

# environmental SCIENTIST

The Institution  
of Environmental  
Sciences

March 2026

Journal of the Institution  
of Environmental Sciences



**UNDER  
CONSTRUCTION**

**DELIVERING  
BETTER  
INFRASTRUCTURE**

# Foreword

## Building resilience into infrastructure

Infrastructure is often positioned in opposition to the environment – with roads, sewers and power stations framed as the antithesis of forests, mountains and oceans. But what is our environment without the things that we construct as humans to mediate our engagement with our surroundings? Moreover, well-planned and maintained infrastructure is essential in protecting the natural environment from the negative consequences of human activity.

The focus of this issue is therefore critical. The recently released United Nations World Urbanization Prospects report characterises settlements as cities, towns, or rural areas according to their degree of urbanization based on both total population and density.<sup>1</sup> This assessment indicates that 45 per cent of the world's population lives in cities with a further 36 per cent in towns. Many of these urban centres are growing rapidly with the extent of the built-up area growing at a faster rate than population increase. How infrastructure is delivered in these expanding urban areas will have significant implications for resource efficiency and greenhouse gas emissions in the coming years and decades. Ensuring that there are low-carbon (and, eventually, net zero) development pathways will be critical, and this is an outcome of both settlement design (e.g. spatial planning) and infrastructure decisions (e.g. enabling greater use of efficient public transportation).

Simultaneously, many of these towns and cities have significant unmet needs for the provision of basic services, including water and sanitation: 2.2 billion people lack safely managed drinking water, and 3.5 billion people lack safely managed sanitation.<sup>2</sup> As climate change impacts intensify (and we enter a period of overshoot, beyond the agreed 1.5C rise

target) protective infrastructure will be increasingly necessary to limit the harm caused by flooding, sea-level rise and intense heat.

Perhaps more important than protective infrastructure is infrastructure planning that considers a holistic approach to engaging with the environment. This can include designing the built environment in ways that increases absorption of rainfall, or that promotes passive heating and cooling. Green, blue or hybrid infrastructure can play an important role here, with many assessments showing both economic and a range of co-benefits. Finally, it will be important to have infrastructure that is resilient in its own right and also builds resilience for individuals, communities and cities. This means that while infrastructure needs to be able to withstand climate hazards, it must also support the everyday activities that enable people to survive and thrive. By taking this into account, planners and engineers can ensure that infrastructure not only lasts but makes a positive impact on people and the environment.

### REFERENCES

1. United Nations Department of Economic and Social Affairs (2025) *World Urbanization Prospects 2025. Summary of Results*. [https://population.un.org/wup/assets/Publications/undesa\\_pd\\_2025\\_wup2025\\_summary\\_of\\_results\\_final.pdf](https://population.un.org/wup/assets/Publications/undesa_pd_2025_wup2025_summary_of_results_final.pdf) (Accessed: 18 February 2026).
2. World Health Organization and United Nations Children's Fund (2025) *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2024: Special Focus on Inequalities*. [https://cdn.who.int/media/docs/default-source/wash-documents/wash-coverage/jmp/jmp-2025-wash-households-lowres-launch.pdf?sfvrsn=12ccab42\\_3&download=true](https://cdn.who.int/media/docs/default-source/wash-documents/wash-coverage/jmp/jmp-2025-wash-households-lowres-launch.pdf?sfvrsn=12ccab42_3&download=true) (Accessed: 18 February 2026).

**David Dodman** is the General Director of the Institute for Housing and Urban Development Studies, Erasmus University Rotterdam. His research focuses on urban climate change resilience, informality and governance. David has also contributed to the Intergovernmental Panel on Climate Change's Fifth, Sixth and Seventh assessments. Photo: © Maarten Zeehandelaar / IHS



# Contents

<b>INTRODUCTION</b> <b>Infrastructure under pressure: challenges and opportunities</b> Lindsay Beevers offers an overview of the issues we face in a changing world and the solutions we need if we are to overcome them.	4
<b>ANALYSIS</b> <b>Estate regeneration: a sustainable solution to London's housing crisis?</b> Timothy J. Dixon asks whether long-term projects provide truly beneficial socially and environmentally sustainable infrastructure.	12
<b>FEATURE</b> <b>Sustainable transport infrastructure: which path to take?</b> Ralph Smyth considers whether we are on the right path to achieving climate change and nature goals.	24
<b>OPINION</b> <b>Building nature back in: the prospect of nature-centric housing</b> Matt Pritchard and Tom Oliver argue that a shift in mindset and values is needed for a genuinely sustainable approach to the housing crisis.	32
<b>FEATURE</b> <b>The Swiss Army knife of energy: powering the UK's reindustrialisation</b> Kirsty Gogan and Eric Ingersoll discuss how new digital tools and factory-built reactors could unlock clean energy on Britain's existing industrial land faster and more cheaply than anyone thought possible.	40

<b>CASE STUDY</b> <b>Microorganism-based composites and the future of regenerative construction</b> Juliana Calabria-Holley and Kevin Paine envision a better future built on the natural properties of bacteria and fungi.	52
<b>FEATURE</b> <b>Building resilience and sustainability into UK housing markets and infrastructure</b> Samer Bagaeen outlines why early and coordinated planning and delivery are key to success.	60
<b>ANALYSIS</b> <b>Are water and sanitation systems resilient to climate change?</b> Guy Howard gives an overview of global and UK systems in the context of a changing climate.	68
<b>CASE STUDY</b> <b>Net zero high-density buildings and infrastructure</b> Sean Smith evaluates the complexities and opportunities of delivering improved housing stock for a variety of building types.	76
<b>ANALYSIS</b> <b>Waste infrastructure for a resource-resilient and circular UK economy</b> Dan Cooke considers the current and future provision of essential recycling, resources and waste management infrastructure in the UK.	84

**Cover design: Joe Magee** is an independent artist, designer, illustrator and filmmaker living and working in Stroud, Gloucestershire. He has designed for *The Guardian*, *Time Magazine*, *The New York Times* and *The Washington Post*.

The Institution  
of Environmental  
Sciences

environmental  
SCIENTIST

The journal of the Institution  
of Environmental Sciences

Volume 36 No 1 | ISSN: 0966 8411

environmental SCIENTIST explores key issues in environmental science research and practice, featuring original articles by professionals, academics, and experts from across the sector.

The views expressed in the journal are those of the authors and do not necessarily reflect IES views or policy.



© Dmytro | Adobe Stock

# Infrastructure under pressure: challenges and opportunities

**Lindsay Beevers** offers an overview of the issues we face in a changing world and the solutions we need if we are to overcome them.

The way we live relies heavily on infrastructure provision. Infrastructure itself plays a pivotal role in supporting the global economy and ensuring connectivity and quality of life. Urban environments are complex, interconnected systems in which human health, livelihoods and key infrastructure (e.g. transportation, water and energy systems) are interdependent, making them attractive places to live and work. Society depends on these highly coupled systems and relies on regional networks for trade and travel, connecting urban centres to their hinterlands and beyond. Connectivity and interdependency provide the desired efficiency of urban living and support economic development. Nonetheless, our infrastructure faces significant challenges in the coming decades.

Both 2024 and 2025 recorded global temperatures above pre-industrial levels, at 1.6C and 1.47C respectively. It is now clear that we must prepare for a 3C warmer world by 2050, which has significant bearing on extreme weather. Climate change influences the frequency and magnitude of the extreme weather we experience, which in turn impacts our infrastructure. The latest UK Climate Change Risk Assessment highlights the significant challenges this places on our infrastructure.<sup>1</sup>

**Flooding** has been the most notable risk in the recent past, with floods disrupting transport and energy, as well as housing infrastructure. Storm Babet in October 2023 brought severe flooding across Scotland and northern England, causing at least £500 million in property damage.<sup>2</sup> The A90 in Scotland was closed following flooding and damages to bridge infrastructure, while roads and railways were closed in Leeds, Sheffield and York. In the case of northern England, the Environment Agency estimated that flood alleviation infrastructure protected nearly 100,000

properties, including flood storage reservoirs, flood defences and temporary barriers.<sup>3</sup> Despite this, 2,146 properties were flooded and a further 75,000 were without power, displacing thousands of people and causing significant disruption.

Future changes to flooding frequency and magnitude are expected to place key infrastructure at risk, with a third of all critical systems (i.e. transport, energy and water) being particularly affected. It is not only flooding that increases risk; extreme heat, heatwaves, drought and wildfires all pose increasing risk to our infrastructure systems.

**Extreme heat** can bring devastation to transport infrastructure, which tends to be designed for temperatures below 35C. During the July 2022 heatwave, temperatures exceeded 40C, which caused the runway tarmac at Luton airport to melt. The airport was temporarily shut and flights were diverted. Similar effects were felt on the railway network, as heat resulted in partial track buckling and forced speed restrictions on some routes.



▲ **Low levels at Ladybower Reservoir, Derbyshire.** © Ben | Adobe Stock



▲ **Waves crash into a sea wall in Scotland during Storm Babet in 2023.** © Sarah | Adobe Stock

Prolonged spells of raised temperatures during 2022 caused issues across households, as the UK housing stock is designed to retain heat in the winter rather than to prevent overheating. Many buildings lack shading, cooling systems or adequate ventilation, which most affect the elderly and vulnerable populations.

**Prolonged dry spells**, leading to droughts, have an impact on water supply infrastructure (e.g. 2022 water levels in Ladybower Reservoir, Derbyshire, were at 50 per cent capacity) as well as destabilising transport infrastructure. During the dry spring of 2025, dehydrating clay soils caused shrinkage and cracking to railway embankments in southern and south-west England, resulting in severe travel delays across the network. Similar issues occurred in the Netherlands during the dry summer of 2022, where river dykes became vulnerable to shrinkage and instability as their clay cores dried out with low water levels. As soils and vegetation dry out during heatwaves and droughts,

the risk of wildfire increases. This growing threat poses risks particularly to critical infrastructure, including energy substations, transport (e.g. roads and railways) and water systems.

**Sea level rise and coastal erosion**, lastly, place growing strain on coastal infrastructure. Perhaps one of the most recent examples is the storm damage and sea wall collapse in January 2026 following Storm Ingrid. The Dawlish–Teignmouth railway line was closed while repairs and maintenance were undertaken. The incident reinforces the vulnerability of the line, which is critical to connecting the south-west of England, to damage after the historical collapse in February 2014 and the subsequent decade of investment to strengthen the coastal defences in the area.

This is not a unique problem. In 2024 the UK national flood and coastal erosion risk assessment identified around 113,000 km of roads

at risk from river and coastal flooding – a number that is likely to increase by 2050, with greatest exposure occurring along the coast.<sup>4</sup> Other critical infrastructure such as electricity substations, sewerage networks and treatment plants, and water supply facilities, often located in low-lying areas, are also at risk.

Sitting alongside climate change is the growing threat of rapid urbanisation. The United Nations projects that 68 per cent of the global population will live in a city by 2050 – an increase from 55 per cent today and an indication of the intensifying role cities will play in the future of the planet.<sup>5</sup> Currently, urban areas represent only 2 per cent of the earth's land surface, yet they are responsible for 75 per cent of material resource use globally.<sup>6</sup> This concentration of people and activities makes cities particularly

vulnerable when they are exposed to natural hazards (floods, heatwaves, droughts and wildfires) or global pandemics.

In the UK our infrastructure has a history of investment and development dating back to the Industrial Revolution and has evolved to meet the needs of a growing population and changing economic landscape, mirroring global trends. However, the rich history of infrastructure development brings with it a further challenge: ageing assets and the need for significant cross-sectoral investment to upgrade provision in order to meet the evolving needs of 21st-century society.

These triple challenges require prioritised investment, innovation and strategic planning to create resilient and efficient interdependent

infrastructure networks. In 2025 the UK Government published its 10-year infrastructure strategy, which placed resilience to climate and security risks at the heart of a £725 billion commitment across economic and social infrastructure. This will require a focus on mitigation approaches (including net zero and low-carbon innovations) coupled with adaptation and resilience planning, including for the transport, water and energy sectors.

Energy systems need to transition to renewable energy sources, upgrade, and modernise transmission networks while also adapting to become climate resilient. The UK's housing stock must adapt to new climate norms, retrofitting technology to deliver sustainable cooling and heating systems, simultaneously delivering new climate-adapted stock.

**“There are renewed opportunities for infrastructure to pivot to a more resilient, low-carbon future.”**

Similarly, climate adaptation and resilience are required in water systems to ensure that water supply can be maintained during droughts and remain secure during floods; and in transport infrastructure and networks to make them resilient during flooding and remain stable during droughts.

As we look to adapt to a new future, innovation in techniques, materials and approaches is needed. Working with nature offers both





▲ **Repair works at Dawlish railway station following the collapse of the tracks during storms in 2014.**  
© Anthony | Adobe Stock

inspiration for adaptation techniques and for novel materials.<sup>7</sup> This approach is not new for flood adaptation, with natural flood management techniques becoming more accepted; however, the infrastructure sector is risk-averse, meaning change can be slow. With the growing urgency to adapt, complemented by novel materials coming to market, there are renewed opportunities for infrastructure to pivot to a more resilient, low-carbon future.

This edition of environmental SCIENTIST highlights best practice, innovation and development across sectors, demonstrating potential solutions to the triple challenges in transport, waste, housing, water and energy infrastructure provision.

ES

**Professor Lindsay Beevers, FRSE** holds the Established Chair in Environmental Engineering (2022–date) and is Director of Research at the University of Edinburgh. Her research focuses on developing numerical models to understand and quantify hydrological extremes, their future climate-change-influenced evolution and the associated effects on society. Lindsay was elected as a Fellow to the Royal Society of Edinburgh in 2024 and was a Co-ordinating Lead Author for the United Nations Environment Programme’s flagship report Global Environmental Outlook (GEO-7).<sup>8</sup>

## REFERENCES

1. Department for Environment, Food & Rural Affairs (2022) *UK Climate Change Risk Assessment 2022*. Policy paper. <https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-2022> (Accessed: 18 March 2026).
2. HM Coastguard (2024) *'A risk to life': remembering Storm Babet one year on*. <https://hmcoastguard.uk/news/risk-life-remembering-storm-babet-one-year> (Accessed: 18 March 2026).
3. Environment Agency (2023) *Nearly 100,000 properties protected from flooding during Storm Babet, but threat remains*. <https://www.gov.uk/government/news/rolling-news-story-flooding-from-storm-babet> (Accessed: 18 March 2026).
4. Environment Agency (2024) *National assessment of flood and coastal erosion risk in England 2024*. <https://www.gov.uk/government/publications/national-assessment-of-flood-and-coastal-erosion-risk-in-england-2024> (Accessed: 18 March 2026).
5. Kundu, D. and Pandey, A.K. (2020) 'World urbanisation: trends and patterns', in D. Kundu, R. Sietching and M. Kinyanjui (eds) *Developing national urban policies: ways forward to green and smart cities*. Springer Nature, pp. 13–49.
6. Ulpiani, G., Vettors, N., Shtjefni, D. et al. (2023) Let's hear it from the cities: on the role of renewable energy in reaching climate neutrality in urban Europe. *Renewable and Sustainable Energy Reviews*, 183 (article: 113444). <https://doi.org/10.1016/j.rser.2023.113444> (Accessed: 18 March 2026).
7. Katiyar, N.K., Goel, G., Hawi, S. and Goel, S. (2021) Nature-inspired materials: emerging trends and prospects. *NPG Asia Materials*, 13 (article: 56). <https://doi.org/10.1038/s41427-021-00322-y> (Accessed: 20 March 2026).
8. United Nations Environment Programme (2025) *Global Environment Outlook 7*. <https://www.unep.org/resources/global-environment-outlook-7> (Accessed: 18 March 2026).

# Estate regeneration: a sustainable solution to London's housing crisis?

**Timothy J. Dixon** asks whether long-term projects provide truly beneficial socially and environmentally sustainable infrastructure.

Today's Kidbrooke Village, a £1 billion estate regeneration project in London's Royal Borough of Greenwich, is quite different from the failing Ferrier council estate of the 1970s that it replaced. Many see the project as an exemplar of estate regeneration. More than 15 years on from the start of the Kidbrooke development, what can we say about its impact on the people who lived there, the outcomes for new residents and the overall effects on the local environment?



### ESTATE REGENERATION

Historically, London's great council estates (e.g. Ferrier, Aylesbury, Carpenters and Woodberry Down) were seen as making a vital contribution to providing low-cost housing in the capital. Built by local authorities and funded through government grants, they were a product of the post-war Labour government's focus on providing affordable rented housing for working-class people in London.<sup>1</sup> However, many fell into disrepair and came to be seen as 'sink estates', often characterised by crime, poverty, overcrowding and anti-social behaviour. The reasons for this are varied and complex – from chronic underspending on physical maintenance (because of public spending cuts) to their inherent physical design flaws.<sup>1</sup>

Since 1997, successive governments have tried to tackle the real and perceived problems of these estates. This was done initially with an area-based approach, where the state played a major role (e.g. the New Deal for Communities programme) but later – specifically, under the 2010 coalition government and the 2015

Conservative government – with a primary focus on estate regeneration.<sup>2</sup> Today, under the Labour government, estate regeneration continues to be governed by the recently revised National Planning Policy Framework (first introduced in 2012), and by further guidance from the Mayor of London, which requires a majority vote of residents for regeneration to go ahead.<sup>3,4</sup>

A crucial driving force for estate regeneration is London's housing crisis, with demand having outstripped supply for several decades. For example, in 2024, only 32,000 homes were completed in London, which is just over one-third of the 88,000 homes needed each year. This represents a 30 per cent fall in the number of homes completed between 2020 and 2024 and paints a bleak picture of the city's housing future.<sup>5</sup> Therefore, estate regeneration was seen as a way of tackling the crisis, not only by increasing housing densities but also by upgrading existing stock to meet modern environmental standards and creating mixed-tenure communities (with more affordable social housing alongside privately owned housing).<sup>6</sup>

Estate regeneration has been defined by the Mayor of London, Sadiq Khan, as 'the process of physical renewal of social housing estates through a range of interventions – from refurbishment and intensification to demolition and rebuilding'.<sup>7</sup> Research in 2021 found that in London there were 200 estate regeneration projects of varying sizes that could deliver over 90,000 new homes, of which 36,000 are replacements of existing properties.<sup>8</sup>

### FROM FERRIER ESTATE TO KIDBROOKE VILLAGE

The development of Kidbrooke Village began in 2009. The project provides for 5,268 homes to be completed by 2032. The new development replaces the old Ferrier council estate, built between 1967 and 1972 on a former Royal Air Force site (where barrage balloons were built), and originally consisted of 1,910 homes intended to house around 5,000 residents.<sup>9,10</sup> At that time, such schemes were seen as the future of social housing and were described as exemplary and progressive. However, the estate was inaccessible and isolated from the surrounding areas. It had a very different character to

the local area and was hampered by severe socio-economic problems.<sup>11,12</sup>

Planning permission was granted in 2009 and demolition of the Ferrier Estate began in 2010. The new development was led by the local authority with Berkeley Homes (part of The Berkeley Group), the Greater London Authority, the then Homes and Communities Agency, and Southern Housing, and is seen as a long-term, 20-year project that blends private and social housing set within 136 acres of green space.<sup>13</sup>

The development was conceived as a suburban village and is well connected by public transport, with Kidbrooke railway station (completed in 2021 at a cost of £2.9 million) providing regular fast services to Central London and other destinations. Kidbrooke Village has delivered over 2,400 new homes (of the 5,268 planned), with 1,129 affordable homes (of the 1,930 planned) so far.<sup>14</sup> Affordable housing, therefore, comprises 37 per cent of the total number of housing units.





▲ Figure 1. Red, amber, green rating for Kidbrooke Village. (Source: Woodcraft and Bacon, 2013<sup>11</sup>)

A core feature of Berkeley Homes' approach to new housing is its emphasis on placemaking and the long-term stewardship of developments.<sup>15</sup> But how successful has Kidbrooke Village been in terms of its social and environmental infrastructure?

**SOCIAL INFRASTRUCTURE**

A new housing development project affects the lives of new and existing residents. Social sustainability is one measure of impact and includes both soft social infrastructure (e.g. health, quality of life, and the social inclusion of residents and their neighbours) and hard community infrastructure (e.g. urban design, accessibility and community spaces).<sup>16</sup>

In 2011–12, social enterprise Social Life and the University of Reading developed a framework for social sustainability for Berkeley Group, defining it as:

'[Being] about people's quality of life, now and in the future. It describes the extent to which a

neighbourhood supports individual and collective wellbeing. Social sustainability combines design of the physical environment with a focus on how the people who live in and use a space relate to each other and function as a community. It is enhanced by development which provides the right infrastructure to support a strong social and cultural life.'<sup>15</sup>

**“Social sustainability combines design of the physical environment with a focus on how the people who live in and use a space relate to each other and function as a community.”**

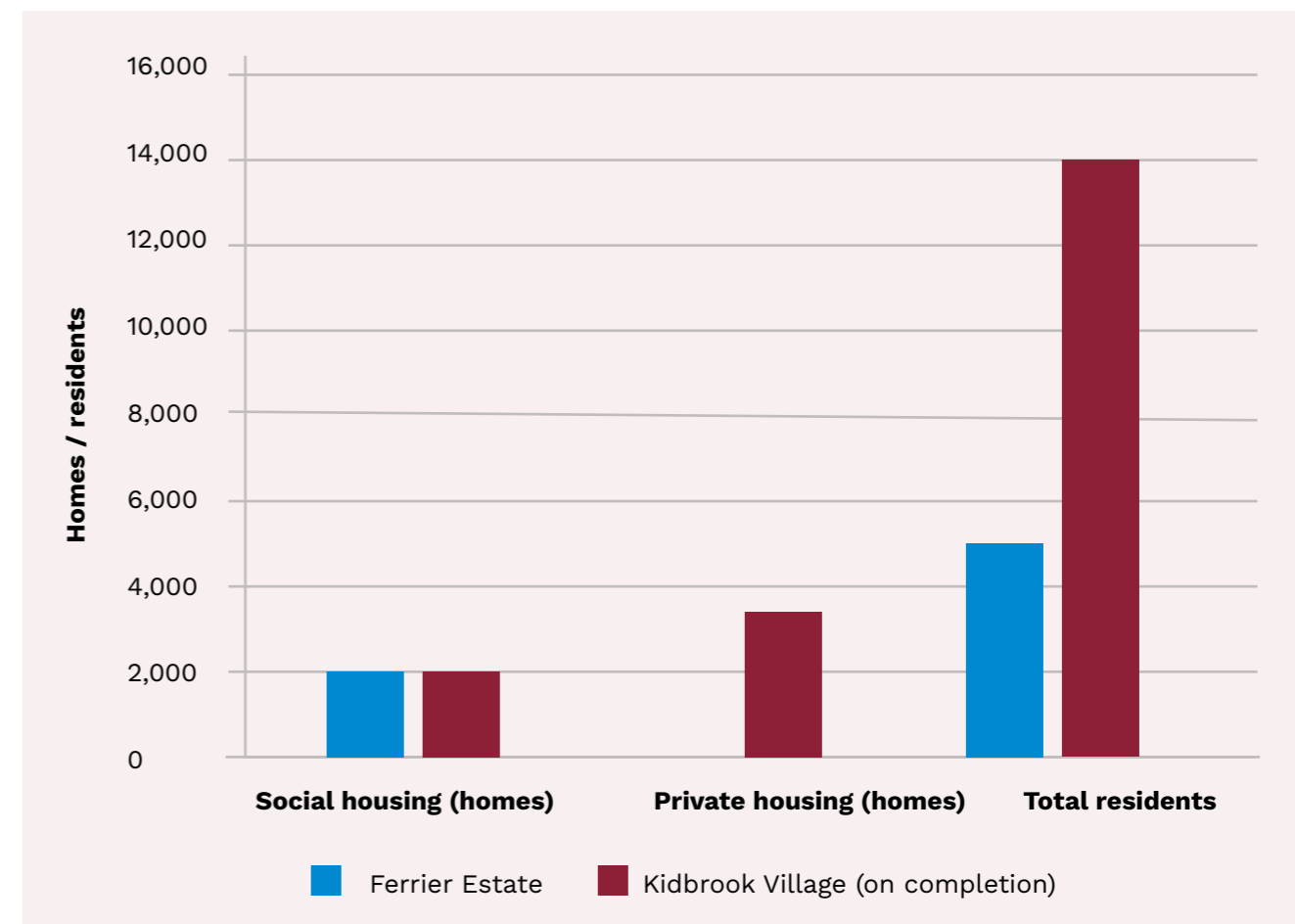
Building on this, an assessment of social sustainability was conducted on Kidbrooke Village in 2013.<sup>16</sup> Using existing comparable

census data as a baseline, the framework measured residents' responses to questions about the new estate and their perceptions of 'social and cultural life' (including quality of life and safety), 'voice and influence' (the potential to influence the future) and 'amenities and infrastructure' (including housing mix, public realm and landscaping). The amenities and infrastructure assessment was also based on a Building for Life site survey and a transport links assessment. The differences between the two datasets were then compared statistically.<sup>17</sup>

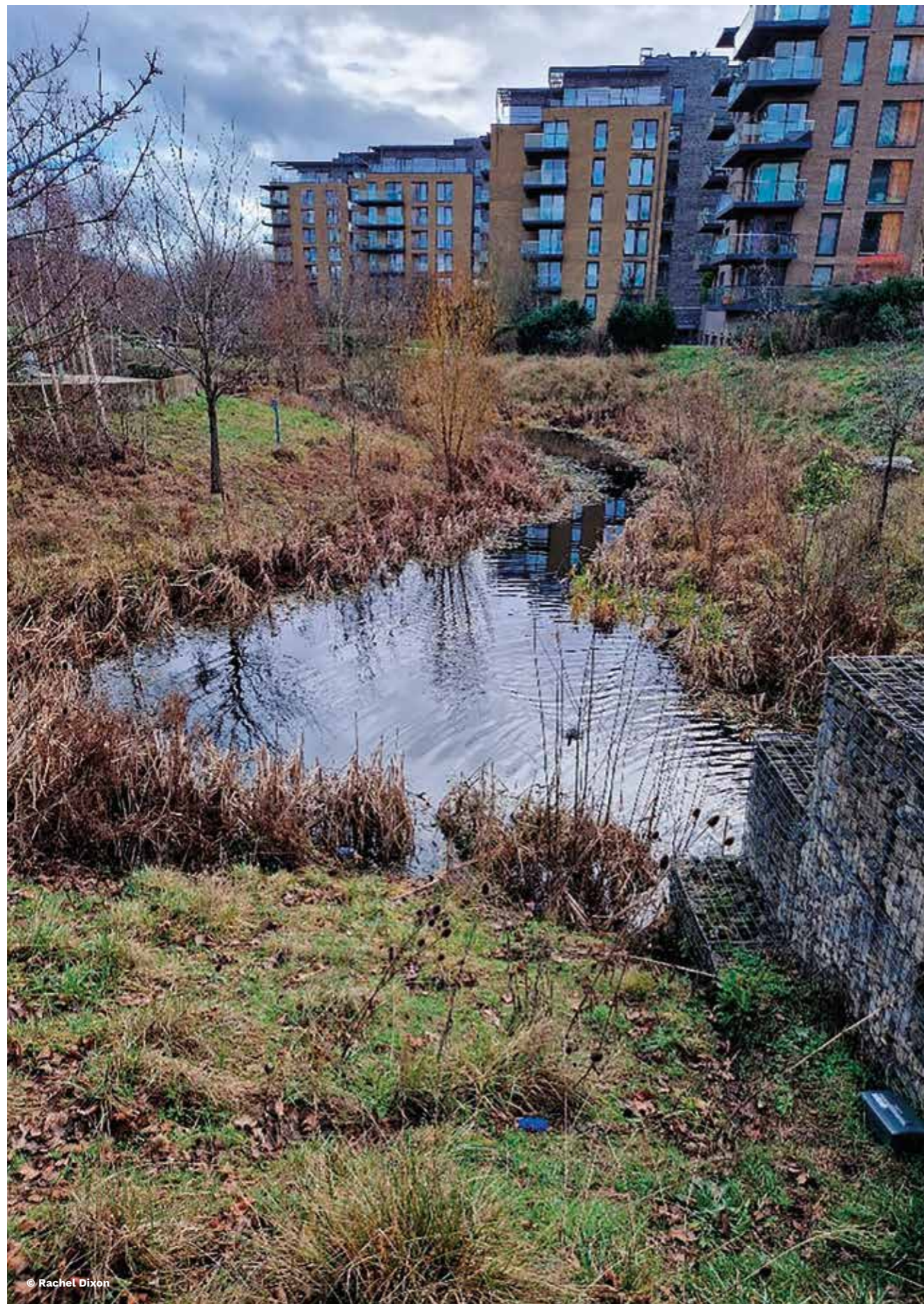
A red, amber, green rating was used for the framework's main indicators (see Figure 1). Ten of the 13 indicators were rated as positive (green), which means the residents' experiences were above the benchmarks for comparable spaces. Two indicators – 'adaptable space' and 'local facilities' – were rated as satisfactory (amber, so comparable to other places), while 'links with neighbours' was rated as red, which reflected the new nature of the development.

However, this was a snapshot at a particular point in time and only included a relatively small sample of new residents.<sup>16</sup> When a new housing project is built, and existing housing is demolished, it clearly has a negative impact on existing social infrastructure, even though the area may be perceived as failing or crime-ridden and in need of reconstruction. Residents, for example, may be moved to other accommodation and may not return.<sup>18,19</sup> Critics of such schemes also point to refurbishment as being a more sustainable choice than demolition and that local people may be priced out of the market.<sup>20,21</sup>

In the case of Kidbrooke Village the long-term outcomes of displacement are still uncertain, although it was reported in 2016 that 500 original residents had moved back.<sup>22</sup> However, recent research of consumer and administrative records suggests that the situation is complex: 85 per cent of those moved in estate regeneration schemes (including at Kidbrooke) are still in London, with



▲ Figure 2. Comparison of social and private housing at the Ferrier Estate and Kidbrooke Village. (Source: Created by the author based on: <sup>9, 14, 24, 25</sup>)



© Rachel Dixon



▲ The Ferrier Estate, London in 2010. | Wikimedia Commons

most remaining in their borough, although not necessarily in the new developments.<sup>23</sup>

In terms of net gain, while the population of the new development (based on the author's estimate from existing data using an average of 12,000 and 16,000 residents<sup>24,25</sup>) will eventually be higher than that of the Ferrier Estate, the amount of social housing will have only risen marginally on final completion (see **Figure 2**). Private housing has also increased significantly from a baseline of zero, and the development was reported in 2013 to have doubled the density of the original estate by building on 35 per cent of the overall site.<sup>26</sup>

#### ENVIRONMENTAL INFRASTRUCTURE

The new development has a strong focus on environmental sustainability. It is on a brownfield site that has been redeveloped in line with eco-design principles. Homes (which follow Code for Sustainable Homes Level 4 standards) are fitted with low-carbon technology, including air source heat pumps, photovoltaic panels (generating 23 per cent of energy demand in some

phases) and high levels of insulation.<sup>27</sup> Walking and cycling are encouraged, and the site has good public transport connectivity.

Green infrastructure has also been a strong feature. For example, Cator Park was the result of Berkeley Homes working with the London Wildlife Trust (LWT) to rewild and build a wildlife-rich landscape, at a cost of £2.9 million.

This public park is set within the area's wider 136 acres of green and open space. Cator Park also includes a new £2.1 million ecological playground, with all materials either sourced or produced in England. Rubble and waste from the old Ferrier Estate were repurposed to create natural, wildflower-covered mounds in the park. Reclaimed telegraph poles and timber from the demolished Woolwich Pier were also used for the structures. The play area was designed to be a nature-first play space.

Evolving from a managed mown-grass space, the park placed a strong focus on encouraging a

wide range of wildlife habitats and biodiversity, including nesting birds, mammals and insects. As a result, the park has received recognition for its sustainability efforts, including the Sir David Attenborough Award for Enhancing Biodiversity (2020), the Landscape Institute's President's Prize (2020) and the Excellence in Habitat Restoration Award (2024).<sup>13</sup>

There has been a real focus on incorporating landscape design that links with the River Quaggy flood alleviation works, carried out by the Environment Agency in 2003, and incorporates sustainable urban drainage. For example, the green space running through the site acts as a primary drainage corridor, while the balancing ponds and new wetlands, especially around Cator Park, hold water on site and mitigate flooding of the River Quaggy. Permeable paving and green roofs also help in terms of flood alleviation.<sup>28</sup>

A key part of this has been the work of Berkeley Homes with the LWT and HTA Design architects to deliver a predicted biodiversity net gain of 250 per cent on completion. The development includes wetland habitats (with lakes and reedbeds), dry swales (shallow channels designed to manage run-off), wildflower meadows, new trees and wild play areas.<sup>29</sup> There is step-free access and the park is used by the wider community, with local volunteer groups such as Friends of Sutcliffe Park playing an active role.<sup>30</sup> Kidbrooke Village forms a green corridor linking Sutcliffe Park in the south with the nature reserves at Kidbrooke Green and LWT's Birdbrook in the north.<sup>29</sup> In Kidbrooke it is now possible to see newts, dragonflies, kingfishers and reed buntings. Bat boxes and swift nesting bricks are also elements of the design. This is all part of a wider Berkeley Homes focus on 'water, water climate, pollution and ecology' in its developments.<sup>30</sup>

#### THE FUTURE OF ESTATE REGENERATION

So how successful has Kidbrooke Village been? More research tracking the development over time is needed to analyse its long-term social sustainability, and further research is also needed into the impacts, not only on existing and new residents but on those living in the surrounding areas as well.

From an environmental sustainability perspective, the published evidence seems to suggest that the development has provided a much greener and more environmentally friendly place than before.

#### BOX 1. LAND TYPES DEFINED

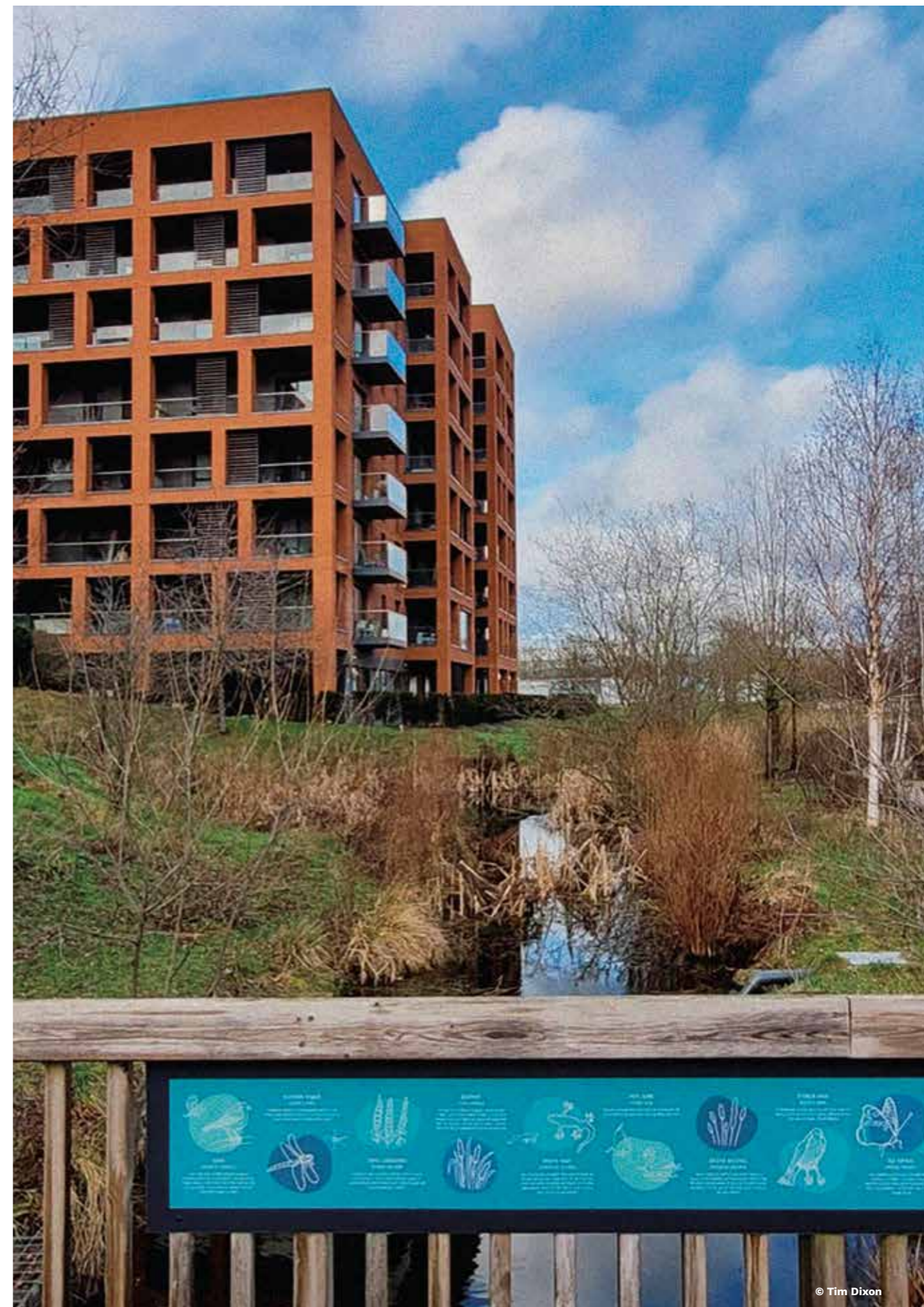
**Brownfield land.** The current UK Government has emphasised the need for brownfield land development (or what is known as previously developed land) in England to be prioritised through the National Planning Policy Framework (NPPF) 2024. This focuses on a presumption in favour of sustainable development on brownfield sites (i.e. brownfield first). Brownfield land can include industrial sites, aerodromes, former retail sites and car parks; some of this land may also be contaminated from previous industrial uses, making development costly and complex.

**Greenfield and green belt land.** In contrast, greenfield land is undeveloped and typically free from any previous structures. It is normally (but not always) found in rural areas, and can include agricultural fields, pastures and farmland. Green belt land – which was formally established around 16 urban cores by statute more than 70 years ago to restrict urban sprawl – forms part of this greenfield category and is today governed by the NPPF. Green belt land (13 per cent of the total land area in England) is protected from most forms of development but can sometimes already include brownfield land within its boundaries.

**Grey belt land.** In its quest to 'get Britain building', the current Government also focused on what it terms grey belt land. This includes areas of land in the green belt that were (i) either previously developed; and/or (ii) contribute little to either the prevention of urban sprawl, keeping settlements separate, or preserving the character of historic towns, but may be considered suitable for development. Examples include wasteland, petrol stations or car parks, and other types of previously developed land. However, it is not clear how much grey belt land there is in England or how many houses it could support.

However, the Government's focus on speeding up development may make schemes like Kidbrooke, which focus on high levels of biodiversity net gain, less common (especially on smaller sites), as nature may be perceived as a 'blocker' rather than a positive force for good.

Kidbrooke Village is also often highlighted as an exemplar of brownfield development, and this links to the brownfield-first policy of successive UK governments over the project's lifetime. Brownfield development is seen by its advocates as being more sustainable than development on green spaces because it reuses existing sites, often tackles contamination from previous uses and reduces urban sprawl (see **Box 1**). However, the Government's target of 1.5 million new homes



by 2029 in England raises major challenges for a brownfield-first policy. Recent research has shown that not only is this target unlikely to be met without a dramatic year-on-year increase in housebuilding, but that grey belt and greenfield land will be required for it to be successful.<sup>31</sup> Moreover, there is evidence to suggest that, pre-development, some brownfield sites are more biodiverse than greenfield sites are post-development.<sup>32</sup>

Kidbrooke Village is also interesting because good rail links are at the heart of its success. Given the Government's current focus on grey belt housing land close to existing rail stations, there is a realisation that protecting all green belt land is not possible and that good transport links are crucial.<sup>31</sup> Further transport extensions such as the proposed Bakerloo line extension, from Elephant and Castle into south London, and the West London Orbital are needed to boost housing development.<sup>33</sup>

Ultimately, estate regeneration alone will not solve London's housing problems: affordable housing needs to be developed in a range of ways, focusing both on planning reforms and on finding ways to address other important issues, such as how to increase densities on brownfield and grey belt sites and tackling empty homes. It is vital to ensure that, as well as speeding up housing development, we do not lose sight of the fact that the outcomes must be socially and environmentally sustainable.

*The views expressed in this article are those of the author and do not necessarily reflect the views of the IES or other organisations or individuals mentioned.* **ES**

**Timothy J. Dixon** is Emeritus Professor in the School of the Built Environment at the University of Reading and Research Associate at the Global Centre on Healthcare and Urbanisation at the University of Oxford. His research focuses on sustainable built environments and urban futures.

✉ [t.j.dixon@reading.ac.uk](mailto:t.j.dixon@reading.ac.uk)  
 in [linkedin.com/in/tim-dixon-b9301819/](https://www.linkedin.com/in/tim-dixon-b9301819/)

## REFERENCES

1. Watt, P. (2021) *Estate Regeneration and Its Discontents: Public Housing, Place and Inequality in London*. Bristol: Policy Press.
2. Prime Minister's Office, 10 Downing Street, Ministry of Housing, Communities & Local Government, The Rt Hon Lord Cameron and The Rt Hon Greg Clark (2016) *Prime Minister pledges to transform sink estates*. Press release. <https://www.gov.uk/government/news/prime-minister-pledges-to-transform-sink-estates> (Accessed: 18 February 2026).
3. Barratt, L. (2018) *Khan backs mandatory ballots for estate regeneration*. <https://www.insidehousing.co.uk/news/khan-backs-mandatory-ballots-for-estate-regeneration-54405> (Accessed: 18 February 2026).
4. Ministry of Housing, Communities & Local Government (2024) *National Planning Policy Framework*. [https://assets.publishing.service.gov.uk/media/67aaf8f3b41f783cca46251/NPPF\\_December\\_2024.pdf](https://assets.publishing.service.gov.uk/media/67aaf8f3b41f783cca46251/NPPF_December_2024.pdf) (Accessed: 18 February 2026).
5. Savills (2025) *Why Has Housing Delivery in London Fallen so Dramatically over the Past Decade?* Savills research for Ballymore Group. <https://pdf.savills.com/documents/Executive-Summary-Why-has-housing-delivery-in-London-fallen-so-dramatically-over-the-past-decade.pdf> (Accessed: 18 February 2026).
6. London Councils (2025) *A decade of renewal: the contribution of London estate regeneration*. <https://www.londoncouncils.gov.uk/news-and-press-releases/2025/decade-renewal-contribution-london-estate-regeneration> (Accessed: 18 February 2026).
7. Mayor of London (2018) *Better Homes for Local People. The Mayor's Good Practice Guide to Estate Regeneration*. <https://www.london.gov.uk/sites/default/files/better-homes-for-local-people-the-mayors-good-practice-guide-to-estate-regeneration.pdf> (Accessed: 18 February 2026).
8. Lichfields (2021) *Great estates. Planning for estate regeneration in London*. <https://lichfields.uk/content/insights/T> (Accessed: 18 February 2026).
9. Kidbrooke Village (no date) *History*. <https://kidbrookevillagelondon.co.uk/history/> (Accessed: 18 February 2026).
10. Royal Borough of Greenwich (2023) *Joining forces for more affordable homes*. <https://www.royalgreenwich.gov.uk/news/2023/joining-forces-more-affordable-homes> (Accessed: 18 February 2026).
11. Woodcraft, S. and Bacon, N. (2013) *Living at Kidbrooke Village*. Report commissioned by the Berkeley Group. [https://www.social-life.co/media/files/Living\\_at\\_Kidbrooke\\_Village.pdf](https://www.social-life.co/media/files/Living_at_Kidbrooke_Village.pdf) (Accessed: 18 February 2026).
12. Architects for Social Housing (2016) *The Intellectual bloodstain: academia and social cleansing on the Ferrier Estate*. <https://architectsforsocialhousing.co.uk/2016/10/26/the-intellectual-bloodstain-academia-and-social-cleansing/> (Accessed: 18 February 2026).

## REFERENCES

13. Berkeley Group (2020) *Kidbrooke Village biodiversity wins Sir David Attenborough Award*. <https://www.berkeleygroup.co.uk/news-and-insights/news-and-features/2020/kidbrooke-village-wins-attenborough-awards> (Accessed: 18 February 2026).
14. Kidbrooke Village (no date) *About Kidbrooke*. <https://www.kidbrookeregeneration.info/> (Accessed: 18 February 2026).
15. Bacon, N., Cochrane, D. and Woodcraft, S. (2012) *Creating Strong Communities: How to Measure the Social Sustainability of New Housing Developments*. Commissioned by the Berkeley Group. [https://www.social-life.co/media/files/Creating\\_Strong\\_Communities.pdf](https://www.social-life.co/media/files/Creating_Strong_Communities.pdf) (Accessed: 18 February 2026).
16. Dixon, T. (2019) Measuring the social sustainability of new housing development: a critical review of assessment methods. *Journal of Sustainable Real Estate*, 11 (1), pp. 16–39. <https://doi.org/10.22300/1949-8276.11.1.16> (Accessed: 18 February 2026).
17. Dixon, T. and Woodcraft, S. (2013) Creating strong communities – measuring social sustainability in new housing development. *Town and Country Planning*, 82, pp. 473–480.
18. Elmer, S. and Dening, G. (2016) The London clearances. *City*, 20 (2), pp. 271–277. <https://doi.org/10.1080/13604813.2016.1143684> (Accessed: 18 February 2026).
19. Cavanough, K. (2025) *Estate Regeneration. Examining Best Practice Approaches to Master Planning and Renewal of Social Housing Estates*. <https://www.churchilltrust.com.au/project/to-examine-best-practice-approaches-to-master-planning-and-renewal-of-social-housing-estates/> (Accessed: 16 February 2026).
20. Public Law Interest Centre (2024) *Report finds that 'affordable' housing increases rents for low-income Londoners*. <https://www.pilc.org.uk/news/affordable-housing-increases-rents-for-low-income-londoners/> (Accessed: 18 February 2026).
21. Estate Watch (2023) *The ALTERNATIVE Good Practice Guide to Estate Regeneration*. <https://estatewatch.london/images/alternative-good-practice-guide-to-estate-regeneration.pdf> (Accessed: 18 February 2026).
22. Ministry of Housing, Communities & Local Government (2016) *Estate regeneration: case studies*. <https://www.gov.uk/government/publications/estate-regeneration-case-studies> (Accessed: 18 February 2026).
23. Reades, J., Lees, L., Hubbard, P. and Lansley, G. (2022) Quantifying state-led gentrification in London: using linked consumer and administrative records to trace displacement from council estates. *Environment and Planning A: Economy and Space*, 55 (4), pp. 810–827. <https://doi.org/10.1177/0308518X221135610> (Accessed: 18 February 2026).
24. Buksh, A. (2014) *Kidbrooke regeneration clash*. [https://www.bbc.co.uk/london/content/articles/2006/12/21\\_kidbrooke\\_feature.shtml](https://www.bbc.co.uk/london/content/articles/2006/12/21_kidbrooke_feature.shtml) (Accessed: 18 February 2026).
25. Scanlon, K., Sagor, E., Whitehead, C. and Mossa, A. (no date) *New London Villages. Creating Community*. Report commissioned by The Berkeley Group. <https://www.lse.ac.uk/business/consulting/assets/documents/New-London-Villages-Final-Report.pdf> (Accessed: 18 February 2026).
26. URBED (2013) *Briefing Pack: Viability, Kidbrooke Village*. [https://urbed.coop/sites/default/files/TEN%20Group%20Kidbrooke%20Briefing%20w%20Background%20Reading\\_18\\_04\\_13.pdf](https://urbed.coop/sites/default/files/TEN%20Group%20Kidbrooke%20Briefing%20w%20Background%20Reading_18_04_13.pdf) (Accessed: 18 February 2026).
27. Croft, Z. (2023) *Kidbrooke Village Redevelopment Phase 5 Buildings A and B. Sustainability Statement*. [https://docs.planning.org.uk/20240111/53/\\_GRNW\\_DCAPR\\_118439/v1g7cprb4iksgfj3.pdf](https://docs.planning.org.uk/20240111/53/_GRNW_DCAPR_118439/v1g7cprb4iksgfj3.pdf) (Accessed: 18 February 2026).
28. Cator Park (no date) Home page. <https://www.hta.co.uk/cator-park/> (Accessed: 20 February 2026).
29. Horton, H. (2015) 'People love being here': London development shows harmony between nature and housing. *The Guardian*, 11 April. <https://www.theguardian.com/environment/2015/apr/11/london-development-shows-harmony-between-nature-and-housing> (Accessed: 18 February 2026).
30. Gritten, E. (2023) *Combining Nature Recovery and Community Health: How to Make the Most of Biodiversity Net Gain*. [https://www.qolf.org/wp-content/uploads/051228\\_BNG-Report\\_Final-compressed\\_2.pdf](https://www.qolf.org/wp-content/uploads/051228_BNG-Report_Final-compressed_2.pdf) (Accessed: 18 February 2026).
31. Dixon, T.J. (2025) *Does the government's target of 1.5 million new homes add up? The role of brownfield, grey belt, and greenfield sites*. <https://www.gchu.org.uk/2025/11/does-the-governments-target-of-1-5-million-new-homes-add-up-the-role-of-brownfield-grey-belt-and-greenfield-sites/> (Accessed: 16 February 2026).
32. Preston, P.D., Dunk, R.M., Smith, G.R. and Cavan, G. (2023) Not all brownfields are equal: a typological assessment reveals hidden green space in the city. *Landscape and Urban Planning*, 229 (article: 104590). <https://www.sciencedirect.com/science/article/pii/S0169204622002390> (Accessed: 18 February 2026).
33. Kumail, J. (2026) London can't hit housing target without Bakerloo Line extension. *Southwark News*, 6 January. <https://southwarknews.co.uk/area/elephant-and-castle/london-cant-hit-housing-target-without-bakerloo-line-extension/> (Accessed: 18 February 2026).

# Sustainable transport infrastructure: which path to take?

**Ralph Smyth** considers whether we are on the right path to achieving climate change and nature goals.

**W**hile transport infrastructure is important for the economy, it dominates the UK's carbon footprint. Roads reach into nearly every mile of the country and have disproportionate effects on nature. The National Audit Office has flagged environmental risks as the highest-likelihood, highest-impact threat for the Department for Transport (DfT), warning that inadequate action 'to provide carbon savings, meet air quality and biodiversity targets, and adapt to climate change' risks breaking the law.'

A series of new policies is due this year – including refreshed road, active travel and integrated transport strategies, a draft airports strategy, legislation for Great British Railways and the next carbon budget. Despite early hopes, the Government has, at least in the transport sector, turned towards high-carbon infrastructure in the hope of unlocking growth. But can technological and regulatory innovations like electrification, biodiversity net gain and carbon management standards close the gap between transport networks' current performance and legislative ambitions for them to contribute to carbon reduction, climate resilience and nature restoration?



**EMISSIONS INCREASINGLY GOING OFF-COURSE**

While public awareness has grown that transport is the sector with the greatest direct climate impact, few are aware that one-tenth of UK carbon emissions comes from using England’s strategic road network, which is operated by National Highways. As an asset under one body’s control (unlike thousands of individually owned and managed farms, for example), this makes it the nation’s largest single climate burden. Behind the scenes, there have been plans to address this for a long time. In 2013, road sector reforms included a promise to deliver an ‘aggressive policy of decarbonisation’.<sup>2</sup> The following year, the commitment in the first road investment strategy to develop carbon metrics seemed to signal a new direction – despite the strategy’s initial priority of road building.<sup>3</sup>

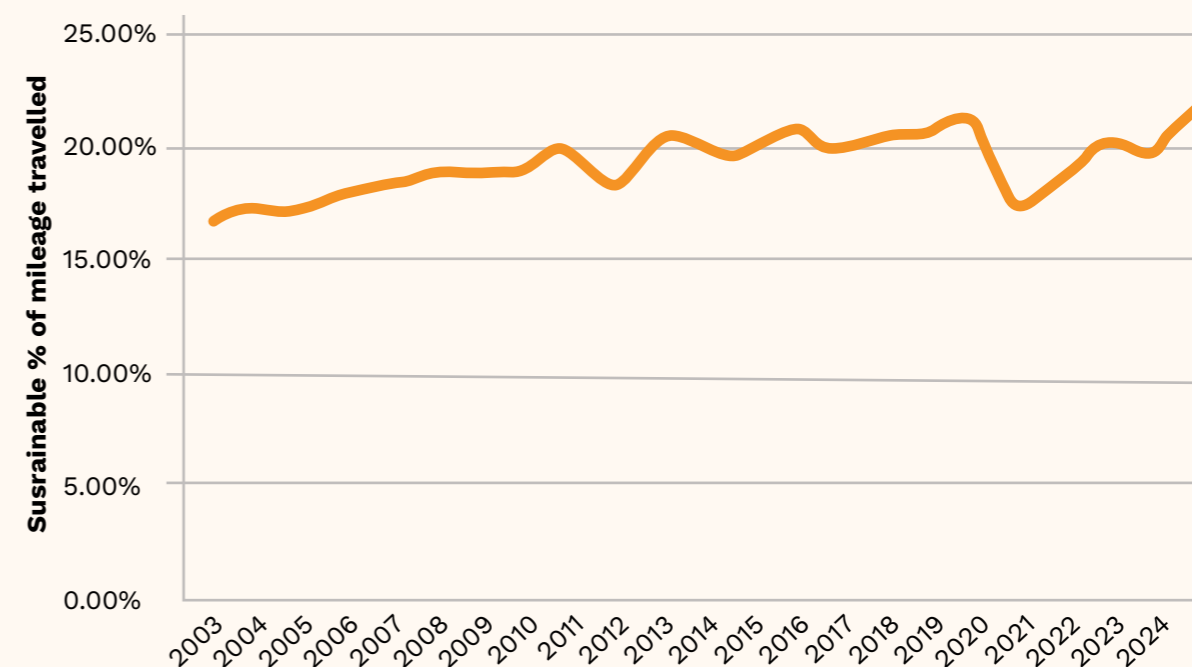
The 2021 Transport Decarbonisation Plan seemed to take things a step further, recognising that ‘we cannot, of course, simply rely on the

electrification of road transport ... particularly for meeting our medium-term carbon reduction targets to 2035’. Electric vehicles still cause disproportionate particulate, water and noise pollution; so, truly sustainable travel refers to walking, cycling and public transport. Ministers pledged to accelerate modal shift to public and active travel, to cut urban traffic and to reduce (if not stabilise) traffic more widely.<sup>4</sup> Despite a commitment to take further action if needed, the plan – the UK’s first – has not been updated in five years, with the DfT relying on high-level cross-governmental commitments instead.

Consequently, ambitions for both technological and behavioural change have fallen behind, other than a one-off boost from London’s Elizabeth Line (see **Figure 1**), which opened in stages between 2022 and 2023 and now accounts for one-seventh of all UK rail trips. Flexibilities added in 2025 to the 2024 electric vehicle mandate, the single biggest carbon-saving policy across



**Sustainable travel share in England (mileage)**



▲ **Figure 1. Modal share trends in England. (Adapted from Department for Transport, 2025)<sup>5</sup>**

government, have cut projected emissions savings by 10 per cent; these include relaxing requirements on diesel vans and allowing future quotas to be borrowed.

Although the Climate Change Committee (CCC) advised a 7–10 per cent modal shift from driving to bus use, cycling and rail by 2035, funding for these sustainable modes is under threat – and often cut in real terms – while the roads budget has been largely protected. Intermediate options to enable more efficient driving options have been stalled by political and cultural disagreements, specifically then-Prime Minister Rishi Sunak speaking out against what he described as ‘compulsory’ car sharing in 2023.<sup>6</sup> As a result of these reversals, transport emissions have declined by 25 per cent less than planned for in 2016 and are currently reducing at a fifth of the rate expected.<sup>7</sup>

**FROM TAILPIPE TO LIFE CYCLE EMISSIONS**

Behind the electric vehicle sales headlines lurks another problem. The assumptions underlying how carbon is accounted for date back decades, such as which activities count for different

sectors of the economy and how to treat consumption emissions abroad, which now account for nearly half the UK’s emissions. What made sense and what could be ignored with the original target in the Climate Change Act 2008 to reduce UK domestic emissions by 80 per cent is not necessarily the same when considering a net zero target set in 2019, which we are halfway towards reaching.

Official estimates that transport emissions make up 29 per cent of UK emissions and have declined 13 per cent since 1990 relate only to fossil fuel emissions from tailpipe or turbine.<sup>8</sup> Most of this reduction has been from the shift to biofuels, which now make up a tenth of commercially sold fuel – and more for some vehicle fleets. Although UK biofuel regulations require carbon savings of two-thirds, the remaining emissions are counted either in the UK’s agriculture budget or abroad if imported. Vehicle electrification has played a smaller role in the savings so far. However, there is a similar issue with emissions from electricity generation not being counted in the transport sector, therefore suggesting greater progress in cutting overall emissions than there has been.



Decarbonisation of infrastructure materials such as concrete is even more challenging. After leading the world in setting economy-wide climate targets in 2008, the UK pioneered the PAS2080 carbon management standard in 2016. Its 2023 update expanded the standard's scope from infrastructure to buildings, such as homes and offices, covering the entire built environment. In recognition that 'most of the built environment expected to exist in 2050 is already built and has locked in high carbon behaviours', its focus has broadened from constructing new assets to retrofitting existing ones to address emissions from operation and use.<sup>9</sup> PAS2080 covers the entire supply chain, so includes consumption emissions from imported goods such as building materials. The CCC estimates these will make up most UK-related emissions by the late 2030s. Although there have been tentative steps to consider them, at present they are outside the scope of UK carbon budgets.

One challenge here is that investment in transport infrastructure is increasingly justified in terms of unlocking housing in order to meet the target of 1.5 million homes during this parliament. The systems approach inherent in PAS2080 requires these to be considered, yet current housing plans alone are forecast to use up the UK's fair share of emissions, if aligned to the ambition in the Paris Agreement.<sup>10</sup> A shift from detached homes to gentle density (mansion blocks and terraces of 3–8 storeys) of continental-style apartments would require less land, less embodied carbon (i.e. fewer external walls) and lower energy consumption for heating and transport. Transport decision-making does not yet integrate these wider climate impacts, missing the opportunity to reprioritise from road- to public transport-oriented development.

The standard further links decarbonisation to climate resilience and environmental gain. This is paralleled by the CCC's recommendation to the Government, calling for a sector-wide roads review to 'permit schemes to be taken forward only if they meaningfully support cost-effective delivery of Net Zero and climate adaptation'.<sup>11</sup> Adaptation has received limited attention to date, despite its potential to force a change in transport priorities due to the costs involved.

#### ADAPTATION PRESSURES

Projections indicate that about half of UK transport infrastructure will experience frequent flooding by 2050, with railways

disproportionately exposed.<sup>12</sup> These forecasts were published in 2024, but relied on the 2018 UK Climate Projections, meaning they were outdated on publication. Even if a 2024 climate model had been used, it would likely have underestimated risk given the accelerated warming observed over the past three years.

The 2023 National Infrastructure Assessment recommended outcome-based resilience standards by 2025 and public reporting of adaptation costs to meet them by 2029.<sup>13</sup> The subsequent 10-year infrastructure strategy published in response merely pledged to explore such measures; then the 2025 transport adaptation strategy deferred making commitments 'where appropriate' to 2030, with no mention of any adaptation-cost transparency.<sup>14,15</sup>

Older motorway sections are due for major renewal, while many rail and local road assets predate modern geotechnical standards, heightening vulnerability. High Speed 2 offers a rare counterexample: its structures (including its tracks) are designed for a 1-in-1,000 year flood event, far exceeding the typical 1-in-100 year design threshold. Recent extreme rainfall in winters has validated this forward-thinking approach, even if the description of risk levels around the past frequency of extreme events is no longer sound.

Future funding must therefore accommodate more frequent maintenance and renewals, more robust assets and landscaperscale resilience measures, all of which will raise the sector's carbon and financial costs.

#### NATURE-POSITIVE TRANSPORT INFRASTRUCTURE

As with the Climate Change Act, the Environment Act 2021 positioned the UK as a global leader in environmental legislation. Its provisions for a biodiversity net gain mandate that development leaves habitats in a measurably better state is due to also apply to nationally significant infrastructure projects (which include airports and major roads) from May 2026.

Defra's 2025 consultation said that if 'elements of the "core" approach are not suitable for specific [project] types ...bespoke arrangements' could be applied.<sup>16</sup> Linear transport infrastructure is one area where such arrangements are surely required, as they have different impacts to other forms of development – such housing, which biodiversity

net gain was designed for.<sup>17</sup> Linear transport construction can involve much deeper changes to land, such as cuttings and pilings, potentially affecting hydrological systems far beyond the development boundary. In use, schemes create significant light, noise, chemical and physical pollution, adversely affecting habitats and species miles away from a scheme's edge.

Another difference is that road schemes that add vehicle capacity can quickly increase traffic on the surrounding road network too. While new infrastructure will have controlled outflows, existing roads rarely do, and with 40 per cent of microplastics in watercourses coming from tyres, ecological damage can extend far.<sup>18</sup>

Biodiversity net gain legally requires 30 years of post-construction aftercare. The A14 widening scheme in Cambridgeshire that pledged 11.5 per cent biodiversity net gain illustrates the challenge. After nearly a million new trees died, highways bosses were derided by MPs for failing to account for how the model scheme ended up looking like 'a desert festooned with plastic tree containers'.<sup>19</sup> With the supply chain struggling to deliver and maintain simple compensation in the short term (e.g. trees), more complex habitat creation faces an even steeper uphill battle as climate extremes intensify in the longer term.

#### TRANSPORT AT A CROSSROADS

Two years after the 2024 general election, the Government can no longer postpone difficult choices in the strategies it is due to publish. National Highways has adopted PAS2080 and its 'hierarchy of: building nothing; building less; building cleverly; and building efficiently'.<sup>20</sup> Yet it continues to champion major road schemes designed in a different era, such as the Lower Thames Crossing and A66 Trans-Pennine dualling, to meet a target of 150 infrastructure projects during this parliament. The UK remains a long way from its emissions reduction targets of 68 per cent by 2030 and 81 per cent by 2035. This is now casting doubt on how it will approach CCC's advice to set an 87 per cent target for the 2038–42 period by the legal deadline of June, since this was based on an assumption that earlier targets would be met.<sup>21</sup>

If current trends persist, the share of emissions attributable to busy roads will rise from today's 10 per cent. Medium- to long-term solutions like tram expansion, rail electrification and broader electric vehicle adoption are essential, but rapid,



low-cost interventions are also required to achieve the 2030 target. Less-known, practical options already exist. Bus and high-occupancy lanes have appeared on motorways in Scotland and France, while the latter has over 100 lift-sharing hubs on major roads, integrated with urban public transport ticketing and active travel. Expanding rail freight, coach services and car sharing, together with speed-limit enforcement, can rapidly deliver carbon savings, benefit nature, reduce travel costs and improve resilience.

Nonetheless, one might be justified in doubting whether carbon targets and hierarchies will change the direction of transport after many years of broken commitments and inaction. Instead, it may

be the shocks transport infrastructure faces from climate breakdown and the costs of adaptation that finally force a rethink and change priorities. **ES**

**Ralph Smyth** is a freelance consultant covering infrastructure, sustainability and governance. He is also a trustee of the Foundation for Integrated Transport and a civil and community mediator. Formerly an environmental lawyer, he then led on transport and infrastructure policy for the Campaign to Protect Rural England (CPRE), the countryside charity, and served on National Highways' Strategic Design Panel.

## REFERENCES

- National Audit Office (2023) *Departmental overview: Department for Transport 2022–23*. <https://www.nao.org.uk/overviews/department-for-transport-2022-23/> (Accessed: 6 March 2026).
- Department for Transport and Highways Agency (2013) *Action for roads: a network for the 21st century*. <https://www.gov.uk/government/publications/action-for-roads-a-network-for-the-21st-century> (Accessed: 6 March 2026).
- Department for Transport and Highways Agency (2014) *Road investment strategy: 2015 to 2020*. <https://www.gov.uk/government/collections/road-investment-strategy> (Accessed: 6 March 2026).
- Department for Transport (2021) *Transport decarbonisation plan*. <https://www.gov.uk/government/publications/transport-decarbonisation-plan> (Accessed: 6 March 2026).
- Department for Transport (2025) *Mode of travel*. Mode of travel: statistical dataset NTS0303c. <https://www.gov.uk/government/statistical-data-sets/nts03-modal-comparisons> (Accessed: 11 March 2026).
- Prime Minister's Office, 10 Downing Street and The Rt Hon Rishi Sunak MP (2023) *PM speech on net zero: 20 September 2023*. <https://www.gov.uk/government/speeches/pm-speech-on-net-zero-20-september-2023> (Accessed: 6 March 2026).
- Marsden, G. (2025) *Headwinds: Transport Decarbonisation in a Storm*. <https://www.edrc.ac.uk/publications/headwinds-transport-decarbonisation-in-a-storm/> (Accessed: 6 March 2026).
- Department for Transport (2025) *Transport and environment statistics: 2023*. <https://www.gov.uk/government/statistics/transport-and-environment-statistics-2023--2> (Accessed: 6 March 2026).
- British Standards Institution (2023) *Carbon Management in Buildings and Infrastructure – PAS 2080*. <https://www.bsigroup.com/en-GB/insights-and-media/insights/brochures/pas-2080-carbon-management-in-infrastructure-and-built-environment/> (Accessed: 6 March 2026).
- zu Ermgassen, S.O.S.E., Drewniok, M.P., Bull, J.W. et al. (2022) A home for all within planetary boundaries: pathways for meeting England's housing needs without transgressing national climate and biodiversity goals. *Ecological Economics*, 201 (article: 107562). <https://doi.org/10.1016/j.ecolecon.2022.107562> (Accessed: 6 March 2026).
- Department for Energy Security and Net Zero (2023) *Committee on Climate Change 2023 progress report: government response*. <https://www.gov.uk/government/publications/committee-on-climate-change-2023-progress-report-government-response> (Accessed: 6 March 2026).
- Environment Agency (2024) *National assessment of flood and coastal erosion risk in England*. <https://www.gov.uk/government/publications/national-assessment-of-flood-and-coastal-erosion-risk-in-england-2024> (Accessed: 6 March 2026).
- National Infrastructure Commission (2023) *Second national infrastructure assessment*. <https://webarchive.nationalarchives.gov.uk/ukgwa/20240306053402/> <https://nic.org.uk/studies-reports/national-infra-structure-assessment/second-nia/#tab-resilience> (Accessed: 6 March 2026).
- HM Treasury and National Infrastructure and Service Transformation Authority (2025) *UK infrastructure: a 10 year strategy*. <https://www.gov.uk/government/publications/uk-infrastructure-a-10-year-strategy> (Accessed: 11 March 2026).
- Department for Transport (2025) *Climate adaptation strategy for transport*. <https://www.gov.uk/government/publications/climate-adaptation-strategy-for-transport> (Accessed: 6 March 2026).
- Department for Environment, Food & Rural Affairs (2025) *Biodiversity net gain for nationally significant infrastructure projects*. <https://www.gov.uk/government/consultations/biodiversity-net-gain-for-nationally-significant-infrastructure-projects> (Accessed: 6 March 2026).
- Donald, P.F. (2023) *Traffication: How Cars Destroy Nature and What We Can Do About It*. Pelagic Publishing.
- UK Parliament (2022) *Water quality in rivers*. <https://committees.parliament.uk/work/891/water-quality-in-rivers/publications/> (Accessed: 6 March 2026).
- House of Commons (2025) *Environmental Audit Committee. Oral evidence: National Highways and environmental sustainability, HC 1284*. <https://committees.parliament.uk/oralevidence/16411/html/> (Accessed: 6 March 2026).
- National Highways (2023) *Strategic Road Network. Initial Report 2024–2030*. [https://nationalhighways.co.uk/media/3v2nqsee/cre22\\_0102-srn-initial-report-2025-2030\\_vn-updated.pdf](https://nationalhighways.co.uk/media/3v2nqsee/cre22_0102-srn-initial-report-2025-2030_vn-updated.pdf) (Accessed: 6 March 2026).
- Climate Change Committee (2026) *Letter: Nigel Topping CMG to chair of Environmental Audit Committee on the Seventh Carbon Budget*. <https://www.theccc.org.uk/publication/letter-nigel-topping-cmg-to-chair-of-environmental-audit-committee-on-seventh-carbon-budget/> (Accessed: 6 March 2026).

# Building nature back in: the prospect of nature-centric housing

**Matt Pritchard and Tom Oliver** argue that a shift in mindset and values is needed for a genuinely sustainable approach to the housing crisis.

**H**ousing is unaffordable for most people in the UK, so the Government plans to enable 1.5 million new homes to be built in just a few years.<sup>1</sup> Assuming it makes housing more affordable (which is not a given), how can it be done without harming wildlife in what is already one of the most nature-depleted countries in the world?<sup>2,3</sup>

According to government reports, a loss of nature drives a loss of benefits to humans, leading to increased risks of flooding and greater food insecurity, disease and pollution.<sup>4</sup> Nature loss already contributes significantly to the declining physical and mental health of the population, with nature poverty varying markedly between UK postcodes.<sup>5</sup> And the UK's position is exacerbated by the wider backdrop: the recently

released Government assessment on global biodiversity loss, ecosystem collapse and national security details how nature degradation threatens national security and prosperity.<sup>6</sup>

With current shortages in both housing and nature having such deleterious consequences, it is not an option to trade one off against the other. What is needed is for nature and housing to flourish together. However, ministerial claims of introducing such a win-win scenario are spurious.

## THE STATUS QUO IS NOT WORKING

Government communications have to date used the cauldron principle, coined by journalist George Monbiot for the tactic of blaming so-called creepy species such as bats, newts, spiders and snails for blocking developments. The Government is considering implementing the recommendations of the Nuclear Regulatory Review 2025 (or Fingleton Review), which seeks to weaken environmental protections at a time when existing safeguards, and their implementation, are already failing: the Government is flunking its own targets for nature recovery and for providing clean water and air.<sup>7</sup>



▲ A swift using swift bricks, which are hollow and contain internal nest boxes. © XJochemx.nl | CC-BY-SA 4.0

According to the Office for Environmental Protection, it remains on track for just nine out of 43 environmental commitments.<sup>8</sup>

An example is biodiversity net gain. It quantifies the habitat that needs to be ‘restored’ in exchange for that destroyed by development, but research suggests that the promised nature restorations rarely happen.<sup>9</sup> Doubling down, the new planning system reforms enable developers to pool promised habitat ‘units’ and restore them elsewhere.<sup>10</sup> But destroying nature in one place and trying to rebuild it elsewhere is not the answer: ecosystems take decades to mature (e.g. consider the complex interactions between soil fungi, plants and insects). Even with a brand-new home, people living in dead zones will pay the price of drastically reduced health benefits, as the Government’s own report on the relationship between the environment and human health confirms.<sup>5</sup>

**MINDSETS AND VALUES**

So what does a genuine win-win look like? Founding members of the modern environmental movement, from Aldo Leopold to Arne Naess

and Thomas Berry, emphasised the importance of a fundamental shift in self-identity, and specifically in how we relate to and with the rest of nature.<sup>11-13</sup> Their emphasis on this philosophical and psychological dimension might seem tangential in the face of a crisis of increasing urgency, but a consensus is emerging among major organisations focused on science-related policy that it is central to any meaningful response to the polycrisis.

Organisations including the United Nations and European Environment Agency consider a worldview shift in our relationship with the rest of nature as essential for a sustainable civilisation.<sup>14,15</sup> In 2024, the Intergovernmental Panel on Biodiversity and Ecosystem Services produced its Transformative Change Assessment, which was ratified by 147 governments, including the UK. The conclusion identified ‘disconnection from and domination over nature and people’ as one of the main causes of global biodiversity loss and stated the need for ‘fundamental system-wide shifts in views, structures and practices’.<sup>16</sup>



▲ Insect hotels on the side of a house. © Harry Wedzinga | Adobe Stock

This makes theoretical sense. Donella Meadows, an environmentalist and systems theorist, analysed the leverage points for systems change.<sup>17</sup> While we can and should continue to do environmental monitoring, reporting and compliance, these are ultimately weak levers for transformation. Changing paradigms is more challenging but has far greater impact.

**A NATURE-CENTRIC HOUSING WORKSHOP**

We have yet to live up to the vision and message of these seminal thinkers. If we did, what would it mean in practice for housing, and for infrastructure development more generally?

Our academic research at the Nature-centric Catalyst, University of Reading, explores how society might assign inherent value to other creatures rather than objectifying them as lifeless assets.<sup>18</sup> Seeing nature as an intrinsic part of us, and vice-versa, is a more scientifically accurate worldview, as well as essential for protecting it.<sup>19</sup> This has widespread implications for the design of our businesses, governance and education systems.<sup>20-22</sup>

In a housebuilding context, this means thinking about developments as multispecies communities. Until we do, we are building homes and infrastructure for people, not a broader community of life of which we are a part and without which we cannot flourish.

We recently ran a workshop involving experts from law, urban planning, architecture, garden design and housing policy. Using the Three Horizons framework, participants began with the principle that other species already have their homes in the area considered for development and explored visions for how humans could live alongside them to the greatest extent possible (Horizon 3). This was then compared to the status quo (Horizon 1). Finally, the group assessed which potential (Horizon 2) interventions might carry us like stepping stones towards a nature-centric vision for housing and which risked being false pathways that lock us into a status quo of ineffective action on nature loss. The group concluded that the technical expertise for introducing nature-centric housing already exists, but that we lack the deeper mindset shift needed to bring about such an



© Nosama | Adobe Stock

ambitious programme. The findings of this work will be published in due course.

**CAN IT BE DONE?**

Living in communities with greater species diversity and abundance may sound idealistic and ultimately impractical. However, while it is also impractical to expect societies to thrive where current approaches drive further ecological breakdown, many nature-centric housing developments already exist, including in Brazil, Italy and the Netherlands. One example is the Oosterwold experiment, located east of Amsterdam.<sup>23-25</sup> In this 4,300-hectare suburb of the city of Almere, residents are free to choose any design for their home with the stipulation that they must devote at least half of the large plots (1,000–2,500 square metres) to agriculture.

Small-scale food production in such urban and peri-urban areas creates a range of benefits including social cohesion, flood prevention, better air quality and food security, as well as making space for nature. In the UK, such approaches do not exist at scale, partly due to a lack of coordination between different government departments, such as the Ministry of Housing, Communities and Local Government and Defra, whose responsibilities form siloed divisions at town and countryside borders. Despite this, there is growing recognition

**BOX 1. GREAT KNEIGHTON CASE STUDY<sup>27</sup>**

A development of more than 2,000 houses at Great Kneighton, on the southern edge of Cambridge, was designed to protect and enhance habitats – particularly for otters.<sup>28</sup> Otters lived in nearby waterways, especially Hobson’s Brook, which run through the site. Ecologists were involved from the early planning stages to survey wildlife and guide habitat design.

At the core of the development is a 120-acre park with ponds, wetlands, woodland planting and grassland habitats that supports fish, amphibians and birds. For otters, these habitats combine aquatic environments, food supply and vegetated riverbanks suitable for resting, hiding or building holts. Planners also left buffer zones of vegetation along the riverbanks, thereby reducing noise, lighting and recreational disturbances from housing while providing a wildlife corridor set aside from roads and buildings. Where roads, footpaths or haulage routes need to cross Hobson’s Brook, there are bridges instead of culverts where possible, leaving open space beneath so that wildlife can move unobstructed.

The project also includes long-term ecological monitoring. Specialists are retained to oversee ecological management of the country park many years after construction. If wildlife populations change, habitat management can be adjusted to maintain favourable conditions.

by development consultancies on the benefits of urban farming and how to integrate it into city planning.<sup>26</sup>

There may be challenges in building nature-centric housing at scale and adapting developments to local ecosystems, but examples show that housing design and surrounding areas can be tailored to help regionally rare animals like otters and certain bat species, as well as amphibians, insects and plants (see **Box 1**).

Is nature-centric housing always more expensive? There is certainly the potential for added up-front costs given the importance of ecological surveys to inform design, construction that avoids unnecessary harm to other species, and features such as native planting and wildlife corridors. However, any cost increase is likely to be much smaller than the price of living in nature-deprived landscapes – including to physical and mental health. There are savings from building energy-efficient homes with natural protection against flooding and other climate impacts, and any additional costs should be compared to the effects of land banking, second homes and other current practices.

Costs could be managed through regulation and standards or, where these are less appealing, by common financial incentives such as tax credits,

subsidies, grants, low-interest loans and lower insurance premiums. Developers could potentially monetise benefits like flood mitigation or carbon sequestration, while closer partnerships between stakeholders could ease transactions or provide design toolkits. Although planning approvals might take longer, this is less likely if more species were protected as part of the initial design rather than through complex offsetting schemes. And while initially there might be supply challenges due to skills shortages for different types of construction and habitat curation, capacity would increase over time to meet rising demand.

Developers, investors and affordable housing advocates might resist changes perceived as reducing housing density; but nature-centric housing need not be low-density.<sup>29,30</sup> Moreover, common objections of local communities – increased traffic, pressure on services, changes to the character of the neighbourhood – may be more applicable to typical anthropocentric developments than to nature-centric ones. There is the potential for conflict between conceptions of individualised property and a spirit of collective more-than-human obligations, but that risk is easily overstated: instances of nature-centric housing suggest these do not always materialise.

**BUILDING WITH NATURE**

Research shows that promoting a nature-centric shift in worldviews must become a top priority.<sup>31</sup> Without realigned value systems, environmental regulations are simply rules that get ignored, as we are witnessing with the poor state of our rivers and the loss of our plants and wildlife.<sup>32,33</sup> In a planning context, the key challenge is to expand our imaginations for how we can live alongside other species and to cultivate the political courage for such homes. Building them may take longer than a single parliamentary term, but anything less will continue to drive the loss of nature on which our health and prosperity depend.

The real solutions to the housing crisis transcend bricks and mortar and rules about where to put them: we need to rebuild both physical infrastructure and our care and responsibility for the natural world.<sup>34</sup> To solve the housing crisis in ways that are genuinely sustainable may require ‘inner development’, but that is highly rewarding in itself.<sup>35</sup> Moreover, it consigns to history the annihilation of local populations based upon weak promises of developing related ecosystems elsewhere, and instead builds a future of healthy, ethical and desirable homes.

A real win-win for nature and housing needs to reweave humans back into the web of life. And who doesn't want to live in a nature reserve? **ES**

**Matt Pritchard** worked in government and as a Director of Sustainability at Baringa Partners before becoming a Research Fellow at the University of Reading. He co-led the Nature-centric Catalyst and now works on collective multispecies intelligence and artificial intelligence. He also advises clients on futures and foresight via SAMI Consulting.

✉ [m.c.pritchard@reading.ac.uk](mailto:m.c.pritchard@reading.ac.uk)  
 in [linkedin.com/in/matt-pritchard-63419822b/](https://www.linkedin.com/in/matt-pritchard-63419822b/)

**Tom Oliver** is Professor of Applied Ecology at the University of Reading and Associate Pro-vice-chancellor for Research (Environment). He currently sits on the Food Standards Agency Science Council and Office for Environmental Protection College of Experts. He is the author of *The Self Delusion and The Nature Delusion*.<sup>19</sup>

✉ [t.oliver@reading.ac.uk](mailto:t.oliver@reading.ac.uk)  
 in [linkedin.com/in/tom-oliver-a76b27167/](https://www.linkedin.com/in/tom-oliver-a76b27167/)

**REFERENCES**

- Office for National Statistics (2025) *Housing affordability in England and Wales: 2024*. <https://www.ons.gov.uk/peoplepopulationandcommunity/housing/bulletins/housingaffordabilityinenglandandwales/2024> (Accessed: 11 March 2026).
- State of Nature Partnership (no date) Home page. <https://stateofnature.org.uk/> (Accessed: 11 March 2026).
- Matthews, W. (2024) *Building more homes won't solve the housing crisis*. <https://www.architectsjournal.co.uk/news/opinion/will-more-homes-really-solve-the-housing-crisis> (Accessed: 11 March 2026).
- UK Government (2025) *Chronic Risks Analysis*. [https://assets.publishing.service.gov.uk/media/6890acc9e8ba9507fc1b09a6/Chronic\\_Risks\\_Analysis\\_\\_CRA\\_.pdf](https://assets.publishing.service.gov.uk/media/6890acc9e8ba9507fc1b09a6/Chronic_Risks_Analysis__CRA_.pdf) (Accessed: 11 March 2026).
- Environment Agency (2023) *State of the environment: health, people and the environment*. <https://www.gov.uk/government/publications/state-of-the-environment/state-of-the-environment-health-people-and-the-environment> (Accessed: 11 March 2026).
- Department for Environment, Food & Rural Affairs (2026) *Nature security assessment on global biodiversity loss, ecosystem collapse and national security*. <https://www.gov.uk/government/publications/nature-security-assessment-on-global-biodiversity-loss-ecosystem-collapse-and-national-security> (Accessed: 11 March 2026).
- Fingleton, J. (2025) *Nuclear Regulatory Review 2025. Enabling Nuclear Delivery Through Regulatory Reform*. <https://assets.publishing.service.gov.uk/media/692080f75c394e481336ab89/nuclear-regulatory-review-2025.pdf> (Accessed: 11 March 2026).
- Office for Environmental Protection (2025) *This Government has the chance to get on track to meet legal environmental commitments – but the window of opportunity is closing fast warns OEP*. <https://www.theoep.org.uk/report/government-has-chance-get-track-meet-legal-environmental-commitments-window-opportunity> (Accessed: 11 March 2026).
- Chapman, K. and Tait, M. (2025) *Property developers installing as few as half of promised ecological features – new report*. <https://theconversation.com/property-developers-installing-as-few-as-half-of-promised-ecological-features-new-report-246391> (Accessed: 11 March 2026).
- Ministry of Housing, Communities & Local Government (2025) *Factsheet: Nature Restoration Fund*. Guidance. <https://www.gov.uk/government/publications/the-planning-and-infrastructure-bill/factsheet-nature-restoration-fund> (Accessed: 11 March 2026).
- Berry, T. (1999) *The Great Work: Our Way into the Future*. Bell Tower.
- Naess, A. (2008) *Ecology of Wisdom: Writings by Arne Naess*. A. Drengson and B. Devall, eds. Counterpoint.

**REFERENCES**

- Leopold, A. (1949) *A Sand County Almanac, and Sketches Here and There*. Oxford University Press.
- Oliver, T. (2023) *Inner change to tackle the climate and biodiversity crisis*. <https://www.psychologytoday.com/gb/blog/environment-and-self-identity/202304/inner-change-to-tackle-the-climate-and-biodiversity> (Accessed: 11 March 2026).
- European Environment Agency (2023) *Exiting the Anthropocene? Exploring fundamental change in our relationship with nature*. <https://www.eea.europa.eu/en/analysis/publications/exiting-the-anthropocene> (Accessed: 11 March 2026).
- Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (2024) *IPBES transformative change assessment*. Media release. <https://www.ipbes.net/transformative-change/media-release> (Accessed: 11 March 2026).
- Meadows, D. (1999) *Leverage Points: Places to Intervene in the System*. [https://donellameadows.org/wp-content/userfiles/Leverage\\_Points.pdf](https://donellameadows.org/wp-content/userfiles/Leverage_Points.pdf) (Accessed: 11 March 2026).
- UK Treasury (2021) *Final Report – The Economics of Biodiversity: The Dasgupta Review*. <https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review> (Accessed: 11 March 2026).
- Oliver, T. (2020) *The Self Delusion: The Surprising Science of our Connection to Each Other and the Natural World*. Weidenfeld & Nicolson.
- V. Kann Rasmussen Foundation (2025) *Nature-Centrism as a Lens for Organizational Behavior and Decision-Making*. <https://static1.squarespace.com/static/6390dd77f81b020e2df52dcc/t/677c63a8d748d67cb77b7649/1736205224661/Call+for+Proposals+-+Spring+2025+-+Nature-Centric+Behavior+%5E0+-+Decision-Making.pdf> (Accessed: 11 March 2026).
- Oliver, T. (2025) *The Rethink. Awakening the nature-centric mindset*. <https://www.asranetwork.org/news/the-rethink-awakening-the-nature-centric-mindset> (Accessed: 11 March 2026).
- Giusti, M., Mäkelä, V., Garbett Skagerlid, A. and Nagatsu, M. (2025) *Shifting relationships with nature through schools: exploring the social and spatial context for transformative sustainability education*. *Ecology & Society*, 30 (2). <https://doi.org/10.5751/ES-15969-300234> (Accessed: 11 March 2026).
- Knikker, J. (2021) *Almere Oosterwold, Netherlands – a Dutch utopia in the making*. *African Journal of Landscape Architecture*, 2 (article: 9). <https://www.ajlajournal.org/articles/almere-oosterwold-netherlands-a-dutch-utopia-in-the-making> (Accessed: 11 March 2026).
- MVRDV (no date) *Almere Oosterwold*. <https://www.mrvd.com/projects/32/almere-oosterwold> (Accessed: 12 March 2026).
- Docter-Loeb, H. (2024) ‘You have to find your own recipe’: Dutch suburb where residents must grow food on at least half of their property, *The Guardian*, 28 November. <https://www.theguardian.com/environment/2024/nov/28/oosterwold-dutch-suburb-where-residents-must-grow-food-on-at-least-half-of-their-property> (Accessed: 11 March 2026).
- Firth, K. (2024) *A more nature-based masterplan: how urban farming improves our cities*. <https://www.arup.com/insights/a-more-nature-based-masterplan-how-urban-farming-improves-our-cities/> (Accessed: 11 March 2026).
- Countryside (no date) *Great Kneighton. Trumpington, Cambridge: A Great Place to Call Home*. <https://homes.bidwells.co.uk/globalassets/residential/new-homes/great-kneighton/great-kneighton-brochure.pdf> (Accessed: 11 March 2026).
- Building & Facilities Management (no date) *Otter-ly loveable – making their home at Great Kneighton*. <https://www.bfmmagazine.co.uk/otter-ly-loveable-making-their-home-at-great-kneighton/> (Accessed: 11 March 2026).
- Ip, T. (2024) *A new form of biophilic design for human-nature interactions in high-density, high-rise contexts*. *IOP Conference Series: Earth and Environmental Science*, 1363 (article: 012007). <https://iopscience.iop.org/article/10.1088/1755-1315/1363/1/012007/meta> (Accessed: 11 March 2026).
- Ehab, A., Burnett, G. and Heath, T. (2025) *Elevating the public realm: a framework for designing resilient urban green spaces in hyperdense cities*. *Discover Sustainability*, 6 (article: 10). <https://doi.org/10.1007/s43621-024-00755-9> (Accessed: 11 March 2026).
- Oliver, T.H., Doherty, B., Dornelles, A. et al. (2022) *A safe and just operating space for human identity: a systems perspective*. *The Lancet: Planetary Health*, 6 (11), article: e919–e927. DOI:10.1016/S2542-5196(22)00217-0.
- Office for Environmental Protection (2024) *OEP finds ‘deeply concerning’ issues with how the laws in place to protect England’s rivers, lakes and coastal waters are being put into practice*. <https://www.theoep.org.uk/report/oep-finds-deeply-concerning-issues-how-laws-place-protect-englands-rivers-lakes-and-coastal> (Accessed: 11 March 2026).
- Office for Environmental Protection (2025) *Progress in improving the natural environment in England 2023 to 2024*. <https://www.gov.uk/government/publications/progress-in-improving-the-natural-environment-in-england-2023-to-2024> (Accessed: 11 March 2026).
- Oliver, T. (2024) *A new campaign wants to redefine the word ‘nature’ to include humans – here’s why this linguistic argument matters*. <https://theconversation.com/a-new-campaign-wants-to-redefine-the-word-nature-to-include-humans-heres-why-this-linguistic-argument-matters-229338> (Accessed: 11 March 2026).
- Bristow, J., Tickell, P., Bell, R. et al. (2024) *The System Within: Addressing the Inner Dimensions of Sustainability and Systems Transformation*. Report by Earth for All for The Club of Rome. <https://www.clubofrome.org/publication/earth4all-bristow-bell/> (Accessed: 11 March 2026).

# The Swiss Army knife of energy: powering the UK's reindustrialisation

**Kirsty Gogan** and **Eric Ingersoll** discuss how new digital tools and factory-built reactors could unlock clean energy on Britain's existing industrial land faster and more cheaply than anyone thought possible.

## THE INFRASTRUCTURE TRILEMMA

The UK faces three simultaneous imperatives: decarbonising the economy, strengthening energy security and reindustrialising communities that have been left behind by decades of deindustrialisation. The conventional wisdom is that these goals are in tension – going fast on net zero means it is expensive, and energy security means clinging to fossil fuels. But a new approach to nuclear energy, enabled by artificial intelligence (AI) and advanced manufacturing, suggests the opposite: that all three objectives could be pursued together, faster and more affordably than the current trajectory allows.



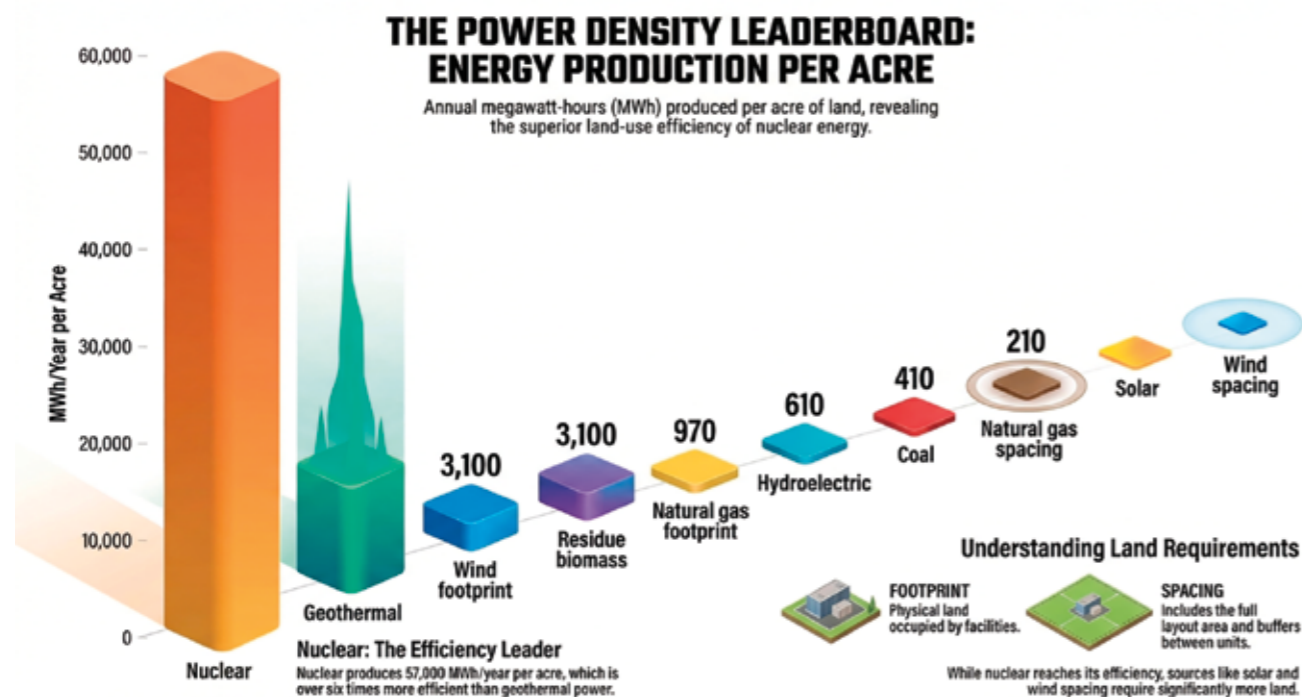
Consider the current plan. The UK is set to spend an estimated £150–200 billion on new transmission and distribution infrastructure, much of it to connect remote renewable energy generation sites to centres of demand. Yet the country already possesses approximately 30 GW of retired coal and nuclear sites with existing high-voltage grid connections – transmission capacity that took decades to build and is fully permitted.

Deploying high-capacity factor generation at these sites could deliver up to 240 TWh annually, meeting the entire electricity demand increase required by 2035 with infrastructure we already have. While investing in new transmission infrastructure is a necessary investment, it is also capital-intensive and money cannot simultaneously be spent on new generation assets. Meanwhile, Hinkley Point C has demonstrated that bespoke nuclear megaprojects, however valuable their output, are not a scalable model: a single station that costs more than £30 billion and takes over a decade to deliver cannot be replicated dozens of times across the country.

Yet across Britain sits an extraordinary and largely overlooked asset: hundreds of brownfield industrial sites – retired coal plants, former refineries, ports, heavy industrial complexes – that already possess high-voltage grid connections, cooling water access, road and rail infrastructure, and communities with deep industrial skills. These are not liabilities to be managed. They are the foundations of a clean energy fleet.

**ONE PLATFORM FOR CLEAN ENERGY**

Nuclear energy is uniquely positioned to serve as a multipurpose platform for decarbonisation. Unlike any other zero-carbon technology, it can deliver dispatchable electricity, high-temperature industrial process heat, district heating, hydrogen via electrolysis and synthetic fuels – all from a single installation with a tiny land footprint. A nuclear facility produces up to 285 times more energy per acre per year than renewables, with capacity factors consistently above 90 per cent compared to 25–35 per cent for wind and solar (see **Figure 1**).<sup>1</sup> For environmental professionals, the life cycle metrics are equally compelling: nuclear’s land use, life cycle carbon dioxide (CO<sub>2</sub>) emissions and material requirements per unit of



▲ **Figure 1. Comparison of energy production per acre across different energy sources. (Created by the authors based on Urenco and LucidCatalyst, 2025)**

energy are among the lowest of any generation technology, as confirmed by the European Commission’s Joint Research Centre.<sup>2</sup>

This versatility matters enormously for the UK. Despite decades of deindustrialisation, UK industry still has significant industrial energy demand for chemicals, steel production, ceramics, food processing and refining – sectors that require reliable, high-temperature heat that renewables may struggle to provide. A recent study analysed 11 key industrial sectors across North America and Europe and found that small modular reactors (SMRs) are technically capable of serving over 80 per cent of total industrial energy demand.<sup>1</sup> In Europe alone, the technical potential amounts to approximately 800 GW – roughly 5,500 TWh per year. The top five accessible markets identified were synthetic aviation and maritime fuels, coal plant repowering, data centres and chemicals. District energy – particularly relevant to the UK – represents 33 GW of opportunity, and European demand is three to four times larger than North America’s.

Nuclear cogeneration, simultaneously producing electricity and process heat, can achieve efficiencies above 80 per cent compared to 35–40 per cent for electricity-only systems. Unlike conventional large reactors such as Sizewell C, which are designed primarily for electricity and sited in remote coastal locations, SMRs are compact enough to be deployed at industrial sites where both power and heat are needed.

In a cogeneration configuration, the thermal energy that would otherwise be rejected as waste heat is instead captured and directed to industrial processes or district heating – dramatically improving overall energy conversion efficiency. Previous modelling has demonstrated that integrating nuclear alongside renewables in the UK energy system could reduce total system spending by 6–9 per cent in net present value terms between 2021 and 2050, while cutting cumulative emissions by 80 million tonnes of CO<sub>2</sub> equivalent and reducing gas consumption by 8,000 TWh.<sup>3,4</sup> Crucially, the study also showed that without dedicated nuclear hydrogen production, fossil-based blue hydrogen would



© Carismarkus | Adobe Stock

still account for over 35 per cent of UK hydrogen demand in 2050 – locking in the fossil fuel dependence the transition is meant to eliminate.

In short, nuclear is like a Swiss Army knife: a single technology platform capable of meeting diverse energy needs with high reliability, minimal environmental footprint and the flexibility to complement renewables rather than compete with them.

#### THE BROWNFIELD ADVANTAGE

The economic case for deploying nuclear to existing industrial and power generation sites is powerful. These locations already have the infrastructure that new nuclear projects need most: grid connections rated at hundreds of

megawatts or more, established water supplies, transport links and planning histories that include industrial use. Analysis suggests that repowering coal sites with SMRs can reduce capital costs by up to 35 per cent compared to greenfield development, simply by reusing what already exists.<sup>1</sup>

But the benefits extend well beyond cost savings. Siting nuclear generation at or near industrial heat consumers – rather than in remote coastal locations – unlocks the full value of the flexible generation model: co-producing electricity, process heat and hydrogen for co-located or nearby industries. This approach puts heat sources where consumers are and maximises the economic output of every installed megawatt.

The socio-economic case is equally compelling. Former coal and industrial communities have borne the heaviest costs of deindustrialisation. Nuclear deployment to brownfield sites brings high-skilled, long-term employment and genuine regeneration to precisely these places. And from an energy security perspective, distributed generation across multiple sites reduces dependence on imported gas and avoids the concentration risk inherent in relying on a small number of very large installations.

Over 300 GW of coal capacity in Europe, 200 GW in the USA and hundreds of gigawatts across Asia represent potential candidates for nuclear conversion – alongside refineries, ports and heavy industry sites.<sup>1,5</sup> The study's modelling found

that, even accounting for economic and supply constraints, coal repowering represents 110 GW of the accessible SMR market in North America and Europe by 2050 – the second-largest sectoral opportunity identified.<sup>1</sup> The UK, with its retiring coal fleet, is exceptionally well positioned to capture an early share.

#### TOOLS THAT TURN YEARS INTO MONTHS

If the opportunity is clear, the question then becomes: What has been holding it back? The answer is not reactor technology. It is the speed and cost of the upstream process – site assessment, design optimisation and licensing – which has typically required years of analysis per site. For a fleet deployment strategy to work, this timeline must be compressed by an order of magnitude.

This is now happening. Terra Praxis, through its Project Phoenix initiative, funded by the US Department of State and launched in 2023, has built four integrated digital analytical engines – geospatial analysis, programmatic modelling, 3D site configuration and data visualisation – that can assess an industrial or coal site and generate an optimised nuclear energy conversion design in days rather than months.<sup>6</sup> These tools were developed and validated in one of the most urgent energy reconstruction efforts in the world: helping Ukraine rebuild its devastated energy infrastructure with clean nuclear power. Thirteen priority Ukrainian sites were selected and analysed – with all four digital engines prototyped – tested and are now operating. This validation demonstrates that the approach works at the pace that real-world crises demand.

In parallel, Terra Praxis has developed an agentic AI-powered licensing accelerator in collaboration with Microsoft software engineers, earning four consecutive wins at Microsoft's AI for Good hackathon and a place on the Microsoft Garage Wall of Fame. This system deploys intelligent software agents to navigate regulatory

complexity, compressing nuclear permitting from years to months. Crucially, it enables fleet licensing – the simultaneous assessment and preparation of dozens of brownfield sites, rather than the serial, one-at-a-time approach that has constrained the sector for decades. These tools work primarily from existing geospatial and infrastructure datasets, identifying suitable sites and reserving physical site investigation for later development stages.

Alongside these digital tools, Terra Praxis is working with the World Nuclear Association and regulators to advance product-based licensing: a regulatory paradigm that treats manufactured reactors as certified products rather than bespoke construction projects. Combined with a standardised site licensing envelope – designed so that multiple reactor vendors can fit within it – this approach could make sites development-ready at a fraction of the current cost and time. This requires regulatory evolution – a significant institutional shift from bespoke project review to type-certification. There is also the challenge of ensuring that standardised envelopes are broad enough to accommodate

multiple reactor designs without becoming so generic that they lose regulatory rigour. However, shifts like these have already been proven in aviation and other safety-critical industries. The Urenco study identified site pre-qualification and regulatory evolution as two of six critical market drivers required to unlock the full 700 GW opportunity.<sup>1</sup> The tools to activate these drivers now exist.

#### FROM FACTORY TO FLEET

Faster site preparation is only half the equation. The other half is reactor cost. The study modelled four supply scenarios, and the results are striking. Under the current bespoke delivery model, costs remain around US\$125 per MWh with decade-long timelines, which would yield just 7 GW of deployment by 2050. Under a full manufacturing transformation – where reactors are designed from inception for factory production using modular assembly and standardised components – costs fall to \$40–60 per MWh with delivery in two to three years. This would unlock nearly 700 GW of deployment: approximately 2,300 reactors representing a \$0.5–1.5 trillion global investment opportunity.<sup>1</sup>

Multiple companies are already investing in factory-based mass manufacturing of reactor modules. The critical inflection point is the shift from site-built construction to shipyard and factory production, which can reduce capital costs by up to 70 per cent. With its advanced manufacturing and shipbuilding heritage the UK is well placed to be both a customer and a manufacturer – capturing export value as well as clean energy.

#### A CALL TO ACTION

The tools for a step-change in nuclear deployment now exist: AI-powered site assessment that works in days, agentic licensing systems that work in months, manufactured reactors that can be delivered in years rather than decades and a vast inventory of brownfield sites ready to be put to productive use.

The barriers are not primarily technological but institutional: the absence of a fleet-level siting and licensing programme, fragmented procurement that fails to value system-wide benefits, and a regulatory framework still designed for bespoke megaprojects rather



▲ Hinkley Point Power Station, England. © Hannah | Adobe Stock



▲ The new Sizewell C construction site in Suffolk. © Nick Beer | Adobe Stock



© Monodio Photography | Adobe Stock

than manufactured products. What is needed is a programme-level commitment to identify and license a fleet of brownfield sites, create standardised licensing envelopes and signal clearly to the global market that the UK is open for nuclear investment.

The prize is substantial: energy security, reindustrialisation, net zero and the regeneration of communities that have waited for too long. The Aurora modelling showed this integrated approach reduces system costs by 6–9 per cent while cutting cumulative emissions by 80 million tonnes.<sup>4</sup> The Urenco study confirmed that the global investment opportunity runs to the trillions – and that capital will flow to the countries that move first to prepare their sites and regulatory frameworks.<sup>1</sup>

The approach that Terra Praxis is proving in Ukraine applies directly to the UK and to hundreds of gigawatts of convertible sites worldwide. The pathway is clear. The time to act is now.

ES

**Kirsty Gogan** is Co-founder and Managing Partner of LucidCatalyst and Terra Praxis. She previously served on the UK Nuclear Innovation and Research Advisory Board.

**Eric Ingersoll** is Co-founder and Managing Director of LucidCatalyst and Terra Praxis. They advise governments, international organisations and industry on clean energy strategy and nuclear innovation.

## REFERENCES

1. Urenco and LucidCatalyst (2025) *A New Nuclear World: How Small Modular Reactors (SMRs) Can Power Industry*. <https://www.lucidcatalyst.com/post/new-study-from-lucidcatalyst-shows-significant-potential-market-for-smrs-providing-net-zero-solution> (Accessed: 10 March 2026).
2. Abousahl, S., Carbol, P., Farrar, B. et al. (2021) *Technical Assessment of Nuclear Energy with Respect to the 'Do no Significant Harm' Criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation')*. [https://publications.jrc.ec.europa.eu/repository/bitstream/JRC125953/jrc125953\\_technical\\_assessment\\_of\\_nuclear\\_energy\\_-\\_v2\\_-\\_public\\_online\\_version\\_1.pdf](https://publications.jrc.ec.europa.eu/repository/bitstream/JRC125953/jrc125953_technical_assessment_of_nuclear_energy_-_v2_-_public_online_version_1.pdf) (Accessed: 13 March 2026).
3. MacDonald, A. and Chow-Kambitsch, F. (2021) *Decarbonising Hydrogen in a Net Zero Economy*. Executive summary. Prepared by Aurora Energy Research for Urenco. [https://www.urengo.com/cdn/uploads/supporting-files/20210927\\_Aurora\\_Hydrogen\\_Study\\_-\\_Decarbonising\\_hydrogen\\_in\\_a\\_net\\_zero\\_economy\\_-\\_Executive\\_Summary.pdf](https://www.urengo.com/cdn/uploads/supporting-files/20210927_Aurora_Hydrogen_Study_-_Decarbonising_hydrogen_in_a_net_zero_economy_-_Executive_Summary.pdf) (Accessed: 10 March 2026).
4. LucidCatalyst (2021) *Hydrogen Modelling 2.0: De-Risking, De-Scoping, and Lowering the Cost of Achieving Net Zero*. [https://www.lucidcatalyst.com/\\_files/ugd/2fed7a\\_cd93206baf2c476bbcc706fc0abab569.pdf](https://www.lucidcatalyst.com/_files/ugd/2fed7a_cd93206baf2c476bbcc706fc0abab569.pdf) (Accessed: 10 March 2026).
5. Global Energy Monitor (no date) Home page. <https://globalenergymonitor.org/> (Accessed: 10 March 2026).
6. US Department of State (2023) *United States launches Project Phoenix to accelerate the adoption of advanced clean energy technologies in Europe*. <https://2021-2025.state.gov/united-states-launches-project-phoenix-to-accelerate-the-adoption-of-advanced-clean-energy-technologies-in-europe/> (Accessed: 10 March 2026).

# New members and re-grades



**MEMBER**

Vito Abbruzzese – Scientific Advisor  
 Laura Anastassiades – Principal Environmental scientist  
 Rose Bailey – Associate Director – Climate Action Planning and Transparency  
 Lisa Baldini – Development Officer – Grants & Trusts  
 Stephen Bazzo – Principal Environmental Consultant  
 Jack Bell – Director & Principal Environmental Consultant  
 Hannah Berry – Remediation Director  
 Serhii Bezv – Principal Environmental Scientist  
 Daniel Borland – Hydrogeologist  
 Kate Carr – Environmental Advisor  
 Hei Lam Cheung – Senior Air Quality Consultant  
 Christopher Clarke – Managing Director  
 Zoe Cullerne – Geo-environmental Consultant  
 Philippa Douglas – Principal Air Quality Scientist  
 Bethany Elliott – Senior Geo-environmental Consultant  
 Lucy Foster – Ecologist  
 Sonia Garcia – Environmental & Sustainability Lead Engineer  
 Rohan Gardner – Environmental Consultant  
 Holly Grant – Geo-environmental Engineer  
 Louise Grimes – Senior Air Quality Officer  
 Usman Gul – Environmental Specialist  
 James Hallier – Principal Geo-environmental Engineer  
 Tabitha Kennedy – Senior Consultant  
 Heather King – Assistant Environmental Consultant  
 Julian Mann – Principal Air Quality Scientist  
 Jamie McCready – Freshwater Ecologist  
 Kirsty McDougall – Environmental Specialist  
 Stephen McKeown – Environmental Planning Officer  
 Diana McLaren – Senior Marine Environmental Chemist  
 Poppy Meighen – Remediation Manager

Runyararo Munondo – Global Climate Change & Livelihoods Advisor  
 Mustafa Nasr – Environmental & Sustainability Consultant  
 Luis Novo – Head of Phytotechnologies Centre & Senior Researcher  
 Qudus Olatunde – Quality Assurance & Quality Technician  
 Isabel O'Mahoney – Senior Environmental Consultant  
 Sam Perkins – Principal Environmental Consultant  
 Vernon Phoenix – Professor  
 Emily Portergill – Senior Consultant  
 Stephen Potter – Senior Nuclear Regulator  
 Kazeem Rabiu – Support Assistant  
 Benjamin Raine – Associate Director  
 Brandon Reilly – Land Quality Advisor  
 Kerry Riley – Environmental Consultant  
 Rebecca Rose – Principal Consultant  
 David Smedley – Head of Soil & Peatland Science  
 Matthew Smith – Associate Environmental Consultant  
 Alana Smith – Network Decarbonisation Manager  
 Christopher Sneddon – Assistant Environmental Manager  
 Carolyn Southam – Associate Director  
 Jessica Storey – Senior Geo-environmental Consultant  
 Damien Teague – Environmental Consultant – Level 3  
 Lowri Thomas – Senior Ecologist  
 Jay Timmins – Environmental Engineer  
 Mark Troughton – Environment Manager  
 Ghassan Ul Haq – Environment & Sustainability Specialist  
 Zixu Wang – Environmental Specialist  
 David Wilkinson – Senior Consultant – EIA & Consenting  
 Olga Zemlyanova – Environmentalist  
 Muhammad Zeshan – Project Management Engineer

Josephine Ambrose – Junior Air Quality Consultant  
 Isabel Anderson – Graduate Environmental Consultant  
 Troy Aston-Wright – Junior Environmental Specialist  
 Hazel Bamford – Graduate Wastewater Modeller  
 Lucas Bennett – Assistant Environmental Consultant  
 Richard Boafa – Environmental Coordinator  
 Helen Brown – Life Cycle Assessment Consultant  
 Rowan Browning – Graduate Environmental Engineer  
 Isabelle Carter – Scientific Officer  
 Richard Cheshire – Graduate  
 Ben Collier – Assistant Air Quality Consultant  
 Roberta Contegreco – Project Manager  
 Samuel Diver – Land Quality Scientist  
 James Fish – Graduate  
 Olivia Francis – Geo-environmental Engineer  
 Isobel Gillyon – Environmental Due Diligence Consultant  
 Sophie Girling – Graduate Environmental Due Diligence Consultant  
 Tanmay Gojamgunde – Air Quality & Climate Consultant & Environmental Consultant  
 Katherine Gray – Air Quality Consultant  
 Leslie Hackett – Head of Volunteering  
 Megan Hall – Air Quality Consultant  
 Olive Harper – Graduate Air Quality Consultant  
 Laura Hewlett – Graduate Air Quality Consultant  
 Lemuel Hobbs – Environmental Consultant  
 Morgan Howcutt – Project Engineer  
 Daniel Howlett – Senior Consultant  
 Justin Jones – Technical Officer  
 Charlotte Jones – Graduate Air Quality Consultant  
 Abdulmajid Kawaf – Environmental Program Manager  
 Viktoria Larsson – Geo-environmental Consultant  
 Thomas Leonard – Environmental Consultant  
 Sarah Marsden – Graduate Air Quality Consultant

Dearbhla McMenamin – Graduate  
 Zachary Megeath – Graduate Geo-environmental Consultant  
 Charlotte Ness – Graduate Sustainability Consultant  
 Gbolahan Okusanya – Graduate Environmental Consultant  
 Amaka Onwuasoanya – Product Manager – Industrial Process & Environmental  
 Kirsty Page – Graduate Environmental Due Diligence Consultant  
 Reece Patel – Graduate Air Quality Consultant  
 Donia Petrovich – Graduate  
 Molly Phillips – Ecologist  
 Camden Polzin – Graduate  
 Jessica Powell – Graduate Environmental Engineer  
 Sam Putman – Assistant Consultant  
 Jack Race – Graduate Air Quality Consultant  
 Finlay Ratcliffe – Air Quality Consultant  
 Freddy Renvoize – Senior Geo-environmental Consultant  
 Cameron Restarick – Assistant Warden  
 Karen Reynolds – Graduate Environmental Scientist  
 Anthony Rogers – Graduate Environmental Consultant  
 Peter Sawford – Environmental Manager  
 Natalie Schreiber – Environmental/Contaminated Land Consultant  
 Max Shaw – Graduate Environmental Scientist  
 Nina Sidhu – Assistant Consultant  
 Jacob Southey – Geochemist  
 Jack Speer – Site/Geo-environmental Engineer  
 Catherine Street – Geo-environmental Consultant  
 Niamh Tait – Senior Environmental Consultant  
 Matthew Thompson – Environmental Specialist  
 Charles Willis – Graduate  
 Joseph Woodfield – Environmental Protection Officer  
 Leon Youngs – Geospatial Information Analyst  
 Chuwei Zhang – PhD Graduate



**AFFILIATE**

Suzanne Bartington – Clinical Associate Professor in Environmental Health  
 Fiona Bassett – Career Change  
 Carys Butler – Student  
 Oain Campbell – Senior Construction Manager  
 Simone Cumberbatch – Permitting Officer  
 Angus Donaldson – MSc Student  
 Nat Easton – Specialist Policy Officer  
 Christian Flavell – Planning Advisor  
 Storm Foldvik – Student  
 Alastair Forbes – Environmental Project Manager  
 Xavier Gardner – Student  
 Maeve Gilmartin Gilmartin – Health & Safety Administrator  
 Tahir Hafiz – Systems Administrator  
 Adam Hartley – PhD Candidate  
 Christopher Hicks – Career Change

Paul Lynch – Career Break  
 Amelie Macafarlane – Student  
 Finley Macfarlane – Student  
 Mirjana Markovic – PhD Candidate  
 Thomas Payne – Book-keeper  
 Nayanika Phukan – Graduate  
 Katherine Roberts – Career Break  
 Saadoun Salimi – PhD Candidate  
 Jason Simmons – Director  
 James Smithers – Environmental Specialist – Air Quality & Emissions Monitoring  
 Leanne Stone – Ecology Operations Manager  
 Anne Tuomisto – Head Gardener  
 Harry Venners – Student  
 Toby Wilson – Environmental Degree Apprentice  
 George Witts – Apprentice Air Quality Consultant



The CSci designation demonstrates a high level of competence and professionalism in science: being a Chartered Scientist allows all scientists working at the full professional level to be recognised on an equal footing.

James Adley – Senior Environmental Engineer  
 Daniel Borland – Hydrogeologist  
 Danielle Lewis – Principal Consultant  
 Leanne Matthews – Senior Geo-environmental Consultant

Gary McClean – Senior Geo-environmental Consultant  
 Xavier Sanchez-Roemmele – Built Environment Director  
 Hannah Taylor – Senior Environmental Scientist  
 Amy Timms – Associate Director – Geo-environmental  
 Geraint Williams – Associate Technical Director



The CEnv qualification denotes sound knowledge, proven experience and a profound commitment to sustainable best practice within their particular profession and field of expertise. within environmental science.

Lee Faulkner – Associate Director – Acoustics  
 Jemma-Anne Lonsdale – Principal Consultant  
 Simeon Onoja – Senior Associate

Jyoti Prabha – Environmental Service Lead  
 Ashley Proctor – Senior Environmental Consultant  
 Benjamin Raine – Associate Director



**ASSOCIATE**



© pjaruwan | Adobe Stock

# Microorganism-based composites and the future of regenerative construction

**Juliana Calabria-Holley and Kevin Paine** envision a better future built on the natural properties of bacteria and fungi.

The construction sector is facing unprecedented pressure to change. Global material consumption has tripled over the last 50 years, and if current trends continue, annual extraction could reach 160 billion tonnes in the coming decades.<sup>1,2</sup> This surge in material use carries profound environmental consequences. Resource extraction and processing are responsible for more than half of global greenhouse gas emissions, placing materials at the centre of both decarbonisation and climate mitigation efforts.<sup>3</sup> At the same time,

the total mass of human-made materials now exceeds all living biomass on Earth, a striking illustration of how profoundly human activity has reshaped natural systems.<sup>4</sup>

These pressures are compounded by escalating climate impacts. As a result, climate adaptation is now just as critical as climate mitigation. Future materials for the built environment, from infrastructure to housing, must not only reduce embodied carbon but also maintain performance under more extreme and unpredictable environmental conditions. This dual imperative is increasingly shaping research priorities across engineering and architecture: there is now a need to move beyond adaptation and towards regenerative approaches that actively create net positive outcomes through their interaction with the environment.

With the global population projected to reach 9.8 billion by 2050, demand for new housing and infrastructure will continue to rise.<sup>5</sup> Meeting this need through conventional, resource-intensive materials would place unsustainable strain on ecosystems and carbon budgets. In this context, bio-based materials are gaining attention as part of a wider shift towards more sustainable and regenerative approaches to construction. Among emerging approaches, microorganism-based composites are attracting particular interest, with the two most promising being bacteria – used to heal cracks in concrete and to potentially form new cementitious materials – and mycelium – used to grow lightweight, low-carbon composites from agricultural by-products. Together, they highlight the potential and the challenges of embedding biological processes into a construction sector that must rapidly decarbonise and adapt to a changing climate.

#### BACTERIA: THE PRESENT SITUATION

Bacterial activity is evident throughout our landscape. Many familiar geological features, including stalactites, stalagmites and stromatolites, are formed through the ability of bacteria to precipitate minerals. These natural processes can be used in a range of biotechnological applications. Within construction, the most advanced of these is the use of bacteria in self-healing concrete.

Concrete is the backbone of infrastructure worldwide, but it has an inherent flaw in that it is weak in tension and cracks. Cracks allow water, oxygen and salts to enter, which accelerates deterioration long before a structure reaches the end of its intended life. In the UK, around 40 per cent of construction spending is on repair and maintenance, much of it concrete-based.<sup>6</sup> These repairs cause disruption and are therefore often

carried out once damage is already extensive. Self-healing concrete provides a biomimetic approach that addresses deterioration at a much earlier stage.

This self-healing behaviour relies on a natural biochemical process: microbially induced calcite precipitation. Dormant bacterial spores are embedded into the concrete, typically inside small capsules, and remain inactive until a crack allows moisture and oxygen to reach them. Once activated, the bacteria use nutrients that were also added during mixing (either directly or in capsules) to produce calcium carbonate, which seals the crack (see **Figure 1**). Research is showing a number of metabolic routes to the formation of calcite and this is broadening the range of useful species.

Substantial progress has been made in developing this technology. Through research and development around 130 calcite-precipitating bacterial strains have been identified that survive and function under a wide range of conditions, including low temperatures, saline environments, intermittent wetting and even in wastewater.<sup>7</sup> Advances in encapsulation have helped spores remain viable during mixing and curing, and improvements in nutrient delivery and carrier materials have supported more consistent healing.

#### BACTERIA: THE FUTURE OUTLOOK

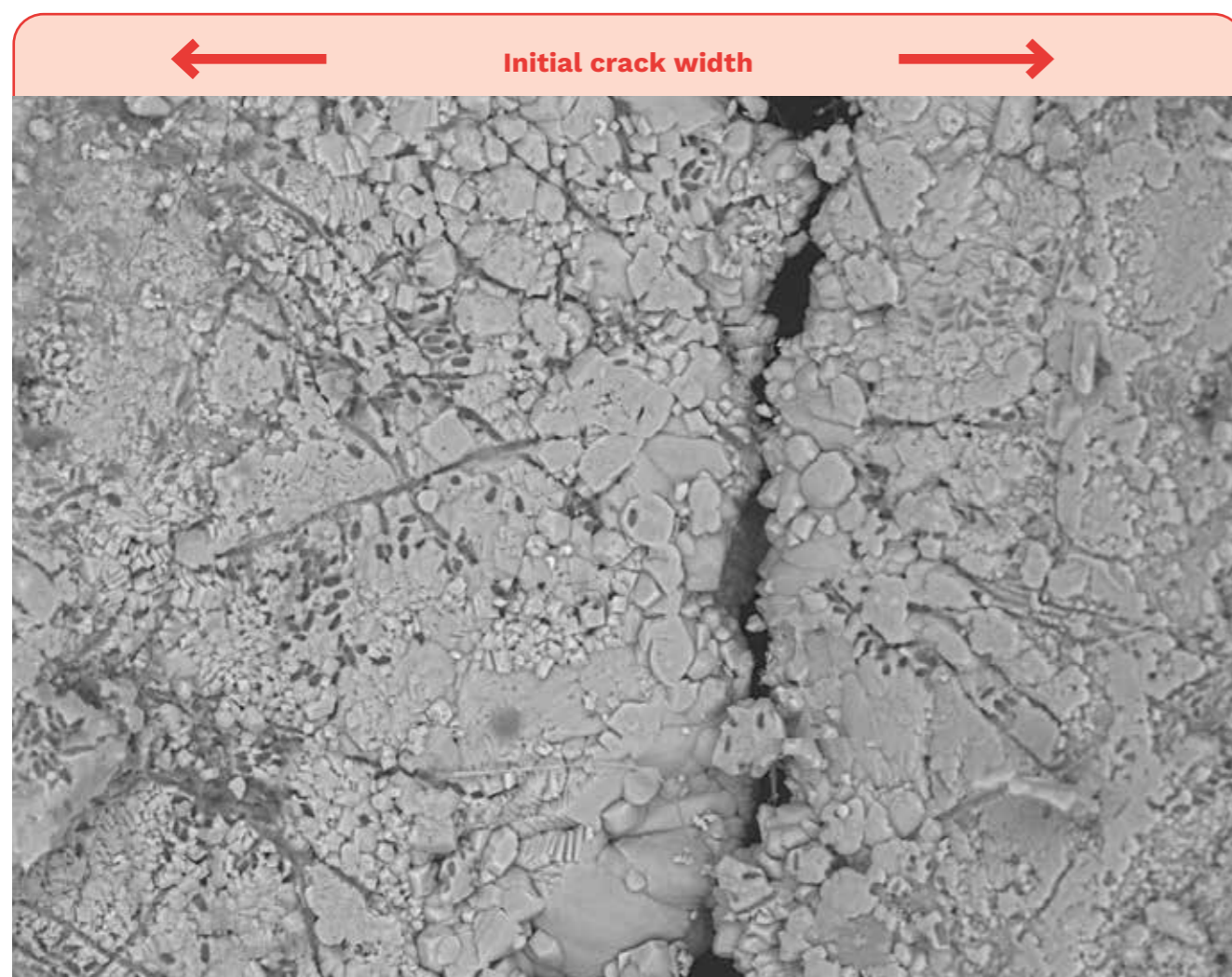
With these foundations in place, attention is turning to how this technology can be expanded. The future of bacteria in construction materials is promising, given the positive early results and emerging solution providers, and it is increasingly feasible that self-healing concrete can become a routine design option. However, further progress will depend on a deeper understanding of the mechanisms behind calcite formation. Although some bacteria appear to mineralise for structural support, ion control or habitat formation, the underlying biological purpose is still not fully understood. This matters because these motivations may influence how reliably bacteria produce calcium carbonate under different conditions.

Bacterial mineralisation has already been applied beyond crack repair. For example, microbial processes have been used to stabilise soils by binding loose particles with calcium carbonate, increasing strength and reducing permeability. This shows that bacterial activity can create cohesive, load-bearing materials and provides a

useful reference point for future developments in cementitious materials.

Building on this, there is potential to use these biological processes to form materials by binding together sand and stones to create bio-composites. Proof-of-concept studies have shown that bacteria can be used to form blocks, although strengths remain limited at present (see **Figure 2**). Notably, the wider range of bacteria now available that has resulted from developments in self-healing concrete may open opportunities for more controlled and lower-impact forms of bio-cementation. The main challenge remains encouraging bacteria to precipitate enough calcium carbonate to bind sand or aggregates into reliable structural materials.

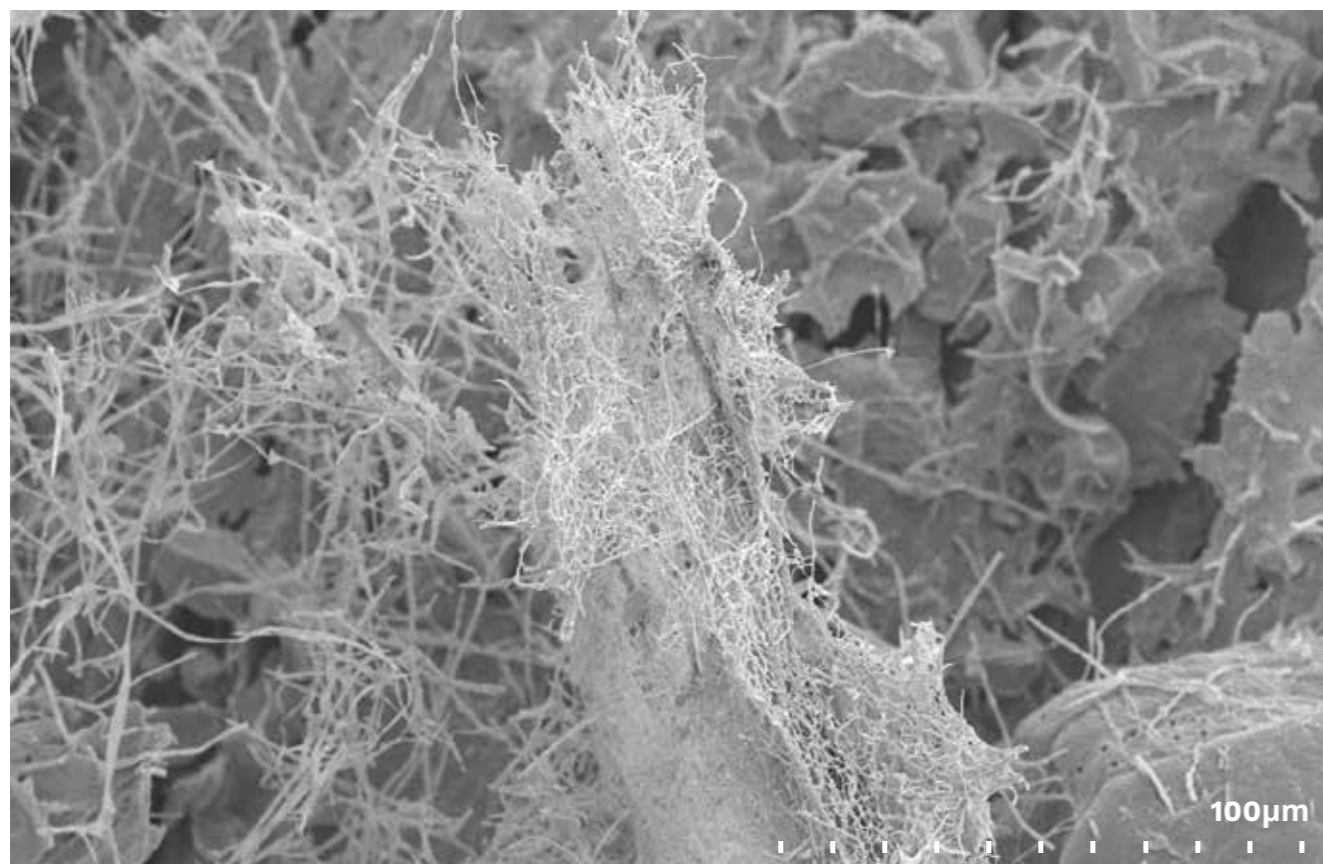
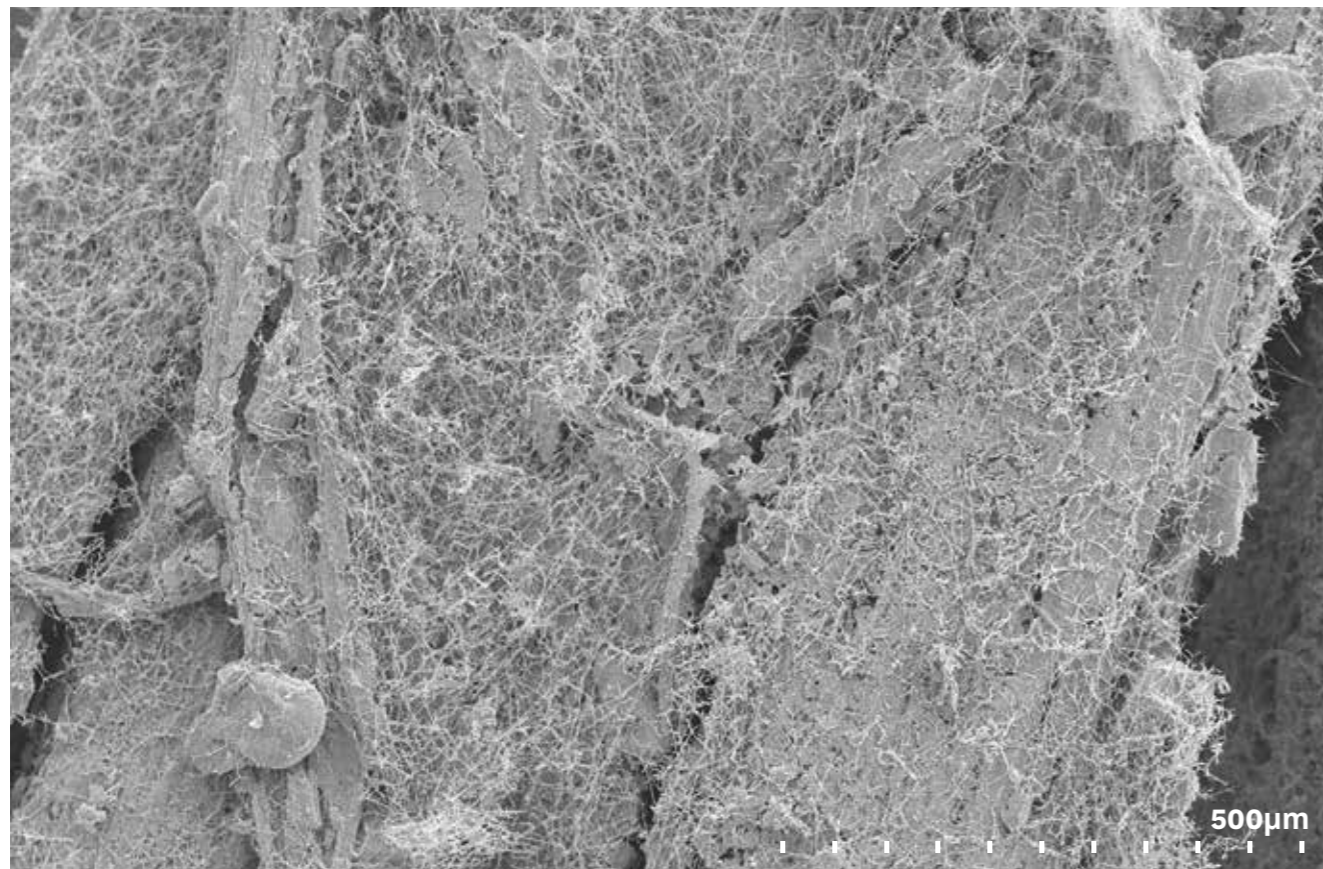
Realising this potential will require deeper insight into how bacteria interact with mineral surfaces and how these interactions influence material performance. At the University of Bath, for example, researchers are using a microfluidic chip (a small device that enables precise control and imaging of microscopic fluid flows) to observe calcite formation at an individual particle scale. This allows direct study of how bacteria and calcium carbonate



▲ **Figure 1. Closure of a crack in concrete by the action of bacteria. The footprints of the bacteria in the microbially induced calcite are clearly visible as small dark spots. (© Dr Lorena Skevi)**



▲ **Figure 2. A sand column bound by microbially induced calcite. (© Dr Ismael Justo-Reinoso)**



▲ **Figure 3. Micrographs of mycelium hyphae growing on top of a lignocellulosic substrate.**  
(© Dr Jamie Wilson)

grow and behave in confined spaces. Although this work is at an early stage, it highlights how advances in fundamental understanding may support the development of new, sustainable and regenerative construction materials.

#### MYCELIUM: THE PRESENT SITUATION

Mycelium, the filamentous, root-like network of fungi, has become a powerful symbol of new material futures (see **Figure 3**). By binding lignocellulosic particles into lightweight, porous composites through biological growth, mycelium offers a low-energy, low-carbon alternative for non-structural building components. Its value arises from the convergence of three key features: it is cultivated rather than extracted, it valorises low-value agricultural residues, and it is biodegradable at the end of a structure's or building's life.

The fabrication process departs fundamentally from mineral or petrochemical material production. Substrates such as hemp hurds, sawdust or rice hulls are first sterilised, then inoculated and allowed to grow into a cohesive form. Growth is subsequently halted through heat or drying to stabilise the composite. Mycelium-based materials, therefore, exemplify a process-driven materiality in which performance arises from cultivation practices rather than high-energy industrial transformation.

However, enthusiasm for mycelium can outpace the evidence. Experimental explorations – for example, integrating bacteria to enhance sensing or biochemical functions – highlight the biological adaptability of fungal systems, but these remain largely conceptual and distant from market integration.<sup>9</sup> In commercial applications, the biological component is typically deactivated to ensure reliability and to satisfy regulatory requirements. As a result, the notion of living materials is more often a provocative metaphor than a practical reality.

Crucially, mycelium is not inherently regenerative. Its contribution to regenerative design depends on the broader systems and production conditions in which it operates. If growth chambers are powered by fossil-based electricity, if agricultural substrates are sourced unsustainably or if composites ultimately enter linear waste streams, the regenerative promise devolves into familiar patterns of merely incremental improvement.

#### MYCELIUM: THE FUTURE OUTLOOK

Scaling mycelium-based composites remains one of the most pressing challenges. The biological growth process takes two to four weeks, and successful colonisation is highly sensitive to humidity, temperature, sterility and strain vitality. Scaling beyond small components introduces further complications – notably, the formation of a dense fungal skin at the air–substrate interface that restricts internal growth. Large-scale production, therefore, requires continuous monitoring, likely supported by automation, sensors and environmental control systems driven by artificial intelligence that are reminiscent of vertical farming.

These demands introduce significant practical constraints. Production requires substantial floor area or vertical stacking systems, and maintaining sterility at an industrial scale is both labour-intensive and costly. Emerging methods such as 3D printing offer geometric flexibility but are limited by slow fabrication times and nozzle clogging at finer resolutions.<sup>9</sup> The tension between biodegradability and durability further narrows potential uses: mycelium–cellulose composites perform well as interior insulation or acoustic panelling because of their porous nature; however, this same porosity makes them susceptible to water ingress. They are typically produced using cellulosic waste as a nutrient source, and the remaining cellulosic components contribute to the material's structural integrity. Therefore, mycelium–cellulose composites do not yet meet the performance requirements for load-bearing structural applications or for long-term exterior exposure.

Life-cycle assessments reveal further complexities. While mycelium outperforms petrochemical foams on climate metrics, its environmental profile is uneven. Some indicators, such as terrestrial ecotoxicity and water consumption, perform less favourably. Energy use during growth and drying consistently emerges as the dominant impact driver. This demonstrates that the regenerative potential of mycelium is highly contingent on the energy systems and circular protocols that govern its production and end-of-life pathways.

Yet it is precisely within these dependencies that the most compelling opportunities lie. Mycelium materials prompt a rethinking of how materials, energy and waste are conceptualised.



▲ Concrete with bacteria-healed cracks. © photosvideos | Adobe Stock

If grown using renewable energy, fed on regionally available agricultural residues and reintegrated into ecological cycles after use, mycelium composites could exemplify a restorative materials practice. Their very biodegradability, often perceived as a disadvantage, could become an asset in systems designed to metabolise materials rather than accumulate waste.

Nanotechnology is a powerful ally in overcoming property shortcomings and promoting multi-functionality. Research at the University of Bath has demonstrated that mycelium-based composites enhanced with sol-gel technology can significantly improve their durability. This method allows for the targeted engineering of materials at the nanoscale, addressing moisture absorption issues. The sol-gel coating forms a hydrophobic barrier that boosts water resistance, reducing maximum water uptake by 45 per cent.

This treatment enhances hygroscopic behaviour, increasing durability and stability, thereby reinforcing mycelium-cellulose composites as a promising low-carbon building material.<sup>10</sup>

Realising this vision will require more than technical refinement. It calls for coordinated regulatory support, harmonised certification frameworks and a construction ecosystem culture willing to redesign material flows around biological timescales. Regenerative attributes are not only about materials that degrade benignly, but also about integrating these materials through an approach that envisions a net positive outcome for people, planet and nature.<sup>11</sup>

#### CONCLUSION

Microorganism-based composites occupy an increasingly important place in discussions on sustainable and regenerative construction.

Whether through the ability of bacteria to heal or bind mineral materials, or the capacity of mycelium to grow lightweight, low-impact composites, these systems offer credible pathways to reducing energy use, valorising waste streams and shifting away from extractive material practices. They also introduce new ways of thinking about materials, in which performance arises from biological activity rather than high-temperature processing or large-scale extraction.

However, the regenerative potential of microorganism-based materials will only be realised when they are supported by wider systems that prioritise ecological restoration, renewable energy and circular resource flows. Their contribution depends on how they are cultivated, regulated and integrated into design practice. While microorganisms cannot regenerate the built environment alone, they can act as catalysts for regenerative engineering, helping to reshape material practices and support greater resilience in a changing climate. **ES**

**Dr Juliana Calabria-Holley**, a materials scientist, architect and Senior Lecturer at the University of Bath, co-directs the RENEW Centre, leading interdisciplinary research on nanotechnology and sustainable and regenerative materials engineering to address climate change challenges. Her work specialises in low-carbon advanced construction materials, including bio-based insulation (such as mycelium), carbon-capture composites, masonry and concrete technologies.

**Professor Kevin Paine** is Director of the Centre for Climate Adaptation and Environment Research, University of Bath. His work focuses on innovative and regenerative concrete technologies including bacteria-based self-healing, self-sensing concretes, and low-carbon materials. He has led major UK and EU projects on resilient infrastructure and advanced cementitious systems.

#### REFERENCES

1. Circle Economy (2019) *The Circularity Gap Report 2019*. <https://www.circularity-gap.world/2019> (Accessed: 11 March 2026).
2. Chen, L., Zhang, Y., Chen, Z., et al. (2024) Biomaterials technology and policies in the building sector: a review. *Environmental Chemistry Letters*, 22, pp. 715–750. <https://doi.org/10.1007/s10311-023-01689-w> (Accessed: 14 March 2026).
3. Watts, J. (2019) Resource extraction responsible for half world's carbon emissions, *The Guardian*, 12 March. <https://www.theguardian.com/environment/2019/mar/12/resource-extraction-carbon-emissions-biodiversity-loss> (Accessed: 11 March 2026).
4. Elhacham, E., Ben-Uri, L., Grozovski, J. et al. (2020) Global human-made mass exceeds all living biomass. *Nature*, 588, pp. 442–444. DOI: [doi.org/10.1038/s41586-020-3010-5](https://doi.org/10.1038/s41586-020-3010-5).
5. United Nations Department of Economic and Social Affairs (no date) *World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100*. <https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100> (Accessed: 11 March 2026).
6. The Institute of Chartered Accountants in England and Wales (2026) *Construction in the UK: industry profile*. <https://www.icaew.com/library/industry-profiles/construction> (Accessed: 16 March 2026).
7. Reeksting, B.J., Hoffmann, T.D., Tan, L. et al. (2020) In-depth profiling of calcite precipitation by environmental bacteria reveals fundamental mechanistic differences with relevance to application. *Applied and Environmental Microbiology*, 86 (article: e02739-19). <https://doi.org/10.1128/AEM.02739-19> (Accessed: 16 March 2026).
8. Sandak, A. (2023) Engineered living materials for sustainable and resilient architecture. *Nature Reviews Materials*, 8, pp. 357–359. <https://doi.org/10.1038/s41578-023-00554-0> (Accessed: 14 March 2026).
9. Le Ferrand, H. (2024) Critical review of mycelium-bound product development to identify barriers to entry and paths to overcome them. *Journal of Cleaner Production*, 450 (article: 141859). <https://doi.org/10.1016/j.jclepro.2024.141859> (Accessed: 11 March 2026).
10. Wilson, J. and Calabria-Holley, J. (2025) 'Enhancement of the hygroscopic properties of mycelium-cellulose composites via the application of silica sol-gel technology' in S. Amziane, R.D. Toledo Filho, M.Y.R. da Gloria and J. Page (eds) *Bio-based building materials – Proceedings of ICBBM 2025 Volume I*, pp. 432–444.
11. Centre for Regenerative Design and Engineering (2025) *RENEW: A Manifesto for Regenerative Design and Engineering*. University of Bath. <https://www.bath.ac.uk/publications/centre-for-regenerative-design-engineering-for-a-net-positive-world-renew-manifesto/attachments/regenerative-design-engineering-for-a-net-positive-world-centre-manifesto-2025.pdf> (Accessed: 11 March 2026).

# Building resilience and sustainability into UK housing markets and infrastructure

**Samer Bagaen** outlines why early and coordinated planning and delivery are key to success.

The UK is at a critical juncture in its approach to housing and infrastructure. The twin challenges of an acute housing shortage and ageing, inflexible infrastructure systems have been exacerbated by rising costs, energy insecurity and climate pressures. To address these challenges, it is imperative that resilience and sustainability are integrated into both housing developments and broader infrastructure delivery. Resilience ensures that communities and systems can withstand shocks – economic, environmental, social and geopolitical – while sustainability focuses on minimising long-term environmental impact, enhancing quality of life and fostering inclusive growth.

Achieving these goals requires a holistic, systems-driven and coordinated approach that spans policy, finance, planning and governance. For example, without mechanisms for households to secure mortgages, the impact of building 1.5 million homes will be somewhat muted.



### CHALLENGES IN HOUSING AND INFRASTRUCTURE

The housing market illustrates the need for systemic change. House prices in the UK have escalated dramatically over the past generation, placing homeownership increasingly out of reach for first-time buyers. At the same time, rental costs have risen sharply, amplifying social inequality and putting pressure on families and younger generations. These affordability pressures are compounded by a mismatch between supply and demand.

Savills reports that UK house price growth slowed in 2025 but remained positive, with an annual growth of around 2.5 per cent and strong regional differences between the north and south of England.<sup>1</sup> Recent analysis highlights that younger households are far less likely to own their homes than previous generations, with home ownership among young adults falling sharply since the early 1990s.<sup>2</sup> Rising rents and a shortage

of affordable housing have also contributed to increasing housing insecurity, with the number of people in temporary accommodation continuing to rise. While some progress has been made on the supply side, demand-side challenges remain acute, particularly in major urban centres such as London, where high prices and limited stock exacerbate social and economic pressures. Alternatively, a house price deflation would be damaging to the economy.

Infrastructure delivery faces parallel difficulties. The UK's energy system, for example, remains highly reliant on imported fossil fuels, revealing vulnerability to geopolitical shocks and market fluctuations – as we are currently witnessing in the wake of the ongoing war in the Middle East. Transport projects, including high-speed rail and regional connectivity initiatives, often struggle due to lengthy planning processes, funding constraints and local opposition. These delays

not only impede economic growth but also hinder the delivery of climate-resilient infrastructure.

A critical underlying barrier across both housing and infrastructure is uncertainty. This is manifest in several forms: national priorities, infrastructure sequencing, environmental mitigation requirements and political support over a project's lifetime. When promoters, investors, local authorities and communities are unclear about long-term strategic direction, every major scheme is contested. This uncertainty slows investment, delays construction, and increases legal and financial risks. Reducing uncertainty through a clearer spatial strategy, consistent policy and stable political commitment is fundamental to unlocking delivery and improving system resilience. This is where top-down and bottom-up emerging approaches to national and strategic spatial planning in England might be helpful.

### EMBEDDING RESILIENCE

Resilience in housing and infrastructure requires both physical and systemic vulnerabilities to be addressed. Physically, homes and infrastructure must be designed to withstand climate impacts such as flooding, heatwaves and severe storms. Strategically, resilience also demands flexible governance systems capable of adapting to changing market conditions, demographic pressures and technological developments.

One approach to enhancing resilience is to establish development corporations for strategic, long-term projects, such as the newly proposed new towns in England. These bodies can coordinate land acquisition, infrastructure investment and community planning over decades, ensuring that ambitious projects are delivered efficiently and sustainably. In cases like Cambridgeshire and certain new settlement initiatives such as Beaulieu Park, development



▲ Temple Works and the South Bank in Leeds, an area chosen for redevelopment by the New Towns Taskforce. © ImageryBT | Adobe Stock | Editorial Use Only

corporations, innovative partnerships and new delivery models have provided funding and governance certainty, mitigating local disputes and delays. This should offer lessons for future new towns.

For instance, Waterbeach, a new town under construction near Cambridge, is being developed by Urban&Civic on the former Waterbeach Barracks site.<sup>3</sup> It is planned as a new town of around 6,500 homes alongside schools, employment areas, a town centre and plenty of green space. What distinguishes it is its long-term, infrastructure-first master planning approach. The project places strong emphasis on early delivery of transport links (including a relocated railway station), extensive landscape and biodiversity planning, employment space, and a clear town centre and civic heart. Urban&Civic's model is to act as a master developer, delivering infrastructure and design frameworks before individual housebuilders build homes. This often produces a more coherent place over time.

#### SUSTAINABILITY IN DELIVERING NEW HOUSES

Sustainable strategic planning for delivery of housing sites entails careful integration with nature. Developments should protect and enhance natural habitats, maintain green spaces, and incorporate nature-based solutions for flood mitigation and urban cooling. Coordination between environmental regulators, developers and local communities ensures that growth does not come at the expense of ecological resilience.

On the supply side, planning reforms, streamlined approvals, and incentives for medium- and small-scale developments, as well as support for small and medium-sized housebuilders, can enhance delivery while maintaining quality and environmental standards. Some researchers have explored how, under certain conditions and collaboration strategies, increased government regulation raises the likelihood that central banks will also adjust interest rates, the property developer will be more likely to engage in compliant green housing developments and residents will be more likely to choose to buy sustainable housing.<sup>4</sup>



From a planning perspective, resolving the 'where and why' questions for major energy, transport and water corridors up front and aligning them with housing and environmental priorities would shorten planning time, reduce legal risk and strengthen investor confidence. When strategic questions are settled at an earlier stage, the system functions as a delivery mechanism rather than a battleground. Beyond environmental measures, sustainability involves social and economic dimensions. Housing must meet people's diverse needs – from first-time buyers to downsizers – while considering affordability, accessibility and long-term quality of life.

Policies such as stamp duty relief for downsizing, or targeted financial incentives can unlock existing housing stock, improve system efficiency and reduce pressure on new construction. This needs leadership from the Treasury in partnership with other government departments. Similarly, sustainable infrastructure investment requires long-term financing certainty, workforce planning (skills for the future) and alignment with broader economic objectives.

#### POLICY AND MARKET SOLUTIONS

Effective integration of resilience and sustainability relies on a combination of public policy and market mechanisms. Demand-side interventions, such as targeted subsidies, tax incentives and mortgage support, can smooth market cycles and ensure consistent uptake of new homes.

The private sector plays a central role, but it responds to market signals rather than societal needs. Housebuilders, registered housing providers and industrial developers often prioritise projects with predictable returns, leaving gaps in affordable housing and socially necessary infrastructure. Public intervention – whether through council-led building, public-private partnerships or development corporations – is necessary to ensure resilience and sustainability objectives are met. Incentives, clear regulatory frameworks and long-term investment commitments align private sector activity with national goals.

Crucially, securing public support for major projects depends on tangible benefits for local communities. Introducing mandatory, up-front community benefit and infrastructure gain agreements that are negotiated early, are transparent and legally binding ensures that

communities receive clear, funded improvements related to transport, skills, green space, energy discounts and revenue sharing. When the public perceives real benefits, opposition diminishes, trust grows, and planning and funding are unlocked far more effectively than through procedural reforms alone.

Skills shortages also present a systemic risk. Long-term infrastructure and housing projects require a workforce equipped with expertise in construction, planning, building, energy systems and climate adaptation. Coordinated training programmes, immigration policies that support skilled labour, and investment in apprenticeships are essential to maintaining a resilient construction and development sector.

Development corporations have enabled coordinated planning and infrastructure delivery, yet local governance, public consultation and inter-authority cooperation remain complex. Smaller-scale projects beyond headline developments often struggle due to fragmented decision-making, limited resources and procedural delays. Lessons learnt from these cases underscores the importance of balancing ambition with practicality, ensuring that both major and minor projects contribute to overall system resilience.

New towns and regional expansions illustrate the value of long-term strategic planning. In 2025, the UK Government published the New Towns Taskforce Final Report, setting out a nationwide blueprint for growth and calling for a new generation of towns that will provide up to 300,000 homes, create thousands of construction jobs and anchor long-term economic regeneration across England.<sup>5</sup> Led by Sir Michael Lyons and commissioned in 2024, the taskforce concluded that the UK's housing shortage has become a national productivity challenge, warning that chronic undersupply is limiting labour mobility, increasing regional inequality and threatening the country's ability to sustain economic growth.

By coordinating planning and delivery of land use, transport and housing over decades, these new towns can embed sustainability from the outset. At the same time, they can demonstrate the need for inclusive governance structures that maintain local accountability, foster community engagement and provide clear pathways for public and private investment.



© Boys in Bristol | Adobe Stock

## CONCLUSION AND RECOMMENDATIONS

Building resilience and sustainability into UK housing and infrastructure requires a systemic, holistic approach. Policy, planning, financing and governance must be coordinated to ensure that both headline and smaller-scale projects progress efficiently, equitably and sustainably. Guidance aimed at the wider housebuilding industry and professions can include the following:

- 1. Reduce uncertainty:** Clear spatial strategies, consistent policy and stable political commitment are essential to unlocking major projects.
- 2. Long-term governance structures:** Development corporations and strategic planning bodies should coordinate major projects while preserving local authority input and community engagement.
- 3. Integrated sustainability standards:** Homes and infrastructure should be designed for low-carbon performance, climate resilience and ecological enhancement.
- 4. Demand- and supply-side policies:** Incentives, tax relief and financial support can smooth market cycles and unlock underused housing stock.
- 5. Community benefit agreements:** Early, transparent, legally binding agreements with communities will ensure public trust and support.
- 6. Sectoral coordination:** Public, private and third-sector participants, including all infrastructure providers, must collaborate across housing, energy, transport and social infrastructure to deliver holistic outcomes.

- 7. Workforce development:** Investment in skills and labour capacity is essential for sustained delivery and adaptation to new technologies.

By adopting a holistic ecosystem approach that resolves strategic questions early, aligns infrastructure with growth and builds community trust, the UK can ensure that housing and infrastructure developments are resilient, sustainable and capable of meeting the needs of future generations. Certainty, clarity and coordinated action are the foundations for long-term success.

ES

**Professor Samer Bagaeen, FRTPI FRICS FICE**, is a Technical Director in Town Planning at Arcadis, Professor and Head of the School of Town Planning at the University of the Built Environment, and Visiting Professor in Urban Resilience at Imperial College London.

## REFERENCES

1. Savills (2025) *UK housing market update*. [https://www.savills.com/research\\_articles/255800/381642-0?utm](https://www.savills.com/research_articles/255800/381642-0?utm) (Accessed: 13 March 2026).
2. Aref-Adib, C. and Stone, I. (no date) *The Resolution Foundation Housing Outlook Q3 2025*. <https://www.resolutionfoundation.org/publications/housing-outlook-q3-2025/> (Accessed: 13 March 2026).
3. Waterbeach (no date) *Our vision*. <https://waterbeachwb.co.uk/our-vision/> (Accessed: 13 March 2026).
4. Li, Q., Qian, T., Hua, Q. et al. (2025) Collaboration and regulation: a dual regulatory game for the sustainable development of green housing. *Research in International Business and Finance*, 74 (article: 102697). <https://doi.org/10.1016/j.ribaf.2024.102697> (Accessed: 13 March 2026).
5. Ministry of Housing, Communities & Local Government (2025) *New Towns Taskforce*. Report to Government. [https://assets.publishing.service.gov.uk/media/68d694b79cb44667f7a1cee7/New\\_Towns\\_Taskforce\\_Final\\_Report.pdf](https://assets.publishing.service.gov.uk/media/68d694b79cb44667f7a1cee7/New_Towns_Taskforce_Final_Report.pdf) (Accessed: 13 March 2026).

# Are water and sanitation systems resilient to climate change?

**Guy Howard** gives an overview of global and UK systems in the context of a changing climate.

It has been well established for some considerable time that water supply and sanitation services will be adversely affected by climate change.<sup>1</sup> Indeed, we have known almost as long as we have had engineered systems that weather events cause infrastructure damage, service interruptions and contamination. The challenges posed by climate change through hazards and events are therefore not new but ones that suppliers have always had to manage. What climate change does bring, however, is a new intensity and frequency of hazards that makes resilience harder to achieve. But what progress is being made globally and in the UK on the vulnerability and resilience of water and sanitation services, and is it happening quickly enough?





© Niks Ads | Adobe Stock

### WATER SUPPLIES

Floods and droughts remain the two principal climate hazards that affect water supplies.<sup>2</sup> Nearly half of the world's population is exposed to severe water scarcity, at least temporarily, because of a mix of climatic and other drivers.<sup>3</sup> Areas in drought have expanded by 74 per cent, affecting 30 per cent of global land area in 2022.<sup>4</sup> For large parts of the world, much more needs to be done to secure water storage through both built and natural infrastructure.

In the UK, resilience to drought is generally being developed.<sup>5</sup> For instance, water companies in England and Wales are required to ensure resilience to a 1-in-500-year drought. Most, but not all, water companies are confident of meeting these targets, although some require

further investment to improve storage capacity. The recent announcements of the construction of new reservoirs across England is evidence of further planning for drought – a UK nation that historically has been particularly more affected than others. Scope for inter-basin transfers – such as between north-east and south-east England – and for expanding desalination – for example, around the east and south coasts of England – as well as ongoing efforts to reduce water losses and to change consumer behaviour, all provide reasonable confidence in the resilience of services.

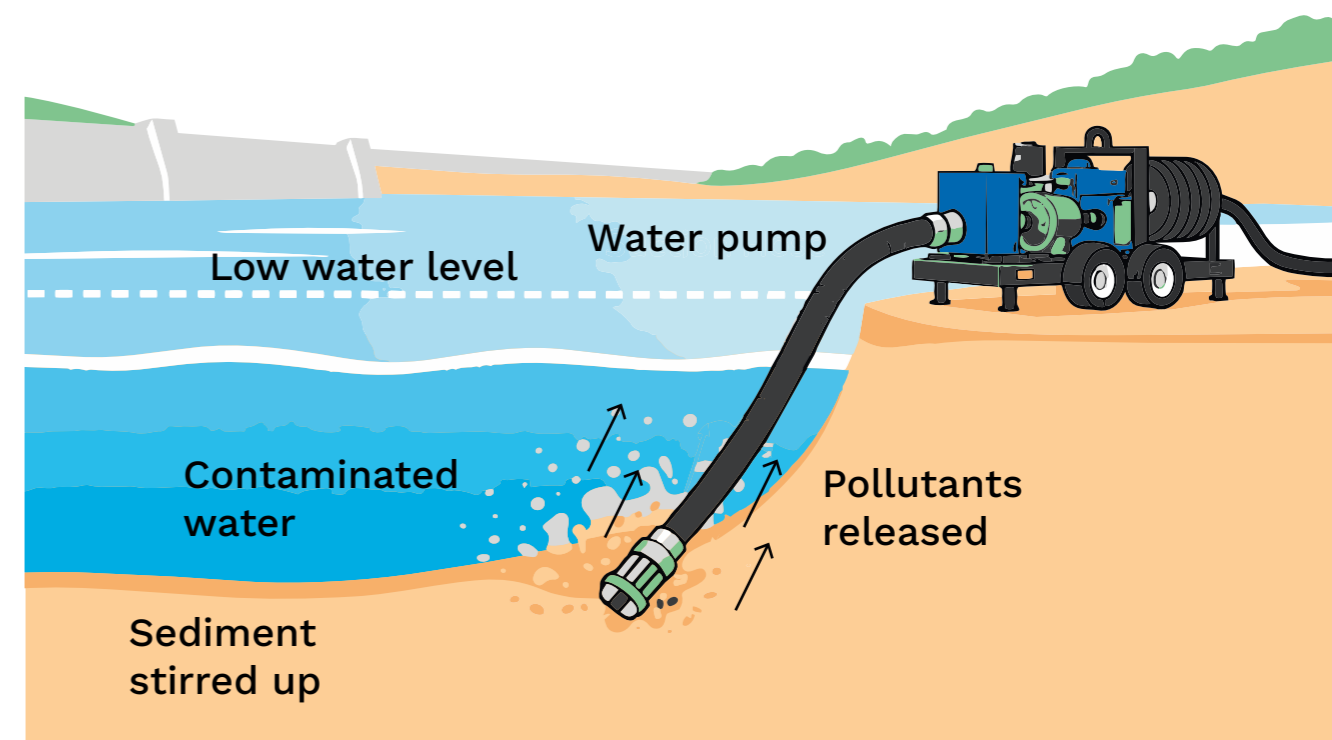
That said, rates of leakage remain higher than in some other European countries, which ultimately reduces resilience. There are also concerns about ageing water storage infrastructure in the UK,

which could ultimately undermine resilience. The sector needs to consider whether an ageing reservoir stock will be able to withstand future threats from climate-induced hazards. It should be noted that the independent review of the Toddbrook incident recommended that the frequency of reservoir inspections be reviewed in light of ageing infrastructure.<sup>6</sup>

Flood impacts on water supplies are generally less well studied, despite flood exposure having increased globally.<sup>7</sup> Much of this exposure is occurring in settlements built in flood-prone areas. It is less clear from the adaptation reports prepared by water companies in advance of the Fourth UK Climate Change Risk Assessment (CCRA4) how well prepared the UK water sector is in relation to protecting critical infrastructure from major floods and windstorms. There is limited detail on how companies have planned to protect extended piped distribution systems from flood damage in the future. Equally important is dealing with the impact of major windstorms and their effect on power and digital services, as noted following Storm Arwen in 2021, during which water supplies for around 2,000 customers in the north of the UK were affected by power outages.<sup>8</sup>

**Water quality.** Linked to floods and droughts are concerns about changing water quality in source waters. Increasing chemical and pathogen loads linked to both are a global problem. A great deal of attention has been paid to the risks of algal blooms, but more commonly in relation to the potential release of toxins rather than on their impact on water treatment works.<sup>9</sup> There are increasing concerns about chemical cocktails that get released into waters during drought periods when reservoir levels are lowered. Pumping that disturbs basal waters or sediments may release pollutants that have been absorbed or concentrated in lower levels of water (see **Figure 1**). There is limited evidence globally on how this issue will be managed. In the UK, it is not clear to what extent these concerns are being addressed and what the implications are for both reservoir management and water treatment.

**Exposure to other climate hazards.** Exposure to some climate hazards is changing. This is perhaps best illustrated by wildfires, which are an increasing challenge in areas not previously at risk; for example, in the UK a definable fire season is starting to emerge. While managing these risks can draw on the extensive experience



▲ **Figure 1. A diagram showing how pumping water from reservoirs with low levels can cause contamination.**

of countries that have been historically exposed to fire risks, such as Australia and the western USA, there are differences in the UK that may require additional adaptation. For example, we know that wildfires in Australia are associated with elevated levels of dissolved organic carbon and this affects source water quality.<sup>10</sup>

The UK has catchments with substantial amounts of peat, and baseline dissolved organic carbon is already high; therefore, wildfires in these catchments may make water increasingly difficult

to treat.<sup>11</sup> This calls for concerted action to manage wildfires in UK catchments. However, in a recent review of water company adaptation reports as part of CCRA4, there was generally very limited consideration of wildfire risks (Severn Trent Water being an exception). While the UK water industry has a good track record of developing new treatment systems as new hazards emerge – and this continues as water companies and researchers explore new forms of disinfection, removal of forever chemicals and use of nano-composites for dissolved organic

carbon removal – it is concerning that more thought has not been given to managing the risk at source.

**Private water supplies.** Globally, billions of people rely on water supplies that they manage themselves in different forms of community-management models.<sup>12</sup> In the UK, up to 3 per cent of the population in Scotland relies on what is known as private water supplies; the total number of users is likely to be substantially higher, as these supplies often serve holiday premises. The evidence to date shows that community-managed water supplies are the least resilient to climate change, and the same is true in the UK.<sup>2,13</sup> The vulnerability comes from myriad factors, but includes limited technical skills, limited finance and inadequate support from local authorities. Certainly, for the UK, this is the type of supply that has consistently been flagged as most challenging in terms of resilience and there remains little evidence of sustained action to improve this.

#### UNDERSTANDING SANITATION

There have been global reviews on the resilience of sanitation in relation to climate change, primarily for urban areas.<sup>14</sup> The findings from these reviews point to the anticipated impact of climate change on sanitation systems, the paucity of findings from low- and middle-income countries and for non-sewered systems, and the lack of city-wide assessments that recognise risks and dependencies on other services.

Across the world, there are issues with extreme rainfall impacting sewer systems and the risks of combined sewer overflows. Furthermore, problems with low flows cause sewer blockages, while increasing groundwater levels and sea-level rise cause corrosion as well as flood and storm damage to sewer infrastructure and ancillary services.<sup>12</sup>

It is no secret that the UK's sewerage network is ageing and already unable to cope with current heavy, but not necessarily extreme, rainfall events. Studies by the Royal Academy of Engineering among other research, lead to the conclusion that sewerage systems in the UK are not resilient to climate change or current climate variability.<sup>15</sup> The reasons for this are well-known: Victorian era infrastructure has been in urgent need of upgrade and replacement for decades, but the investment response has been patchy and generally limited. In England and Wales,

investment plans are made more complicated because of the divestiture of assets during privatisation and the consequent challenges in developing a national infrastructure response from a fragmented commercial landscape.

Globally, more people rely on non-sewered than sewer sanitation.<sup>12</sup> There is relatively limited research into the climate resilience of such systems, but recent studies have identified the vulnerability of on-site sanitation systems to climate hazards, and to floods in particular.<sup>16,17</sup> In the UK, while most people are on sewer systems, a substantial number still use septic tanks. In common with private water supplies, there is a dearth of studies on the resilience of these systems to future climate change. However, studies in North America make clear such systems face many similar problems as those in low- and middle-income countries in relation to flooding vulnerability and to increases in groundwater and sea-level rise that affect performance.<sup>18,19</sup>

#### WHAT CONSTRAINS RESILIENCE?

The limited resilience of water supply and sanitation services arises for a number of reasons. At a global level there are billions of people who have access to only basic or limited water and sanitation services. This backlog in providing a safely managed services has often resulted in little attention being paid to climate change, as it is considered a long-term problem when immediate challenges need to be overcome. Consequently, the water and sanitation services sector lags behind other water sectors in addressing climate adaptation and building resilience. This is reflected in limited budgets, and in operational practices that are largely set up to be reactive when challenges emerge rather than proactively seeking preventive solutions.

Some of these issues relate to policies and regulations that offer few incentives for action and because climate, water, sanitation and hygiene policy-makers do not really talk to each other. Within the UK, the lack of resilience of the water supply and sanitation sector has been repeatedly raised, and this has continued into CCRA4.<sup>20,21</sup> While water companies point to the development of long-term adaptation plans, implementation is often tied to outcomes from the five-year periodic pricing reviews, which means that the necessary long-term investments become more challenging.



▲ Fire burning on a moorland, Wales. © whitcomberd | Adobe Stock



© D Evans | Adobe Stock

## CONCLUSION

Resilience in water and sanitation services both globally and in the UK is challenging. This is partly related to the infrastructure that is in place, but it is as much a systems management problem as it is an engineering one. Weak policies and regulations undermine investment strategies. Sanitation systems are less resilient than water supply systems, with major improvements required. Both water supply and sanitation that rely on community or household management are at greatest risk, and much more needs to be done to improve their resilience. **ES**

**Professor Guy Howard** is an environmental engineer and scientist at the University of Bristol's School of Civil, Aerospace and Design Engineering, and the Cabot Institute for the Environment. He has over 30 years' experience in policy and research into water and sanitation. His work currently focuses on how resilience of water, sanitation and health systems in the UK and in low- and middle-income countries is measured and built.

✉ [guy.howard@bristol.ac.uk](mailto:guy.howard@bristol.ac.uk)

## REFERENCES

- Bates, B.C., Kundzewicz, Z.W., Wu, S. and Palutikof, J.P. (eds) (2008) *Climate Change and Water*. Technical paper VI. Geneva, Switzerland: Intergovernmental Panel on Climate Change. <https://www.ipcc.ch/site/assets/uploads/2018/03/climate-change-water-en.pdf> (Accessed: 5 March 2026).
- Howard, G., Beevers, L., Charles, K. and Nijhawan, A. (2026) The vulnerability and resilience of drinking water systems to extreme weather events and future climate change. *Current Environmental Health Reports*, 13 (article: 5). <https://doi.org/10.1007/s40572-026-00524-y> (Accessed: 5 March 2026).
- Caretta, M.A., Mukherji, A., Arfanuzzaman, M. et al. (2022) 'Water', in H-O. Pörtner, D.C. Roberts, M. Tignor et al. (eds) *Climate change 2022: impacts, adaptation and vulnerability*. Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 551–712. <https://doi.org/10.1017/9781009325844.006> (Accessed: 5 March 2026).
- Gebrechorkos, S.H., Sheffield, J., Vicente-Serrano, S.M. et al. (2025) Warming accelerates global drought severity. *Nature*, 642 (8068), pp. 628–635. DOI:10.1038/S41586-025-09047-2.
- Murgatroyd, A., Gavin, H., Becher, O. et al. (2022) Strategic analysis of the drought resilience of water supply systems. *Philosophical Transactions of the Royal Society A*, 380 (2238), article: 20210292. <https://doi.org/10.1098/rsta.2021.0292> (Accessed: 6 March 2026).
- Balmforth, D. (2020) *Toddbrook Reservoir Independent Review Report*. <https://assets.publishing.service.gov.uk/media/5e6f3f56d3bf7f2690785d52/toddbrook-reservoir-independent-review-reporta.pdf> (Accessed: 5 March 2026).
- Bernhofen, M.V., Trigg, M.A., Sleigh, P.A. et al. (2021) Global flood exposure from different sized rivers. *Natural Hazards and Earth System Sciences*, 21 (9), pp. 2829–2847. <https://doi.org/10.5194/nhess-21-2829-2021> (Accessed: 5 March 2026).
- Department for Business, Energy & Industrial Strategy (2022) *Energy Emergencies Executive Committee Storm Arwen Review*. Final report. <https://assets.publishing.service.gov.uk/media/629fa8b1d3bf7f0371a9b0ca/storm-arwen-review-final-report.pdf> (Accessed: 5 March 2026).
- Nijhawan, A. and Howard, G. (2022) Associations between climate variables and water quality in low- and middle-income countries: a scoping review. *Water Research*, 210 (article: 117996). DOI:10.1016/j.watres.2021.117996.
- Khan, S.J., Deere, D., Leusch, F.D.L. et al. (2015) Extreme weather events: should drinking water quality management systems adapt to changing risk profiles? *Water Research*, 85, pp. 124–136. <https://doi.org/10.1016/j.watres.2015.08.018> (Accessed: 6 March 2026).
- Xu, J., Morris, P.J., Liu, J. et al. (2020) Increased dissolved organic carbon concentrations in peat-fed UK water supplies under future climate and sulfate deposition scenarios. *Water Resources Research*, 56 (1), article: e2019WR025592. <https://doi.org/10.1029/2019WR025592> (Accessed: 6 March 2026).
- World Health Organization and United Nations Children's Fund (2025) *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2024: Special Focus on Inequalities*. <https://data.unicef.org/wp-content/uploads/2025/09/jmp-2025-wash-households-launch.pdf> (Accessed: 5 March 2026).
- Rivington, M., Akoumianaki, I. and Coull, M. (2020) *Private Water Supplies and Climate Change. The Likely Impacts of Climate Change (Amount, Frequency and Distribution of Precipitation), and the Resilience of Private Water Supplies*. Policy brief, prepared for the Centre of Expertise for Waters. [https://www.crew.ac.uk/sites/www.crew.ac.uk/files/publication/CRW2018\\_05\\_Policy\\_Brief\\_FINAL%2Blink\\_0.pdf](https://www.crew.ac.uk/sites/www.crew.ac.uk/files/publication/CRW2018_05_Policy_Brief_FINAL%2Blink_0.pdf) (Accessed: 7 March 2026).
- Hyde-Smith, L., Zhan, Z., Roelich, K. et al. (2022) Climate change impacts on urban sanitation: a systematic review and failure mode analysis. *Environmental Science & Technology*, 56 (9), pp. 5306–5321. <https://doi.org/10.1021/acs.est.1c07424> (Accessed: 7 March 2026).
- Royal Academy of Engineering (2024) *Testing the Waters. Priorities for Mitigating Health Risks from Wastewater Pollution*. <https://nepc.raeng.org.uk/media/qi2eyivp/testing-the-waters-priorities-for-mitigating-health-risks-from-wastewater-pollution.pdf> (Accessed: 7 March 2026).
- Lebu, S., Gyimah, R., Nandoya, E. et al. (2024) Assessment of sanitation infrastructure resilience to extreme rainfall and flooding: evidence from an informal settlement in Kenya. *Journal of Environmental Management*, 354 (article: 120264). <https://doi.org/10.1016/j.jenvman.2024.120264> (Accessed: 5 March 2026).
- Kohlitz, J., Geremew, A., Okurut, K. et al. (2026) What makes household sanitation systems resilient to floods? Evidence from Ethiopia, Uganda, and Nepal. *ACS ES&T Water*. <https://doi.org/10.1021/acsestwater.5c01055> (Accessed: 5 March 2026).
- Rakhimbekova, S., Power, C., O'Carroll, D.M. and Robinson, C.E. (2023) Potential for shoreline recession to accelerate discharge of groundwater pollutants to coastal waters. *Water Resources Research*, 59 (6), article: e2022WR034230. <https://doi.org/10.1029/2022WR034230> (Accessed: 5 March 2026).
- O'Driscoll, M., Humphrey, C., Iverson, G. et al. (2024) Rising groundwater levels in Dare County, North Carolina: implications for onsite wastewater management for coastal communities. *Journal of Water and Climate*, 15 (8), pp. 3666–3688. [https://repository.library.noaa.gov/view/noaa/67994/noaa\\_67994\\_DS1.pdf](https://repository.library.noaa.gov/view/noaa/67994/noaa_67994_DS1.pdf) (Accessed: 5 March 2026).
- Climate Change Committee (2023) *Progress in Adapting to Climate Change. 2023 Report to Parliament*. <https://www.theccc.org.uk/wp-content/uploads/2023/03/WEB-Progress-in-adapting-to-climate-change-2023-Report-to-Parliament.pdf> (Accessed: 5 March 2026).
- Jaroszweski, D., Wood, R. and Chapman, L. (2021) *Technical Report. Chapter 4: Infrastructure*. UK Climate Risk Independent Assessment (CCRA3). <https://www.ukclimaterisk.org/wp-content/uploads/2021/06/CCRA3-Chapter-4-FINAL.pdf> (Accessed: 5 March 2026).



# Net zero high-density buildings and infrastructure

**Sean Smith** evaluates the complexities and opportunities of delivering improved housing stock for a variety of building types.

**B**uildings within urban environments involve an array of construction material archetypes, high-density streetscapes and restricted space for adapting infrastructure (see **Figure 1**). The UK's cities and towns also range from modern constructions to historic, listed buildings; this means the complexity of solutions and constraints can lead to a sense of playing Snakes and Ladders, where the merits of one approach can clash with those required on adjacent buildings and streetscapes.

◀ **Figure 1. Edinburgh city streetscape of modern and historic high-density buildings.** (© Sean Smith)

High-density buildings, such as flats, are often home to the lowest-income households and very often to key workers. As such, there is an urgency to ensure that future solutions lower carbon emissions and deliver healthy and warm homes, but do not increase fuel poverty. While previously the push for net zero and low-carbon solutions has more often focused on houses, few large-scale projects have attempted to tackle the combined approach involving high-density buildings and associated infrastructure. This includes high-density living such as blocks of flats or apartments, high-density streetscapes with diverse building archetypes, public and commercial buildings in close proximity, and associated high-voltage substations and large-scale heating systems. Importantly, through this combined approach there is an opportunity to also address key parameters including future scalability and place-based solutions, to use economies of scale, and to deliver a legacy of healthy, warm and comfortable buildings.

In 2024 the Centre for Net Zero High Density Buildings (CeNZ-HighDB) was founded thanks to funding from UK Research and Innovation towards green economy centres as part of the Government's Building a Greener Future programme.<sup>1</sup> The centre is led by the University of Edinburgh and partners with the universities of Glasgow, Edinburgh Napier, Strathclyde and West of Scotland as well as with over 50 industry and public sector partners. Engagement and impact are led by the Built Environment-Smarter Transformation unit, which also manages the Retrofit Scotland web portal. The centre was fully operational by March 2025 and formally launched in May 2025 (see **Figure 2**). The centre was heavily oversubscribed for the launch due to the scale of interest across multiple stakeholders. By October 2025, CeNZ-HighDB was already undertaking over 30 research and development projects with industry and public sector partners, six months ahead of schedule.

**HIGH-DENSITY LIVING**

Glasgow and Edinburgh have the highest proportion of flats and apartments in the UK at

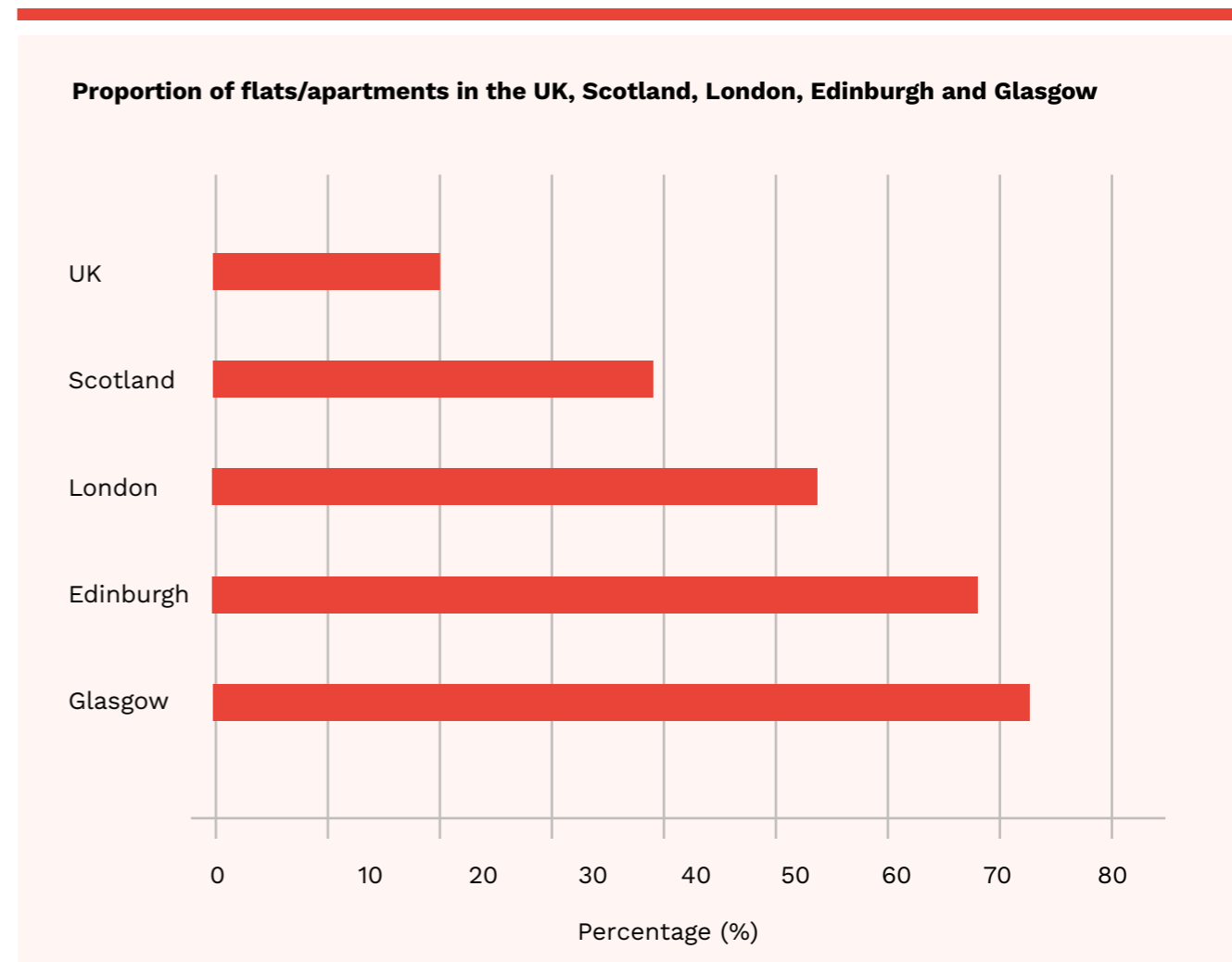
73 per cent and 68 per cent, respectively, with London at 54 per cent.<sup>2</sup> Scotland as a whole has 39 per cent, far higher than the UK average of 20 per cent (see **Figure 3**).

High-density living often has limitations on extensions, adaptability, and additional space for the water systems and services (pipework) required for some of the net zero solutions. There is further complexity in the diversity of occupancy types (i.e. owned, rented etc.), which may limit some solutions for apartment blocks. Furthermore, there is a lack of legal frameworks such as an owners association for flats that share a common stairwell and, importantly, the electrical and gas utility risers that are located within that.

Addressing high-density buildings in cities and towns requires a multifaceted approach but also provides opportunities for cross-cutting themes and interdisciplinary approaches. The centre has six primary interlinked themes to assess, pilot and develop solutions. Each of the six thematic working groups is led by the centre's higher



▲ **Figure 2. Formal launch of the Centre for Net Zero High Density Buildings in May 2025. (© Sean Smith)**



▲ **Figure 3. Proportion of flats and apartments in the UK, Scotland, London, Glasgow and Edinburgh. (Source: Smith, 2023<sup>2</sup>)**

education institution partners, combining the knowledge of over 90 experts from industry, academia, the public sector and community organisations (see **Box 1**).

**ARCHETYPE APPROACHES**

In 2021 the Zero Emission Social Housing Taskforce report (known as the ZEST Report) was published.<sup>3</sup> This brought together many social housing providers from Scottish housing associations and local authorities to address how to scale up and plan consistent approaches to retrofitting. A key report recommendation was to focus on common archetypes that are found in many cities and towns from which the outcomes from retrofit testing, trials and pilots could be shared.<sup>4</sup> The centre is currently assessing some of the most common archetypes and testing fabric solutions that will be published via Retrofit Scotland as a central go-to open portal for knowledge exchange.

**BOX 1. THEMATIC WORKING GROUPS<sup>1</sup>**

1. Archetypes, building performance and green materials. (Lead: Dr Julio Bros-Williamson, University of Edinburgh)
2. Low-carbon heating solutions within a home. (Lead: Professor Des Gibson, University of the West of Scotland)
3. Common heating measures such as district and network heating. (Lead: Professor Gioia Falcone, University of Glasgow)
4. Data modelling and analysis. (Lead: Professor Nick Kelly, University of Strathclyde)
5. Occupant behaviours and needs. (Lead: Professor Lori McElroy, University of Strathclyde)
6. Future skills and equity, diversity and inclusion support. (Lead: Professor Robert Hairstans, Edinburgh Napier University)



© sforzza | Adobe Stock

Examples of common archetypes include:

- Historic Georgian stone terraced buildings;
- Pre-1919 stone tenement apartments (circa 170,000);
- Timber frame buildings (circa 450,000); and
- Four-in-a block brick and block cavity (160,000).

#### HEATING: INDIVIDUAL HOMES OR NETWORKED?

In 2024 all Scottish local authorities had published their local heat and energy efficiency scheme plans. Across the 32 reports it was identified that in many of the cities and towns there was a future opportunity to include heat networks involving piped heating systems from a common energy source and distributed to homes and buildings. Local authorities have been assessing the scale of existing waste heat from sewers and other nearby industrial estates, which can underpin part of the energy-heat load to housing in the adjacent areas. In addition, recent developments in large-scale industrial

heat pumps have provided new opportunities to feed into heat networks, which can be more environmentally friendly overall when compared to other low-carbon heating systems. A new forum to support and share knowledge and developments in this sector is led by Heat Network Scotland.

While the legal frameworks for heat network approaches to existing buildings are still under development, ascertaining existing heat sources and identifying gaps in future heat generation has assisted industry and local authorities. However, one of the biggest constraints to net zero urban developments and electricity-based low-carbon heating systems is the electric grid, both in terms of available megawatts and substation infrastructure.

#### BUILDING OWNERS AND LANDLORDS

Approximately 76 per cent of Scotland's 2.8 million homes are privately owned. As such,

retrofit and low-carbon solutions must also engage this critical sector if delivery and scale-up of Scotland's net zero target by 2045 is to be achieved. Also, many of the solutions for Scotland's key archetypes have synergy with other UK housing building stock, such as stone-based, cavity block walls and timber frame buildings constructed during similar eras.

A recent study on retrofitting Scotland's private rented sector identified a range of challenges and landlord attitudes.<sup>5</sup> The findings provided valuable evidence to support targeted improvements in the private rented dwellings sector by addressing the key retrofit challenges, including difficulties associated with hard-to-treat dwellings, high retrofit costs, flaws in the compliance energy assessment and complications with mixed tenure retrofit. Hard-to-treat dwellings include pre-1919 stone buildings where requirements for energy efficiency improvements can clash with the

breathability of the stone if specification and works are not undertaken correctly. This can lead to damp, mould and unhealthy buildings for occupants.

It was found that these challenges shape private landlords' attitudes towards retrofit approaches, and are reflected in two main patterns:

1. Hesitation to undertake retrofits due to policy uncertainty and perceived post-retrofit property risks; and
2. A low preference for adopting key energy efficiency and carbon-reduction measures such as fabric upgrades and heat pumps.

To address these, it is critical to support policy development and provide pathways for tried and tested (evidence-based) retrofit solutions, as this has a critical role in reaching

### South-east Scotland City Region Construction Workforce

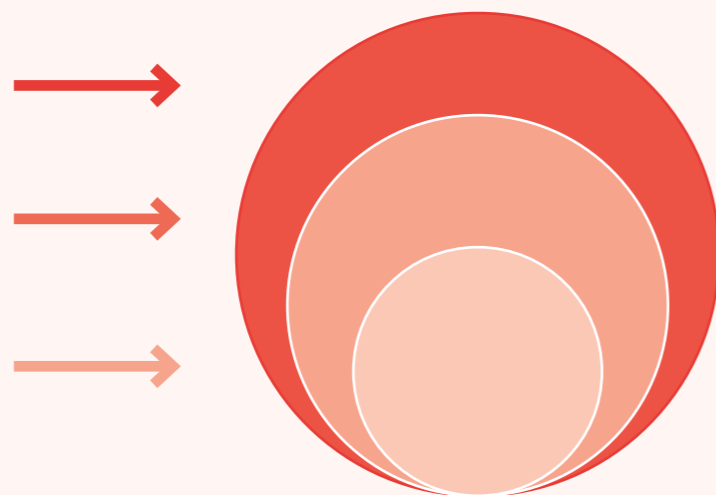
(Current, transiting and future required)

#### ALL CONSTRUCTION

Future construction workforce need  
**79,000** (by 2035)

Current city region construction workforce  
**57,500**

Non-local based workforce transiting into city region annually  
**21,000**



▲ **Figure 4. South-east Scotland city region: all construction workers – current, non-region-based and future need. (Source: Smith and Earp, 2024<sup>6</sup>)**

### South-east Scotland City Region Construction Workforce

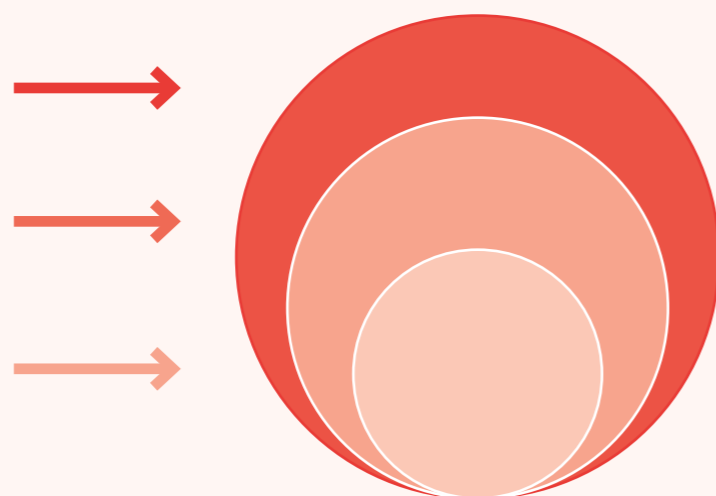
(Current and future min. and max. required)

#### RETROFIT CONSTRUCTION

Future max. required  
**34,000** (by 2035)

Future min. required  
**21,500** (by 2035)

Current estimated  
**8,000**



▲ **Figure 5. South-east Scotland city region: retrofit construction workforce – current, future minimum and maximum required. (Source: Smith and Earp, 2024<sup>6</sup>)**

such audiences, and to underpin scale-up and adoption.

#### FEASIBILITY AND IMPLEMENTATION

Even if all the retrofit solutions were available to the sector now and cost effective, a key factor in the delivery pathway is the availability of regional skills and workforce capabilities to meet the demand. An example of such constraints is in south-east Scotland, encompassing Edinburgh and the five adjacent local authorities (the Lothians, Fife and Scottish Borders). Recent studies have identified this region as the fastest growing in Scotland in terms of population growth and housing demand.

The region currently employs a construction workforce of 57,500. However, approximately 20,000 of these workers commute into the region from other parts of Scotland. By 2035 the region will require a combined new-build and retrofit workforce of 79,000 (see **Figure 4** and **Figure 5**). Therefore, there is a dual complexity. The region not only needs to grow its own construction workforce but also plan to backfill as many of the existing 20,000 commuting workers who are more likely to stay within their own area as the scale-up of retrofit progresses locally.

To support and accelerate the training and growth of a future local workforce the centre has supported regional colleges in the design and development proposal for a Net Zero Accelerator Hub.<sup>6</sup> This would allow the region to provide almost double the training capacity for new entrants and also assist upskilling the existing workforce through new net zero construction skills facilities. Importantly, these facilities would offer night classes to small, medium- and micro-sized companies that are economically unable to stop work for training during the working day.

#### LOOKING AHEAD

The range of ongoing centre projects includes testing novel heating systems, new fabric approaches, new circular economy construction products, common archetype solutions, heat network policies and solutions, energy modelling, occupant studies pre- and post-retrofit, and supporting workers' future skills and growth.

The array of pilots and solutions includes the evaluation of other critical aspects such as moisture penetration, ventilation, ability for scale-up, industry readiness, and alignment

with policies and frameworks whether for social housing standards, net zero impacts or future required maintenance and servicing.

The ambition is to deliver a series of solutions over the centre's four-year programme, which is due to be completed by early 2029. Benefits already delivered by the centre include: advice and guidance for multimillion-pound retrofit programmes; attracting investment into new manufacturing facilities for low-carbon construction products; evaluation of new heating systems; and engaging with more than 80 high schools to underpin the next generation of workforce entrants. While the scale of the task is large and complex, the opportunities for the environment, society and the economy are significant.

ES

**Professor Sean Smith** is Principal Investigator for the CeNZ-HighDB research programme, Chair of Future Construction and Director of the Centre for Future Infrastructure at the University of Edinburgh.

#### REFERENCES

1. The Centre for Net Zero High Density Buildings (no date) Home page. <https://cenz-highdb.ac.uk/> (Accessed: 11 March 2026).
2. Built Environment – Smarter Transformation (2023) *International Retrofit Conference 2023 – Professor Sean Smith, University of Edinburgh*. YouTube video, 26:14. [https://youtu.be/10XZL8\\_tZ4U?si=iliYUTiP-Fq-e2gq-](https://youtu.be/10XZL8_tZ4U?si=iliYUTiP-Fq-e2gq-) (Accessed: 11 March 2026).
3. Scottish Government (2021) *Achieving net zero in social housing: Zero Emissions Social Housing Taskforce report*. <https://www.gov.scot/publications/achieving-net-zero-social-housing-zero-emissions-social-housing-taskforce-report/> (Accessed: 11 March 2026).
4. Smith, S. (2021) *Developing Net Zero Technical Solutions for Scotland's Future Mass Retrofit Housing Programme*. Proposal paper. <https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/07/developing-net-zero-technical-solutions-for-scotland-future-mass-retrofit-housing-programme/documents/zest-proposal-paper/zest-proposal-paper/govscot%3Adocument/Structured%2BRetrofit%2BSolution%2BProgramme%2Bpaper%2Bfor%2BZEST%2BTechnical%2Bgroup%2B03082021.pdf> (Accessed: 11 March 2026).
5. Ibrahim A., Carter K., Brennan J. and Bros-Williamson, J. (2026) Retrofitting Scotland's private rented sector: challenges and landlord attitudes. *Energy Research & Social Science*, 133 (article: 104578). <https://doi.org/10.1016/j.erss.2026.104578> (Accessed: 11 March 2026).
6. Smith, R.S. and Earp, S. (2024) *Presentation to the South East Scotland Economic Partnership Forum*.



# Waste infrastructure for a resource-resilient and circular UK economy

**Dan Cooke** considers the current and future provision of essential recycling, resources and waste management infrastructure in the UK.

Reflecting on the current Government's position and policies, part of the 10 Year Infrastructure Strategy published in June 2025, it is clear that 'the UK is implementing a £725 billion, ten-year infrastructure strategy to modernise economic and social infrastructure, improve productivity, and support regional growth'.<sup>1</sup> This plan is expected to run until 2035.

Historically, the UK has faced underinvestment in its infrastructure, with capital spending lagging behind comparator countries like France, Germany and the USA, leading to slower project

delivery, higher costs and reduced productivity. Key deficiencies include regional transport systems, water supply infrastructure, and delays in high-speed rail and nuclear projects. So far, so predictable. The 2025 strategy sets out a long-term coordinated plan covering both economic (e.g. transport, water, energy and digital) and social (e.g. schools, hospitals and housing) infrastructure, and aims to:<sup>1</sup>

- Drive economic growth and improve regional connectivity;
- Transition to a clean energy future and enhance environmental quality;
- Deliver high-quality social infrastructure; and
- Provide resilience against climate change and other key risks.

There is also an emphasis on long-term certainty to attract private investment, boost UK supply chains and, of course, create jobs.



© Belish | Adobe Stock

To improve and streamline planning to enable delivery of these vital projects, the Government has established the National Infrastructure and Service Transformation Authority (NISTA), combining strategic expertise with project assurance. NISTA has three strategic supporting pillars: reforming institutions and regulators; providing long-term funding and project pipelines to ensure stability and to remove barriers to delivery; and improving coordination across sectors (builders versus blockers).

Infrastructure investment in the UK has been volatile, limiting efficiency and productivity.<sup>1</sup> The strategy emphasises the role of private capital alongside public funding, recognising that well-planned investment can significantly boost gross domestic product.

#### INVESTING IN WASTE

So where is fundamental recycling, resource and waste management infrastructure in all this strategic planning? While there is mention of the environment and clean energy – and waste infrastructure meets those criteria – when it comes to government strategic planning, the resource and waste management sector is largely ignored: bottom of the pile and undervalued.

Despite everyone in the UK relying on the waste sector's services and infrastructure – to protect human health, the environment and local economies' ability to thrive – this is common practice.

It is also clear that provision of infrastructure does not necessarily rely on being identified and coordinated via central strategic planning; a combination of regulatory and economic conditions created or steered by government can be an effective enabler too. This is certainly the case when it comes to successes (e.g. investment in energy from waste, or EfW) and failures (e.g. recycling infrastructure availability) in the provision of recycling and waste management infrastructure. It is therefore necessary to consider the sector-specific strategies in place for the sector as a whole before analysing each key infrastructure category in terms of current provision.

#### WASTE POLICIES AND STRATEGIES

There is a framework of alignment or ongoing commitment to relevant EU frameworks and regulations, post-Brexit – notably the Landfill Directive and emerging Circular Economy Act (from the Circular Economy Plan and Green



© ungvar | Adobe Stock

Deal).<sup>2,3</sup> These set important context, and over the last couple of decades have been key drivers of sectoral behaviour change.

At the UK level there is the Environmental Improvement Plan (reviewed every five years and replacing the original 25 Year Environment Plan) with a set of key indicators, summed up as 'maximise our resources, minimise our waste, eliminate avoidable waste, and double resource productivity'.<sup>4</sup> The Environmental Improvement Plan implements relevant targets and measures from the Environment Act 2021 – as well as the Resources and Waste Strategy (for England) 2018 – related to: resource productivity; raw materials consumed; waste reduction (total and kilogram per head); plastic marine litter (as measured in the stomachs of fulmars, a type of seabird); waste crime (number of illegal waste sites and fly-tipping incidents); recycling targets; and hazardous waste disposal.

Equivalent strategies and plans exist for the UK nations, as waste policy and regulations are fully devolved. All are broadly aligned, with some regulations (e.g. extended producer responsibility for packaging, or pEPR) being implemented at a UK level.<sup>5</sup> Wales has a notably higher recycling

rate than other UK nations (and indeed claims to be the second best in the world), with regulatory requirements for businesses and local authorities being more stringent and costing approximately 20 per cent more.<sup>6,7</sup>

These add to an existing plethora of legislation and regulations – underpinned by permitting – and monitoring of operational facilities and enforcement conducted by the Environment Agency in England, the Scottish Environment Protection Agency, Natural Resources Wales, the Northern Ireland Environment Agency and local authorities.

#### MOVING TOWARDS RESOURCE EFFICIENCY?

How does all of this translate to the sector infrastructure in place today and what are the forecast requirements for continuing to improve the UK's resource efficiency? The waste sector is worth £24 billion a year to the UK economy and employs over 140,000 people. The UK currently generates 25.9 million tonnes per year of household waste (21.7 million tonnes in England) and 40.4 million tonnes of commercial and industrial wastes (33.7 million tonnes in England).<sup>9</sup> These are the materials covered by the strategic and regulatory framework.

The UK Government's waste statistics list relevant final treatment infrastructure as:

- Recycling and recovery;
- Incineration with energy recovery, with R1 status (the EU and UK measure of energy efficiency) being the most efficient;<sup>10</sup> and
- Landfill.

This excludes other important infrastructure for controlled waste management, including anaerobic digestion facilities, composting plant, and waste collection and transfer facilities. There are over 12,000 permitted waste facilities in operation at approximately 9,300 sites across the UK.

At the bottom of the waste hierarchy is landfill. This is yesterday's solution to waste disposal, but operational capacity is still required as a contingency and for hard-to-dispose-of materials. It is also still the second-biggest method of treatment or disposal with around 620 permitted facilities disposing of 45 million tonnes per year – much of which is supposedly inert material charged at the lower rate of Landfill Tax (£4 per tonne, due to double in April 2026). The standard rate of Landfill Tax – currently £126 per tonne and due to rise to £130 in April 2026 – is the key disposal cost benchmark and the economic driver that has pushed material up the hierarchy and enabled the viability of and investment into EfW facilities.

However, evidence shows that waste misclassification and tax fraud are rife: they are the main types of waste crime, currently undercutting professional sector operators, and a significant factor in the existing number of operational sites. There are clear signs that His Majesty's Revenue and Customs is now focusing on this issue, with a ban on biodegradable waste to landfill proposed for 2028 in England. (A ban in Scotland was due to be introduced in January this year but was deferred for two years while EfW capacity is built.) The number of operating facilities and tonnages disposed of to landfill should continue to reduce substantially over the coming years.

The significant reduction in landfilling is the main factor in the waste sector's success in reducing its carbon emissions by 46 per cent since 1990, as the breakdown of biodegradable materials in landfill releases methane. This is the third-best sector performance across all industries.

### ENERGY FROM WASTE FACILITIES

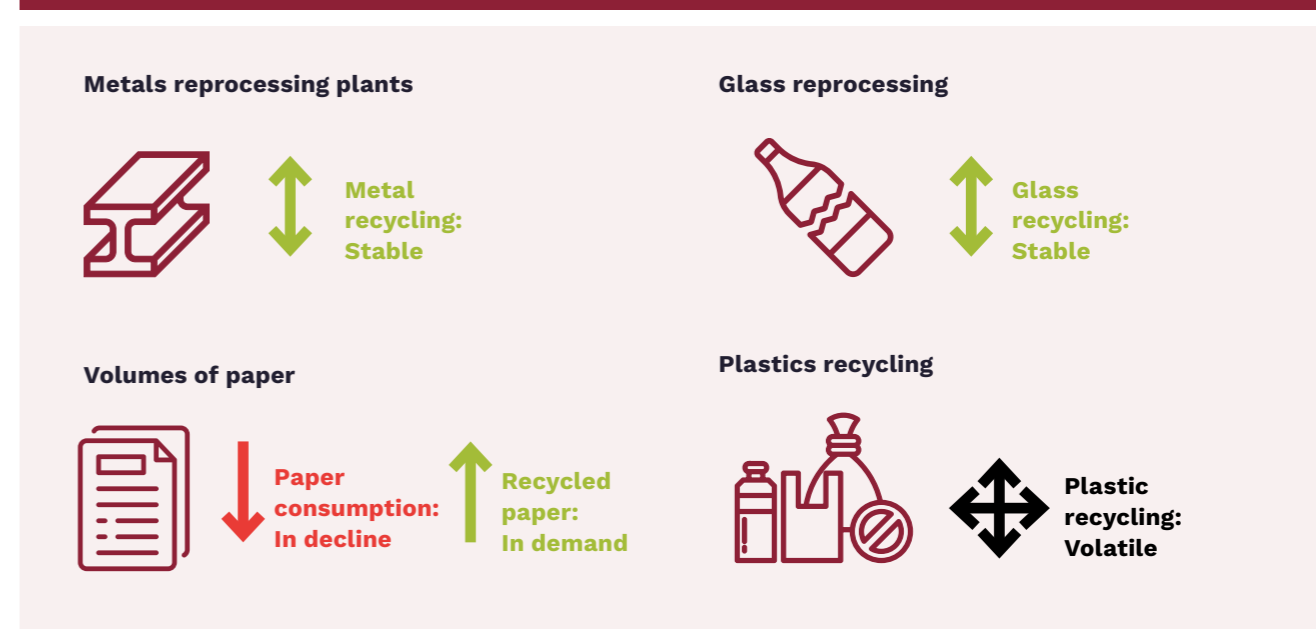
This trend has enabled the sector to invest over £10 billion in alternative treatment infrastructure, mainly in a fleet of EfW facilities. This is a major success story in infrastructure provision, with 65 operational facilities (and at least five more under construction) now processing approximately 19 million tonnes a year of residual wastes. The whole fleet deploys sophisticated engineering, effective pollution control and strict monitoring of emissions to provide public and customer assurance regarding efficiency, reliability, safety, environmental protection and value for money. The median gate fee – charged to the customer by the operator – stands at £125 per tonne.

The UK has gone from almost a standing start with just a handful of operating EfW sites in the late 1990s (most previously operating facilities were shut down as they were unable to meet new EU emissions standards) to close to full (and possibly over) capacity by 2027–8. This is indicated by a regulatory and planning note issued by the Government stating that new facilities will now only be permitted in exceptional circumstances.

As well as providing reliable treatment for residual wastes, these facilities produce around 3 per cent of the UK's baseload power, of which 50 per cent is renewable. The bottom ash and air pollution residues are recycled, as are the reclaimed metals. Seven plants are now also supplying local heat networks, and the first facility (the Protos plant in Ellesmere Port) has signed a contract supported by the Department for Energy Security & Net Zero for 370,000 tonnes of carbon capture and storage as part of the HyNet decarbonisation cluster.<sup>11</sup> Heat utilisation and carbon capture, usage and storage will be the challenges for such infrastructure in the coming years, and will be further driven by the forthcoming Emissions Trading Scheme (due to be applied in 2028), as the plants need to reduce the 50 per cent of power currently produced by burning fossil fuel plastics.<sup>12</sup>

### ANAEROBIC DIGESTION

Another sector success story is the provision of anaerobic digestion (and to a lesser extent composting) infrastructure for the processing of food and organic wastes. This has again gone from very few facilities in the 1990s to an oversupply of capacity today, with approximately 700 operational plants (and a median gate fee of £24 per tonne).



▲ Figure 1. The current state of materials consumption versus recycling in the UK.

These include plants dealing with sewage sludge and agricultural wastes, as well as those providing controlled waste management services, and show the success of a resurgent UK biogas industry by producing a combination of gas for the grid and renewable energy generated on site. This infrastructure will likely cope with increased food waste collections due to become mandatory for all English households from April 2026 (around 50 per cent of local authorities already provide this service).

### RECYCLING FACILITIES

This is the more problematic area of waste infrastructure, and likely the one with the highest public and political expectations but the most volatile economics. There is a relatively good provision of materials recycling facilities, which sort dry mixed recyclables – mainly paper and cardboard, metals, glass and plastics – for further reprocessing. There are currently 108 operating facilities across the UK, processing around 4.3 million tonnes a year.

Around 50 per cent of these are large-scale facilities, processing 50,000–125,000 tonnes per year, with four processing over 125,000 tonnes a year. These contribute to the – currently flatlining – UK household waste recycling rates and to the overall packaging recycling rate of 63 per cent.<sup>8</sup>

It is in considering material-specific reprocessing plants that we begin to spot the challenges. In general, the following trends are observed in a

packaging materials market of around 13 million tonnes a year (see Figure 1):

- **Volumes of paper** being consumed are declining due to rise of digital media, while demand for recycled cardboard is healthy due to packaging requirements (especially due to the rise of online shopping). There are mixed signals regarding the provision of UK paper and card infrastructure, with European and global firms shifting production bases.
- **Metals reprocessing plants** remain well established and relatively steady due to higher prices compared to other materials (especially aluminium).
- **Glass reprocessing** also remains relatively steady due to consistent and high volumes in packaging (albeit at consistently low prices).
- **Plastics recycling** sees the greatest volatility. The UK, along with other European countries, has targeted recycling as the optimum method to deal with large volumes of complex plastic waste. (There are many grades of plastics and over 1,000 additives for different applications.) The Government supports this through policies including recycling rates, pEPR, the Simpler Recycling initiative and the Plastic Packaging Tax.

Policies are accompanied by expectations of progress towards a circular economy and the creation of new employment opportunities.



Recent market developments, however, show a downward shift in the sector's trajectory, with many plant closures, bankruptcies and postponed investments, and a total loss of 600,000 tonnes of lost capacity in northern Europe, including the UK.

Other essential resources and waste management infrastructure providing services for specific and specialist materials include facilities processing hazardous waste, wood wastes, the production of refuse-derived fuels for export or UK recovery, and depot and servicing facilities for the collection and cleansing of vehicles (including increasing electric vehicle charging requirements). All are relatively stable and sufficiently provisioned.

It would be remiss not to consider infrastructure required for services and solutions at the top of the waste hierarchy – namely, material rentals (e.g. tool and clothing hire services), repair and reuse. Infrastructure provision will be driven by cost savings (i.e. where repair is cheaper than replacement for faulty goods) and policies such as designing for reparability. There are some low-profile successes in this space, including electrical retailers such as Currys' repair facility networks and Suez's household waste repair and refurbishment centres. But this infrastructure is in its relative infancy and the market requirements for scaling up and investment are immature.

#### FUTURE INFRASTRUCTURE NEEDS

What might future infrastructure provision look like across this crucial sector? This may partly be driven by the forthcoming Circular Economy Growth Plan and accompanying sector roadmaps.<sup>13</sup> The Chartered Institution of Wastes Management (CIWM) is calling for a specific roadmap for the resources and waste sector to clarify the future capacity needs of these vital infrastructure types, accounting for facility and economic life

cycles as well as economic and policy drivers that can be forecasted. Government and regulators also need to address the current issue of waste crime, with up to 30 million tonnes a year being illegally managed, which significantly undermines investment in services and infrastructure by established sector businesses and financiers.

As the UK continues its drive to become a clean energy superpower and looks to unlock regional growth through coordinated infrastructure development and its industrial strategies, the largely overlooked resources and waste sector will continue in its quietly determined manner to deliver value, jobs, growth and vital infrastructure to move the UK towards greater materials resilience, carbon reduction and resource efficiency.

ES

**Dan Cooke** is Director of Policy, Communications and External Affairs at the CIWM. He has held previous roles at Cornwall Council, FTSE 250-listed Pennon Group, Viridor, Tidy Britain Group/Environmental Campaigns and Coventry City Council. He served as President and Chair of CIWM, Director of Viridor Credits Environmental, Trustee of the Carymoor Environmental Trust and Trustee of Cornwall Wildlife Trust.

#### REFERENCES

1. HM Treasury and National Infrastructure and Service Transformation Authority (2025) *UK infrastructure: a 10 year strategy*. Policy paper. <https://www.gov.uk/government/publications/uk-infrastructure-a-10-year-strategy> (Accessed: 18 March 2026).
2. Department for Environment, Food & Rural Affairs (2011) *Environmental permitting guidance: the landfill directive*. Guidance. <https://www.gov.uk/government/publications/environmental-permitting-guidance-the-landfill-directive> (Accessed: 18 March 2026).

#### REFERENCES

3. European Commission (no date) *Circular economy*. [https://environment.ec.europa.eu/strategy/circular-economy\\_en](https://environment.ec.europa.eu/strategy/circular-economy_en) (Accessed: 18 March 2026).
4. Department for Environment, Food & Rural Affairs (2025) *Environmental Improvement Plan (EIP) 2025*. Corporate report. <https://www.gov.uk/government/publications/environmental-improvement-plan-2025/environmental-improvement-plan-eip-2025> (Accessed: 18 March 2026).
5. Department for Environment, Food & Rural Affairs and Environment Agency (2026) *Extended producer responsibility for packaging: who is affected and what to do*. Guidance. <https://www.gov.uk/guidance/extended-producer-responsibility-for-packaging-who-is-affected-and-what-to-do> (Accessed: 18 March 2026).
6. Welsh Government (2024) *Da iawn Cymru! Wales named as second best recycling nation in the world*. <https://www.gov.wales/da-iawn-cymru-wales-named-second-best-recycling-nation-world> (Accessed: 18 March 2026).
7. Welsh Government (2026) *Statistics: Local Authority Municipal Waste Management: April 2024 to March 2025*. <https://www.gov.wales/sites/default/files/pdf-versions/2026/1/4/1769679058/local-authority-municipal-waste-management-april-2024-march-2025.pdf> (Accessed: 18 March 2026).
8. Environmental Services Association (2024) *UK Recycling and Waste Treatment Market Overview*. [https://storage-us-gcs.bfldr.com/7hsg8bmjisp5hzt-x-q6wkgrc/v/1202071835/original/UK%20Recycling%20Waste%20Treatment%20Market%20Overview%20\(July%202024\)\\_%20Full%20Report.pdf?dl=true&Expires=1773895153&KeyName=gcs-bfldr-prod&Signature=M5UPipBASgLDzsnlZB47dSGY2s=](https://storage-us-gcs.bfldr.com/7hsg8bmjisp5hzt-x-q6wkgrc/v/1202071835/original/UK%20Recycling%20Waste%20Treatment%20Market%20Overview%20(July%202024)_%20Full%20Report.pdf?dl=true&Expires=1773895153&KeyName=gcs-bfldr-prod&Signature=M5UPipBASgLDzsnlZB47dSGY2s=) (Accessed: 18 March 2026).
9. Department for Environment, Food & Rural Affairs (2025) *UK statistics on waste*. <https://www.gov.uk/government/statistics/uk-waste-data/uk-statistics-on-waste> (Accessed: 18 March 2026).
10. Environment Agency (2026) *Waste incinerator plant: apply for R1 status*. Guidance. <https://www.gov.uk/guidance/waste-incinerator-plant-apply-for-ri-status> (Accessed: 18 March 2026).
11. Protos ERF (no date) *The facility*. <https://www.protoserf.co.uk/about-the-facility/> (Accessed: 18 March 2026).
12. Department for Energy Security & Net Zero (2026) *UK Emissions Trading Scheme (UK ETS): a policy overview*. Policy paper. <https://www.gov.uk/government/publications/uk-emissions-trading-scheme-uk-ets-policy-overview/uk-emissions-trading-scheme-uk-ets-a-policy-overview> (Accessed: 18 March 2026).
13. European Recycling Platform (2026) *The circular economy growth plan*. <https://erp-recycling.org/uk/news-and-events/2026/02/the-circular-economy-growth-plan/> (Accessed: 18 March 2026).

## The Institution of Environmental Sciences

Editors	Bea Gilbert and Lucy Rowland
Guest editor	Professor Lindsay Beevers
Subeditor	Christina Petrides <a href="http://www.lastglance.net">www.lastglance.net</a>
Designer	Kate Saker <a href="http://katesaker.com">katesaker.com</a>
Printer	Lavenham Press Ltd
Published by	Institution of Environmental Sciences c/o The Association for Laboratory Medicine 130-132 Tooley Street London SE1 2TU
Tel	+44 (0)20 3862 7484
Email	<a href="mailto:info@the-ies.org">info@the-ies.org</a>
Web	<a href="http://www.the-ies.org">www.the-ies.org</a>

If you are interested in advertising in this publication, please contact:  
**publications@the-ies.org**

This journal is printed on Forest Stewardship Council® certified paper. The CO<sub>2</sub> emissions generated by the production, storage and distribution of the paper are captured through the Woodland Trust's Carbon Capture scheme.

Copyright © 1971–2026  
The Institution of Environmental Sciences Ltd.





NoiseActionWeek

# Noise Action Week

11<sup>th</sup>-15<sup>th</sup> May 2026

## The UK's campaign to reduce noise pollution

Noise Action Week Noise is a campaign to spread the message that noise matters for our health and wellbeing. Join us by visiting the Noise Action Week webpage for upcoming events, educational resources, and news.

[the-ies.org/noise-action-week](https://the-ies.org/noise-action-week)



Environmental Policy  
Implementation  
Community

Part of the IES family

