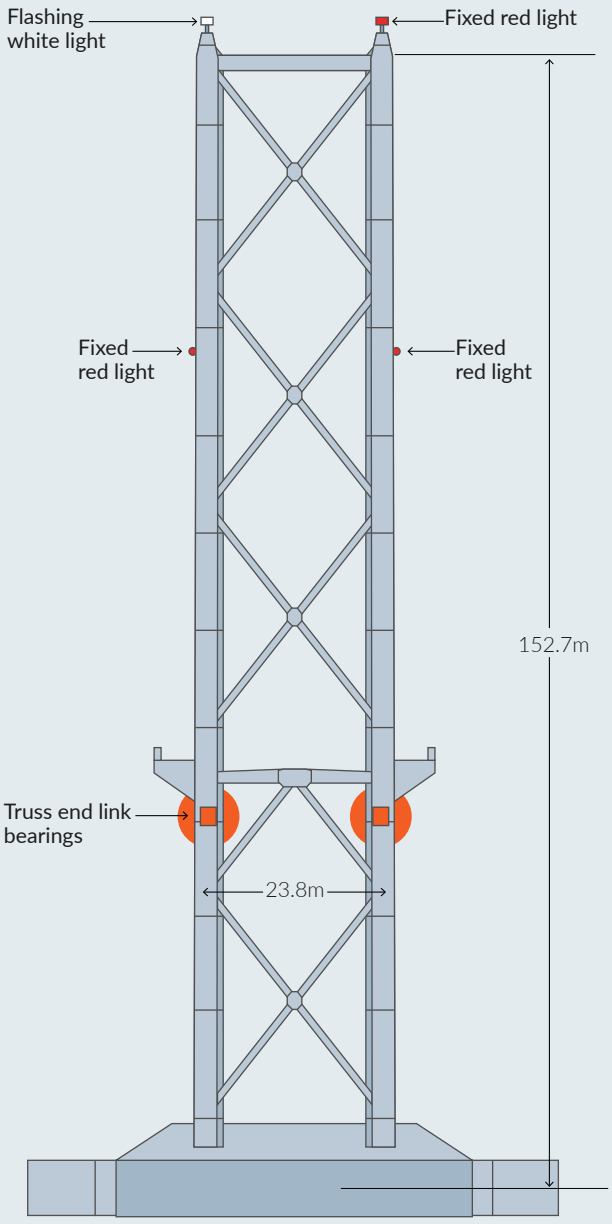
The bridge has **238** SHM sensors:
19 on each of its eight truss ends,
74 on its side towers and
12 on its anchorages



Elevation at suspended span deck



Typical deck section



Section at main tower

SOURCE: FORTH ESTUARY TRANSPORT AUTHORITY

In 2008, dehumidification works arrested corrosion in the main cables at a cost of £10.3m. The method injected dry air into the voids between the cables' strands, removing moisture and keeping their relative humidity below 40%. This technique proved successful and has since been applied to several bridges around the world.

The acoustic monitoring system, which remains in use, is barely recording any breakages at present, but earlier concerns about the FRB's structural integrity had prompted Transport Scotland to start planning a replacement road bridge in 2007. This culminated in Queensferry Crossing, which opened in 2017.

FRB versus Queensferry Crossing

In line with global best practice, the team that developed Queensferry Crossing incorporated SHM technology into the bridge's design. While the FRB has 238 sensors, its new neighbour has nearly five times more, transmitting data that's set to be useful for decades to come.

Unlike the FRB, Queensferry Crossing is a cable-stayed bridge – one that's been designed with a greater emphasis on accessibility, making it easier for people to conduct inspections and carry out other maintenance work.

Just as Queensferry Crossing was having its sensors fitted in 2015, an inspector on the FRB spotted a crack in a key component known as a truss end link. The bridge was closed for investigation and instruments including strain gauges, temperature sensors and tilt meters were installed to monitor all eight of its truss end links.

This marked the start of the FRB's comprehensive critical element programme (see panel, next page). The bridge was closed to all traffic for three weeks while temporary repairs using steel splints and jacks were completed. The SHM system assessed load testing before the reopening to ensure that it was safe to allow cars back first. Heavier vehicles were obliged to cross at 30-second intervals until the team could install a more permanent solution using a steel frame. It took two further months before the bridge was deemed fit enough to carry normal traffic loads again.

The structural health monitoring data gathered over this period revealed that the crack had been caused by the seizure of a pin in the truss end link. This component could no longer rotate freely like the pins in the other links. The eventual permanent structural solution entailed removing these links altogether and supporting the truss from a new bracket connected to the main towers.

TIMELINE OF KEY MAINTENANCE WORKS

1978
Strengthening viaduct box girders

1980-89, 2009, 2011, 2015-24
Suspended span under-deck access work

1992
Main tower wind-bracing strengthening

1997
Main tower strengthening

1998
Construction of pier defences

2000
Hanger replacement

2004, 2008, 2012, 2015, 2018
Main cable internal inspections

2006, 2015
Main cable acoustic monitoring

2006
Structural health monitoring starts

2008, 2024
Main cable dehumidification

2012
Viaduct bearing replacement

2013
Cable band bolt replacement

2013, 2022
Anchorage investigations

2015
Critical element programme starts

2015-19
Truss end link failure and repairs in three phases

2017
Queensferry Crossing opens to traffic

2021
Main expansion joint replacement (in deck at main tower)

2023
Side span lateral thrust bearing strengthening and elastomeric bearing replacement (on side-span side of side tower)

2024
Main cable dehumidification upgrade

Due to start in 2025
Main cable internal inspection

Due to start in 2025
Main tower lateral thrust bearing replacement (on either side of main tower)

Due to start in 2025
Suspended span truss strengthening

Trials under way
Suspended span truss painting and steelwork repairs

TBA
Side tower truss end rocker column and bearing replacement (on main-span side of side tower)

Feasibility studies ongoing
Suspended span half joint replacement

Today's maintenance technology

SHM sensors on the bridge are focused on the eight truss ends (19 on each), two side towers (74 on bearings, anchorage saddles and the towers themselves) and in four anchorages (three on each). They measure displacement, distance, temperature and pressure alongside strain gauges and tilt meters. In-person inspection remains a key maintenance procedure, but this has been supplemented by drone surveys.

SHM will next be used at the splice connections on the bottom chord of the main bridge truss to detect signs of potential fatigue. This is because wind-load calculations and subsequent analyses have shown it as a point of concerningly high stress. Dynamic strain gauges giving real-time readings will enable the maintenance team to monitor and analyse the chord's reactions to a range of environmental conditions and traffic loads.

The prognosis for the FRB is good. Bear Scotland has built up a large database of structural variables that it can use in conjunction with artificial intelligence and a future digital twin to model the bridge's long-term performance.

"In 2015, an inspector on the FRB spotted a crack in a key component known as a truss end link. The bridge was closed for investigation"

A supporting role

Since October 2017, the Forth Road Bridge has been reserved for buses, taxis, non-motorway vehicles and pedestrians. This division of the traffic burden enabled Queensferry Crossing to be narrower (carrying a two-lane dual carriageway with hard shoulders) and therefore cheaper to build than a bridge having to accommodate more lanes.

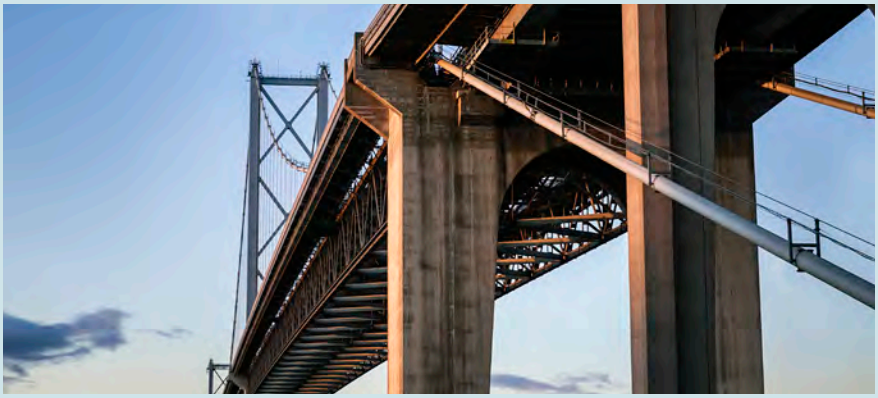
The FRB remains sound enough to support full loading, although this would happen only as a temporary emergency measure. Its reduced burden enables Bear Scotland to

The Forth Road Bridge's critical element programme

A critical element programme is a vital part of managing any ageing structure, particularly one where it's impractical to repair all items that need attention at the same time.

Established in 2015, the FRB's critical element programme is a holistic, risk-based review of key components of the bridge.

A build-up of strain in an element may lead to a failure. Repeated exposure to fluctuating strain cycles may lead to fatigue damage in individual elements that could cause longer-term problems for the bridge. By examining these cycles, an assessment can predict whether an element is reaching the end of its fatigue or service life. Analysing data gathered using their structural health monitoring (SHM) systems, the bridge's engineers can determine whether, say, a lack of movement in a given component is leading to a build-up of strain in it that might warrant closer attention.



When an SHM sensor produces an abnormal reading, a longer-term analysis of the data generated can help the engineers to determine whether that anomaly was caused by a structural fault or merely by a temporary site activity or even a change of weather.

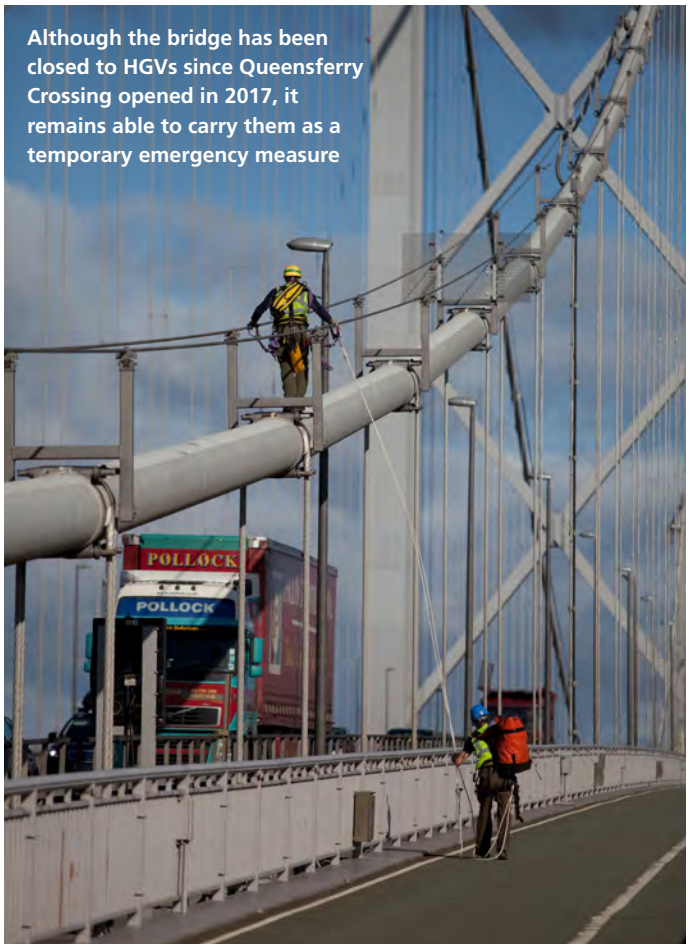
If it becomes clear that the component in question is continuing to behave in unexpected ways, they can prioritise its repair or replacement.

ISTOCK/GEORGECLERK

maintain the bridge more efficiently. The FRB's maintenance bill in 2023-24 was £6.3m, for instance, compared with £20.7m in 2017-18.

While the bridge's designers obviously didn't have sophisticated SHM systems at their disposal in the late 1950s, they might have built in what monitoring tech was available to them at the time. If that's easy to say in hindsight, the design could at least have made vital components more accessible to inspectors, given that the bridge was intended to last 120 years. Still, future-proofing such infrastructure at the planning stage is never easy, especially when the construction budget is tight, as assets can easily be subjected to unforeseen stresses later in their lives.

The next one of these in transport is likely to result from the Road Vehicles (Authorised Weight) (Amendment) Regulations 2023. This legislation has lifted the weight limit on certain zero-emission vehicles by 2t. As the number of heavier alternatively fuelled lorries on the road increases, the UK's highways authorities are watching closely, concerned about the impact this could have.



Although the bridge has been closed to HGVs since Queensferry Crossing opened in 2017, it remains able to carry them as a temporary emergency measure

ALAMY/MACDONALD IMAGES

Related links

- **American Society of Civil Engineers:** Review of bridge structural health monitoring aided by big data and artificial intelligence: from condition assessment to damage detection
- **Developments in the Built Environment:** Abnormal data detection for structural health monitoring: state-of-the-art review
- **Achintya Halder, Abdullah Al-Hussein (eds):** Recent Developments in Structural Health Monitoring and Assessment – Opportunities and Challenges
- **Handbook of Experimental Structural Dynamics:** Structural health monitoring and damage identification
- **ICE:** Bearing replacements for Forth Road Bridge approach viaducts
- **ICE:** Deflection and frequency monitoring of the Forth Road Bridge, Scotland, by GPS
- **ICE:** Forth Road Bridge – maintenance and remedial works
- **ICE:** Structural health monitoring

ICE Knowledge Hub: CPD content for members

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- **Explainer: DfMA for transport projects**
- **Explainer: How to ensure structural resilience**
- **Explainer: The observational method**
- **Tech Talk video: What engineers can learn from the Flow bridge**

The UN Sustainable Development Goals

This case study ties in with the following SDGs:

TRANSPORT CASE STUDIES IN BRIEF

Stopping the rot

This century alone, 66 bridge failures are known to have caused fatalities, with even wealthy nations skimping on maintenance. But, as the following examples show, the will exists in certain quarters to tackle this costly problem

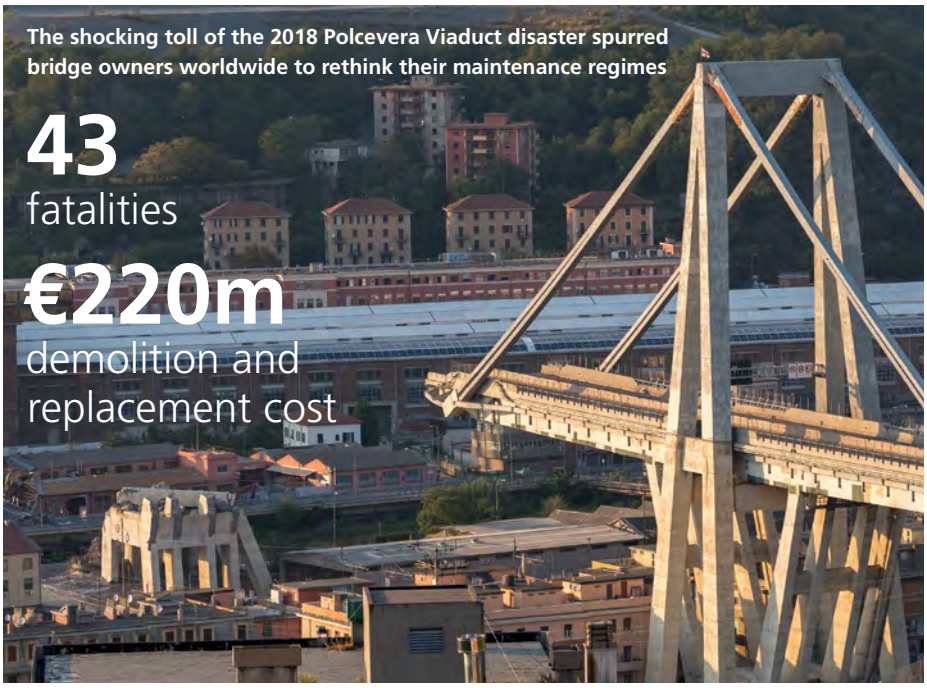
How the ICE is helping to prevent further catastrophic bridge failures

Although safe, reliable national road and rail networks are important enablers of economic growth, many countries have underinvested in maintaining the critical infrastructure underpinning them in recent years.

This means that the fabric of many elderly assets is deteriorating at an alarming rate as the effects of climate change take an increasingly heavy toll, especially on bridges carrying far heavier traffic loads than their designers had originally envisaged.

The catastrophic collapse of Genoa's Polcevera Viaduct, a 50-year-old motorway bridge that was undergoing structural retrofitting at the time of its failure in 2018, has proved something of a wake-up call. It has prompted bridge owners and operators not only in Italy but far beyond to question the robustness of their assets and rethink the maintenance regimes they have in place.

With such concerns in mind, the ICE has been engaged in a joint initiative encouraging bridge designers, builders and maintainers worldwide to take more responsibility for preventing further calamitous failures. In May 2024, it joined forces with the UK Bridges Board and the Bridge Owners Forum to encourage civil engineers and other professionals working on bridges to report close calls and so-called precursor events to Confidential Reporting on Structural Safety UK (CROSS-UK).



ISTOCK/LUCA REINA MAFARACI

Improving people's knowledge, recognition and reporting of precursor events is known to be vital in preventing these from leading to more serious incidents. Examples of precursor events include the unexpected failure of a component; structural cracks that appear or reopen after repairs; and other signs of distress that can't be explained. This approach – endorsed by the Infrastructure Client Group – reflects best practice originally established in the aviation industry.

Co-owned by the ICE and the Institution of Structural Engineers, the CROSS-UK reporting system enables anyone with an interest in, or responsibility for, the safety of structures to share their observations in confidence via its website. Reports and key findings are anonymised, commented upon by experts and shared to disseminate knowledge and so help to prevent another potential Polcevera.

The US steps up its multibillion-dollar Bridge Investment Program

In 2024, the non-partisan American Road & Transportation Builders Association (ARTBA) published an analysis of US government data. It indicated that 36% of bridges across the nation needed to be replaced or repaired.

ISTOCK/LONG_STRANGE_TRIP_01

The original structure forming half of the I-5 Interstate Bridge has been in service for well over a century

Nearly 221,800 bridges required remedial work of some description, according to the ARTBA, with full replacement being necessary in just over a third of those cases. Although more than 42,000 bridges were classed as being structurally deficient, these were still collectively sustaining 168.5 million vehicle crossings daily.

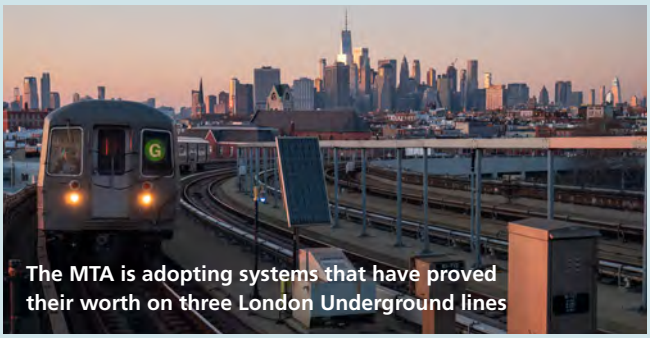
The White House announced last year that it would spend US$5bn (£4bn) on revitalising some of the most economically important highway bridges. Awards were made to the 13 deemed in most urgent need of an overhaul through the Bridge Investment Program – part of the Biden administration's US$27.5bn Infrastructure and Investment Jobs Act 2021.

States have received US$15.9bn since that law was enacted. At the time of writing, they have committed almost half of that total to 4,170 bridge projects.

The most recent funding schemes are aimed at some of the largest assets. Awards have ranged from US$63m for the project to replace Kansas City's 66-year-old 18th Street Expressway Bridge to a US$1.4bn contribution towards replacing the two structures (67 and 108 years old) forming the Interstate Bridge that carries the I-5 between Oregon and Washington over the Columbia River.

NYC's Metropolitan Transportation Authority gets data-driven

New York City's transport networks are no strangers to the combined risks of fast-ageing infrastructure assets, changing usage patterns and the increasing impacts of climate change. Indeed, they're still feeling the after-effects of Super Storm Sandy, which hit the city back in 2012.



ISTOCK/STEFAN TOMIC

The MTA is adopting systems that have proved their worth on three London Underground lines

The Metropolitan Transportation Authority (MTA) owns and operates New York's public transport infrastructure. It views the next 20 years as "pivotal" in ensuring that it can continue satisfying the needs of its users. The authority's US$55bn capital programme for 2020-24 set out to deliver projects more efficiently and effectively. It implemented recommendations based on a 2019 audit into its capital planning process.

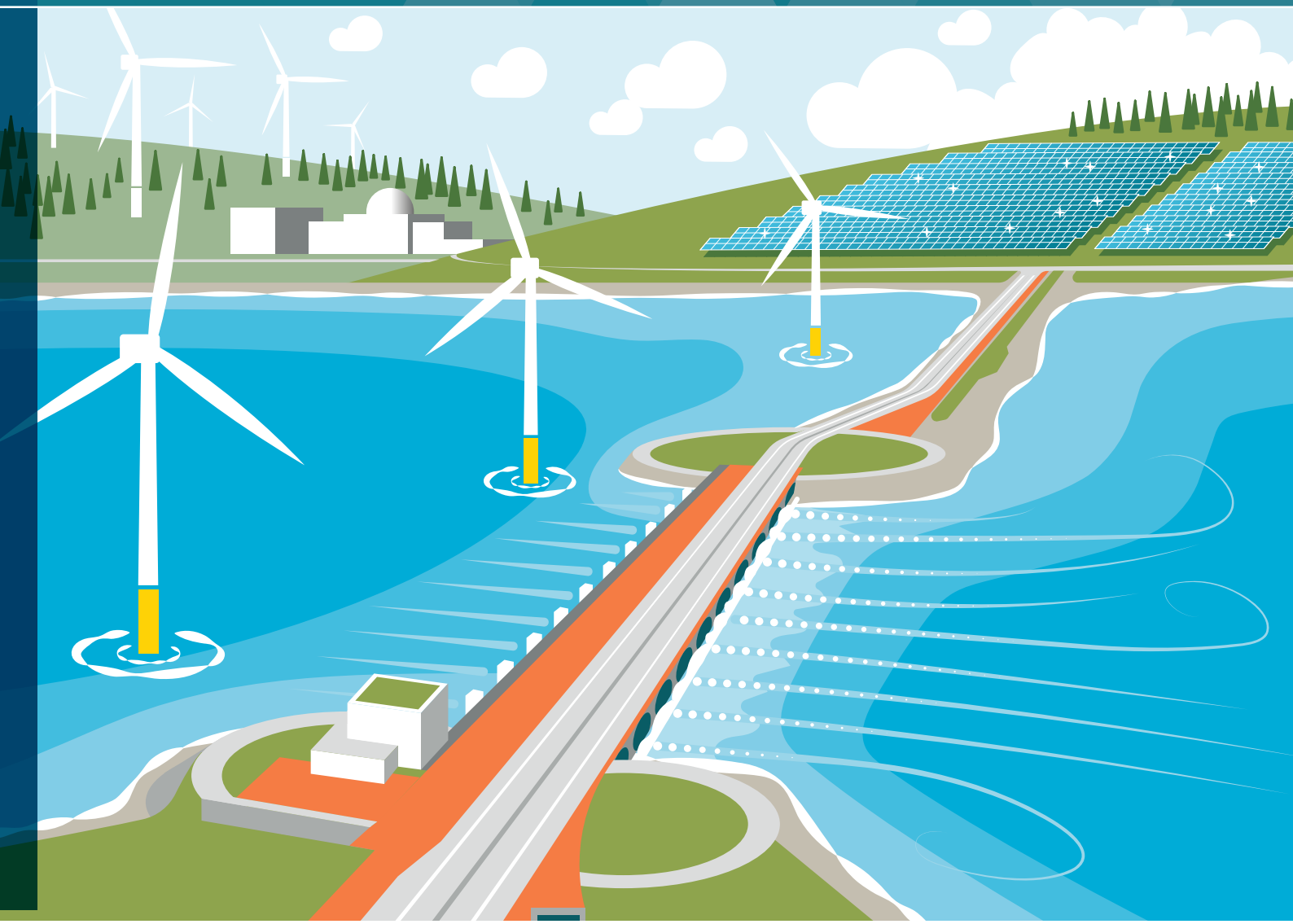
One recommendation was for the MTA to modernise its approach to data. It has since established detailed infrastructure inventories and applied enterprise asset management (EAM) tools and techniques where possible. It has also incorporated performance metrics along with information on aspects such as criticality and parts obsolescence.

Amey has been helping the MTA to develop this systems approach to managing its complex array of infrastructure assets. The experience gained by the company while performing its long-running maintenance and management role on the London Underground's Jubilee, Northern and Piccadilly lines has proved valuable in New York.

Amey's data-led methods, which included installing an EAM system, had resulted in whole-life costs approaching 25% less than those of the other Tube lines. The regime that it established in London optimised processes including planning, procurement, material management and the scheduling and execution of works. The MTA is aiming to derive a similar set of improvements, which are predicted to reduce whole-life costs by more than 20%.

02 Low-carbon energy

The government hopes that its flagship Great British Energy initiative will recharge a sector facing several intractable problems. But might tidal power become key to the nation's clean energy future?



The global market instability and supply disruption triggered chiefly by Russia's invasion of Ukraine has made the security and cost of energy in the UK a serious public concern over the past three years. In 2022 alone, the typical household energy bill nearly doubled.

Faced with these factors, along with a worsening climate crisis and the nation's ambitious and legally binding net zero targets, the industry has a complex challenge to overcome if it's to ensure a reliable supply of affordable clean energy for all.

The National Infrastructure Commission's latest review of the sector's progress in this area, published last May, is clear: "While gas prices have fallen from the highs of 2022, the UK remains too reliant on high-cost, high-carbon natural gas."

Adding that it is feasible for the nation to "move away from fossil fuels" and develop a secure supply of renewable energy, the review urges the industry to accelerate its decarbonisation efforts.

While the policy landscape may change even more over the coming months, the new government made some bold moves soon after it took over in July 2024. The secretary of state for energy and net zero, Ed Miliband, perhaps motivated by the fact that he'd served as energy secretary in the previous Labour administration, quickly honoured the party's manifesto pledge to set up Great British Energy (see panel, page 25).

Once the Great British Energy bill is enacted – it's making rapid progress through the House of Lords at the time of writing – this publicly owned company will develop and manage clean energy projects in partnership with the private sector.

Miliband then established the Clean Power 2030 Advisory Commission. This group of eight industry experts and academics will help Chris Stark, former chief executive of the Climate Change Committee, to plan a "path to decarbonise the electricity grid" and "deliver a clean power system by 2030".

These bodies will work alongside a new National Energy System Operator, established through the 2023 Energy Act to create an independent system planner and operator to help accelerate Great Britain's energy transition.

The UK has already made some progress with this transition. In 2022, for instance, it became the first major economy to cut its annual greenhouse gas emissions to half of the total recorded in 1990, largely through energy decarbonisation. And, in Q2 2024, renewable sources accounted for more than 50% of total electricity generation in the UK for the third quarter running.

17+

Number of new key electricity transmission projects needed in England and Wales by 2030

£8.3bn

Investment pledged by the government into Great British Energy over this Parliament

£17bn

The latest estimated cost overrun on the Hinkley Point C atomic power station project

Sources: National Infrastructure Commission, Department for Energy Security and Net Zero, Électricité de France

Rewiring the nation

Despite these advances, the challenge remains enormous – and developments in renewable energy, particularly the offshore wind sector, have slowed recently. Last year's State of the Nation report called on infrastructure engineers to ensure the practicality of wind and solar schemes, with a focus on circularity to help prolong the useful life of materials and mitigate unintended environmental costs. That imperative has not changed.

The UK's ageing transmission infrastructure isn't helping matters. New assets are needed urgently if communities nationwide are to obtain the clean energy they need. The National Infrastructure Commission sets clear targets for this in its latest progress review. It states that "additional capacity in the electricity transmission

"Once the Great British Energy bill is enacted – it's making rapid progress through the Lords at the time of writing – this publicly owned company will develop and manage clean energy projects in partnership with the private sector"

and distribution networks will be required to meet the higher levels of electricity demand from electrifying heat, transport and industry. More than 17 new nationally significant electricity transmission projects will be required in England and Wales by 2030 to support electrification – a more than fourfold increase on historic rates."

To achieve this objective, National Grid has established its Great Grid Upgrade programme (see page 34). It's promising to spend £30bn between 2025 and 2029 on projects that support the UK's decarbonisation targets.

The heavy lifting will be done by the Great Grid Partnership. Initially comprising seven companies, this is a supply-chain alliance working to the enterprise model of integration and collaboration. It will help to deliver nine so-called accelerated strategic transmission investment projects.

The nuclear option

Although the Great Grid Upgrade is a significant enabler, even bigger ideas will be required to provide the nation with totally clean power. The National Infrastructure Commission considers nuclear generation to be an acceptable part of that clean future – as does the government, which pledged in its election manifesto to get the controversial and much-delayed Hinkley Point C project "over the line".

The original construction plan for this atomic power station had scheduled the completion for 2025 at a cost of £18bn. In early 2024, its majority owner, Électricité de France, revised those numbers to 2031 and £35bn.

The government also remains supportive of Sizewell C, a project described by its promoters as a "close copy" of Hinkley Point C. Having overcome legal challenges in 2024, it could be operational in 10 years. Still, the nation requires more than the combined 6.4GW these proposed plants offer, which means that a new strategy is needed.

The government promised this in its 2024 Autumn Budget. It pledged a substantial infrastructure investment and "an end to short-termism" in the shape of a 10-year national

The government is determined to see through the controversial and much-delayed nuclear plant construction at Hinkley Point C

EDF/HINKLEY POINT C

infrastructure strategy to be published alongside its Spring 2025 Spending Review. This document will outline plans for energy (and transport, housing and social infrastructure) and an "industrial strategy" to attract long-term investments in economically important sectors such as clean energy and digital technology. It builds on a pre-Budget announcement earmarking £21.7bn for carbon capture and storage schemes and hydrogen projects over 25 years.

Ebb and flow

Labour's election manifesto also mentioned marine energy, so what of this as a big idea? When the ICE held a series of events last year exploring areas where members want their expertise to make a real difference, tidal power was high on the agenda. Its potential as a source of clean, stable energy is clearly exciting to engineers.

Much of the technology and construction methodology involved is proven. A large tidal lagoon would be a significant global engineering project that would probably also attract investment into turbine manufacturing in the UK and create a significant number of skilled jobs here.

Support for such thinking exists outside the engineering arena. The House of Commons environmental audit committee argued in a 2023 report that "tidal and other marine energy projects should be a vital component of the government's strategies for delivering both net zero and energy security".

The historic obstacles to tidal power developments have been the high upfront costs involved, the lack of an investment structure, uncertainty about some of the newer technologies and concerns about their potential ecological impacts.

In 2016, Charles Hendry, a former minister of state for energy and climate change, conducted an independent review of the generating potential of tidal lagoons. Hendry and his team visited Bristol, Cardiff, Liverpool, Newport, Sheffield and Swansea, consulting people who might be involved in, or be otherwise affected by, possible lagoon projects. The evidence they gathered led him to conclude that "tidal lagoons can play a cost-effective part of the UK's energy mix". He argued that such projects would help to "deliver security of supply; they would assist in delivering our decarbonisation commitments; and they would bring real and substantial opportunities for the UK supply chain".

Hendry called on the government to establish a national policy statement for tidal lagoons along the lines of its one for new nuclear power stations, "where specific sites are

The Great British switch-on

The government is legislating to set up Great British Energy, a state-owned company that will be backed with an £8.3bn investment over this Parliament.

Once enacted, the provisions of the Great British Energy bill will apply nationwide and the company will have its HQ in Scotland. Westminster will work with Stormont, which has devolved control over energy policy, to implement the legislation in Northern Ireland.

The government aims to double onshore wind generation, triple solar power and quadruple offshore wind by 2030. As well as pledging extensive planning reforms, it has made the following moves to support the attainment of climate targets and, ultimately, give the public a stake in their country's energy security:

- Banning new drilling licences for oil and gas under the North Sea.
- Approving three large solar power projects in the east of England.
- Ending the effective ban on onshore wind farms.

Great British Energy's first big partnership will be with the Crown Estate, which manages £16bn-worth of land and seabed around England, Wales and Northern Ireland, including one of the world's largest floating wind-leasing programmes in the Celtic Sea. This is expected to deliver an estimated 25GW of new offshore wind capacity at lease stage by 2030 – enough to power nearly 20 million homes.

A proposed amendment to the Crown Estate Act 1961 will extend the estate's investment and borrowing capabilities and enable it to adopt digital technologies to streamline its work.

SHUTTERSTOCK/U EISENLOHR

designated by the government as being suitable for development". He also recommended a competitive tender process to be run for ownership of those sites, run by a new arm's-length body designed to "maximise UK advantage from a tidal lagoon programme".

The then government didn't share Hendry's enthusiasm and ignored his recommendations. In 2018 it even withdrew its support for the proposed tidal lagoon project in Swansea Bay – which had been included in 2014's national infrastructure plan – for cost reasons.

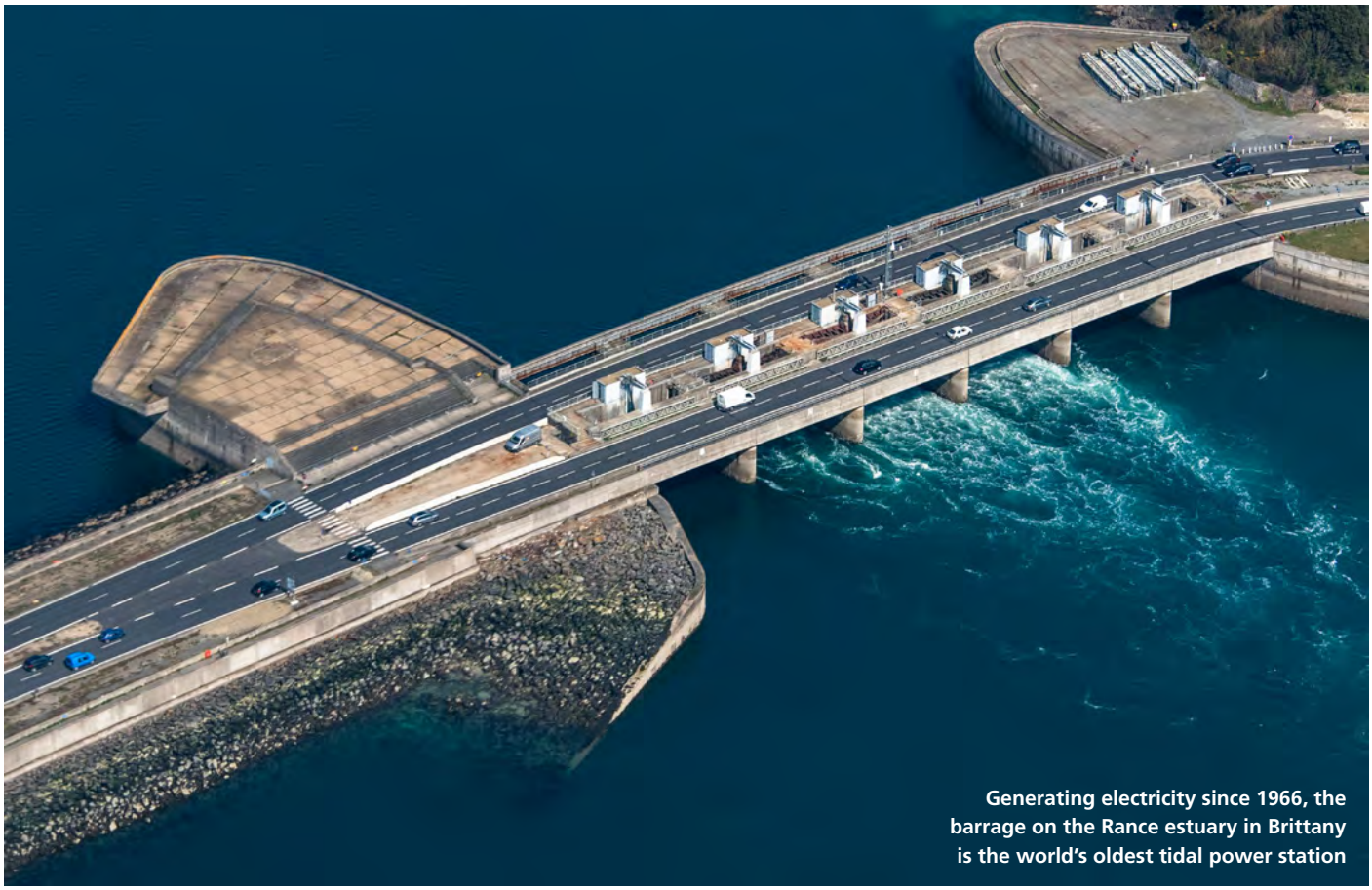
Is a sea change approaching?

Nonetheless, the inclusion of marine energy in Labour's election manifesto suggests that the new government might be more interested in exploring the strategic benefits of tidal power – particularly if putting an "end to short-termism" is more than mere political rhetoric. The long-term nature of tidal infrastructure is one of its most obvious advantages. The Hendry review estimated that a large tidal project would cost "less than 50p per household per year over the first 60 years".

"The inclusion of marine energy in Labour's election manifesto suggests that the new government might be more interested in exploring the strategic benefits of tidal power"

The Rance tidal power station in Brittany offers a case in point. After this pioneering plant opened in 1966, it was producing the most expensive electricity in France. It took about 20 years to pay for itself and today its output is cheaper than that provided by solar and nuclear generation.

Other claimed benefits include improvements to the prosperity of local communities and their quality of life. That's an argument being made by backers of the proposed



SHUTTERSTOCK/FRANCOIS BOIZOT

Generating electricity since 1966, the barrage on the Rance estuary in Brittany is the world's oldest tidal power station

1GW tidal power station on the Mersey estuary, which has strong support from the Liverpool City Region Combined Authority (see case study, next page).

It's by no means a new idea: the first plans for a barrage to harness the Mersey's tidal power date back to 1924 and feasibility studies were published in the 1980s. But the project took a big step forward last year with submission of a scoping report to the Planning Inspectorate – the first formal planning stage – and the start of a public consultation.

Footpath 'cross the Mersey

Supporters of this £6bn scheme say that, alongside the obvious clean energy intent, it would lift many thousands of local people out of fuel poverty, create jobs and improve public health by forming an active travel route between Liverpool and the Wirral peninsula for pedestrians and cyclists.

It has also been argued that the barrage could serve as a defence against flooding and become a nature-positive asset by boosting biodiversity. The latter claim may be contentious among environmentalists: one of the main reasons why the tidal power plant on Nova Scotia's Annapolis River was retired in 2019 after only 35 years' service was that turbine strikes had caused unacceptable levels of fish mortality in the estuary.

Those marketing the Mersey tidal power station project have learnt from other infrastructure schemes and are ensuring that all of these potential advantages are well communicated. They recognise that their proposal stands a better chance of surmounting the planning hurdles that all large infrastructure projects face if its purported public benefits are widely accepted.

Research cited by the government in 2013 estimated the UK's maximum tidal power-generating potential at 30GW – enough to satisfy about 12% of the country's electricity demand at the time. The Severn estuary, which has the world's third-widest tidal range, could generate up to 12GW of that total. A feasibility study completed by Westminster and the Welsh government in 2010 concluded that there was no compelling strategic case for public investment in a power station on the Severn, but perhaps the tide of opinion is starting to turn at last.

Planning reforms may well prompt positive action, but promoters of any such scheme will need to sell a convincing vision to the public. With household finances still under strain, consumers need to know that net zero is happening *for* them, not *to* them. Public choice will play a fundamental role in meeting the UK's net zero ambitions – political will and investment alone won't be enough.

Related links

- **Gary Brase and Larry Erickson:** Sustainable Energy Pathways to Net Zero
- **ICE:** Socio-technical transitions in UK electricity: part 2 – technologies and sustainability
- **ICE:** State of the Nation 2024 podcast: Low-carbon energy: ensuring a whole-life approach to renewable infrastructure delivery
- **ICE:** Tidal energy from the Severn estuary, UK
- **International Energy Agency:** Innovation Gaps – Renewable Power
- **Victor Lyatkher and Ziaur Rahman:** Wave, Wind and Current Power Generation
- **Nanomaterials and Energy:** Energy transition: paving the way for a greener future
- **National Engineering Policy Centre and Royal Academy of Engineering:** Rapid Decarbonisation of the GB Electricity System

ICE Knowledge Hub: CPD content for members
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- **Tech Talk video: How to integrate renewable energy into the grid**

The UN Sustainable Development Goals

This chapter ties in with the following SDGs:

LOW-CARBON ENERGY CASE STUDY

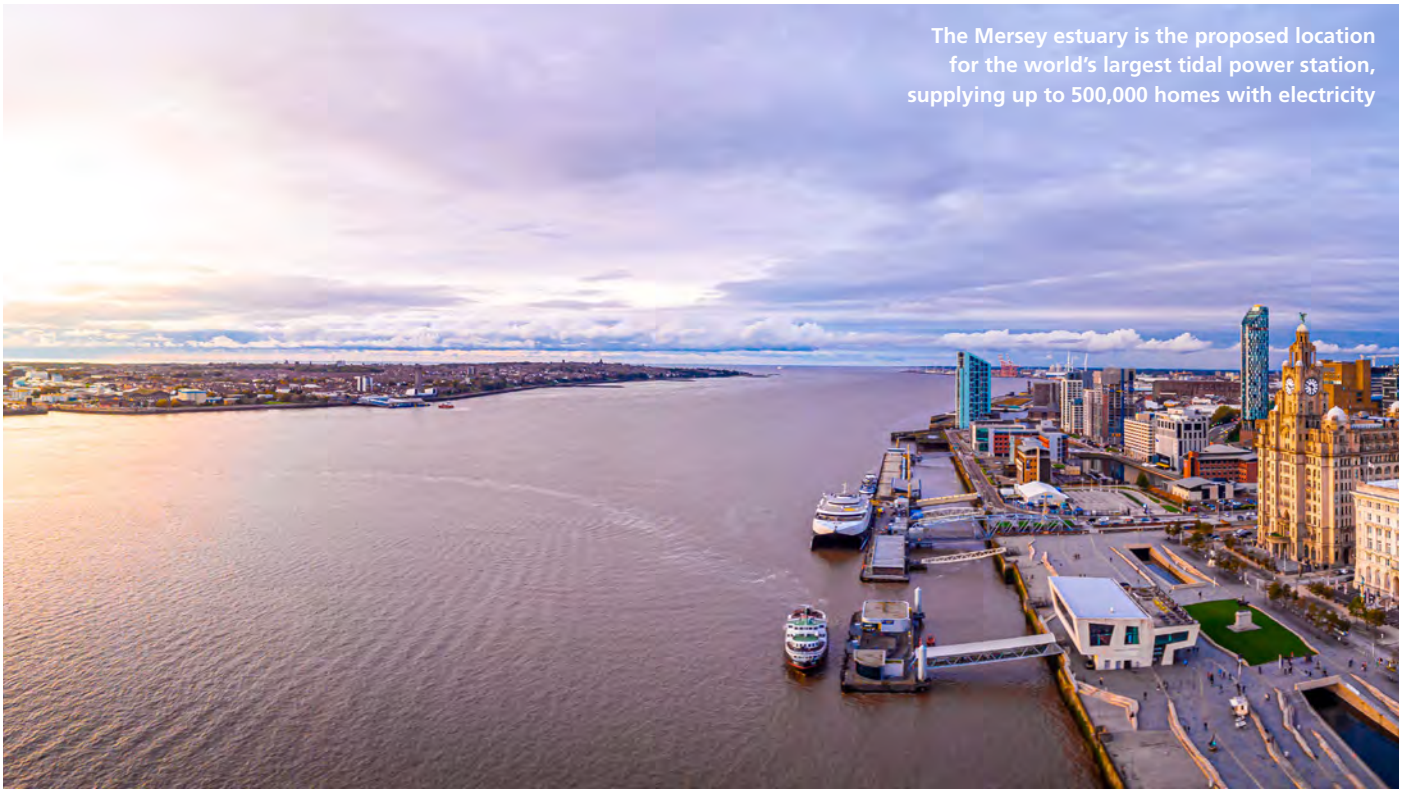
Liverpool seeks empowerment from its most liquid asset

The River Mersey has been proposed – and abandoned – as a site for a barrage-based tidal power station before. The city's devolved government has put considerable energy behind the latest scheme, which could make all the difference in propelling it off the drawing board this time

Mersey Tidal Power (MTP) is an ambitious project, with backers who are determined that it will succeed where all other schemes of its scale and type in the UK have failed.

Last spring, Steve Rotheram, metro mayor of the Liverpool City Region Combined Authority, started the formal planning process, unveiling proposals to build what he hopes could become the largest tidal power station in the world on the Mersey estuary.

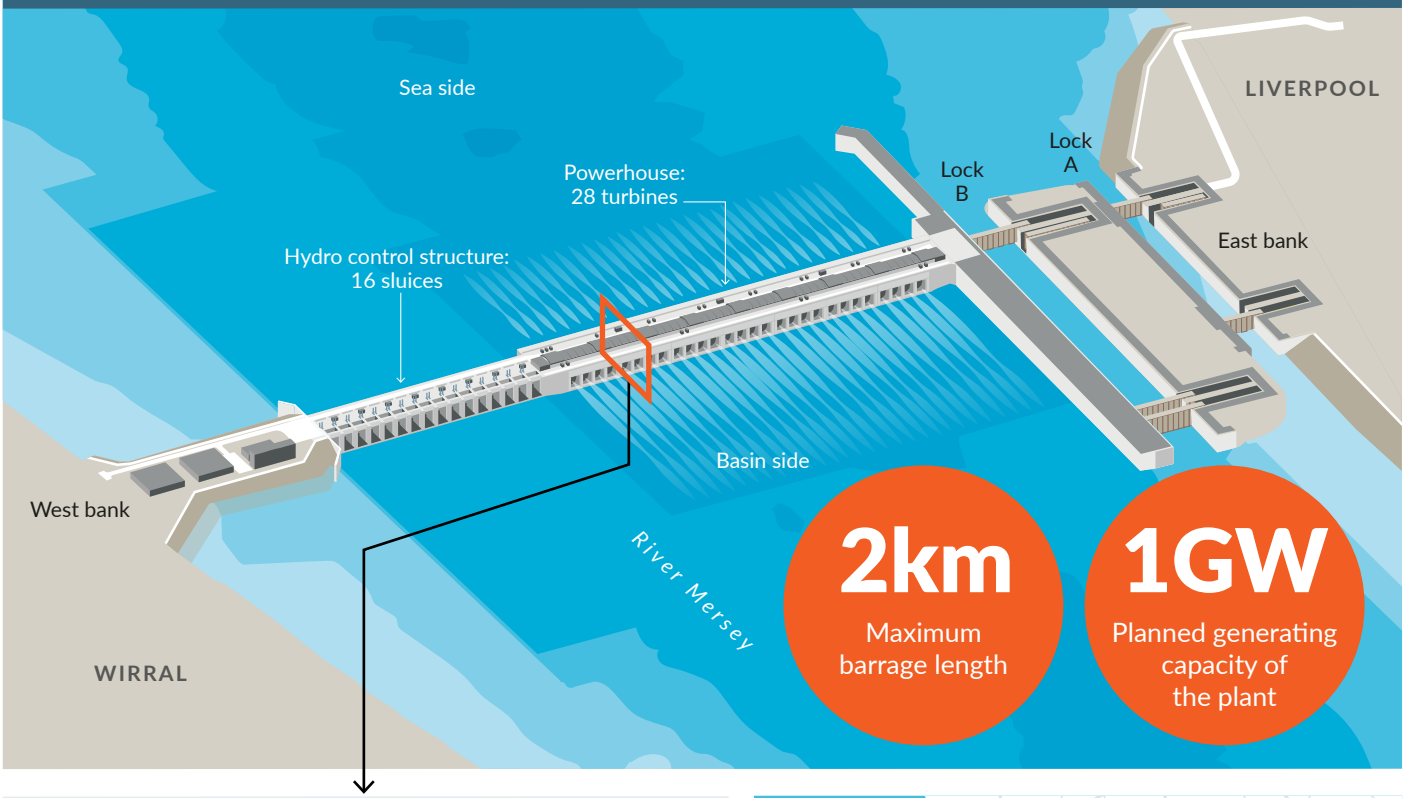
MTP builds on some of the planning work completed for Swansea's ultimately abortive tidal lagoon scheme, its most notable UK forerunner. Before that 240MW power plant was cancelled in 2018, deemed by the then government to offer insufficient value for money, it had actually obtained a development consent order. MTP features a comparable barrage design with some distinct differences that, its supporters hope, should make the project more viable. ▶ p30



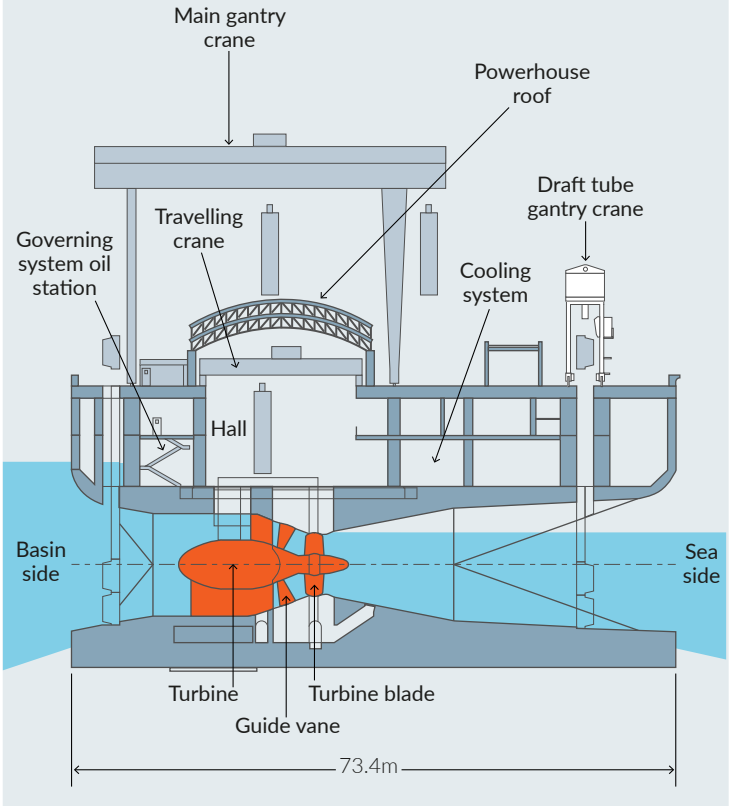
The Mersey estuary is the proposed location for the world's largest tidal power station, supplying up to 500,000 homes with electricity

ISTOCK/ALEXEY FEDOREN

MERSEY TIDAL POWER PROJECT: DESIGN CONCEPT



Powerhouse section at turbine



SOURCE: MERSEY TIDAL POWER

The barrage construction challenge

Building the two main structures that form the barrage will be no mean feat. Working in any marine location comes with several environmental and logistical challenges that will have a strong bearing on the design and construction methods applied.

The probable approach to building the system of locks allowing vessels through the barrage will involve dredging and the installation of a temporary cofferdam. Percussive or vibro-piling rigs will install sheet-piled cofferdam walls. Diaphragm walling will be installed alongside to form a watertight perimeter before the space is pumped dry enough to work in.

Both in-situ and offsite builds are likely to be needed for the elements forming the lock walls, floors and gates. The plan is that this phase would be one of the earliest completed, thereby minimising the project's disruption to river traffic.

Building the barrage will likely require a temporary cofferdam to be installed

EDF/HENRI BARANGER

The hydro control and power generation systems will probably also use a temporary cofferdam and dewatering approach to give a dry working area before crane-lifted prefabricated concrete units can be installed where needed. Prefabricated caissons might also be used to form the structure.

If caissons are required, it's envisaged that they would be made at a dock near the site before being towed to their final locations and sunk into position using water, concrete or sand ballast – potentially alongside site-won dredged material, if testing allows.

Once the barrage structure is formed, a top slab will be cast above and the surface prepared for operational access. That will be followed by the installation of any remaining rock armour or protection measures and the completion of landscaping ready for commissioning.

"Depending on its operational mode, the MTP barrage could have up to four generation periods every 24 hours, based on the twice-daily ebb and flood tides"

With a planned capacity of 1GW, MTP could power up to 500,000 homes and, while it would be groundbreaking for the UK, the project's favoured generation tech is tried and tested, with similarities to what's in place at the world's two largest tidal power stations. The Sihwa Lake plant in South Korea has been running its 10 turbines, each generating 25.4MW, since 2011, while 24 turbines have been turning on the Rance estuary in France since 1966, delivering 10MW apiece.

The project team is open about the technology's limitations, acknowledging that it can never be the sole answer to the region's energy problems. But it does see MTP as a key piece in a broader mix of elements that could together provide a low-carbon – and secure – supply of electricity.

Offshore wind is already very much part of this mix. From the Solway Firth down to Anglesey there are already more than a dozen wind farms, with a combined capacity of 3GW. Planners are seeking consent for four more, offering 4GW in total, across Liverpool Bay before 2030.

The height of ambition

The UK's north-west coast has a predictable tidal pattern that repeats itself every 17.6 years. Crucially, the tidal ranges in this area are among the widest in the world. The difference between mean high water and low water on the Mersey at Liverpool during spring tides is 8.27m, for instance. Depending on its operational mode, the MTP barrage could have up to four generation periods every 24 hours, based on the twice-daily ebb and flood tides here.

Given that the scheme is still in the planning phase, several fundamental components – including the materials – have yet to

be finalised. That said, the barrage would probably be formed of reinforced concrete and supporting steel components.

A preferred site hasn't even been specified, either. A previous tidal power plan, which was cancelled in 2011, had proposed a barrage between the Liverpool neighbourhood of Dingle and New Ferry on the Wirral peninsula, but this scheme is more likely to be located further downstream "towards the mouth of the Mersey", according to the latest disclosures to the Planning Inspectorate.

As it stands, the Mersey Tidal Power plan covers the following key areas:

- **Electricity production.** The barrage's most important structure – its power generation system – houses the bidirectional turbines, which would always be fully submerged. It contains other important elements too, including control equipment, a water-cooling system to prevent the turbines from overheating, firefighting kit, dewatering pumps and cranes.
- **Hydro control.** This structure comprises a foundation support for the sluice gates that would enable the plant to adjust the flow of water through the barrage. These straight vertical or curved radial gates will be made of steel, so they'll need effective protection (passive or cathodic) against the corrosive effects of the estuary's brackish water.
- **Marine navigation.** A system of locks will enable vessels using this important shipping route to pass through the barrage. The locks' number, size and position have yet to be determined.
- **Breakwaters.** Watertight structures, probably formed with rock faces, will join the barrage to the riverbanks.
- **Connection to the grid.** Cables, transformers and other equipment will collect electricity produced by the turbines. An export substation, located on or near the barrage, will handle what's generated and send it into the distribution system.
- **Operational facilities.** These will include a control room, offices, car parks and buildings housing maintenance equipment. Some of these assets may be built on the barrage itself, while others will be located on adjoining reclaimed land.

Details such as the number, size and model of turbines to be used will be determined in later design and procurement stages. An environmental impact assessment scoping report by engineering consultancy WSP in 2024 proposed that the hydro control structure could contain up to 50 sluice gates, while the power generation system could feature as many as 50 turbines. One such unit could have a diameter of 10m and a maximum generation capacity of 30MW.

Notes from an earlier Planning Inspectorate meeting suggest more modest numbers from previous feasibility studies: between 26 and 30 turbines, each with diameters of about 8m.

INDICATIVE PROJECT TIMELINE

November 2024
The end of a six-week non-statutory community consultation on the preliminary plans

2024-25
Further project development, including the consideration of consultation feedback, stakeholder engagement, engineering design work and environmental assessments

2025
A statutory consultation with stakeholders, including local landowners and communities, on the refined plans

2026
The submission of an application to the Planning Inspectorate for a development consent order (DCO)

2026-27
The Planning Inspectorate spends an estimated six months examining the application before issuing its recommendation. The secretary of state for energy security and net zero then decides whether to grant the DCO

2028
If the DCO is granted, construction work starts on the barrage and its associated infrastructure

2036-38
The two-year commissioning phase, during which all elements of the barrage are tested thoroughly

2038
The barrage and its turbines start operating and generating power

The hydro control structure is likely to have a maximum width of 70m and a depth of 30m below Ordnance datum (mean sea level). The barrage is expected to have a length of 2km and a height of 7m above Ordnance datum, rising to 8m at its abutments.

A barrier and a passageway

As well as generating clean renewable electricity, the barrage would potentially help to protect the surrounding area against the increased risk of flooding caused by future sea-level rises. It would also encourage active travel by creating a walking and cycling route between Liverpool and the Wirral.

There are well-founded concerns that a tidal plant could potentially alter the natural environment, both upstream and downstream from the barrage, and disrupt marine ecosystems. With these in mind, the MTP team has conducted modelling to start understanding such effects and planning ways to mitigate these.

While construction methods have yet to be finalised for the barrage, the use of temporary cofferdams to provide dry working areas, diaphragm walling and prefabricated offsite caissons are all considerations (see panel, page 30).

The project calls for a mega-excavation operation that would remove between 7 million and 20 million m^3 of material. The project team hopes to re-use as much of what gets dredged onsite. Some material could also be used for a local marine enhancement scheme, thereby minimising the amount that might otherwise require disposal offshore.

Estimates have suggested that the building work could take between seven and 10 years, depending on the approach chosen, and employ about 5,000 temporary construction workers during peak activities.

To keep disruption to the environment, river users and people living near the site to a minimum, the project team has proposed a staged approach to construction. Planning is under way for future maintenance needs too. Among these are dredging operations, the extent of which would be confirmed based on the barrage's final chosen location.

The project team completed its first (non-statutory) public consultation in Q4 2024 and is planning to apply for a development consent order next year. It hopes that the Mersey Tidal Power scheme will gain approval to enable commissioning in 2036 and be fully operational – and generating electricity for the region – by 2038.

Related links

- **Applied Sciences:** Tidal range barrage design and construction
- **Charles Hendry:** The Role of Tidal Lagoons
- **ICE:** The Rance tidal power station: a quarter of a century
- **Ocean Engineering:** Lake Sihwa tidal power plant project
- **Renewable and Sustainable Energy Reviews:** A world first: Swansea Bay tidal lagoon in review

ICE Knowledge Hub: CPD content for members
knowledgehub.ice.org.uk/learn

- **Tech Talk video: How engineers can influence the move to low-carbon energy**

The UN Sustainable Development Goals

This case study ties in with the following SDGs:

LOW-CARBON ENERGY CASE STUDIES IN BRIEF

Turning the tide

Tidal stream power might prove a key addition to the renewable energy mix if it can become more cost-efficient – and if the National Grid can develop sufficient capacity to distribute it

Cross-Channel entente highlights the viability of tidal stream tech

ORBITAL MARINE POWER

Citing research suggesting that tidal stream energy could meet 11% of the UK's electricity needs, an Anglo-French R&D programme has tested several technologies that could make this mode of generation a more affordable part of the energy mix.

Differing from range technology, which relies on building a barrage across an estuary or coastal lagoon to benefit from the rise and fall of tidal water, tidal stream generation converts the lateral kinetic energy of tidal currents into electricity.

The Tidal Stream Industry Energiser (Tiger) project – a partnership of 18 organisations spanning industry, academia and local government – enabled the installation of four tidal stream devices at test sites off the coasts of France and the UK, creating 3.6MW of generation capacity. It also supported the development of 16 further devices that could collectively provide as much as 57.4MW more.

Tiger drew €48.4m (£40.8m) in funding, two-thirds of which came via the EU-backed Interreg France (Channel) England

programme. The project, which ran from 2019 to 2023, aimed to show how the costs of tidal stream generation could be reduced and highlight its potential economic benefits, thereby making such schemes more attractive to investors.

One of Tiger's partner organisations, the Offshore Renewable Energy Catapult, estimated the cost of tidal stream generation at £260 per MWh in 2022. It published a research report concluding that the potential is there to slash that figure to £78 per MWh by 2035 and to £50 per MWh by 2047.

The findings of the Tiger project helped three of its developers to access £20m per year of energy generation subsidies via the UK government's Contracts for Difference scheme.

Commenting on those funding awards, the UK Marine Energy Council's chair, Sue Barr, noted that "tidal stream is forecast to be cheaper than new nuclear at the point of 1GW of deployment. It supports the UK, creating sustainable jobs and supply chains in coastal communities and beyond, while boosting energy security through an entirely predictable baseload-style renewable energy resource."

Can the grid take the strain imposed by the green energy revolution?

The UK's ability to supply all consumers with clean electricity harnessed from tidal energy, along with other renewable sources, will depend on the capacity of the transmission and distribution network to handle the increasing demands placed on it.

SHUTTERSTOCK/PAUL MAGUIRE

National Grid plc expects the nation's consumption of electricity to double over the next 25 years, as heating and transport in particular shift away from fossil fuels. The company faces a serious challenge in realising the government's goal of "transitioning to an electricity system [where, during a year in which the country experiences typical weather], clean sources produce at least as much power as Great Britain consumes" by 2030.

The National Grid was originally built in the mid-1930s to distribute electricity produced from fossil fuels – primarily coal. Given that the UK has committed to connecting 40GW of offshore wind generation capacity to it within five years, this 90-year-old network of cables, pylons and substations requires a thorough upgrade if it's to stand any chance of meeting the demand.

National Grid plc has therefore embarked on the biggest overhaul of its infrastructure in a generation. Its Great Grid Upgrade programme features 17 programmes of work. Some of these entail improving existing infrastructure while others involve installing entirely new systems.

Last year the company established an enterprise delivery model in collaboration with seven businesses to work on the first nine projects. The so-called Great Grid Partnership encompasses five construction companies – Laing O'Rourke, Morgan Sindall Infrastructure, Morrison Energy Services, Murphy Power Networks and OTW – and two design and consenting service providers: WSP and a joint venture between AECOM and Arup.

One project already under way, with preparatory works starting in the autumn of 2024, is the Yorkshire Green scheme. Its main objectives are to build two new substations in rural North Yorkshire, refurbish 28km of extant overhead lines and install 10km of new lines (and 33 pylons), plus 1km of underground cabling.

Morrison has been selected for the overhead line work, while Murphy is to deliver the substations. They're aiming to finish the project by the end of 2028.

03 Water

The sector's clean-up efforts haven't impressed consumers so far, but infrastructure engineers must rebuild public trust and support if they're to establish urgently needed new resources

The nation's water and wastewater infrastructure faces an enormous challenge over the coming decades. The following statistics indicate the daunting scale of the main problems urgently awaiting a package of resilient, sustainable solutions.

The UK uses about 14 billion litres of water every day. England alone will need almost 5 billion litres more by 2050, according to the Environment Agency's latest estimate. And the thousands of kilometres of Victorian sewers still in use are struggling so badly to handle demand that discharges of raw sewage into rivers and coastal waters are far more than everyday occurrences. In 2022, for instance, there were 301,000 known spills from UK water companies' storm overflows – more than one every two minutes on average over the year.

This has left the water quality of our rivers, lakes and seas in a perilous state. Only 20% of British waterways are in, or nearing, good ecological condition.

This has caused widespread anger among those who have seen little effective action from water companies to improve the situation. Public trust in these businesses is at its lowest level since the Consumer Council for Water started tracking the views of bill payers in England and Wales 13 years ago.

The ICE has called for stronger regulation and longer-term planning in the water sector. Reflecting the new government's stated priorities, an ICE policy programme is looking in depth at potential reforms.

The government has claimed that forthcoming legislation will "fundamentally transform" the industry and improve the nation's waterways. As a first step down that path, its water (special measures) bill proposes to introduce a code of conduct for water companies. It would grant industry regulator Ofwat powers to impose automatic fines on those failing to meet environmental standards, ban executive bonus payments and prosecute law-breaking bosses.

Once enacted, it would also require firms to monitor their sewage outfalls in real time and share the data gathered with Ofwat. Spills remain the industry's most public defect. Following its investigation into illegal discharges in August 2024, the watchdog recommended that Northumbrian Water, Thames Water and Yorkshire Water should pay fines totalling £168m for various wastewater treatment failures.

In last year's State of the Nation report, the ICE called for greater innovation in, and use of, nature-based solutions and sustainable drainage systems as an affordable way to reduce the volume of stormwater entering sewerage systems and causing overflows. The institution continues to work with other bodies, including the Chartered Institution of Water and Environmental Management, to produce guidance and support aimed at removing barriers to the widespread retrofitting of sustainable drainage systems in towns and cities nationwide.

33%

Proportion of consumers satisfied with water companies' environmental efforts in England and Wales

1992

The year that Carsington Water in Derbyshire – the last major reservoir to be built in the UK – was opened

570m

Litres of water estimated to have been lost by Thames Water to leakage each day on average in 2023-24

Sources: Consumer Council for Water, Severn Trent Water, Thames Water

Reservoir planning

This report will focus more on the resources challenge. That's because, despite the UK's reputation for having a damp climate, the nation's daily demand for water is expected to exceed the current supply by more than a third within 25 years.

The National Infrastructure Commission's Second National Infrastructure Assessment (NIA), published in October 2023, is clear on the way forward. Yes, leakage from water mains

"Despite the UK's reputation for having a damp climate, the nation's daily demand for water is expected to exceed the current supply by more than a third in 25 years"

must continue to be targeted – and work is progressing here. And yes, demand has to be reduced, most obviously by compulsory metering and pricing, although that's politically sensitive. But the real challenge lies in securing new resources and adequate storage.

The NIA points out that no major reservoir has been created in the UK in the past 30 years. That drought could be about to end, though: Thames Water, Anglian Water and Portsmouth Water are all planning new ones.

Thames is preparing for a public inquiry this summer into its proposed 150 billion litre reservoir near Abingdon, Oxfordshire, with a view to submitting a planning application in 2026 and starting construction in 2029. Anglian is at a similar stage with its proposed reservoir near Chatteris, Cambridgeshire.

Portsmouth Water is the most advanced with its plans for an 8.7 billion litre reservoir at Havant Thicket, Hampshire. Already under construction, this is expected to enter service in 2029. The project is being funded over time by neighbouring company Southern Water. It will help Southern to reduce abstractions from the rivers Test and Itchen, both of which are rare and ecologically important chalk streams.

"No major reservoir has been created in the UK in the past 30 years. That drought could be about to end, though: Thames Water, Anglian Water and Portsmouth Water are all planning new ones"

Comprising Mackley Engineering and Jones Bros Civil Engineering UK, a joint venture called Future Water MJJV is delivering the reservoir, having won the £167m contract in

Artificial intelligence: a problematically thirsty technology

Tackling leaks and building new capacity are two parts of the National Infrastructure Commission's three-part solution to the UK's shortage of drinking water. The third – reducing demand – could also prove difficult, not least because demand is increasing in some surprising ways.

Artificial intelligence (AI) offers potentially huge benefits to society. When combined with the internet of things, it can perform certain tasks far more efficiently and effectively than humans could ever manage. Water companies are using AI to expedite the detection of leaks, identify toxic chemicals in drinking water, map underground assets and predict pollution incidents so that they can take timely preventive action.

SHUTTERSTOCK/DC STUDIO

Yet, despite all it has to offer us, is AI an environmentally sustainable solution?

AI demands much more energy than previous digital technologies have required. The massive data centres it relies on emit a lot of heat and require huge volumes of water for cooling. While one Google search consumes about half a millilitre of water, the AI-powered chatbot ChatGPT "drinks" about half a litre for every 50 or so questions it answers.

AI's global annual water consumption could hit 6.6 trillion litres by 2027. Many people have grasped that this technology consumes vast amounts of energy, but its excessive thirst is not so well known.

Could AI be a source of water demand that also needs to be reduced? Given that developing countries are most affected by shortages, further contributing to global injustice, this emerging dilemma must be addressed urgently.

February 2023. GHD is the engineering consultant and Atkins developed the early design. Once operational, this asset will be able to supply up to 21 million litres of water every day. That's enough for about 160,000 people – three-quarters of Portsmouth's population – in an average year.

Also of interest is a separate planning application seeking to allow Southern Water to add highly treated purified recycled water to the reservoir and so enable it to be more productive during droughts. Supplementing the reservoir with recycled water – the use of which is also recommended in the NIA – could secure an extra 90 million litres daily. Known as the Hampshire Water Transfer and Water Recycling Project, it would be the first scheme of its kind in the UK and a potential breakthrough in water resourcing (see case study, page 41).

A case study in circularity

Similar work is already in progress, albeit on a smaller scale, in western France. An innovative scheme is being implemented in the seaside town of Les Sables-d'Olonne that will send recycled water from sewers to household taps later this year. The water will be processed several times on that journey, including being sent through a constructed marshland, partly to restore minerals lost during its passage through two separate treatment plants.

Although using treated wastewater for drinking purposes is technically feasible, some people consider overcoming the so-called yuck factor and gaining acceptance from UK consumers to be a huge challenge. But are they right? A 2022 survey conducted for the Drinking Water Inspectorate indicated that 79% of the UK population would accept the use of recycled water to supplement supplies of drinking water. Portsmouth Water's own research last year found that 70% of its customers supported wastewater recycling and would be content to consume water processed that way.

Infrastructure engineers must help to ensure that more innovations of the type Portsmouth Water is proposing become a reality. One way of achieving this is to be open and honest about what's being done – and committing to doing it when promised – because engineers need the public back on side.

French water company Vendée Eau has built a new plant to enable it to recycle wastewater from the town of Les Sables-d'Olonne

VENDÉE EAU

That's going to be a challenge, given that the sewage discharge problem is not a quick or cheap fix.

Main street blues

Tackling leaks is no easy task either, given that much of the leakiest pipework runs through densely populated areas. Digging up busy urban thoroughfares to repair or replace mains is both costly and highly disruptive.

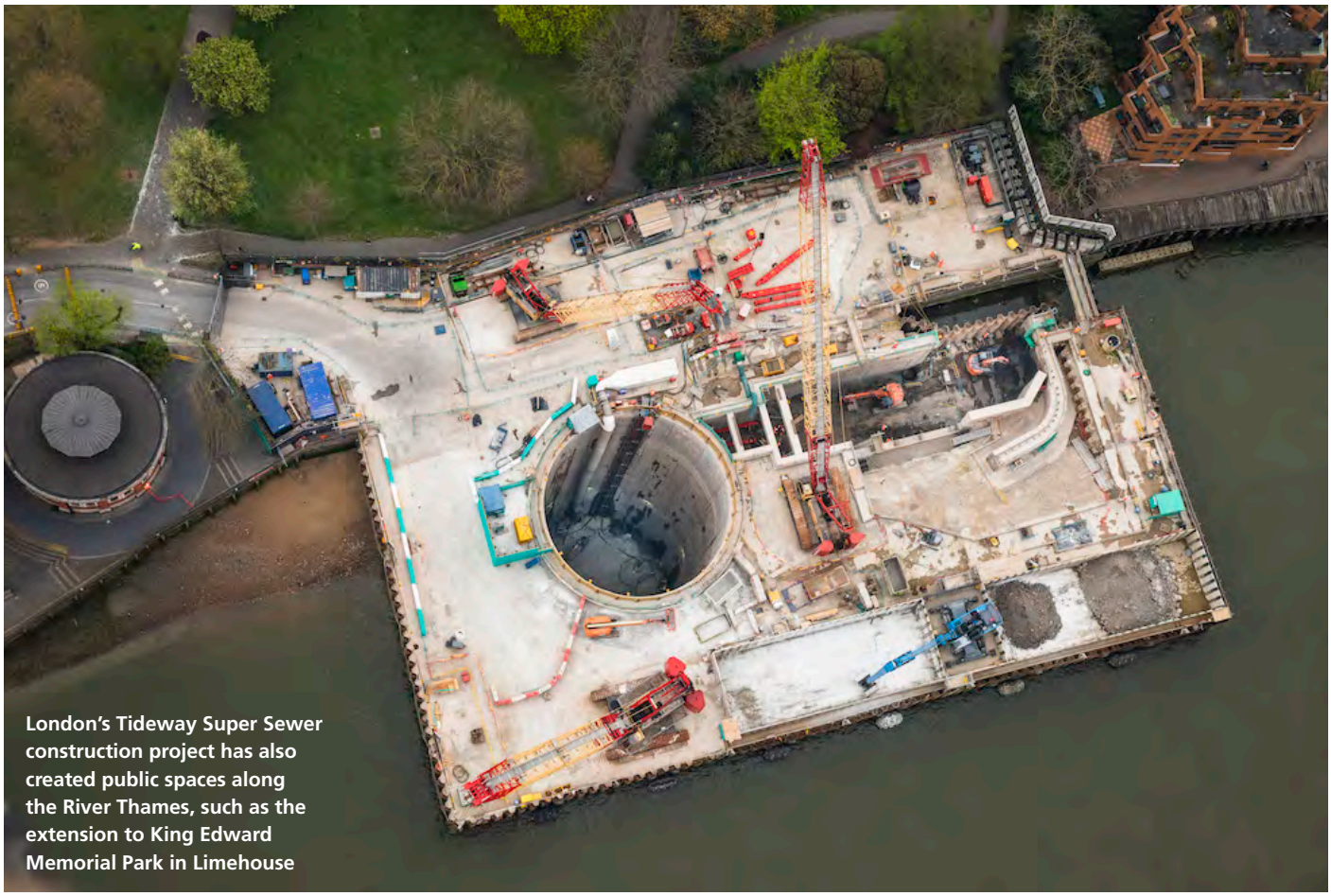
UK water companies have historically focused more on repair than on replacement. It's understandable: they're subject to fines if they are too slow to restore supplies to their customers, who are rightly protected from extended service interruptions. Utility companies must also pay surcharges if their works overrun. In this context, a quick fix makes more sense than a big asset renewal programme.

Thames Water has valued its ongoing project to replace 1.3km of mains in London's East End at £20m. Much of that can be attributed to the costs of traffic management and settling claims for loss of income from local businesses disrupted by the works.

"UK water companies have historically focused more on repair than on replacement. It's understandable: they're subject to fines if they are too slow to restore supplies to their customers"

Water companies previously worked to a "sustainable economic level of leakage". It's only in the past few years, now that climate change is firmly on the agenda, that they have been asked by the government to reduce leakage by half before 2050.

Until recently, relatively little of the sector's R&D work was devoted to making pipe repairs more efficient and less disruptive.



London's Tideway Super Sewer construction project has also created public spaces along the River Thames, such as the extension to King Edward Memorial Park in Limehouse

TIDEWAY

But now there are 420 water company projects tackling this problem around the country, according to a leakage innovation heatmap created by UK Water Industry Research. Some firms are experimenting with gels to seal leaks from the inside of pipes, for example. Others are sending robots through them to perform inspections. It's been suggested that these will be able to make repairs themselves in five to 10 years' time.

Much innovation in leak-detection tech is happening too. A trial using artificial intelligence and the internet of things, for instance, has slashed the average time taken by one firm to identify a leak and attend to it from three days to two hours. And sound-pulse technology is being used to assess the condition of pipes to ensure that sections in good repair aren't replaced unnecessarily.

Time to pipe up

Such stories need to be shared widely to win over the public. Consumers might not realise that their own faulty plumbing is responsible for a third of leakage in the UK or that climate change is making burst pipes more common. And few people know about all of the R&D that water companies are doing, the regulatory constraints they're operating under or the sheer amount of work it takes to produce a glassful of clean H_2O.

Still, consumers certainly do understand how environmentally damaging large-scale discharges of untreated sewage are to rivers and coastal waters. They're also coming to appreciate the public health ramifications. While the cryptosporidium contamination of water supplies in south Devon last summer may have been a rare incident, it attracted considerable negative publicity.

Certain initiatives have been able to communicate well and secure widespread backing, with some even creating a supportive extended community for themselves. The Thames Tideway Tunnel, for instance, provides a case study in shrewd public relations. The so-called Super Sewer construction project has sold itself effectively as an environmental initiative with the guiding ethos of reconnecting London with its river.

Tideway took inspiration from Singapore, which constructed a barrage across the Marina Channel in 2008 to create a vital reservoir, a flood defence and a leisure facility. In turn, Anglian Water is determined to apply lessons from Tideway to its reservoir project – and there's evidence to suggest that Portsmouth Water is following suit at Havant Thicket too. But engineers everywhere should take note of all effective methods of promoting their good – and crucial – work and explore ever more creative ways to listen to the public and take their concerns about big infrastructure on board.

Related links

- **Dams and Reservoirs:** Development of strategic water resources in England
- **ICE:** The ICE Manual of Blue-Green Infrastructure
- **ICE:** Towards a Sustainable Water Future: Proceedings of Oman's International Conference on Water Engineering and Management of Water Resources
- **ICE:** Water Supply and Distribution Systems
- **Water Magazine:** Securing resilient water supplies for south-east England
- **Water Research:** The role of deep learning in urban water management: a critical review
- **Water Reuse Europe:** Innovative water recycling project in Les Sables-d'Olonne

ICE Knowledge Hub: CPD content for members
knowledgehub.ice.org.uk/learn

- **Explainer: What engineers can learn from Mansfield's flood-resilient SuDS**
- **Explainer: Why storm overflows exist and how to minimise spills**
- **Tech Talk podcast: How engineers can help make rivers safe for bathing**

The UN Sustainable Development Goals

This chapter ties in with the following SDGs:

WATER CASE STUDY

Southern Water's bid for recycling proficiency

A visualisation of Havant Thicket Reservoir, which will play a key role in ensuring that supply meets demand as the local population increases

PORTSMOUTH WATER

The company has groundbreaking plans to convert wastewater into drinkable condition on a large scale. Will its proposed solution to resource scarcity prove clear and palatable to the authorities?

In the most water-stressed region of the UK, Southern Water is developing innovative ways to ensure that taps and rivers here will never run dry, even during the severest of droughts.

Until recently, most of what the company delivered to 700,000 customers across much of Hampshire and the Isle of Wight – about 180 million litres a day – came from only two rivers: the Test and the Itchen (and their local aquifers). But growing concerns about the threats posed by abstraction to their rare and sensitive chalk-stream ecosystems prompted the Environment Agency to limit the volume of water that could be removed from them.

These restrictions on Southern's abstraction licences, along with the forecast effects of climate change and the region's

projected population growth over the next 25 years, have left the firm facing a possible daily supply shortfall of 200 million litres by 2050.

To tackle this problem, it has started a programme called Water for Life – Hampshire. This incorporates several schemes to transform how Southern sources, treats and supplies water around the county, along with significant work to fix leaks.

A reservoir with a difference

One of the programme's central measures is the creation of south-east England's first sizeable reservoir since 1978, when Ardingly Reservoir was completed in West Sussex. Havant Thicket Reservoir (HTR), being constructed in partnership with Portsmouth Water, will be funded over time by Southern's supply bills.

8.7bn

Havant Thicket Reservoir's projected capacity in litres – about 85% bigger than Ardingly Reservoir in neighbouring West Sussex

40km

Length of the planned pipeline linking Southern's proposed recycling plant and its water supply works in Otterbourne

£1.2bn

Expected minimum cost of Southern's proposed Hampshire Water Transfer and Water Recycling Project

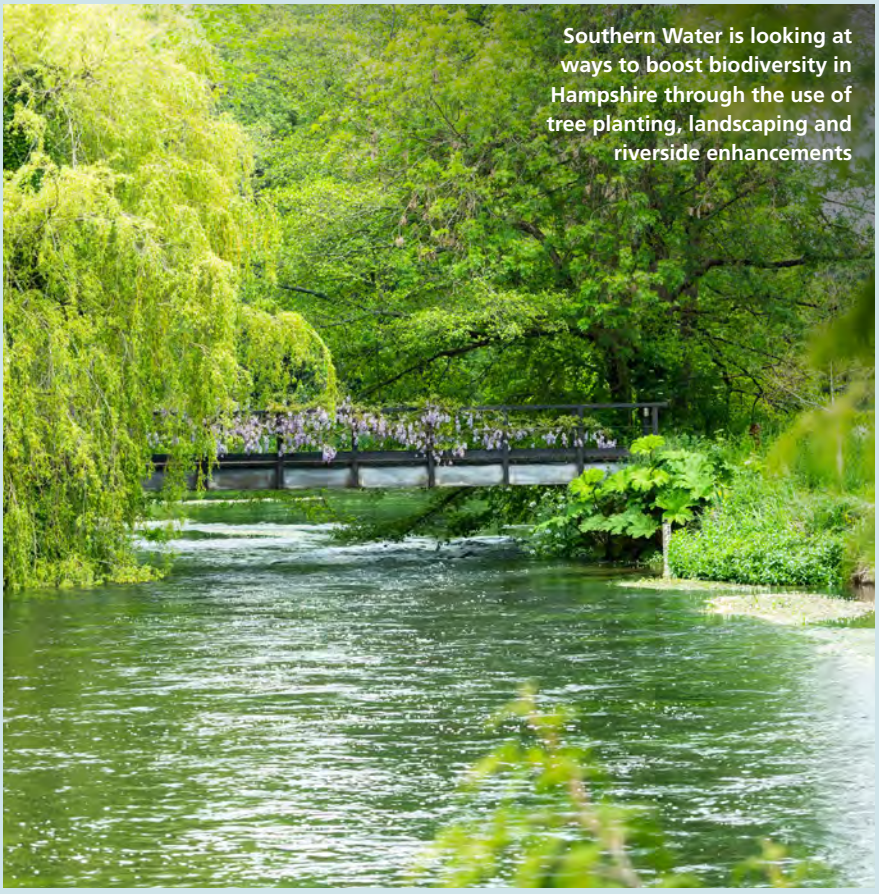
Source: Southern Water

How Southern Water is planning to achieve an environmental net gain

Environmental net gain (ENG) is an approach to new developments that aims to ensure that they have a positive ecological impact, leaving every area covered by a given construction project in a significantly better condition than they were in before the works started.

Biodiversity net gain is a crucial element of ENG. Southern is exploring ways to achieve a 10% increase in biodiversity with the Hampshire Water Transfer and Water Recycling Project. It's considering measures including tree planting, landscaping and other enhancements to grassland and riverside habitats.

Such opportunities could involve onsite and offsite measures and collaborations with other parties to support existing or planned initiatives. Southern will include proposals for achieving a biodiversity net gain and an ENG in its application for a development consent order.



Southern Water is looking at ways to boost biodiversity in Hampshire through the use of tree planting, landscaping and riverside enhancements

SOUTHERN WATER

PORTSMOUTH WATER

A visualisation of the visitor centre at Havant Thicket Reservoir, where the main construction phase is expected to start this spring

Once completed, this spring-fed reservoir should be able to provide 21 million litres a day, but Southern is hoping to make optimal use of its new asset's planned storage capacity of 8.7 billion litres by adding as much as 60 million litres of purified recycled water on each day of a drought. In doing so, the firm would gain the potential to transfer an extra 90 million litres daily from HTR to its supply works at Otterbourne, which renders the water fit for distribution to consumers.

If these plans are approved – the final decision rests with the secretary of state for environment, food and rural affairs – the proposed Hampshire Water Transfer and Water Recycling Project (HWTWRP) is set to cost at least £1.2bn.

"Water recycling applies advanced methods to purify treated wastewater so it can become a source for supply after further processing"

Water recycling, a process already being used in countries including Australia, Namibia and South Africa, applies advanced methods to purify treated wastewater so that it can become a source for supply after further processing. The HWTWRP would take some of the output from Southern's Budds Farm wastewater treatment works in Havant as its source. This would be purified at a new recycling plant before being pumped into HTR, where it would mix with spring water.

Southern's preferred recycling treatment process applies a technique called reverse osmosis. This filters out microbes and harmful dissolved chemicals by forcing the water through membranes with molecule-sized pores. The reject stream, containing impurities that are already routinely pumped into the sea in treated wastewater from Budds Farm, would be sent through an existing outfall extending 5.7km from the beach at Eastney, south-east Portsmouth. The company is working with both Natural England and the Environment Agency to ensure that this would have no additional harmful impacts on the local marine ecology.

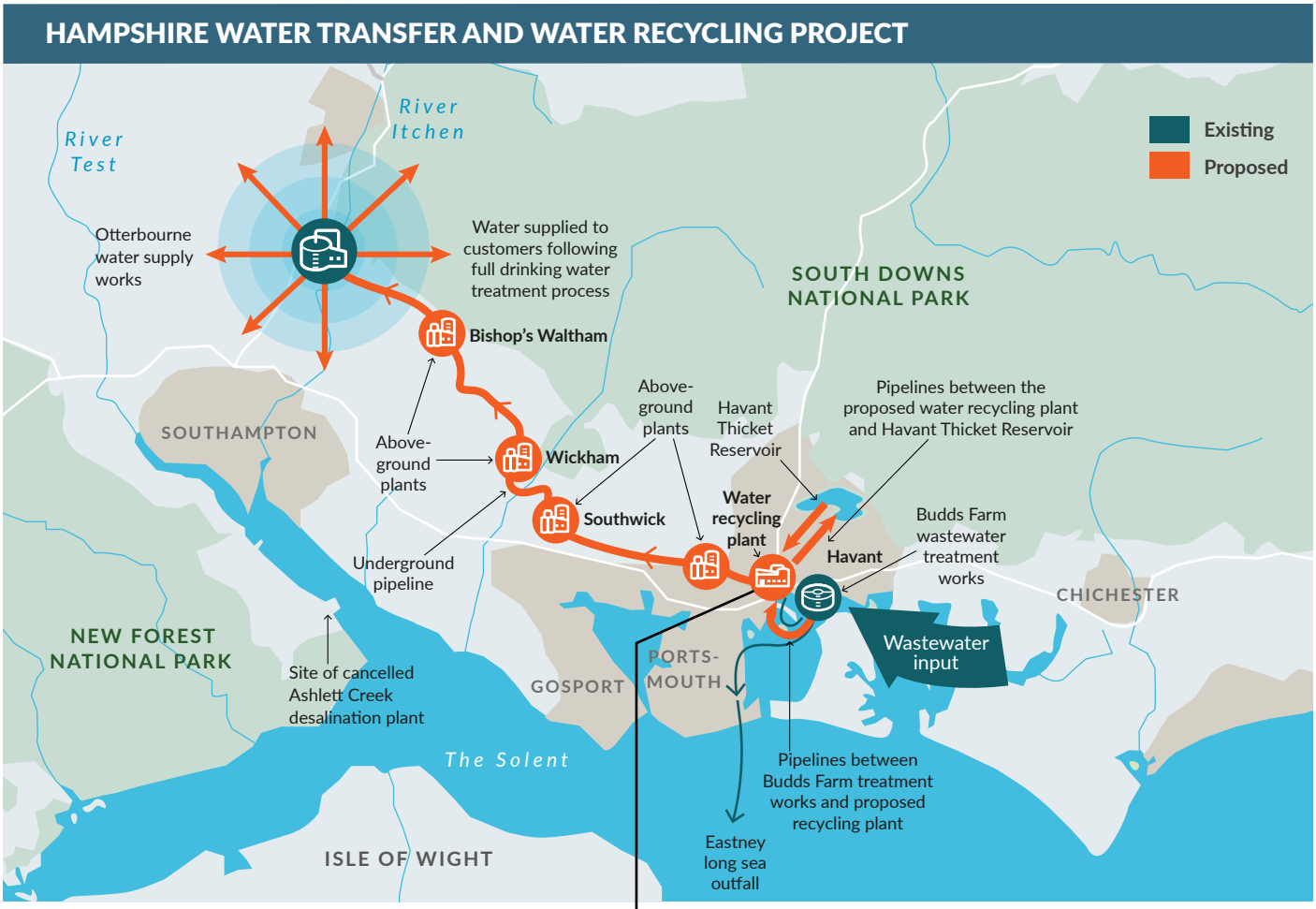
Southern has also been collaborating with the University of Brighton on a test facility to assess its favoured techniques and technologies. This has attracted site visits from more than 100 people representing local government, the environmental lobby and other interest groups.

Progress to date

The firm has worked extensively on stakeholder engagement in recent years as its plans have evolved. In 2021, for instance, it held a public consultation on the proposed construction of a desalination plant at Ashlett Creek near the New Forest village of Fawley. These plans were scrapped after conservationists and local politicians raised objections about the facility's potential ecological impact. Desalination is also far less energy-efficient than water recycling. This is because seawater contains significantly more dissolved solids and therefore needs to be forced through reverse-osmosis membranes at higher pressures.

The company consulted on the HWTWRP in 2022, seeking views on issues including the proposed location of the recycling plant, preferred pipeline routes and even the very concept of wastewater recycling. It will use feedback gained from a further consultation in the summer of 2024 to refine its plans as it prepares its application for a development consent order this year.

Southern has adopted a so-called direct procurement for customers (DPC) approach to building the plant and its related infrastructure. DPC is a tendering process that seeks bids from third parties to design, finance, build, operate and maintain assets. ▶ p45

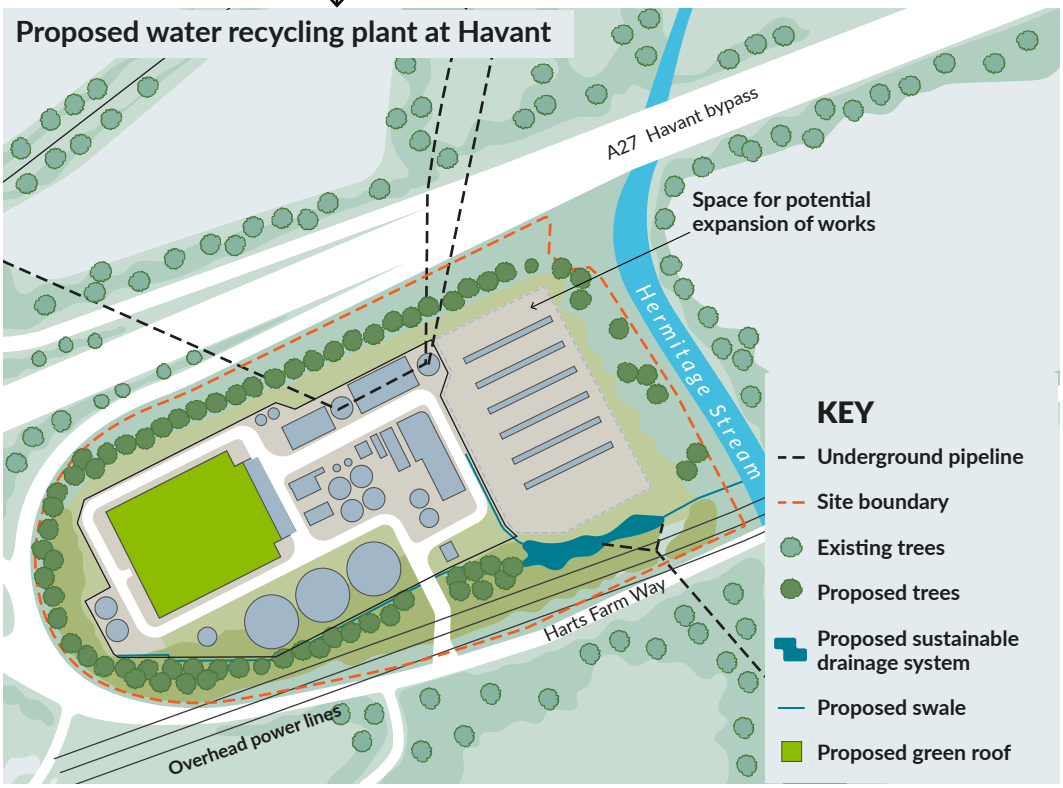


80m litres

Volume of treated wastewater the plant could receive daily in drought conditions

60m litres

Volume of purified recycled water the plant could produce each day



SOURCE: SOUTHERN WATER

“Most of the subterranean pipework will be installed simply by digging a trench, laying a length of pipe and backfilling the trench”

The company has held a series of market engagement events over the past 12 months and is planning further ones.

Technology and construction

The HWTWRP has several key components, the first of which is the construction of a water recycling plant and three adjacent pumping stations north-west of the Budds Farm wastewater treatment works.

The scheme also requires several underground pipelines to be built. They include one pipe to transfer treated wastewater from the Budds Farm works to the new recycling plant and another to move reject water from the plant back through Budds Farm to the long sea outfall off Eastney beach.

Pipelines will be needed between the recycling plant and Bedhampton springs in Havant too. These would join pipes being proposed by Portsmouth Water between the springs and HTR.

The network created this way would transfer purified recycled water from the plant to HTR and transfer the resultant mix of recycled and spring water from the reservoir back to the recycling plant’s adjoining high-lift pumping station. (Southern is forming back-up plans for its own pipelines between the recycling plant and HTR, should Portsmouth Water not obtain planning permission.)

Then an underground pipeline of about 40km will be needed to move water from the high-lift pumping station to Southern’s supply works at Otterbourne. To propel it that distance, two new intermediate pumping stations, one break-pressure tank and one combined pumping station and break-pressure tank will be required.

Most of the subterranean pipework will be installed simply by digging a trench, laying a length of pipe and backfilling the trench. In heavily populated areas and those with particularly stringent environmental constraints, trenchless construction techniques will be applied, including the use of tunnel boring machines and pipe jacking.

Related links

- Mudhar Al-Obaidi, Chakib Kara-Zaitri and Iqbal Mujtaba: Wastewater Treatment by Reverse Osmosis Process
- Department for Environment, Food and Rural Affairs: National Policy Statement for Water Resources Infrastructure
- ICE: Basic Water Treatment
- ICE: Towards a Sustainable Water Future
- ICE: Water Supply and Distribution Systems
- National Infrastructure Commission: Preparing for a Drier Future: England’s Water Infrastructure Needs
- Ofwat: Creating Tomorrow, Together: Our Final Methodology for PR24

ICE Knowledge Hub: CPD content for members
knowledgehub.ice.org.uk/learn

- Tech Talk video: How to raise water infrastructure standards worldwide
- Tech Talk podcast: The five-minute water infrastructure benefits explainer

The UN Sustainable Development Goals

This case study ties in with the following SDGs:

WATER CASE STUDIES IN BRIEF

Waste not, want not

Singapore and California differ in many respects, but they're both highly water-stressed states – which has called for radical solutions. Persuading residents to accept recycled wastewater through their taps has been almost as much of a strategic concern as installing the right infrastructure

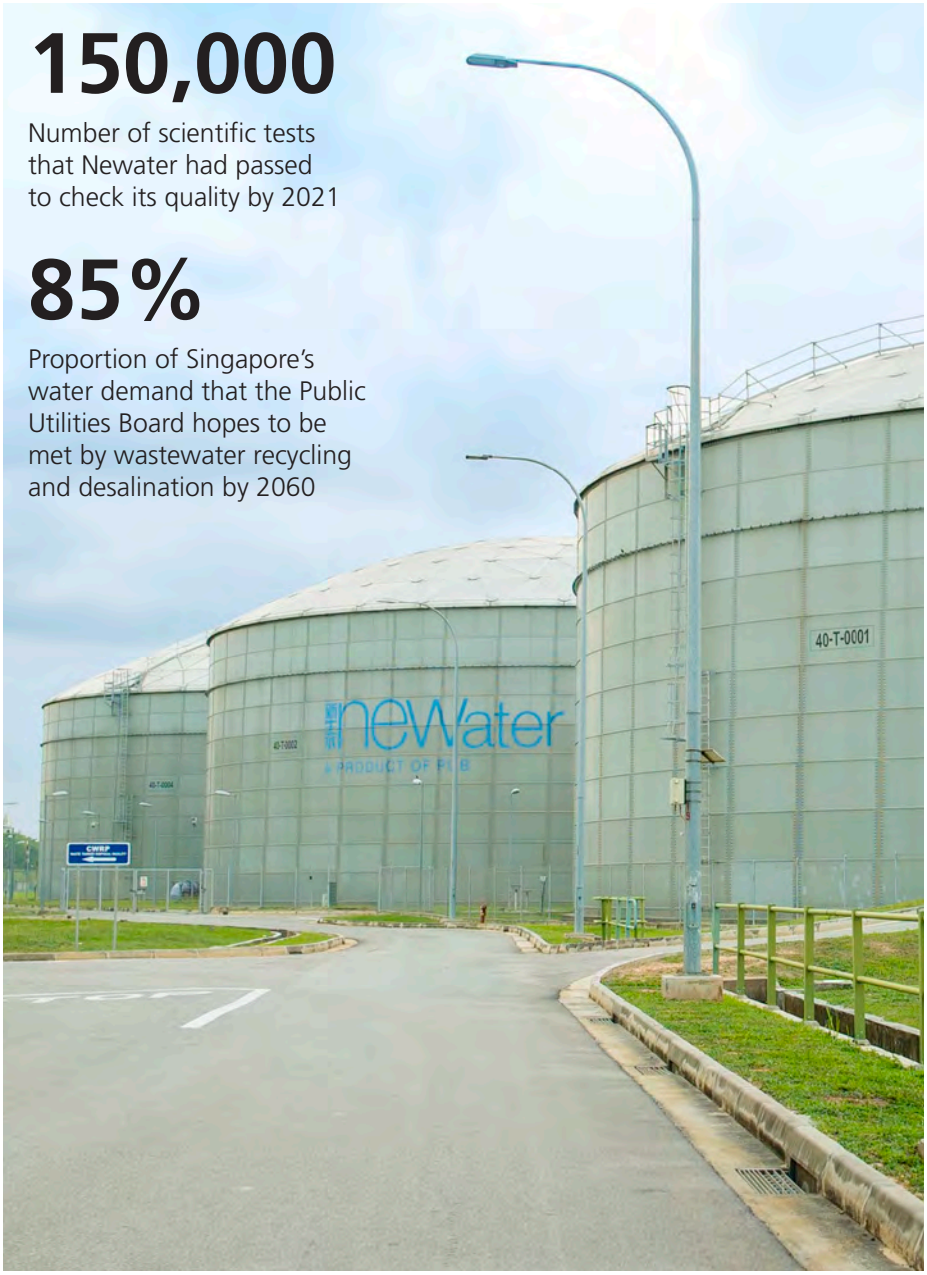
Singapore's shrewd PR campaign pays dividends

Perhaps the most systematic example of large-scale wastewater recycling is to be found in Singapore. The output from its so-called Newater process can meet up to 40% of the city-state's entire demand for potable water.

This diminutive yet dynamic island nation has experienced rapid population growth and extensive urbanisation over the past century. This has left little space to store rainwater from the exceedingly wet months of the north-east monsoon season (November to January) for use over the rest of the year. That is problematic, given that there's also a lack of fresh groundwater.

Singapore originally explored wastewater recycling in the early 1970s, but soon shelved the initiative for cost reasons. Demand for water in the country increased over the ensuing years, while other nations adopted recycling and became more efficient consumers.

Such advances prompted the national water agency, the Public Utilities Board (PUB), to commission a demonstration facility recycling 10 million litres a day to review the idea in 1998. Its output surpassed quality benchmarks based on drinking water requirements set by the World Health Organization and the US Environmental Protection Agency. The success of this trial encouraged the PUB to plan a full-scale roll-out.



SINGAPORE PUBLIC UTILITIES BOARD

Water recycling plants (WRPs) would be designed to take effluent from existing wastewater treatment works and apply advanced membrane-based purification techniques. Their output would either be distributed directly for non-potable uses such as industrial processes or sent into reservoirs feeding water treatment works.

The PUB understood that obtaining widespread public support for the scheme would be key to its success. A government-led outreach campaign made further use of the demonstration facility, providing a family-orientated visitor centre. On the basis that no one teaches adults more than their children, schools in Singapore were asked to give pupils lessons about wastewater recycling and its benefits.

While it was happy for performance data to be shared openly, benchmarked and peer reviewed, the government avoided using terms with clear and potentially off-putting associations with sewage – for instance, "effluent re-use" and even "wastewater recycling". In a marketing gambit to counter the so-called yuck factor, the product was branded as Newater, implying that it would be as good as new.

MPs, including the then prime minister, Goh Chok Tong, also ensured that they were often seen drinking bottled Newater. And the campaign worked: an independent survey of Singaporean consumers in Q4 2002 revealed that 98% of respondents found Newater acceptable.

With public backing secured, the deployment could begin. Full-scale WRPs opened at Bedok and Kranji in 2003, offering a total daily capacity of 132 million litres. Three more plants have been built since then, including the Ulu Pandan WRP (148 million litres a day), designed by Stantec, in 2004. Last year the Bedok WRP was retired, but a larger replacement plant in Tuas is set for completion in 2026.

These are big treatment works with big civil requirements. At Ulu Pandan, for instance, Stantec's design features an 80m by 40m reinforced concrete tank to balance the feed to the reverse-osmosis system. It also incorporates two circular bolted steel tanks, each with a diameter of 55m.

Last year, the PUB estimated that Singapore's demand for water would almost double by 2065, but it remains confident that wastewater recycling and desalination can cope with an increase of that scale.

A legislative leg-up for wastewater recycling in the Golden State

On 6 August 2024, California's Office of Administrative Law approved the Direct Potable Re-use Regulations, representing another key advance in the provision of recycled wastewater as drinking-quality water in the state.

STANTEC

California, where a prolonged drought contributed to catastrophic wildfires in January, has long been a pioneer in this field. The Montebello Forebay Groundwater Recharge Project in LA made history in 1962 by putting purified recycled wastewater into an aquifer. Today, communities across the state are adding it to groundwater, reservoirs and rivers using a technique called indirect potable re-use.

The new law has made the system more flexible, because it permits recycled wastewater to be added directly into drinking water systems where it isn't viable to blend it into a larger body first.

Several organisations in California have been working with Stantec, which has brought with it insights taken from its participation in Singapore's Newater programme. The firm has applied various combinations of microfiltration, ultraviolet disinfection and reverse-osmosis tech in recycling plants across the US. It is looking to build the microfiltration component into membrane bioreactors offering more than 1.4 billion litres per day of new recycling capacity in California.

Stantec's demonstration plants in the state have been specifically designed to complement the type of outreach efforts that proved so successful in Singapore. They include award-winning facilities at Anaheim and San Diego (pictured). The latter, which has been used as the staging point for all stakeholder engagement, has helped to increase support for wastewater recycling among Californians.

The Institution of Civil Engineers (ICE) is a 97,000-strong global membership organisation with more than 200 years of history. It is a centre of engineering excellence, qualifying engineers and helping them to maintain lifelong competence, assuring society that the infrastructure they create is safe, dependable and well designed. Its network of experts offers trusted, impartial advice to politicians and decision-makers on how to build and adapt infrastructure to create a more sustainable world.

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