Built for the environment

Addressing the climate and biodiversity emergency with a fair and sustainable built environment

Architects Declare Climate and Biodiversity Emergency

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Authors

Maria Smith, Buro Happold and RIBA Councillor (editor)
Joshua Apperley, Buro Happold
Alex Couling, Buro Happold
Martha Dillon, Buro Happold
Andrew Forth, RIBA
Phoebe MacDonald, RIBA

Built Environment Summit Steering Group

Simon Allford, RIBA President; Executive Director, Head of Design Studio at Allford Hall Monaghan Morris
Adrian Dobson, Executive Director Professional Services, RIBA
Maria Smith, RIBA Councillor; Director of Sustainability and Physics at Buro Happold
Andrew Waugh, Architects Declare Steering Group Member; Founding Director of Waugh Thistleton Architects

Advisors

Mel Allwood, Director and Sustainable Buildings Lead, Ove Arup & Partners Ltd
Jane Anderson, Director of Construction, LCA Limited
Jake Attwood-Harris, Sustainable Design Advisor of Hawkins\Brown Architects LLP
Duncan Baker-Brown, Founder of BakerBrown
Adrian Campbell, Founder of Changebuilding
Christhina Candido, Associate Professor and Director of Sustainable and Healthy Environments (SHE) Lab, The University of Melbourne
Hélène Chartier, Head of Zero Carbon Development at C40 Climate Leadership Group
Ben Derbyshire, Chair of HTA Design LLP
Pooran Desai, CEO of OnePlanet.com
Asif Din, Sustainability Director, Perkins & Will
Cécile Faraud, Clean Construction programme manager, C40 Cities
Judit Kimpian, Chair of Environment and Sustainable Architecture Work Group, Architects Council of Europe
James Mitchell, Co-Founder and CEO of BuildX Studio
Ted Ochieng Otieno, Chair of Kenya Green Building Society
Sonja Oliveira, Founder of Radical Architecture Practice for Sustainability Network
Caroline Pidcock, Director of Pidcock PTY Ltd
Michael Ramage, Director of Centre for Natural Material Innovation, University of Cambridge
Nora Steurer, Programme Management Officer, UN Environment Programme & GlobalABC Secretariat
Nigel Tonks, Director and Senior Adviser to Climate Champions Team of Ove Arup & Partners Ltd
Pete Winslow, Associate Director of Expedition

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US Architects Declare
Wellbeing Economy Alliance (WEAll)
Wood Knowledge Wales

Designers, Consultants, and Advisors

5th Studio
Absolute Project Management London Limited
AEW Architects
Alexandra Steed URBAN
ALGREEN
Allford Hall Monaghan Morris
aNNeKS architects aps
ARC Design Studio
Architect Benjamin Machin
architectura.be
Architectural Emporium
Architype
Archon Inmod
Ark Brut
ArtBuild
Arup
Ash Sakula
Assemble
Atelier Lira Luis Limited x Leapfrog Project
Austin-Smith:Lord
Avanto Architects Ltd
BakerBrown
Beehive Architecture
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Buckley Gray Yeoman
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BVN
C.F. Møller Architects
chapmanbdsp
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Government Architect NSW
Graeme North, Earth and Natural Building Consultant
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Haworth Tompkins
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Foreword

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If the goal of the built environment is to create safe, comfortable habitats that facilitate individual and community health and wellbeing, then addressing the climate and biodiversity emergencies is firmly within the remit of all those operating within this sector, including design teams, contractors, investors, developers, asset managers, educators, regulators, and building users.

As set out in the Intergovernmental Panel on Climate Change's (IPCC) 2021 Sixth Assessment Report (1), the climate and biodiversity emergencies are unfolding in a web of interconnected disasters that threaten all life. Sea level rises, extreme weather events, changing weather patterns, biodiversity loss, crop failures, water scarcity, forest fires, and changing disease patterns are just some of the disruptions to ecosystems that are resulting in ever deeper inequality, displacement and migration, political and social unrest, conflict, hunger, illness, and death. However, while climate change and biodiversity loss are already happening, it is not too late to avoid catastrophic breakdown. Working collectively, it is possible to change course and instead ensure safe, comfortable habitats that facilitate individual and community health and wellbeing for humans and non-humans alike.

To avoid long-lasting and irreversible risks to natural and human systems, global temperature rises must be limited to 1.5 degrees Celsius (°C) above pre-industrial levels (2). Today they are at 1.2 °C (3), and the IPCC's 'best estimate' for the average change in the Earth's surface temperature is 3 °C (1). Even if all current Paris Agreement climate pledges are met, the world is still set to see temperature rises of about 2.4 °C by the end of the century (3). In the words of US Climate Envoy John Kerry, the COP26 climate summit in the UK this November is our 'last best chance' (4) to take the action urgently needed.

With nearly 40% of global energy-related greenhouse gas emissions attributable to buildings and construction, it is imperative that the outcomes from COP26 include robust, ambitious, and extensive action on the built environment. Whatever actions are taken now, average global surface temperature will continue to increase until at least the mid-century (1). Given the scale of existing built environment and the time it takes to transform systems effectively, we need robust interim targets to hit breakthroughs in the coming years and decades'. While it is fair to say that changes to norms, customs, and culture do take time, understanding of human-induced climate change has been developing for several decades. We now stand on the brink of a global breakthrough in climate action (5).

This report shows that it is possible for the built environment to operate within planetary limits, and as such all those involved in the sector – including policymakers – can and must take decisive and ambitious action now.

Simon Allford, RIBA President; Executive Director, Head of Design Studio at Allford Hall Monaghan Morris

Maria Smith, RIBA Councillor; Director of Sustainability and Physics at Buro Happold

Andrew Waugh, Architects Declare Steering Group Member; Founding Director of Waugh Thistleton Architects

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Executive summary

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The built environment has a significant environmental footprint

We:

- **must change the way the built environment is designed, built, maintained, operated, and regulated**
- **urge all governments to include built environment actions in their net zero plans**

Rises in global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in carbon dioxide and other greenhouse gas (GHG) emissions occur in the coming decades. With the built environment accounting for 38% of global GHG emissions, the sector must take urgent action if we are to limit climate change.

There are roughly 255 billion m^2 of buildings in the world today – a number that grows by around 5.5 billion m^2 every year. We are building the equivalent of a new city the size of Paris every week. The need for action grows ever more urgent.

We need to see changes across the whole sector. This means making better use of existing buildings to reduce the demand for new construction, minimising the negative environmental impact of new buildings, and making decisions which put the long-term health of the planet above near-term financial interests.

Around half the building area that exists today will still exist in 2050 (6), and of the new buildings that will be constructed between now and 2050, more than two thirds are expected to be built in countries currently without energy codes. Without a much greater level of investment in improving these buildings, we will not be able to meet our targets.

This report builds on research and publications from across the sector and around the world to set out how the built environment can play its part in tackling the climate and biodiversity emergency. We believe these proposals are as relevant to those countries with detailed national net zero plans as they are for those which currently lack them. The recommendations cover the change needed by the built environment sector as well as those who shape, regulate, and fund it.

Ambitious change in the built environment sector is possible

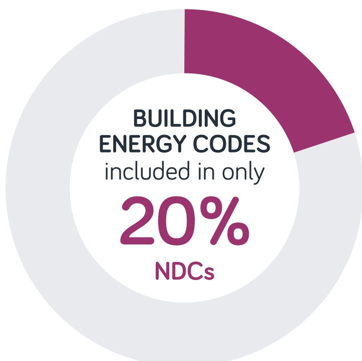
Together:

- **we can harness the potential of the complex built environment sector**
- **with governments, we can scale up and speed up change**
- **with all who are impacted and involved, we can make a transition to a fair and sustainable built environment**

Addressing the climate and biodiversity emergency requires the urgent, widespread deployment of our existing capabilities and technologies. We cannot – and do not need to – wait for emerging technologies: we already possess the skills and tools to help to restore ecosystems and limit the impact that the built environment has on the planet. We need action now to invest in the application of today's technologies, while continuing to look for new ways to deliver net-zero emissions.

The potential of the construction sector to address the climate and biodiversity emergency can be realised through system-wide analysis and action. By enabling greater collaboration between the sector and the public, policymakers, investors, owners, and regulators, we can scale up and speed up change. Governments have a vital role to play. Through leadership and regulatory oversight, governments can maximise the potential of the built environment, support all those impacted by change (both local to and remote from the project site), and provide the infrastructure that enables collective action from the sector and wider society.

Worryingly, only 20% of countries include building energy codes as part of their Nationally Determined Contributions (NDCs). However, well-designed regulations can promote innovation, allowing us to achieve broader social, economic, and environmental goals.



Alongside effective regulations, changes to policies affecting planning and permitting systems, public procurement, grants and incentives, and enabling infrastructure are required. Sub-national governments, including cities and regions, can accelerate the transition to decarbonised, more resilient, more equitable outcomes.

Governments need to work to address the negative impacts that the move to net-zero will have on many people and businesses – including those in the built environment sector. Employment, training, and social policies, developed with the involvement of those impacted, are key to supporting the transition.

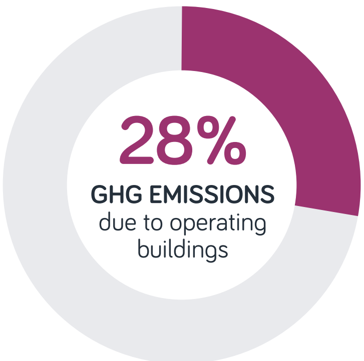
The built environment is central to our quality of life. With greater emphasis in government policy, it can become a central partner in addressing the climate and biodiversity emergencies.

The built environment has the capability to transition to a sustainable future

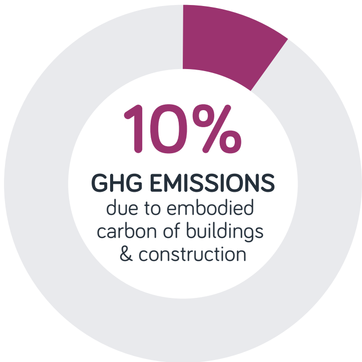
We can:

- **maximise the value of existing structures**
- **decarbonise building materials and construction**
- **reduce the energy required to operate new and existing buildings**

Over a quarter (28%) of global energy-related GHG emissions are due to heating, cooling, and operating buildings. However, the sector can deliver low or zero energy demand buildings, which illustrates just one way that climate action on the built environment can have an enormous impact on wider decarbonisation efforts. Current legislation focuses almost exclusively on the energy use of new buildings, but a focus on energy retrofit of existing buildings could reduce emissions significantly.



Around 10% of global energy-related GHG emissions are attributable to materials and products used in the construction and maintenance of buildings. This is known as embodied carbon. Designers are addressing these emissions with lean design techniques, structural innovations, traditional ecological knowledge and a preference for natural and bio-based materials. Projects are being successfully delivered for a wide range of building typologies and climates, including at scale.



The most effective way to avoid embodied carbon emissions is to refurbish, retrofit, and extend the lives of existing buildings, instead of demolishing them and building a new. However, despite embodied carbon being one of the most important sustainability topics for the sector, it is almost entirely unregulated. This needs to change urgently.

The sector is already able to deliver low or zero carbon buildings with very low or zero energy demand. However, building codes are not only missing entirely in many parts of the world but, where they do exist, they leave out significant emissions sources and do not attempt to regulate actual energy use.

The built environment sector is committed to change

We are:

- **working to upskill and organise through climate action groups**
- **shifting towards interdisciplinary education and practice**
- **committed to reporting our successes and lessons learned**
- **changing the design process to align with sustainable goals**

Built environment practitioners all over the world have declared a climate and biodiversity emergency and are working together to create the change needed. Training and upskilling in the sector are crucial to meet decarbonisation goals. In many countries, sustainability is already being integrated into training, accreditations and chartership schemes across the sector. A growing number of professionals work or train in interdisciplinary environments.

These approaches enable us to understand, share, and explain our successes and failures better. They are also aligning our design and construction processes with sustainability goals, ultimately allowing us to serve society more effectively.

There are enormous social, economic, health, and wellbeing benefits to shifting to a sustainable built environment

We can:

- **meet the needs of all people, including future generations**
- **address overheating, damp, and cold homes, and alleviate fuel poverty**
- **improve internal and external air quality**
- **realise mental health benefits**
- **create jobs and opportunities for upskilling**
- **improve asset values**

The climate is changing at an unprecedented speed and the built environment is ill-prepared for its effects. Outdoor and indoor air quality is an international health crisis. Extreme and unseasonable temperatures are becoming more common. We are seeing more frequent storms, heavy rain, and persistent droughts. Without action, things will continue to get worse.

Design and management of urban spaces can increase resilience to current and future climate challenges. This includes protecting people from the rising heat stresses, cold weather, and storms, by integrating sustainable urban drainage to reduce flooding, developing strategies for access to buildings and spaces during emergencies, and designing contingency systems in the event of infrastructure, utilities, and other systems failures.

Around the world, millions of people live in homes that do not meet their needs and cause unnecessary environmental and health damage. Investment in solving social problems caused by poor housing (such as fuel poverty and overheating) can create jobs, reduce pollution, provide upskilling opportunities, and help to meet legal targets.

The built environment is an expression of our values and has a fundamental impact on every aspect of our lives. Taking concerted action on our built environment can bring an enormous range of benefits, so long as people – including individuals, groups, communities, cultures, and future generations – are central to all our actions.

2.1 Ten principles for a transition to a fair and sustainable built environment

1. **The built environment is a system**, and the transition to a fair and sustainable built environment can be brought about through collaborative and strategic system-wide analysis and action. This means going beyond the actions and role of each person, group, or business operating in the built environment to considering how we are organised and the ways that we all influence and impact each other. Understanding the challenge this way enables us to change faster, more fairly, and with far fewer unintended consequences.
2. **Governments must deliver public resources and spending based on social and environmental justice**, and not be restricted by surmountable limits. The role of governments (both national and sub-national) is not only to regulate the built environment, but to support all those impacted by change, and to facilitate the provision of shared infrastructure.
3. **Environmental targets must be science-based and fair**. This means reporting GHG emissions on a consumption-basis to avoid unjustly shifting the burden for decarbonisation. This means that all countries should include built environment actions as part of their net zero plans (including in their NDCs), and all sources of emissions must be included.
4. **Achieving net zero requires absolute emissions reductions**, not only reductions per square metre of building area, or per person. Greenwashing or reliance on large offsets will not help us to meet our collective goals.
5. **Carbon is not the only environmental indicator**. Water, nutrient cycles, habitats, biodiversity, and many other indicators of ecosystem health must be considered. We must not underestimate the impact of the built environment on ecosystems, nor the potential of positive, reciprocal relationships between humans and wider ecosystems in addressing the climate and biodiversity emergency.
6. **Mitigating and adapting to the climate and biodiversity emergency must happen together**. Nature-based solutions and traditional ecological knowledge, wisdom, and technologies are central to both.
7. **Those of us operating within the built environment must change the way we work**. From breaking down silos between disciplines and competencies, to communicating and sharing information, to shifting our cultural ideas of beauty and design, we must all adapt to this challenge.
8. **We have the tools, knowledge, and technology to address the climate and biodiversity emergency**. The challenge is to deploy them at the speed and scale necessary. To do this, we must collectively agree and apply hierarchies that prioritise the environment (such as refurbishment over demolition, bio-based over extractive materials, and renewable over fossil-fuel energy) and only employ strategies with more dangerous environmental impacts when less dangerous options have been tested and exhausted.
9. **Information should be shared openly and widely** to enable collaboration and transparent decision-making. This includes information about land, buildings, ownership, ecosystems, and infrastructure, as well as knowledge and skills.
10. **Social justice must be at the heart of all action on the climate and biodiversity emergency**. This means ensuring that decision-making happens with the involvement of those impacted by change, and together designing social policies to facilitate a transition to a fair and sustainable built environment, taking steps to ensure unintended negative consequences are addressed quickly and fairly.

3

The built environment has a significant environmental footprint

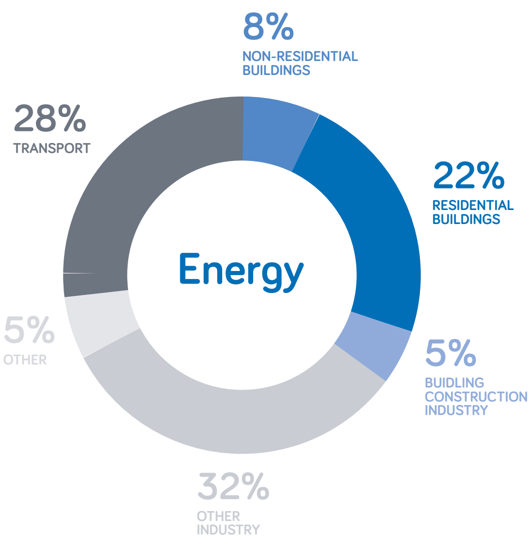
3 | The built environment has a significant environmental footprint

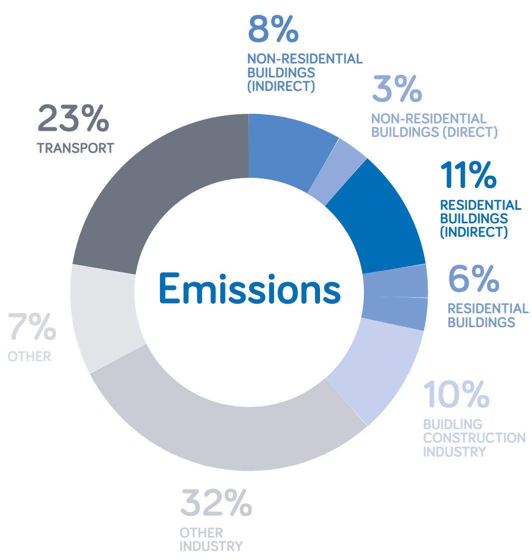
3.1 We must change the way the built environment is designed, built, maintained, operated, and regulated

By changing the way we build, operate, maintain, and adapt our built environment (7), we can take huge strides towards addressing the climate and biodiversity emergency and creating a society where all people have equal access to the material and social means necessary to live a flourishing life.

The Paris Agreement[1] requires limiting global warming to well below 2 degrees Celsius (°C), preferably to 1.5°C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas (GHG) emissions as soon as possible to achieve a climate neutral world by mid-century (8).

However, the most recent report from the United Nations Intergovernmental Panel on Climate Change suggests that inaction to date means that unless there are immediate, rapid, and large-scale reductions in GHG emissions, limiting warming to close to 1.5°C or even 2°C will be beyond reach (1). Rising sea levels, flooding, extreme hot weather, and droughts, resulting in water scarcity, food shortages, biodiversity loss and extinction, and increased conflict and migration, are all expected if we do not dramatically and rapidly reduce the GHG emissions released into the atmosphere (2) (9).





Adapted from Global ABC's 2020 Global Status Report for Buildings and Construction (7)

Currently, approximately 38% of global energy-related GHG emissions are attributable to buildings and construction. 28% come from operating buildings, including but not limited to their heating and cooling systems, electricity use and plumbing systems, with the other 10% coming from the materials used in their construction and maintenance (7). It is estimated that approximately 255 billion m^2 of buildings currently exist in the world, with an addition of roughly 5.5 billion m^2 every year, or a city the size of Paris, every single week (10). Rapid increases in floor area and demand for energy-consuming equipment and services are contributing to the growth of carbon emissions, outpacing emissions reductions gained from efficiency improvements and the decarbonisation of electricity and heat (7).

The environmental impacts of the built environment include not only GHG emissions from energy use but also material and resource use, the generation of waste, impacts on water systems, and harm to habitats, biodiversity, soil health and more (11). In many cities, the bulk of the raw material consumption and waste generation is associated with the construction and demolition of buildings (12). In the case of biodiversity loss (13), estimates show that between 1992 and 2014, produced capital per person doubled, but the stock of natural capital per person declined by nearly 40% (14).

The true environmental impacts of buildings, products and materials must be understood to drive proportionate climate action in a context of often conflicting factors, including finance, well-being, lifespan, operational and whole-life impacts.

Recommendations

We recommend that:

3.1.1 Governments, together with organisations, companies, and groups involved with and/or impacting the built environment, declare a climate and biodiversity emergency (if they have not already done so) and publicly commit to implementing inclusive and resilient climate action.[2]

3.1.2 Governments develop and commit to clear, consistent guidance for monitoring, reporting, and target-setting linked to the climate and GHG emissions associated with the built environment (15). This should cover national, sub-national and project levels, and provide guidance on key principles such as consumption and territorial emissions, and offsetting (16), with a warning that offsetting should be a last resort measure for hard-to-solve, necessary activities.

3.1.3 All legislation impacting the built environment, including but not limited to planning systems, building codes, regulation affecting finance and insurance, public investment, and procurement, enables and supports a trajectory for a net zero whole-life carbon built environment, including both new and existing buildings, and incorporates the design principles and other measures laid out in this document.

3.1.4 Ambitious near-term interim targets and milestones are set out on the route to zero carbon (17).

Building codes are implemented by governments to regulate the construction and operation of buildings to, among other things, minimise or control buildings energy use. Building codes can take many forms as the energy use of a building is dependent on many factors, including construction typologies, building fabric choices, and the operation and efficiency of heating and cooling systems (7).

Embodied carbon emissions of an asset are the total GHG emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset (155).

Operational carbon or energy is the GHG emissions arising from all energy consumed by an asset in-use, over its life cycle (155).

Whole-life carbon emissions are the sum total of all asset-related GHG emissions and removals, both operational and embodied over the life cycle of an asset, including its disposal (155)

3.2 We urge all governments to include built environment actions in their net zero plans

Nationally Determined Contributions (NDCs) are at the heart of the Paris Agreement and the achievement of our global long-term goals. NDCs outline national goals for GHG emissions reductions and embody efforts by each country to reduce national emissions and adapt to the impacts of climate change (18). However, at present NDCs are not on track to meet Paris Agreement goals (19). Even if all current Paris Agreement climate pledges are met, the world is still set to see temperature rises of about 2.4°C degrees by the end of the century (3).

Although almost all countries who signed up to the Paris Agreement have submitted their first NDC, many are yet to submit their second (20). The built environment lacks specific mitigation policies despite its important potential for reducing global carbon emissions. Just over two-thirds of NDCs mention buildings, but a significantly smaller proportion mention energy efficiency or building codes (21).[3]

Also, the NDCs currently submitted consider territorial emissions[4] rather than consumption emissions[5]. Taking a consumption-based approach captures direct and whole life cycle GHG emissions of goods and services (including those from raw materials, manufacture, distribution, retail, and disposal) (22). This approach allocates emissions to the consumers benefiting from those goods and services. Reporting emissions on a consumption-basis attributes responsibility to those driving the demand, rather than 'offshoring' (23) emissions, i.e. attributing them to those territories servicing the demand. Failing to account for the balance of net importers and net exporters of emissions (24) makes the context for policymaking less clear and promotes international inequality (25). These policies have led to embodied carbon emissions rarely being accounted for, meaning that opportunities for reducing emissions from the built environment sector have been missed.

For the built environment sector to be on a pathway to reach the 1.5°C Paris Agreement targets, we need all countries to include consumption-based emissions reduction commitments in NDCs, with specific, holistic actions for the building sector (21).

Countries that already have built environment sector actions included in their NDCs must show more ambition and ensure their efforts are compatible with net zero and science-based[6] goals (21). This means that building codes must tackle both operational and embodied emissions, with specific guidance for both new and existing buildings.

Recommendations

We recommend that:

3.2.1 Targets on consumption emissions are set to avoid shifting the burden of GHG emissions to high-production, low-consumption countries (21).

3.2.2 Specific, holistic, consumption-based built environment sector actions, which include science-based targets to ensure that the Paris Agreement target areas met, are included in NDCs (21).

3.2.3 Current built environment sector actions, for both new and existing buildings, included in NDCs are more ambitious to ensure that they are fully compatible with net zero and science-based goals, and help ecological and community flourishing (21).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4

Ambitious change in the built environment sector is possible

4 | Ambitious change in the built environment sector is possible

4.1 Together, we can harness the potential of the complex built environment sector

The built environment sector is a complex system with a fragmented value chain that spans many industries, government departments, regulations, and areas of concern and influence (26). Understanding how to effect change across different territories that interact through trade, culture and more is difficult but critical. A systems-based approach can overcome policy and procurement barriers and analysing the system can identify key areas for intervention, facilitating a step change towards regenerative development[7] (27) (28).

Mapping global trends and initiatives to reduce resource use and emissions can help to stimulate understanding, bridge transnational boundaries, and facilitate innovation (29) (30) (31) (32). Coordinated international action can accelerate the development and take-up of sustainable practices. Identifying viable technologies more quickly increases incentives for investment and scaling up.

International collaboration in policymaking also supports innovation and faster change by ensuring everyone is operating to the same standards and requirements so that first-movers are not held back by the constraints of competitiveness (33).

Retrofit is an integrated approach to transforming the energy and water needs and technical systems in our buildings and homes which requires quality in design, installation, and customer care (54).

The built environment sector should acknowledge the complexity of these issues by embracing interdisciplinary work and the farther-reaching intersections of action-oriented research and partnership. Better collaboration between the private sector, national governments, sub-national governments, and designers is required, and all parties should actively work to end harmful practices from the past (34) (35).

The sector's ability to effectively communicate with and genuinely involve all parties is critical in influencing project outcomes, maximising opportunities to break historical lock-in to unsustainable practices (36), and in creating good design solutions (37).

We should consider all aspects of the built environment, such as strategic planning (38), extensive urban greening (39) (40), food production effectiveness (41), land restoration and habitat conservation (42)(43). Projects of all durations are important, with temporary projects presenting further opportunities to innovate and make effective use of space (44).

“A systems-based approach can overcome policy and procurement barriers and analysing the system can identify key areas for intervention, facilitating a step change towards regenerative development.”

Recommendations

We recommend that:

4.1.1 Fundamental assumptions about why and how buildings and cities are commissioned, designed, and used are reassessed, with wellbeing and environmental impact prioritised above short-term economic gain (45) (46). National interests should collaborate to review and align all policy, regulation, and legislation impacting the built environment.

4.1.2 Platforms (for example, industry-specific climate assemblies (47) (48) comprising built environment sector actors, policymakers, and representatives of civil society) are created to develop a policy and regulatory landscape that facilitates change across the sector at the scale and speed required. These platforms should be designed to help overcome lock-in to orthodox practices and policymaking by introducing new people and players to focus on carbon-saving opportunities and create a more dynamic exploration of approaches (36).

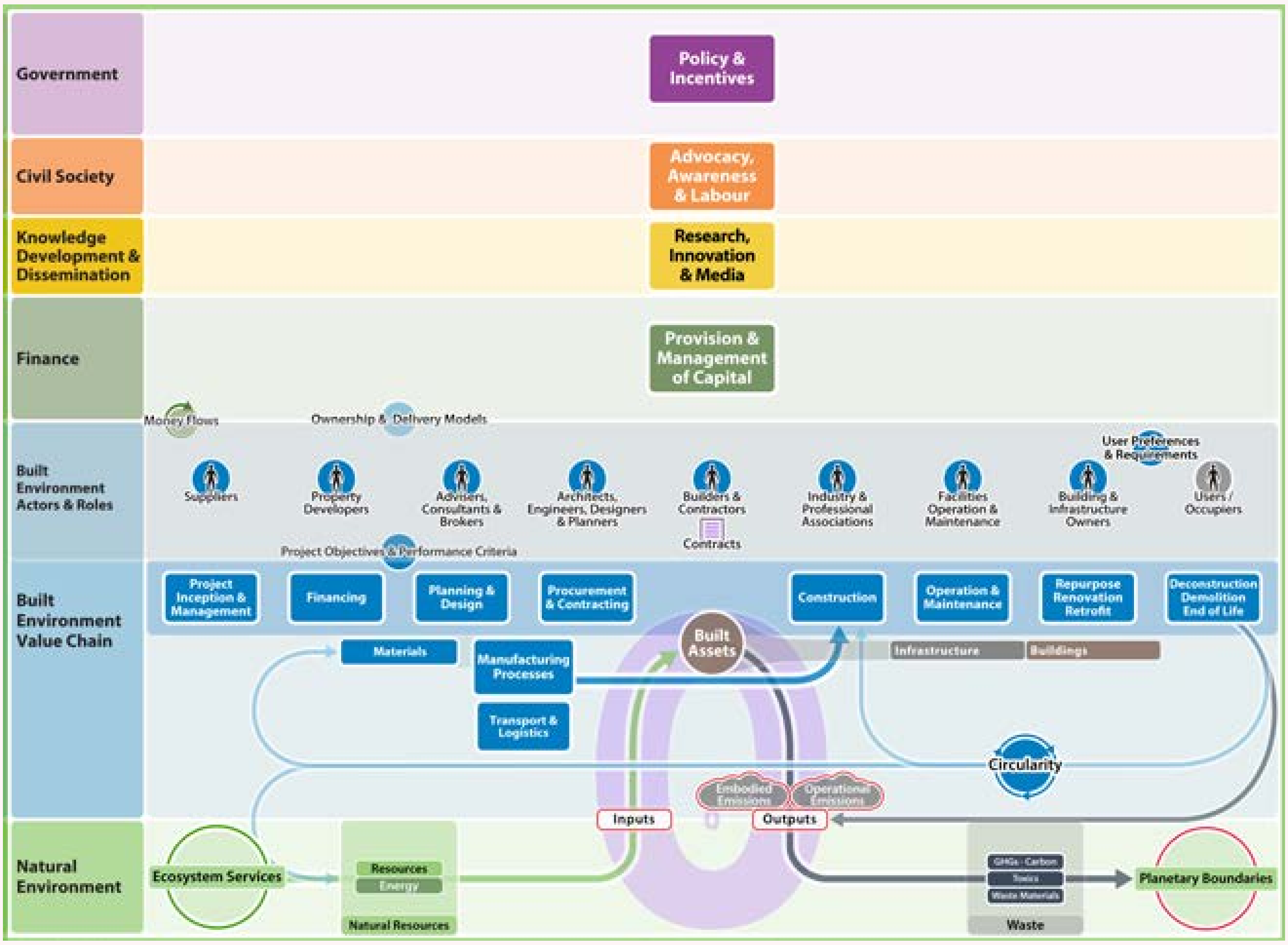
4.1.3 National transition plans such as national roadmaps (49) (50) are developed (51) and reviewed frequently. These national transition plans should be implemented by adopting robust policies that take explicit account of the major emitting sectors. These plans should also include complementary arrangements for related sectors (such as infrastructure, energy, and transport (52)), and take into account both demand drivers (such as population growth, increasing affluence in some parts of society, desire for real estate investment opportunities, increases in energy-consuming services, etc) as well as reduction targets to ensure an absolute (not only relative) reduction in environmental impacts.

4.1.4 Strategies for national-scale technical changes and infrastructure deployment (such as retrofit programmes (53) (54) and circular economy infrastructure[8]) are based on detailed mapping, modelling, prioritising, and implementing (55), allowing barriers to change to be unlocked.[9]

4.1.5 Strategies for planned public investment in emerging and low-carbon technologies, informed by industry-led research and recommendations, are developed, and implemented. Funding will be required to pay for new actors and processes to join existing supply chain networks (36), research and development, market creation for near-zero emission technologies, support for demonstration projects, and worker reskilling (56) (57). This will give direction to the built environment sector and encourage private investment in, for example, equipment and processes for recovering and reconditioning products and materials and active transport, among others (58).

4.1.6 Public investment in moving to a sustainable and equitable built environment should be proportional to the scale of the emergency, and not limited by arbitrary factors such as self-imposed short-term borrowing limits.[10]

> National transition plans such as national roadmaps should be developed and reviewed frequently. These should be implemented by adopting robust policies that take explicit account of the major emitting sectors.



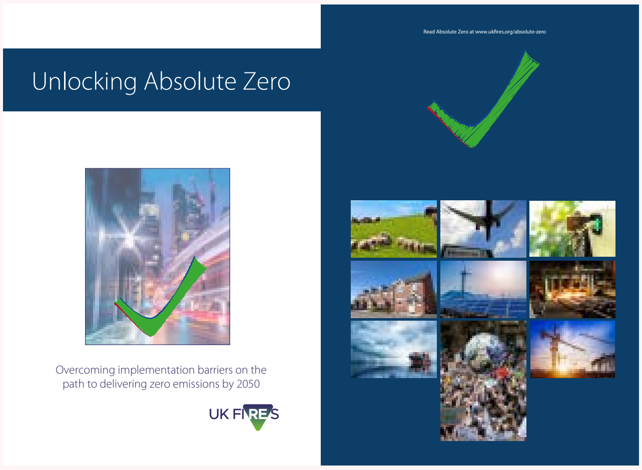
Race to Zero Built Environment System Map, created by the UN Climate Champions team, Laudes Foundation and Nexial

Case study
Race to Zero Built Environment System Map (28)

The Race to Zero Built Environment System Map is a digital platform that enables radical collaboration for system change. It is an interactive space for policymakers, businesses, investors, innovators, and citizens alike to explore and visualise their individual and collective roles in the transition to a net zero built environment. The platform was co-created by the UN High-level Climate Action Champions and a cohort of built environment experts.

The map provides different views of the built environment value chain and was designed to stimulate more insightful conversations about where and how the system needs to change.

The built environment system is complex and dynamic with multiple stakeholders – fragmented yet interdependent. A common understanding of the value chain can enable each of us to find value and opportunity in taking action.



Unlocking Absolute Zero

Case study
Unlocking Absolute Zero (36)

Reaching the UK government's legally binding commitment of net zero carbon requires unprecedented change in society and industry. In its latest technical report, UK FIRES examines the process of industry-wide change and the sources of lock-in that inhibit change. The Unlocking Absolute Zero report presents a simple model for lock-in and applies it to case studies across multiple industries. By examining the organisation of production and the associated network of interactions, the model reveals the structural difficulties a firm or sector can face even when all stakeholders are willing to change. It provides valuable guidance to industry leaders responsible for the process of change and seeks to pre-empt the various potential modes of failure.

LETI, London Energy Transformation Initiative

Case study
London Energy Transformation Initiative (LETI) (263)

LETI is a network of over 1,000 industry professionals that volunteer time and expertise to set out how the built environment can tackle its contribution to the climate crisis. LETI shows what is possible when professionals unite behind a critical cause to stimulate change.

Ongoing workstreams include retrofit, embodied carbon, building codes, client guidance, and a pioneers group that commits to sharing information on successes and lessons learnt. One of its most significant outputs so far has been the LETI Climate Emergency Design Guide, which outlines the requirements of new buildings to ensure climate change targets are met. As well as the LETI Climate Emergency Retrofit Guide, outlining the how existing homes need to be adapted to meet UK climate targets. They set out a definitive path to a net zero carbon future. The guidance is aimed at developers, landowners, designers, policymakers and the supply chain, and looks to redefine 'good' with clear and achievable targets.

4.2 Together with governments, we can scale up and speed up change

Well-designed environmental regulations are effective in encouraging innovation, creating new jobs, providing upskilling opportunities, and helping to meet legal environmental targets (59). For the built environment, these should centre around thoughtfully designed and robustly enforced planning systems and buildings codes and extend to a range of national and sub-national policy tools (31) (60). Regional specific policy, informed by local expertise and insights, can align effectively with other intersecting priorities to yield maximum benefits. Sub-national governments, including cities and regions, can accelerate the transition to a decarbonised economy and more resilient, more equitable outcomes.[11]

As well as legislation, regulation, and standards, governments are able to create change in various ways, including with public investment, physical and digital infrastructure, setting ambitious standards for public procurement (61) (including increasing the credibility of voluntary standards), facilitating cross-sectoral collaboration, environmentally aligned tax mechanisms, and more (26). Scaling up and replicating best practice in the built environment requires a systems approach, which may include introducing new actors to the system and/or new processes.[12] Governments can accelerate these shifts by investing in and directly procuring these new actors and processes.

There is relatively little research on the climate change implications and adaptation measures for buildings (62). This is worrying given the size of the sector and the importance of climate adaptation for the built environment. Most research focuses on problems related to increasing temperatures, neglecting the implications of climate change and the consequential adaptation measures needed in cold climates and for the increasing severity and incidence of extreme rain or wind events. In addition, there are not enough studies based on physical experiments. This should be a key area of focus for government investment.

Governments, alongside sub-national governments, businesses, and other organisations have made ambitious commitments to carbon reductions,[13] however these commitments must urgently be followed up with ambitious, collaborative actions.

Recommendations

We recommend that:

4.2.1 Environmental legislation is progressive, regionally specific, and cross-sectoral, and enables technological development, business planning, and the development of implementation mechanisms (59).

4.2.2 Grants, tax incentives, and the removal of structural barriers and misaligned incentives are used to prioritise sustainable design and facilitate the development of low-carbon future infrastructure, including initiatives such as community energy schemes (63), electric charging, and active transportation (64). This should include funding from national to sub-national governments to facilitate rollout of schemes and initiatives such as mass retrofit.

4.2.3 Green finance initiatives are piloted and implemented rapidly to facilitate decarbonising and reducing the energy use of existing building stock. Initiatives might include national district heating investment funds (65) that facilitate public investment, community climate bonds (66) to facilitate private and community investment, and salary sacrifice platforms (67) that provide tax-efficient mechanisms for individual employees while aggregating demand, inspiring confidence in the supply chain.

4.2.4 Innovation funding, granted exclusively on its potential to meet climate and biodiversity goals, is used to help to create open-source workflows, tools, and software to facilitate a sustainable built environment, and to fund climate adaptation measures, an area that is in urgent need of more research (62).

4.2.5 Apprenticeships, later-life education, and skills guarantee schemes are well funded and accessible to all (68).

4.2.6 Stop-start funding cycles, which have negatively impacted the sector in some countries to date, must end.[14]

4.2.7 Industry-leading standards are agreed for publicly procured projects, and publicly funded buildings to help to encourage wider change by using Green Public Procurement principles (69).

4.2.8 Physical and digital infrastructure is created to facilitate the adoption of circular economy principles throughout the built environment to include the recovery, storage, sorting, and redistribution of salvaged materials (56). National circular economy strategies should be publicly funded alongside other national infrastructure.

4.3 Together with all who are impacted and involved, we can make a transition to a fair and sustainable built environment

The shift to a sustainable built environment and, indeed, the economy as a whole, must be inclusive and equitable (70) (71).

Built environment projects that draw on participation from local groups and communities can nurture social, ecological, and human development as well as meeting decarbonisation goals. However, it is important to acknowledge that the transition to an environmentally sustainable, climate-neutral economy is not socially inclusive by default. Employment and social policies, developed with the involvement of those impacted, are therefore key to supporting the transition (68)

The reframing of urban planning priorities based on equity, climate, and returning land to nature helps to meet sustainability and social justice goals (72). Designers can use design toolkits to make positive change in urban environments and can set good and clear development targets by defining actors' key roles (73) (74).

Participatory planning and user-led design processes make it possible to design schemes that meet carbon targets more effectively because they are site-specific and sensitive to diverse social needs (75). Built environment projects that draw on participation from local groups and communities[15] can nurture social, ecological, and human development as well as meeting decarbonisation goals.[16] This is one of the proposed UN principles for ecosystem restoration[17] (76).

With the right design and management, urban spaces can increase community and ecosystem resilience to future climate challenges. Crucially, measures for climate adaptation should be developed in parallel with those for climate mitigation (77) (78). This includes arranging for cooperative custodianship by using transparent procurement and investment policy safeguards (79). It also means designing to include cool spaces to mitigate rising heat stresses[18], integrating sustainable urban drainage to reduce flooding (80), developing strategies for occupants and local communities to use spaces during emergencies, and designing contingency systems in the event of infrastructure, utilities and other systems failures (77). There is great potential for the use of nature-based solutions in response to these design challenges (81) (82).

Procurement processes can also be used to require all in the supply chain to consider social value and contract award criteria can include factors such as community cohesion, health and wellbeing, access and inclusion, social sustainability, innovation, and resilience (83).

Recommendations

We recommend that:

4.3.1 Governments enable open and free access to information about land ownership and control and compile a register of vacant and underused spaces, as well as shared access to collective resources (84). Built environment projects should contribute to these systems by reporting on the ownership and adaptive reuse opportunities associated with building works.

4.3.2 Governments mitigate unintended negative consequences for the wider community by developing legislation that ensures changes made to the built environment are equitable. This can be achieved by requiring equity and social justice risk assessments, quality management processes, and ensuring genuine involvement in the development from members of communities impacted by the project.[19] For example, legislation must prevent the extra production costs associated with environmental measures being passed on to building tenants and users.[20]

4.3.3 Governments develop employment and social policies to support the transition to a sustainable and regenerative[21] built environment. Social partners should be involved in the design and implementation of transition measures (68) and policies should explore job guarantees (85), skills guarantees, and income guarantees for those impacted, such as workers in carbon-intensive industries (85).

4.3.4 Governments revise planning systems to prioritise participatory planning and community engagement (48) in a way that accounts for occupancy rates (56) and adaptability, and uses specific local knowledge to create developments that meet local needs (15).

4.3.5 Projects are facilitated through planning systems so that communities can realise the social and environmental benefits of making use of vacant spaces. Efforts should be made to support new communities and to allow temporary projects that have flourished to continue.

4.3.6 Emergency plans are widespread and all communities have access to climate resilient buildings during emergencies (including pandemics).

4.3.7 Social value requirements are embedded in all procurement processes relating to the built environment (86).

4.3.8 Procedures for conducting ecological restoration are expanded beyond discrete habitat areas considered critical, to conserve and sustain those ecosystems and the livelihoods of those that depend on them. Restoration should be based on clear principles that integrate science, communities, industry, and land management, and as such inform land negotiations.[22]

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5

The built environment has the capability to transition to a sustainable future

5 | The built environment has the capability to transition to a sustainable future

5.1 We can maximise the value of existing structures

Built environment professionals can meet communities' needs in a variety of ways (87). This will sometimes entail the construction of new buildings, with their associated carbon impacts. However, there are other ways, and built environment professionals are well placed to offer strategic advice on what they might be. For example, existing built assets can be optimised, and both existing and emerging policy and design approaches can facilitate broader and more equal access to built assets (15) (88).

Possible approaches include restoring, adapting, or repairing existing buildings and structures (89) (90). People working in the built environment sector are beginning to prioritise these approaches wherever feasible in a way that delivers meaningful carbon and community benefits (91) (92) (93). Adopting these approaches can improve quality of life, deliver more homes, and retain cultural heritage and community ties as well as avoid carbon-intensive and costly demolition and rebuild processes (56) (94). A 20% reduction in demand for new buildings by using existing structures better could save up to 12% of global emissions in the building and infrastructure sector (15).

Buildings' lifespans can be prolonged by designing them so that they can be easily repaired, for example, by using modular components, designing for disassembly, (56) making use of extended producer responsibility agreements,[23] and by ensuring smart, performance-based maintenance schemes and facilitating occupier participation in building management (95).

Built environment professionals can recognise opportunities to increase the adoption of low-carbon retrofit (94) (96). Retrofit schemes are not only achievable but can significantly reduce embodied carbon by extending building lifespans.

Our built environment must also be cared for to ensure that it remains safe under rapidly changing climatic conditions.[24] Nature-based solutions (82) and traditional ecological knowledge, wisdom, and technologies (97) like sustainable urban drainage systems, green cover, natural flooding of rivers, native landscaping and more can be used to manage material flows and climate challenges such as flooding (98), overheating (99), ecosystem damage (100), and water usage[25], while also helping local ecologies and communities to flourish (40).

Building codes, planning and permitting rules, and best practice guidance can be successfully rewritten to encourage more sustainable approaches to construction (101). They can require project teams to think strategically about climate adaptation and resilience and move away from an assumption that new buildings and materials are the preferred solution, including for informal settlements. These regulations, rules and guidance should be regionally specific, accounting for local climate conditions, local policy mechanisms and structures, and specific community needs. Policy should encourage collaborative approaches across the sector, including between local officials, community representatives and design teams.

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Recommendations

We recommend that:

5.1.1 Information on derelict and vacant building stock is collected, held, and made available to encourage adaptive reuse of existing structures and clear zoning plans, (72) both of which should accommodate local priorities and the needs of existing communities.[26] Projects should prioritise the reuse of existing spaces first, guided by the principles of environmental stewardship and protection of the local community.[27]

5.1.2 Financial and non-financial mechanisms include incentives for owner-occupiers (102) and private landlords to improve existing building performance through low-carbon retrofit (53)[28], for example emphasising real long-term asset values and by using tax levies that penalise carbon-intensive new building and the use of virgin resources.[29]

5.1.3 Climate risks and requirements for building adaptation measures are integrated into building codes, regulations, and standards. Guidance may include performance-based standards (to make revisions easier following climatic shifts), methods for assessing potential impacts of climate stresses (77), and recommendations on adaptive pathways planning.[30]

5.1.4 Natural solutions, ecosystem restoration (103) and traditional ecological knowledge, wisdom, and technologies are integrated into building codes and planning requirements. These should be developed through fair knowledge shares and engagement with relevant communities, ensuring that cultural context and implications for these communities are included.

5.1.5 Definitions of listed or protected buildings are reformed to disincentivise demolition and instead encourage maintenance, energy retrofits, and structural refurbishment of existing buildings. These definitions should incorporate guidance developed in collaboration with local residents (104), and should consider the particular needs of heritage buildings (105) with protected façades and aging structures where retrofit is often most needed but also particularly challenging.

5.1.6 Demolition permits are used to ensure that adaptive reuse is promoted in preference to demolition and rebuild wherever feasible. Rules in connection with these permits can prohibit demolition where buildings remain structurally sound (unless a whole-life carbon benefit from demolition can be demonstrated) (56) and require feasibility studies to show that the potential for retrofit has been thoroughly explored (56) and audits to identify what materials can be reused. There is also the possibility of charging more for demolition permits (56).

5.1.7 Building renovation passports[31] are made the norm in planning processes to track the history of structures and spaces and their potential for adaptive reuse.

> “Projects should prioritise the reuse of existing spaces first, guided by the principles of environmental stewardship and protection of the local community.”

Hassell

Case Study
Colma Creek, California, USA: climate adaptation planning (98)

The Colma Creek Climate Adaptation Planning project brings community and experts together, creating a brighter future for a neglected urban waterway in South San Francisco, using storytelling to engage future custodians. The aims are to manage flooding, restore ecology and access to the San Francisco Bay waterway, and build environmental stewardship. As well as enabling native creek ecologies to thrive, the project connects people to, and along, the creek. The project will restore up to 30 hectares of native ecology, sequester over 3,000 tonnes of carbon, consume 85% less water than a typical lawn in Northern California, and supports a 20% shift to cycling for trips under 5 miles (8 km) within the city.

The Colma Creek Climate Adaptation Planning project includes an adaptable toolkit for use by local communities, government, relevant agencies, and other San Francisco Bay Area communities that face similar challenges. It outlines various opportunities, options, solutions, and methods for adapting to sea-level rise and flood risk.

The toolkit divides the creek into character areas (defined by the varying shape and width of the channel and existing conditions nearby) and explores a comprehensive catalogue of nature-based adaptation options. Each proposal is assessed against the project's key principles (water, ecology, and access), as well as cost and construction impact – enabling choice of appropriate, effective, and flexible solutions at each location. This modular system means the toolkit can be applied to other Bay Area creeks and communities, offering a versatile framework for improving resilience throughout the regional creek network.

Integrated Environmental Solutions, IES

Case study
Eday, Scotland, UK: digital twins for strategic planning (63)

A digital twin is a virtual representation that serves as the real-time digital counterpart of a physical object or process.

Digital twins can be used to minimise waste or excess wind generation, improve building efficiency, and create a Zero Energy Community. On the Orkney island of Eday, digital twins and community surveys were used to determine ways to reduce the community's reliance on grid imports using retrofit, integrated renewable generation, and sensor controls. It was found that a Community Net-Zero status could be won with a combination of retrofit measures achieving energy savings of 76% and eliminating fossil fuel consumption on the island by relying on the existing wind turbines and a community battery. The project would pay for itself in 5.6 years, or even sooner if homes were found to be eligible for retrofit funding under schemes such as the Energy Company Obligation (ECO) scheme.

The project demonstrates that advanced digital twin simulation technology and deep engagement with communities are a viable route to solving multiple problems without building.

© XVW architectuur

Case study
Kleiburg, the Netherlands: retrofitting the old to create new affordable housing (92)

XVW Architectuur's Kleiburg project is an exemplar of retrofitting housing stock on a major scale – in this case a 10-storey, 400-metre-long modernist building in Amsterdam comprising 500 apartments. Delivered on a tight budget for a developer, this affordable housing model acknowledged the existing structure's embodied carbon and delivered social value.

The 1960s building sits within a masterplanned urban extension for 100,000 residents. Dilapidated and set for demolition, protests led to a competition calling for an economically viable plan for its renovation.

XVW's winning proposal centred on how individuals experience the building in everyday life and created a new affordable housing model: a do-it-yourself concept enabling people to purchase, renovate and fit out units for themselves.

Ongoing collaboration with the developer and residents engendered a new way of working, yielding economic benefits for all, and both environmental and social value.

The scheme minimised additional carbon loads by retaining and strengthening structurally sound areas (the concrete structure and floorplans) and carrying out targeted improvements to problematic areas (the ground floors, lifts, and circulation spaces).

© Buro Happold

Case study
Mayfield, Manchester, UK: delivering a new urban neighbourhood (100)

The Mayfield project in Manchester recognises the potential of existing environmental assets on an urban site to yield meaningful environmental benefits. The park will deliver a 90% net gain in biodiversity including 28 specific habitat features for protected and priority species, including bat boxes, bird boxes and invertebrate refugia.

U+I is working with Studio Egret West, Allford Hall Monaghan Morris, and Buro Happold to restore degraded ecosystems to improve the resilience of human habitats against climate change with nature-based solutions. Doing so will also improve the resilience of non-human habitats and the species that depend on them by providing new food sources, resting places, and connections, all within a major city.

The project exploits bioengineering techniques to manage natural flooding. It proposes to partially remove existing brick-built river walls to allow riparian species to be re-introduced to this stretch of the river. Also, artificially high levels along the river will be lowered in places to allow flooding during high rainfall events, creating a 'wildscape' area that mitigates the impact of flooding more successfully.

Planting with native species, and providing habitat features for wildlife will create attractive, multifunctional spaces for people and wildlife. The large new area of green space and opening up the river will help to reduce the urban heat island effect. Overall, the new park will be an important resource for the local community by increasing access to nature within an otherwise densely developed part of the city.

5.2 We can decarbonise building materials and construction

It is the embodied carbon emissions of most new buildings created between now and 2050 that will be more significant than those emissions released through energy use during the building's lifetime (107). This is why the built environment sector has turned its attention to reducing whole-life carbon emissions (108). Architects and engineers are increasingly calculating embodied carbon as an integral part of the design process. Industry groups are working to lobby regulatory bodies (109), to align their scope, targets and methodologies (110) (111), and to factor embodied carbon into awards and prizes (112).

Lean design techniques and structural innovations are being used by designers to reduce the volume of materials used in new buildings (15). This means reducing excess structural material, often driven by overly conservative building codes and overspecification by designers and engineers. This does not reduce the size of the structure but reduces the amount of material used to construct it. Techniques include ensuring the building isn't overdesigned for its purpose, using accurate structural loading and design criteria, and optimising the use of the structure in the design (113). Designers can also ensure that the building's form factor[32] reduces embodied carbon, and experiment with different options to minimise the façade's carbon impact (114).

The built environment sector is also able to draw on circular economy principles to reduce rates of extraction and disposal of materials for building projects (115). This means reusing materials, components, and structures during construction (116) and fit-out (117), and ensuring that at the end of a building's life, the materials that made it up can be reused, all of which adds value to materials already in use. Crucially, the sector is developing methods to reuse materials for their original application rather than 'downcycling' to low-grade applications like fill and aggregate. To this end, projects are integrating demountable components into designs (118), treating and reprocessing used materials, including timber (119), and using BIM-integrated technologies to identify reusable materials and parts at the end of a building's life (120).

Natural and bio-based materials are being used by the built environment sector to help displace petrochemicals, reduce embodied carbon and improve quality of life (121) (122) (123). For example, for every 100,000 homes built from timber, over 1 metric tons of carbon dioxide equivalent ($MtCO_2e$) of carbon is stored (121). Deliveries linked to the construction of those homes and their associated congestion and air pollution reduce by half, and local ecosystems flourish (15). Existing projects have been successfully built with timber, hemp, earth, cork, bio-plastics, cob, and more. These projects are being delivered at mass scale, for a wide range of building typologies, often without major changes to well-established construction techniques (124). Sustainable accreditation systems like EU Ecolabel (121) assess products' life cycles, embodied carbon, pollution potential, and resource efficiency, and stipulate rigorous laboratory testing for Volatile Organic Compounds (VOCs) and other harmful substances.

Off-site fabrication and 'flying factories' are able to reduce waste and maximise material efficiency (125). Because work is carried out in quality-controlled factories, off-site fabrication also improves the health and wellbeing of builders and those who eventually occupy the resulting buildings (126). Construction sites are rapidly decarbonising, with electric and battery storage technologies enabling quiet, smart, and low-carbon site processes (127).

Regulations, building codes and planning guidance can be reformed to accommodate bio-based and reused materials, encourage material recapture and reclamation,[33] and incorporate lean design techniques. Doing so would help to dispel misconceptions about durability and safety of low-carbon design strategies, encourage best practice design standards, and change minds across the built environment sector.

Recommendations

We recommend that:

5.2.1 Embodied carbon is regulated through building codes, requiring design teams and clients to consider alternative design options (108). This should include mandatory, regulated life cycle assessments linked to verified international accreditation systems and mandatory minimum benchmarks. A consistent and clear approach is needed within nations, if not internationally, with interoperability between reporting tools (128). This might include details of how buildings will be disassembled, and materials recaptured to save embodied carbon in the future, opportunities taken to improve structural efficiency, and feasibility studies on alternative structural frames and systems (45).

5.2.2 Standards for the reuse of materials are added to building codes and planning requirements. This could include a minimum recycled content in materials, a minimum percentage of reused fabric within buildings, and limits on the final raw material intensity of buildings, measured against internal floor area (110). Regulations should include informal settlements, prioritising locally available, affordable materials and reclamation of materials already in use.

5.2.3 Research into best practice structural design efficiencies, provided they are safe and capable of being built safely, are incorporated into design and building codes. This should include guidance and metrics about structural mass and efficiency, utilisation ratios, serviceability limit states, and loading factors (56).

5.2.4 Standards for mass timber[34] and other bio-based materials are added to building codes. This should include certification standards (56), standards for fire and life safety, and grading and strength classes (129). All standards should be developed in collaboration with local insurers, real estate practitioners, designers, and timber sourcing specialists to ensure that the resulting codes are specific to the relevant material, and will encourage sustainable sourcing and use (121).

5.2.5 Planning authorities have carbon budgets that limit the total amount of embodied carbon they can approve each year[35], which should incentivise project teams to adopt strategies to reduce embodied carbon. Budgets should be set and reviewed through fair processes that consider local needs and regional and national carbon budgets.

5.2.6 Planning systems are reformed to facilitate circular economy principles, for example to allow changes and variation in the exact material palette, detailing, and dimensions so that project teams can make use of reclaimed materials.

5.2.7 Permissions for below-ground developments are only granted if a feasibility study (including a whole-life carbon assessment (130)) has been carried out that shows that below ground proposals can be justified on environmental grounds (110).

5.2.8 Locally-specific product certifications and bans on products that have a damaging impact are integrated into planning policy, and development zones that require tighter environmental standards are established. For example, certification standards could specify the use of particular materials or construction techniques (56).

5.2.9 All construction machinery is required to produce zero GHG emissions (with public subsidies to make this possible (131)) except by special permit (with permissions of this kind to be phased out over a defined period) (132).

> The embodied carbon emissions of most new buildings created between now and 2050 will be more significant than those emissions released through energy use during the building's lifetime.

Case study
Pondicherry, India: Sharanam Centre for Rural Development (133)

Built in a rural landscape that has been ravaged ecologically, socially, and economically by illegal quarrying, Sharanam Centre supports the affected village communities with pioneering development, health, education, and poverty alleviation programmes. Hand-built from earth, the low-carbon campus comprises vaulted halls, meeting spaces, offices, gardens, and community facilities integrated into a revitalised five-acre site.

Comparative studies convinced the client, communities, and funders to commit to contemporary low-carbon construction from earth with minimal cement and steel. Optimised self-supporting techniques reduced material extraction and costs by half.

The buildings are constructed from the earth from the site: rammed foundations, earthen finishes, and exposed fabric and structure in unfired, sun-cured earth blocks (stabilised with 5% cement) possessing one-tenth of the embodied energy of fired bricks.

Reclaimed hardwoods, local granite and re-usable precast components further reduced the embodied carbon. Nothing was wasted: sieved pebbles from the earth formed flooring finishes, and excavation pits were used to harvest rainwater. A local drip system was revived, reducing irrigation water requirements by 75%.

© Henning Larsen Architects

Case study

Feldballe Independent School, Denmark: bio-based materials reducing the carbon footprint (134)

With a focus on bio-based building materials, the design for an extension for the Feldballe Friskole in Denmark responds to the school's goal of preparing future generations of thinkers, leaders, and community members committed to creating a more sustainable world.

The result is an extremely low carbon building using straw bale construction, a technique that uses tightly compressed organic materials in wooden cassettes that can last for centuries provided they are properly installed. The whole-life carbon cost of the building is less than 150 $kgCO_2e/m^2$.

Once constructed, the airtight straw layer is long-lasting and surprisingly fire-resistant. The straw is packed densely, and manufacturer EcoCocon's fire tests show that, without oxygen to feed the fire, it can withstand flames at 1,050°C for over two hours.

The straw insulation is packed densely enough to keep warm air in yet permeable enough for humidity to escape, creating a healthy and comfortable indoor climate, with estimates suggesting a saving of 1 of tonne CO_2 per year on heating and cooling. Straw sequesters carbon, and retains it for the lifespan of the building product. At the end of its life, it can be safely composted.

Overall, the extension contributes to a healthy environment locally, a central tenet of the school's educational program.

© Forbes Massie

Case study
London, UK: Black and White Building

The Black and White building is a six-storey office building in Shoreditch, East London. Designed by Waugh Thistleton Architects in collaboration with Structural Engineers Eckersley O'Callaghan for The Office Group.

This fully engineered timber office building sets a clear sustainability agenda with only 477kgCO_2e/m^2 embodied carbon (A1-A5 excluding sequestration, LETI Rating: C). Each component has been designed to be as efficient as possible and low embodied carbon has been a priority for every design decision.

Designed to offer flexible, shared workspace, the building has a hybrid structure comprising a beech Laminated Veneer Lumber frame with Cross Laminated Timber slabs and core to create large open workspaces. With no structural internal partition walls and the building services carefully co-ordinated to minimise visual intrusion, the layout can be easily adapted as needs change in the future.

The timber structure is framed by the glazed curtain wall, with solar shading provided by a second skin of vertical timber louvres. A parametric model simulating the movement and impact of the sun against the façade determines the layout and form of the louvres, demonstrating how timber, combined with cutting edge digital analysis can result in a high-performance low-carbon 21st century building.

5.3 We can reduce the energy required to operate new and existing buildings

The built environment sector is able to retrofit existing buildings so that they consume less energy at a mass scale (135) and can deliver new buildings which minimise operational energy (136) (137). The sector is currently producing low or zero energy demand buildings for a wide range of projects, including in bespoke leisure facilities (138), aging social housing (96), traditional properties (139), and integrated into structural refurbishments (91). Projects are taking place in both formal and informal settlements (140).

Exploiting passive design features like building orientation, overhangs and shading, insulation, double- or triple-glazing, and thermal mass can greatly reduce buildings' energy demand (141) (142). This can be supported with user-friendly controls (143) and smart metering.

Passive design techniques can be coupled with solar panels, heat pumps, and energy storage on new and existing sites to deliver exceptionally low or negative annual energy costs and net zero operational emissions (144) (145) (146). Design options are location specific – for example, the efficacy of solar panels will depend on daylight and sunlight levels, while their relative contribution to emissions savings will depend on the existing grid's carbon factor. District-scale schemes complement building-scale schemes for maximum, cost-effective energy savings (147).

Buildings sometimes do not perform as well as modelled during the design process, which is known as the performance gap. To close this gap, the built environment sector has created 'design for performance' tools (148) to better plan for supply chain and operating factors, measurement and verification protocols to validate as-built quality, and post-occupancy evaluation (POE) methodologies that enable designers to gather feedback[36] from performance in use (149). The data collected through POE is also being used to improve predictive energy modelling through verification and comparison in use (150). Certification systems for POE are becoming more widely used and recognised(151).

A holistic approach to building energy use can be taken to account for the energy (and its associated emissions) consumed by occupants (for example, in having showers and using electrical appliances and installed systems) that is routinely excluded from consideration in building codes and standards. Design teams can specify products and building management systems that control or minimise total building energy use and incorporate all loads into building management systems.

Operational energy use benchmarks, guidance and standards are being developed and implemented across the world, stimulating demand, motivating landlords, and ensuring supply chain investment (67). It is crucial that momentum continues to build, with policies and regulations made consistent internationally and within policy frameworks. Regulations and standards should apply to both domestic and non-domestic buildings, across formal and informal settlements (29).

Countries that currently lack building codes are predicted to build two-thirds of the buildings that will be constructed between now and 2050 (29). Therefore, it is crucial for these countries to introduce building codes that set a trajectory for a net zero whole-life carbon buildings.

A net zero carbon – operational energy asset is one where no fossil fuels are used, all energy use has been minimised, it meets the local energy use target and all energy use is generated on- or off- site using renewables. Any residual direct or indirect emissions from energy generation and distribution are offset (155).

A net zero (whole life) carbon asset is one where the sum total of all asset related GHG emissions, both operational and embodied, over an asset's life cycle are minimised, meet local carbon, energy and water targets, and with residual 'offsets', equals zero (155).

> Passive design techniques can be coupled with solar panels, heat pumps, and energy storage on new and existing sites to deliver exceptionally low or negative annual energy costs and net zero operational emissions.

Recommendations

We recommend that:

5.3.1 In-use operational energy performance of both existing and new buildings is covered by regulation by ensuring the scope of mandatory building codes includes building renovations (for example, only permitting extensions to buildings if the energy performance of the whole building is improved) (152), requiring upgrades to building codes for targeted building types regardless of whether they are undergoing extension and/or renovations,[37] and mandatory energy standards and labelling (153). Energy performance requirements must consider moisture control (154) for different climates and building types to avoid unintended negative consequences.

5.3.2 Clear methodologies for accounting for emissions and a definition (155) of 'net zero' are set out in building codes (156). These should include principles related to carbon removals, energy purchasing models, and offsetting.

5.3.3 Operational energy targets and benchmarks are developed, seeking to reconcile design with as-built performance. Feedback should be gathered from buildings in-use to prioritise the targeting of performance in-use and ensure that buildings perform as designed i.e. to close the performance gap. This will help to maximise the value of investments and encourage faster innovation cycles (157). The process should include fabric performance standards that incorporate airtightness, overheating, thermal comfort, thermal bridging, and technical systems performance. Energy labelling for all buildings, new and existing, should be validated with measured performance, which is recorded and shared to inform targeted strategies for further decarbonisation.

5.3.4 All possible emissions sources are included in regulations and standards (108). This means in-use energy and carbon from all influential sources, including those which are typically avoided or excluded from standards, such as plug loads (TV's, fridges and cookers etc).

5.3.5 Renewable technologies, smart metering, and user-friendly controls, together with passive techniques for delivering exceptionally low or negative annual energy costs are promoted in regulations, guidance, and benchmarks, with the whole-life financial and carbon costs adequately planned for (158).

5.3.6 Building codes require the integration of energy generation as part of all building development projects unless a whole-life carbon assessment shows that the project is carbon negative (130), or robust power purchase agreements[38] are adopted. Regulations should specify accompanying sub-metering and other design techniques that help to minimise operational emissions. Options should include off-site contribution mechanisms and community-scale or district schemes.

5.3.7 In-use monitoring and post-occupancy evaluation are required in building codes, with data made publicly available through harmonised reporting protocols so that the findings can be used to inform future design. New policy or reforms to existing policy should shift regulations to focus on the actual, in-use performance of buildings (157).

5.3.8 Health and wellbeing metrics – such as thermal comfort, indoor air quality and daylight – are included in building codes.[39] In-use verification of buildings should also ensure projects satisfy users and meet their requirements, with the data fed back into new projects (159).

5.3.9 Certification and accreditation systems are updated to align with fast-changing industry best practice in relation to regulated emissions, low or no energy demand intensity benchmarks, and net zero operational emissions. Updates should ensure that high certification ratings are only achievable with low energy consumption and low whole-life carbon emissions.

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Case study
REBUS (Renovating Buildings Sustainably), Denmark: Low-carbon energy retrofitting strategy for social housing from the 60s and 70s (96)

REBUS is a cross-industry research project to address the decaying 1960s and 70s social housing stock in Denmark. It proposes energy and façade renovation with the lowest possible carbon footprint, without re-housing occupants. The project features prefabricated modular panels that simply mount on top of existing façades to transform the energy performance, indoor climate, and aesthetic quality of the existing building.

REBUS quickly and economically brings aging buildings up to today's low energy consumption and performance standards without the carbon cost of building from scratch. Renovating, rather than building new façades, let alone entirely new buildings, is by far the least carbon-intensive building approach. For the carbon cost of just one new building, it is possible to complete over 50 REBUS renovations.

Installing the REBUS system reduces energy demand by 50% and resource use overall by 30%. Because the panels' structural components are made of timber, they have a far lower carbon footprint than traditional steel construction.

REBUS revolutionises the renovation process: there is no need for scaffolding or even, in most cases, to re-house tenants during the works.

Case study
EnerPHit and tenements, Scotland: how radical retrofit can work in historic housing (139)

The project, applies EnerPHit, the *Passivhaus* standard, to retrofit some of Glasgow's older tenement housing, helping to meet Scotland's zero carbon goals. It promotes new skills, innovation in design, and the use of traditional materials.

Assessments using EnerPHit show that it is possible to reduce whole-life carbon emissions by 40% compared to the minimum targets required by Scottish Building Regulations.

The project, which is a collaboration between John Gilbert Architects and Southside Housing Association, working with industry partners and Glasgow University, is developing technical details for use by the wider built environment sector. The team is undertaking post-occupancy evaluations to validate their retrofit model for residents over the long term.

© Hoare Lea

Case study
Bryn Bragl, Wales: Wales' First Energy-Positive Social Housing Development (144)

Bryn Bragl is a pioneering residential development in South Wales. Supported and part-funded by the Welsh Government's Innovative Homes Programme, it aims to deliver 14 new, energy-positive social homes, some of the first in Wales.

The design follows the Solcer concept, originally developed by the Welsh School of Architecture, which uses a well-balanced and integrated blend of design methods and technologies. In this case, the homes feature passive design strategies, mechanical ventilation with heat recovery[40], exhaust air-source heat pumps, photovoltaics (PV), battery storage, and optimised controls and electricity tariffs, reducing energy bills by 90%.

While superficially similar to many other housing developments, Bryn Bragl is technologically very different. PV panels on the roofs generate electricity which is stored in a Tesla battery. Instead of gas central heating and radiators, each home is fitted with a heat pump and ventilation system, drawing in fresh air, which is warmed and gently circulated through the house. During warmer months, the heat pump can provide efficient cooling to eliminate overheating risk.

Exceptional levels of insulation and airtightness help to reduce heating demand significantly. Detailed modelling based on real-world operational performance goes beyond regulatory compliance to find the optimal balance of controls between the heat pumps, PV systems and batteries to minimise grid electricity demand and associated CO_2 emissions. User controls were optimised using smart-metered innovative tariffs to deliver exceptionally low, and even negative, annual energy costs.

Bryn Bragl demonstrates that the industry has the knowledge and technology to build energy-positive social housing today, within affordable budgets and saving residents money through exceptionally low energy bills.

6

The built environment sector is committed to change

6 | The built environment sector is committed to change

6.1 We are working to upskill and organise through climate action groups

The built environment sector has recognised that it is a significant emitter of GHG emissions. Many understand its role in addressing the dual climate and biodiversity emergencies, and to meet the needs of society without breaching earth's planetary boundaries. Commitment to climate action by public, private, and industry groups is widespread (160), with groups across the world seeking to change business-as-usual and upskill to working practices aligned with a transition to a fair and sustainable built environment. This is set out in, for example, the Architect's Climate Action Network's Education Toolkit (136), Arch4Change's co-created digital architecture curriculum (161), the Australian Institute of Architects Coordinated Climate Action Plan (87), and recommendations made to the Danish government by the construction industry's Climate Partnership (45). Actions need to be scaled up and replicated across the industry for maximum impact.

Training and upskilling in the construction sector are crucial to meeting decarbonisation goals (162). As a result, sustainability is being integrated into training schemes across the sector. This includes industry upskilling initiatives, university courses, apprenticeship programmes, and chartership and accreditation requirements. The Architects Registration Board's safety and sustainability guidelines demonstrate industry-driven change, ensuring architects have the necessary skills, knowledge, and experience to create a sustainable built environment (163).

The sector intends to increase awareness and spread the word about its role in the transition to a fair and sustainable future over the coming decades. Effective application of knowledge and pressure stimulates policy development, enables conversations and innovation, and generates demand for improvements.[41] The influence and effectiveness of these movements is exemplified by: Architects Declare (164), Construction Declares (165), the Architects Climate Action Network (166), and similar construction groups and movements; the production of collaborative research and guidance across the sector (74); media lead campaigns like the Architect's Journal's RetroFirst campaign (167); and the actions of many grassroots advocacy groups. Governments, corporations, and industry support of and engagement with these initiatives can enable rapid knowledge transfer and targeted policy development, building on a wealth of expertise and insight.

Recommendations

We recommend that:

6.1.1 Built environment businesses sign up to international declarations and pledges such as the Net Zero Carbon Buildings Commitment (160) and Race to Zero (35) to demonstrate the sector's willingness and ability to meet our climate targets.

6.1.2 Individual built environment practitioners are encouraged and supported to engage with industry collective action groups and campaigns by their employers.

6.1.3 Professional institutions promote best-practice, lessons learnt, and leading literature, including the Construction Industry Council's Carbon Zero action plan (169), RIBA's 2030 Climate Challenge (170), and the Climate Positive Design initiative (171). Community engagement, co-design practices, and the knowledge and skills needed to address the climate and biodiversity emergencies should be embedded into professional ethics commitments and codes of conduct, accreditation standards, competence frameworks, continuing professional development requirements, and training tools for all built environment practitioners.

6.1.4 Professional institutions that accredit built environment qualifications incorporate the most up-to-date climate and biodiversity knowledge in their evaluation criteria for higher education and professional qualifications recognition.[42]

6.1.5 University curricula are regularly updated and evaluated to ensure they align with the most up-to-date climate and biodiversity knowledge, as well as making sustainable practices a central aspect of their curriculum, directly addressing the climate and biodiversity emergency through teaching. This should be embedded into all areas of the curriculum, and not confined to dedicated 'sustainability modules'.

6.2 We are shifting towards interdisciplinary education and practice

The built environment sector recognises that the climate and biodiversity emergency is a complex challenge with wide-reaching impacts. The effects of climate change are interconnected and require a cross-disciplinary approach (28). Collaboration across the sector and breaking down traditional boundaries between disciplines provide opportunities for innovation and new ways of thinking. Beyond increasing collaboration within the sector, collaboration between it and scientists, community groups, economists, and politicians and others will offer the greatest opportunity to successfully address climate and biodiversity breakdown.

Collaborative research, such as Arup and C40 Cities' Green and Thriving Neighbourhoods Guidebook (172), proposes ways that cities and industries can work together to identify key issues that need to be addressed for low-carbon and sustainable cities, and challenges siloed design practices.

Partnerships between industry and academia are helping to upscale technological development rapidly by speeding up feedback loops between theory and practice. The Climate Framework (173) demonstrates a truly whole-industry approach to the challenge of upskilling, drawing on industry knowledge and making use of the best academic research to provide a shared curriculum for a sustainable built environment.[43]

Recommendations

We recommend that:

6.2.1 Integrated climate action is facilitated by built environment professionals working together and collaborating across sectors and government levels, from early stages and throughout the design process, to address issues such as land-use efficiency, transit-oriented design, access to green space, and resilience (77).

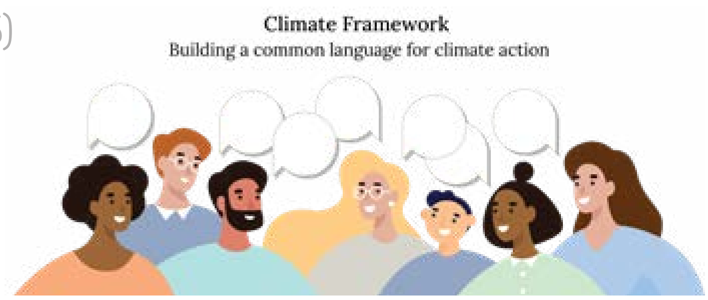
6.2.2 Boundaries between built environment disciplines and siloed working practices are broken down in firms by improved internal and external communication (174), promoting the use of open-source platforms such as Creative Commons (175) to share sustainability achievements (176).

6.2.3 Cross-disciplinary education is introduced at undergraduate level to open up inter-disciplinary working practices. This is already happening at many universities. In the UK, for example, Heriot Watt University's 'Shaping Tomorrow Together' multi-disciplinary module addressing the climate emergency (177), and Queen's University Belfast's joint teaching department for the built and natural environments (178).

6.2.4 Educational and academic institutions collaborate with industry through formal and informal partnerships, and public funding is invested in action and real-world research and industry knowledge to encourage change.

Case study
The Climate Framework: building capacity in an era of rapid change (173)

A trans-disciplinary initiative, jointly developed with input from 400+ organisations from industry and academia, and officially supported by 70+ organisations, the Climate Framework provides a shared curriculum for education and upskilling, drawing on industry knowledge, leveraging academic research, cross-pollinating experiences and expertise across global construction industry and academia.



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6.3 We are committed to reporting our successes and lessons learnt

Mass reporting schemes such as certification programmes, prizes and awards,[44] and reporting required by regulation have proven effective ways to drive and monitor new processes. Data transparency allows validation, both of which are key to delivering reliable measurement and assessment practices (179). The built environment sector and cities globally are already taking steps towards a resource-efficient and low- to zero-emissions construction sector (180). Mapping these global trends and initiatives as C40 Cities and others have done (31) can help to bridge transnational boundaries, share best practice and innovations, and support built environment professionals to effect change directly through their design work (181). Collecting data at national or sub-national level through planning systems can also be a valuable way to target policy, spot industry trends, and monitor policy uptake.[45]

As highlighted in earlier sections, the sector is experiencing considerable changes in mindsets. Reporting tools, material and building passports, and planning requirements can encourage design teams to approach construction projects differently. For example, the increasing up-take of new materials such as reused products or bio-based materials has been helped by new tools and frameworks such as the Orms Material Passport (182), which organises data about materials contained within a building, and the Institute of Civil Engineers (ICE) Database (183), which provides freely available data on the embodied carbon of over 200 materials. Consistent reporting guidance on standard assumptions, such as the Greater London Authority's Whole-Life Cycle Carbon Assessment guidance (184), which sets out a reporting methodology and is currently part of London's regional planning requirements, ensures fair and accurate reporting in the sector.

The built environment sector needs to take a holistic view of sustainability, considering wider environmental, social and governance (ESG) implications of projects as well as the embodied carbon of its materials. Formal ESG reporting by building owners and developers should be mandatory to ensure the holistic sustainability of projects is considered alongside mainstreamed aspects such as energy efficiency.

Recommendations

We recommend that:

6.3.1 Information about best practice low-carbon initiatives is more widely shared around the world. People working in the built environment can be more proactive about sharing their work with networks such as Architects Declare, which already has a global reach. Conferences and webinars are a good way to share knowledge internationally.

6.3.2 Public commitments to ESG standards (for example, through professional institutions) are made by built environment practitioners and practices, and clients favour private sector companies that make these commitments.

6.3.3 Open-source databases of construction materials are created, used, and promoted by the industry, such as the ICE Database (183) and Madaster (185), as well as databases for digital environmental product declarations (EPDs) (186) (187). This is especially important for bio-based and low-carbon materials, and their potential for use in design and construction.

6.3.4 Life cycle inventory tools (such as building passports (106)) are incorporated into projects by design teams, ensuring information on building materials is stored securely and made available to future building owners. When making a decision about whether to retrofit a building or, demolish and build new at the end of a built asset's life, owners are then able to understand what materials are in their buildings, their equivalent embodied carbon impact, and their financial value.

6.3.5 The built environment sector continues to develop shared, open-data platforms, such as the Europe-wide framework for embodied carbon benchmarks currently being developed by the Laudes Foundation and Ramboll (188), to enable easier comparison and learning. We also recommend that frameworks and assessment tools (such as Life Cycle Assessments) that enable project teams to understand the impact of decisions and explore alternative design strategies, are integrated into the design process to help to maximise sustainability and efficiency (189). Consistent reporting rules and guidance on standard assumptions should continue to be developed to ensure fair and accurate reporting.

Case study
Orms Material Passport (182)

To address the climate emergency, the circular economy is a necessity, not a choice. Material passports offer an opportunity to gather and organise data about materials contained within a building.

Research to date has largely focused on gathering data on new products, for future reuse. However, most buildings that exist today will still exist in 2050, so it is imperative that we make the most of the materials already in existence. Orms have developed a strategy that centres around the development of a Material Database, with Material Passports acting as a user interface to filter relevant information for the reader.

The Orms Material Passport initiative demonstrates the industry's commitment to change, and the availability of a toolkit encourages and supports design teams to challenge current design practices. By making it possible to know what processed material is already in existence, it offers project teams a way to avoid the extraction of raw materials and any associated waste, further reducing the embodied carbon of projects.

© Orms Architects

6.4 We are changing the design process to align with sustainable goals

Designers can reduce environmental impacts by changing the way they design. Systems-based, participatory, and user-centric approaches to design are effective and help to align outcomes with peoples' needs, without excessive costs to the environment. Nature, wellbeing, and community concerns are quickly rising in prominence within the design agenda and within the definition of sustainability (190).

The shift to regenerative design[27] practices within a circular economy requires a change in the order of steps and decisions in the typical design process, with audits of available buildings, structures, and materials being undertaken first and informing the design. The industry is developing novel and innovative tools to improve the efficiency of the built environment, such as the Structural Efficiency Classification System, which helps to identify ways to improve material efficiency (191). Certification schemes help designers and builders understand materials' credentials and to make sustainable choices. Designers are also better able to balance the complex and often conflicting factors affecting performance, quality, and resilience if they have more performance data and feedback from projects in use (149).

Designers can design and specify low-carbon, environmentally sustainable materials. To move away from decisions dominated by capital cost, we need to understand how adopting a whole-life costing model would encourage and support good design. The sector has a responsibility to question, investigate and test if any new buildings are needed by first exploring whether existing buildings and systems can be used differently, adapted, or retrofitted.

Crucially, we should challenge our perceptions of what is beautiful, purposeful, and culturally important. This would allow us to move away from buildings that incorporate large areas of glass, concrete, and brick to low-carbon and/or renewable materials such as timber or reclaimed elements. We would move away from long spans and slender structures in favour of tighter grids and expressive structures, and prefer patinated and weathered to flawless and new. More rapidly renewable materials such as hemp (192) and mycelium offer quicker forms of carbon sequestration (193). This also applies to more climate-resilient design, and features such as permeable pavements and design passive cooling, should be the default rather than the exception, given their resource efficiency.

Recommendations

We recommend that:

6.4.1 Novel and innovative systems (especially different metrics to support early-stage decision processes (36), workflows to facilitate optimisation[46], and continuous and rapid improvement based on feedback) currently being developed to improve the efficiency of the built environment (as described in this report) are incorporated into standard practice by built environment professionals. Also, outcomes should be publicly available so that others can use them to inform new innovations, and that lessons learnt are embedded consistently into the built environment sector's processes and body of knowledge. (194)

6.4.2 The capacity, willingness, and confidence to make and explain decisions about refurbishment and demolition and to invest in refurbishment on the part of tenants, local authorities, housing associations, developers, and lenders, becomes a key focus for education and research efforts across the sector. In part, this can be tackled through collecting more data on costs; analysing the impacts of different scenarios on different peoples and places over time; and investigating the feasibility of demolition and refurbishment as standard at project concept stages (195).

6.4.3 Participatory design tools are promoted by clients, professional institutions, and design teams during the design process. Local participation and site-specific knowledge can challenge ideas of beauty, creating buildings that are user-centred and integrate low-carbon materials and nature-based solutions (82) to provide a range of social and environmental benefits.[47]

6.4.4 Current ideas of beauty, cultural importance and purpose are challenged by designers, the media, awards organisations, professional institutions, and universities. For example, building on the way that European leaders and the New European Bauhaus (196) have called for a new definition of beauty in design to meet the requirements of the climate and biodiversity emergencies, using natural materials and incorporating nature- and people-centred approaches.

6.4.5 Industry bodies and academia review their evaluation criteria for best practice in consideration of whole-life environmental performance criteria, such as the EU Level(s) framework (197) or the Davos Baukultur Quality System (198).

6.4.6 Industry prizes and universities promote sustainable practices, for example, by rewarding successful retrofit projects and those championing the most sustainable materials, and require evidence for the success of interventions, even if it challenges the status quo of contemporary architecture. The industry needs to build on the progress it has made in this area with awards such as the Architects Journal Retrofit Awards (199), the Institution of Structural Engineers Award for Minimal Structural Intervention (200) and the International Green Apple Awards for Environmental Best Practice (201).

6.4.7 Providers of professional indemnity insurances and similar professional insurances review their policies to enable the shift to sustainable design practices.[48]

6.4.8 Construction law professionals support changes to design processes and supply chain relationships by adapting agreements to facilitate collaboration that targets sustainability goals (202).

Case study
Waterloo City Farm (44)

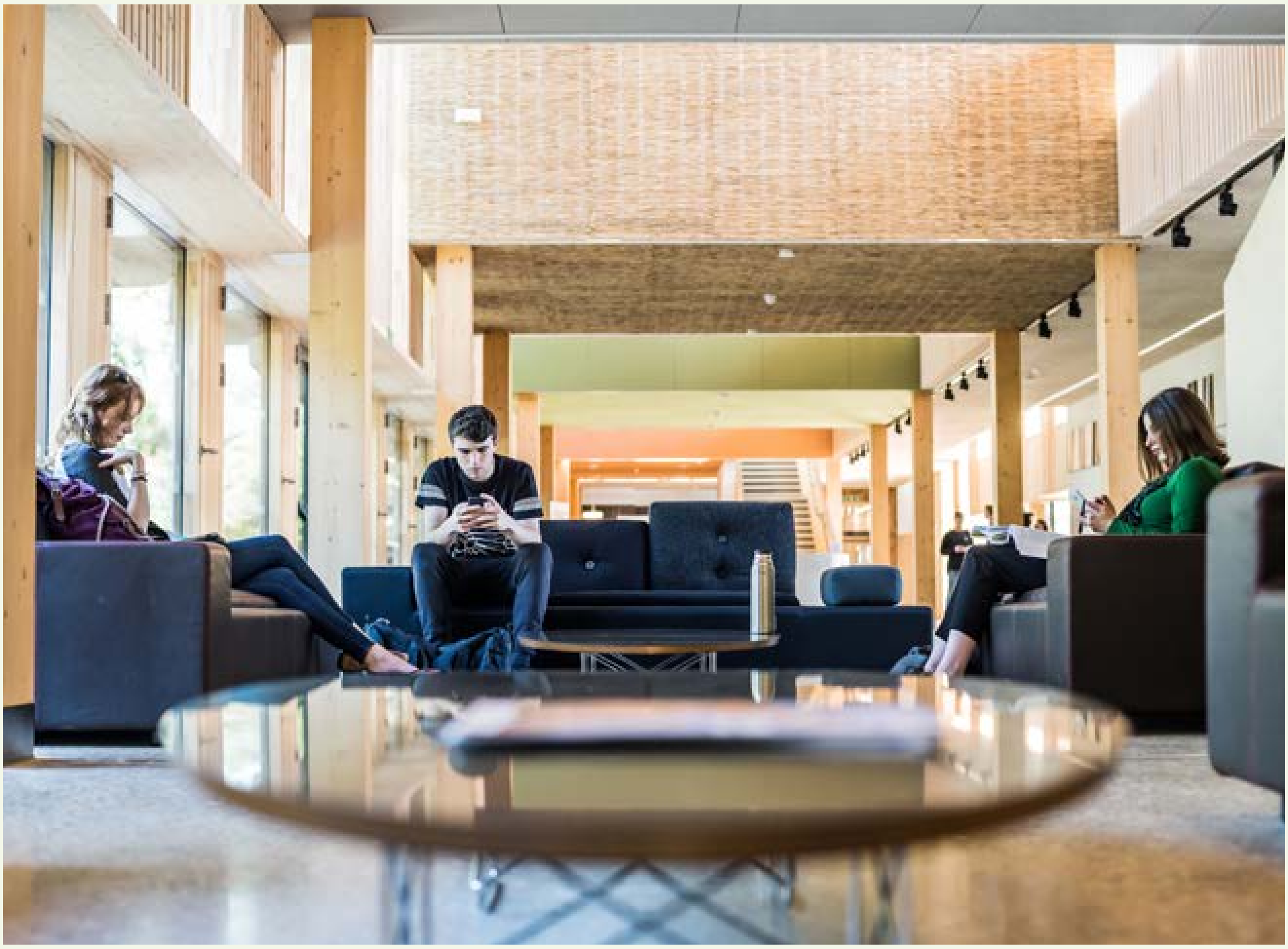
Waterloo City Farm, London's most central urban farm, was established in 2014 by a trio of organisations with a shared focus on education: architects Feilden Fowles and charities Jamie's Farm and Oasis Waterloo.

As a temporary use of previously neglected and under-used land owned by a hospital, the site's four demountable, timber-framed buildings accommodate animal pens, a barn, a garden room, a studio, and educational workshops for children and adults.

Designed with awareness of the temporary nature of the project, the flexible kit of parts can be easily re-used at the end of the buildings' lives.

The project demonstrates how low-tech construction guided by circular economy principles (including deconstruction and re-use of materials), and providing access to nature, can have a positive effect on the community.

© Feilden Fowles



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Case study

The Enterprise Centre, University of East Anglia, and the Adapt Low Carbon Group (257)

The Enterprise Centre at the University of East Anglia has been designed and delivered to achieve the *Passivhaus* standard and a BREEAM outstanding rating. The new building and landscape are exemplars of low embodied energy and carbon construction technologies, with natural and bio-based materials sourced through local supply chains.

Embodied energy was a major focus, with embodied carbon (including sequestration) between a fifth and a quarter that of many new university buildings.

The development of the project was underpinned by a significant amount of consultation and engagement at many different levels, from intimate sessions with the user, to large stakeholder workshops and numerous engagements with Norwich City Council's Planning Authority, conservation officers, Greater Norwich Development Partnership Design Review Panel, Highway and Parks and Open Spaces Committees, as part of the formal pre-application process. The process also included an exhibition of the proposed designs during August 2012, where members of the community were invited to comment on the proposals, and a presentation was given to the Norwich Forum for the Construction Industry. The design team also held a structured series of intensive workshops with staff from across the university including students, teachers, and estates management and maintenance. As part of this process of engagement, and to ensure that the building properly met the needs of users at each design stage, the project utilised a Design Quality Indicator process to record user consultation and is also following BSRIA's Soft Landings Framework.

7

There are enormous social, economic, health, and wellbeing benefits to shifting to a sustainable built environment

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7 | There are enormous social, economic, health, and wellbeing benefits to shifting to a sustainable built environment

7.1 We can meet the needs of all people, including future generations

We spend over 90% of our time in buildings, and close to 100% of our time in the built environment as a whole. The built environment is an expression of our values and has a fundamental impact on every aspect of our lives. The recommendations above focus on reducing the contribution of buildings and construction to the climate and biodiversity crises, however taking concerted action on our built environment also brings an enormous range of social, health, and wellbeing benefits (149). For example, improving the energy efficiency of our buildings can reduce the negative health impacts of both overheating and leaky, cold homes; addressing indoor and outdoor air quality can reduce instances of illness; and green spaces can improve mental health. Investing in sustainability can also create new green jobs and help alleviate fuel poverty.

Recommendations

We recommend that:

7.1.1 In implementing policy on the built environment, the drivers, metrics of success, and determinants for investment are not limited to financial and environmental impacts, but consider all people: individuals, groups, communities, cultures, and future generations.

> The built environment is an expression of our values and has a fundamental impact on every aspect of our lives.

7.2 We can address overheating, damp and cold homes, and alleviate fuel poverty

Heatwaves are estimated to cause 12,000 deaths annually across the world (29). The World Health Organization (WHO) forecasts that by 2030 there will be almost 92,000 deaths per year from heatwaves, with that figure expected to rise in 2050 to 255,000 deaths annually unless national and local governments adapt to heat-related risks. In the UK, a country not typically known for its warm weather, there are around 2,000 heat-related deaths each year (203). Much of this increased risk is thought to be caused by exposure to high indoor temperatures.

In addition, each year tens of thousands of people die from extreme cold (29). The five-year moving average of excess winter deaths in Great Britain is 35,600 per year. Of these, over 10,000 were attributable to living in a cold home and one in ten excess winter deaths are directly linked to fuel poverty (204). Warmer homes provide a better environment and reduce health problems. Inadequate heating can exacerbate health problems such as pneumonia, asthma, and arthritis, and can even lead to premature deaths (205). Investing in energy efficiency can minimise risks to health and wellbeing, at the same time, reducing pressure on health services. In England alone, it is estimated that the cost to the NHS of health conditions made worse by poor housing is between £1.4 and £2.0 billion each year (204).

Increased mortality is only one component of the effects of overheating. Illness, poor thermal comfort and reduced productivity and wellbeing are all major economic and social concerns (203), one in ten households in England are fuel poor, equating to around 2.4 million homes (206).[49] Poor energy efficiency is a major determinant of fuel poverty, where high energy consumption and costs are combined with low household income (207).

Research shows that global energy efficiency measures could save an estimated €280 to €410 billion on energy spending (and the equivalent to almost double the annual electricity consumption of the US) (208). Addressing fuel poverty is an area in which, with carefully planned and delivered policy, realising social justice, and reducing carbon emissions can be achieved simultaneously.[50] Alleviating fuel poverty is a worthwhile goal in and of itself as a means of improving the quality of life and health outcomes for the poorest and most vulnerable in society. It also provides economic stimulus opportunities – both through the creation of construction jobs and the improved personal finances of previously fuel-poor households (207).

© Marcel van der Burg

Case study
Wilmcote House: Retrofit to the rescue (205)

Wilmcote House is a large concrete panel building in the Somerstown area of Portsmouth owned by Portsmouth City Council. The building comprises three linked, 11-storey high-rise blocks. It contains 107 units: 100 three-bedroom maisonettes, and seven one-bedroom ground floor flats. Wilmcote House is located very close to the city centre and is in an area with high levels of deprivation. Retrofit works to the building included super-insulation, roof replacement, installation of triple glazed windows, extension of the living areas, more efficient heating and hot water, and installation of a heat recovery system. Prior to the works, many problems arose due to lack of insulation and poor energy performance of the blocks. According to the Council, in 2012 one-third of tenants reported issues of damp, condensation and mould growth. Residents also found the heating very expensive to run (often using night storage heaters), the windows were draughty, and the roofs were leaking.

Research and monitoring of a sample of 18 resident properties throughout the 2013-14 winter season highlighted that most residents were not heating their properties to an adequate level, because the night storage heaters were inefficient and too expensive to run.

Following the retrofit project, residents reported that their flats were warmer, more comfortable and attractive, and draughts and mould have been excluded. Most people use the radiators significantly less and when they do, the heat is better retained. Tenants' energy bills have fallen by an average of £700 a year, making bills more affordable while living in warmer flats.

7.3 We can improve internal and external air quality

Making our building stock more sustainable also has a positive impact on air quality. Indoor air quality is affected by several factors including construction products, which can be long term emitters of VOCs and formaldehyde, building design not providing adequate ventilation (209), and gas cooking appliances (210). Poor indoor air quality can lead to respiratory and other health concerns (209). Understanding and controlling building ventilation can improve the quality of the air we breathe and reduce the spread of respiratory viral diseases, including the virus that causes COVID-19 (211) (212).

Outdoor air quality is also a concern. Nine out of ten people around the world are breathing dirty air (213). The WHO estimated that in 2016, outdoor air pollution in both cities and rural areas caused 4.2 million premature deaths globally and around 91% of these premature deaths were in low- and middle-income countries (214). Additionally, in 2016, 91% of the world's population were living in places where WHO air quality guidelines were not met (214).

The built environment's responsibility for the health impacts of degraded outdoor air quality also extends to areas remote from the building site, where the production of building materials is taking place. For example, in 2019-20 the US imported over 600 million USD worth of cement from low- and middle- income countries (215). The processes of cement production degrade the air quality within 3-4 km radius periphery of the factory, contributing to a wide range of negative health effects that include respiratory diseases, brain damage, lung cancer, and heart diseases (216).

7.4 We can realise mental health benefits

Sustainable urban planning can support improved physical and mental health through improved access to employment, transportation, greater use of active modes for commuting (walking, biking), reduced air and noise pollution, reduced time spent in transport, and improved access to green spaces and other amenities. Sustainable new buildings deliver better thermal comfort, light, noise control, and indoor air quality, improving physical and mental health and well-being (217) (218).

There is evidence to show improved mental health can be a result of retrofit and refurbishment projects, particularly if it improves energy efficiency. At the community level, retrofit and refurbishment can reduce the sense of isolation and build or retain community connections (219). Issues (such as flooding) caused by a lack of climate change resilience can also have a negative impact on mental health. Public Health England data shows that people experience higher rates of anxiety, depression, and post-traumatic stress disorder after a flood (220).

Biophilic design integrates natural elements and processes into the creation of the built environment. Research shows biophilic design can reduce stress, improve cognitive function and creativity, and improve our well-being (221). In addition, research shows that those who worked in well-ventilated offices recorded higher cognitive scores (brain function) than those who worked in conventional buildings (222) and employees in offices with windows (and thereby daylight) slept an average of 46 minutes more per night (223). Access to these health, wellbeing and quality of life drivers is also often split along socio-economic, racial, and other marginalised community lines, making addressing these discrepancies an important social justice issue (224). It should also be considered that different ethnicities prefer different kinds of green spaces for cultural reasons, and ideals of beauty or leisure activity that are considered best practice aren't always shared across cultures (225).

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Case study
15-minute neighbourhoods (261)

The '15-minute city' is an intuitive, adaptable, and popular vision of city living that weaves together strands of climate action and people-centric urban development. A key element of a 15-minute neighbourhood is the ability of residents to access all services and amenities with a short walk or cycle. This includes community-scale education and healthcare, essential retail like grocery shops and pharmacies, parks for recreation, working spaces and more. Equity and inclusivity are central to a 15-minute city, with any strategy emphasising equal access to services, amenities, and green spaces. This means approaches must actively reduce social inequalities. This approach offers a way to boost local economies and deliver lasting health, wellbeing, equity, and climate benefits.

Leading examples include Bogotá, Colombia's Barrios Vitales, Portland, USA's Complete Neighbourhoods and Melbourne, Australia's 20-Minute Neighbourhoods.

7.5 We can create jobs and opportunities for upskilling

The training and employment opportunities from improving the built environment are vast (226). Undertaking training and education on net zero construction and retrofit, for example training to become a retrofit coordinator or to install new heating technologies (227), would help to provide the skills we need to reach net zero. This is an opportunity to upskill or reskill the workforce and create a high quality, professional construction sector (228) (229) (230).

A move away from demolition to maintenance can also help to create jobs at a local level and a stable pipeline of work in repair and retrofit. Case studies have shown that this can include significant increases in demand for labour, job creation at a local level, and better employment conditions and educational opportunities. If deconstruction were fully integrated into the USA's demolition industry, which takes down about 200,000 buildings annually, the equivalent of 200,000 jobs would be created (231).

7.6 We can improve asset values

Environmentally sustainable buildings offer several economic or financial benefits. For building owners, this includes reducing the running cost of buildings and increasing their value (29).

Reuse, prolonging lifespan, and adaptation add value to a building for its investors and owners and can increase the protection against physical risks from climate change (95). Upgrading a building is quicker than demolition and replacement, because generally it involves adaptation of the existing structure and layout rather than starting from scratch (232).

Building owners report that green buildings - whether new or renovated - command a 7% increase in asset value over traditional buildings (208).

Reusing materials through resale or redistribution can create economic as well as social and environmental benefits. This can stimulate greater collaboration between asset owners and operators, technology companies, platform developers, and other industry partners. These collaborations can lead to technical innovation, help cut costs, and reduce resource use (233).

The process of constructing modular buildings, or parts of a building as may be the case in retrofits, begins off-site, where most of the construction is done in controlled factory conditions. Modular units are assembled on-site and are constructed with the same codes and standards as traditionally built structures (234).

Modular construction has several benefits including less material waste and better working conditions. Factory-controlled conditions can reduce costs through a better quality of build, better finishes, and fewer defects (235), meaning certainty that you are getting what you pay for and less on-site labour. (202) Modular projects can be up to twice as fast as traditional construction projects. By choosing offsite modular construction, traditional processes like site foundation work can occur at the same time as the modular units are being made.

Using factory production lines for accurate cutting, aligning and other works can drastically reduce material waste. Any waste that is produced is controlled and recycled (235). Modular systems can also have better production control, ensuring better quality and longer-lasting outputs, that save money in the long run (236) and can complement renewable or sustainable material specification.

The cost advantages extend to the workforce that carry out this work. Because the workspace is controlled, there is less risk of accidents (235) and greater certainty for employees on hours and location of work, which can be more unpredictable on a building site (237). This industrialised approach to construction creates safety and predictability, making construction jobs more desirable to a more diverse pool of talent (237).

8

Summary recommendations

8 | Summary recommendations

All of us operating within the sector have a critical role to play in bringing about a transition to a fair and sustainable built environment.

Governments should set ambitious policy, regulation, and legislation, covering strategies and roadmaps, financial frameworks, building codes, and planning systems, as well as creating the system change needed through public infrastructure.

Client bodies and their advisors should campaign for ambitious policy and infrastructure, as well as demonstrating that a sustainable and fair built environment is possible by facilitating and requiring best practice in all their activities.

The built environment sector should campaign for ambitious policy and infrastructure, as well as demonstrating that a sustainable and fair built environment is possible by striving to deliver best practice in all their activities.

Civil society organisations, the media, and building users also have a key role to play in campaigning and facilitating communication between governments, industry and client bodies, and society as a whole.

We can achieve a sustainable and fair built environment, but we must push forward on all fronts, together.

We recommend that **international agreements and commitments**:

- include the declaration of climate and biodiversity emergency (3.1.1)
- require emissions reporting and target-setting on a consumption-basis (3.2.1)
- include ambitious built environment actions in NDCs (3.2.2, 3.2.3), including ambitious near-term targets (3.1.4)
- prioritise environmental and social impact (4.1.1)
- consider the needs of all people, including future generations (7.1.1)

We recommend that **national strategies and roadmaps**:

- are created in the context of a declared climate and biodiversity emergency (3.1.1), and are consistent with a net zero carbon built environment (3.1.3) with ambitious near-term targets (3.1.4), and national and industry carbon budgets met through mechanisms including planning systems (5.2.5)
- are based on consumption emissions (3.2.1) and offer guidance for consistent environmental reporting (3.1.2)
- are based on an approach that includes mapping, modelling, prioritising, implementing, and monitoring (4.1.4) in collaboration with industry and civil society to overcome system inertia (4.1.2)
- are complemented by robust policy to implement and achieve stated goals (4.1.3) with environmental impact prioritised over economic gain (4.1.1)
- are progressive, regionally specific, cross-sectoral, and give clear foresight to allow industry to plan (4.2.1)
- include employment and social policies (4.3.3) with approaches such as social justice risk assessments to mitigate against unintended negative consequences (4.3.2) and ensure the needs of all people (including future generations) are considered (7.1.1)

We recommend that **financial frameworks**, including subsidies, sanctions, and taxes:

- are consistent with a net zero carbon built environment (3.1.3), at a scale proportionate to the emergency (4.1.6), maintained over suitable time periods (4.2.6), consider all people, including future generations (7.1.1), and include sufficient contingencies to mitigate unintended negative consequences (4.3.2)
- drive public investment into emerging and low-carbon technologies (4.1.5) - including open-source tools and software (4.2.4), and partnerships between education and industry (6.2.4) - and into removing structural barriers that prevent the uptake of new technologies (4.2.2)
- support green finance initiatives that focus on maintaining and reducing energy use of existing buildings (4.2.3), including schemes directed at private landlords (5.1.2)

- support well-funded, widely accessible employment and social policies (4.3.3), including apprenticeships and skills guarantee schemes (4.2.5) and cross-disciplinary (6.2.3) education with climate and biodiversity knowledge embedded within curricula (6.1.5)

We recommend that **building codes**:

- are consistent with a net zero carbon built environment (3.1.3), and include climate risks and adaptation measures (5.1.3) alongside mitigation measures, integrating nature-based solutions (5.1.4)
- set standards for embodied carbon (5.2.1), reuse of materials (5.2.2), structural design efficiencies (5.2.3), and bio-based materials including timber (5.2.4) as well as innovative low-carbon materials
- regulate the energy performance of both new and existing buildings, considering internal environmental quality (5.3.1) and the whole range of building emissions sources (5.3.4)
- define operational energy targets and benchmarks (5.3.3) under a clear shared definition of 'net zero' in operation (5.3.2)
- promote renewable technologies, smart metering, and controls (5.3.5), and energy generation (5.3.6)
- require health and wellbeing targets to be met (5.3.8) and in-use monitoring and post-occupancy evaluation (5.3.7)

We recommend that **planning systems**:

- are reviewed and reformed to ensure development permitting, zoning laws, and development plans are consistent with a net zero carbon built environment (3.1.3), for example by incorporating embodied carbon budgets (5.2.5)
- consider all people (7.1.1) and involve communities at all stages (4.3.4) informed by open and free access to information about land ownership (4.1.3)
- hold and keep up-to-date information about existing building stock through building renovation passports (5.1.7), with registers for derelict and vacant building stock (5.1.1) to encourage adaptive reuse of existing structures, including community-led uses (4.3.5) and spaces for use during emergencies (4.3.6)
- incorporate reformed definitions and approaches to protected buildings (5.1.5), require demolition permits for all prospective demolitions, and require feasibility studies to be carried out for adaptive reuse of any existing structures prior to granting permission for new builds (5.1.6)
- encourage low and zero carbon development by requiring feasibility studies of low-carbon strategies including above-ground-only development (5.2.7) and bio-based structures (5.2.1) as a condition of all permissions, requiring all construction machinery to be zero emissions except by special permit (5.2.9), and locally specific certification and bans on damaging materials and products (5.2.8)
- promote systems that are flexible to the use of available reclaimed materials (5.2.6) and the incorporation of nature-based solutions (5.1.4)

We recommend that **public infrastructure and procurement**:

- are consistent with a net zero carbon built environment (3.1.3) with publicly procured and funded projects driving change by requiring conformance to industry leading standards (4.2.7), including integrated social value requirements (4.3.7) and holistic ecological restoration (4.3.8)
- provide the infrastructure to enable a circular economy within construction to include the recovery, storage, sorting, and redistribution of salvaged materials (4.2.8)
- facilitate open and free access to land ownership information (4.3.1) and derelict and vacant building stock (5.1.1)
- provide spaces and infrastructure for community use during emergencies (4.3.6)
- provide grants and platforms for fair knowledge and skills exchange with communities with traditional ecological knowledge, wisdom, and technologies (5.1.4)
- consider the needs of all people, including future generations (7.1.1)

We recommend that **voluntary standards** (including but not limited to BREEAM, LEED, Environmental Product Declarations, etc):

- are reviewed and reformed to align with best practice (5.3.9) and ensure that high certification ratings are only achievable with low energy consumption (5.3.2, 5.3.3) and low whole-life carbon emissions (5.2.1)
- encourage ambitious improvements in all environmental concerns, including holistic ecological restoration (4.3.8), climate risk and adaptation (5.1.3), bio-based materials (5.2.4), healthy materials (5.2.8), and zero-emissions machinery (5.2.9)
- provide non-financial incentives (5.1.2) to improve energy (5.3.3, 5.3.4, 5.3.5, 5.3.6) and material efficiency of the built environment (5.1.7, 5.2.1, 5.2.2, 5.2.3, 6.3.3, 6.3.4)
- increase ambition in connection with improving health and wellbeing (5.3.8) and post-occupancy evaluation (5.3.7)

- facilitate communication and public commitments of ESG standards (6.3.2)

We recommend that **contracts, appointments, and procurement documents**:

- support a transition to a fair (7.1.1) and sustainable built environment and enable the use of emerging and bio-based materials (5.2.4) as well as innovative low-carbon materials, with reforms to legal documents and related processes (6.4.8), and insurances (6.4.7) facilitate just communication and exchange with communities with traditional ecological knowledge, wisdom, and technologies (5.1.4)
- enable new and emerging standards and responsibilities such as building renovation passports (5.1.7), material efficiencies (5.2.2, 5.2.3, 6.3.4), embodied carbon (5.2.5), healthy materials (5.2.8), zero-emissions machinery (5.2.9), post-occupancy evaluation (5.3.7), sustainable sourcing (5.2.4), and ESG commitments (6.3.2)

We recommend that **design processes and collaborative approaches**:

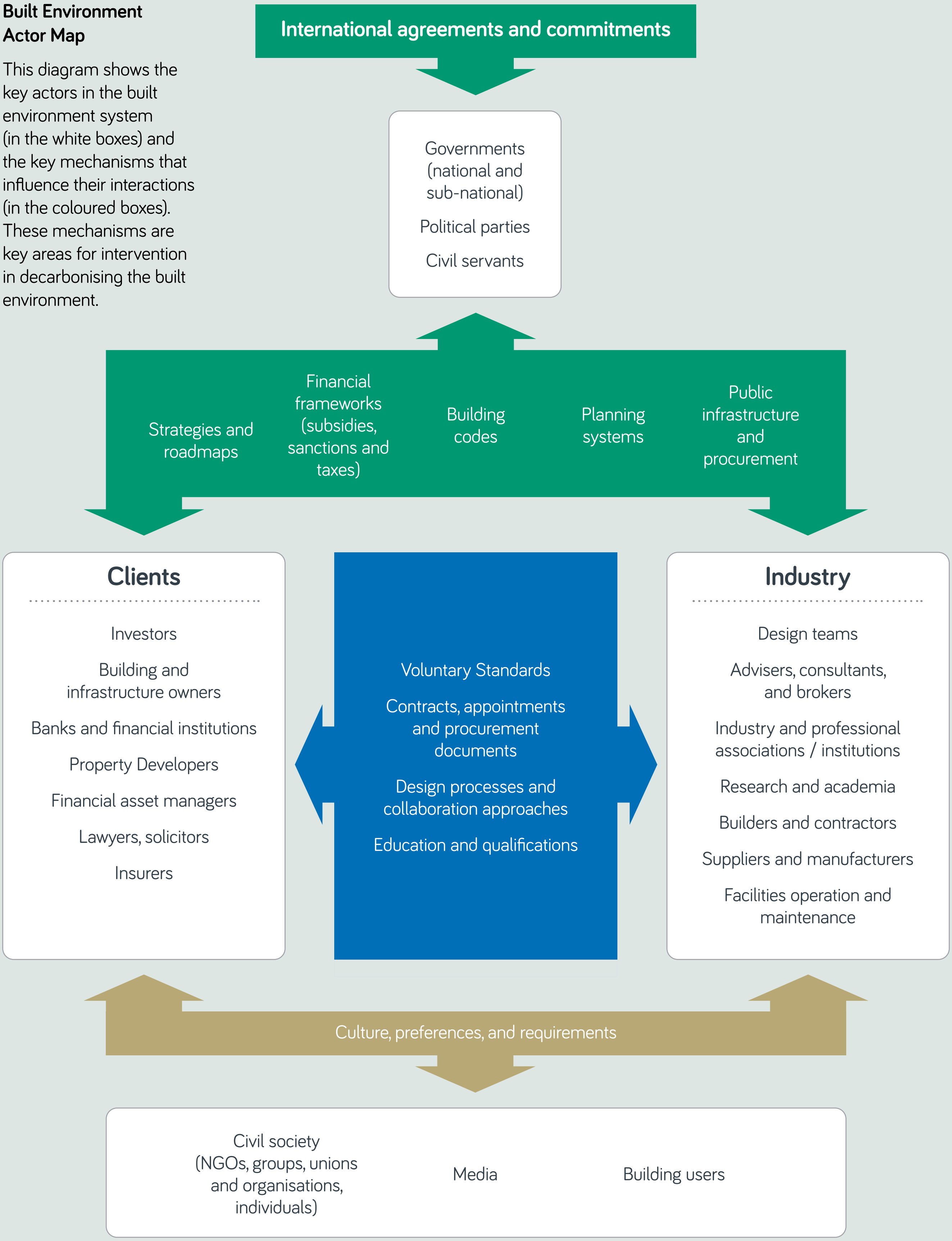
- embed, replicate, and scale up sustainable (6.4.1), participatory (6.4.3) best practice that considers the needs of all people, including future generations (7.1.1)
- incorporate communicating (6.4.2) and sharing information (6.2.2, 6.3.1, 6.3.3) including achieved operational energy (5.3.3), whole-life carbon (6.3.4), and lessons learnt (6.3.5) from processes including in-use monitoring and post-occupancy evaluation (5.3.7)
- incorporate making public commitments (6.1.1, 6.3.2), engaging with industry collective action (6.1.2) and collaborating across disciplines and sectors (6.2.1)
- promote and reward sustainable best practice (6.4.6) and engage with how this changes ideas of beauty, cultural importance, and meaning (6.4.4)
- as promoted by professional institutions, incorporate best-practice sustainability and community engagement ways of working (6.1.3, 6.4.5)

We recommend that **education and qualifications**:

- are well funded (4.2.5), and reoriented towards the climate and biodiversity emergency (3.1.3, 6.4.5) and its implications for all people, including future generations (7.1.1)
- focus research efforts on climate risk and adaptation (4.2.4), locally specific, healthy, and damaging materials (5.2.8), shared definitions and benchmarks (5.3.2, 5.3.3, 6.3.4), smart metering and controls (5.3.5), energy generation (5.3.6), health and wellbeing (5.3.8), post-occupancy evaluation (5.3.7), life cycle inventory tools (6.3.4), and shifts in ideas of beauty, cultural importance and meaning (6.4.4)
- embed climate and biodiversity issues in curricula (6.1.5), with this being a requirement of accreditation by professional institutions (6.1.4), and both schools and students rewarded for excellence in these topics (6.4.6)
- are cross-disciplinary (6.2.3) and build strong partnerships with practice (6.2.4)

Built Environment Actor Map

This diagram shows the key actors in the built environment system (in the white boxes) and the key mechanisms that influence their interactions (in the coloured boxes). These mechanisms are key areas for intervention in decarbonising the built environment.



9 | Endnotes

1 The Paris Agreement was adopted at COP21 in 2015, informed by the IPCC's Fifth Assessment Report. We now have the IPCC's Sixth Assessment Report (1) and must urgently take robust action accordingly.

2 For example, by committing under programmes such as Cities Race to Zero (268)

3 There is increasing recognition of weakness in built environment policy (ie planning policy and building codes) in many Commonwealth countries in terms of standards, implementation, and enforcement (271).

4 The UN Framework Convention for Climate Change requires that countries (Parties) report their GHG emissions on a territorial basis. This includes emissions produced within a county's border but excludes those embodied within imports. This therefore excludes many of the emissions associated with the built environment (243).

5 Consumption-based emissions reporting also brings significant benefits in terms of international justice. If we calculated and reported our emissions to include all the carbon embodied in imports, high-consumption/low-production countries like the UK would have a much higher carbon footprint, while low-consumption high-production countries (like Kazakhstan, whose consumption-based carbon footprint is 25% lower than its territorial based footprint) would have a much lower carbon footprint. This would incentivise countries like the UK to implement policies to reduce our actual total carbon footprint, and the building regulations might regulate embodied carbon (242).

6 Targets are considered science-based if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement - limiting global warming to well-below 2°C above pre-industrial levels and pursuing efforts to limit warming to 1.5°C (244).

7 Regenerative development is a system of technologies and strategies for generating the patterned whole system understanding of a place, and developing the strategic systemic thinking capacities, and the stakeholder engagement/commitment required to ensure regenerative design processes to achieve maximum systemic leverage and support, that is self-organizing and self-evolving (245).

8 This includes physical and digital infrastructure that enable material reuse, repair, refurbishment, recycling, resource recovery, and waste-to-energy. (259)

9 Barriers to change include the nature of relationships (coordination lock-in), historical practices and technology choices (historical lock-in), and the availability of (and/or resources to process) information (informational lock-in). These barriers can be unlocked by adjusting the remit and/or capability of existing actors, adding or removing actors, or reconfiguring relationships. Detailed mapping of how aspects of the industry work and modelling interventions can help to facilitate change at the speed and scale required (36).

10 Throughout the COVID-19 pandemic, we have seen that the central banks of many countries are able to finance public spending. In the UK, for example, the Bank of England's purchases of government bonds between March 2020 and March 2021 exceeded public sector net borrowing. Such collaboration between The Bank of England and Treasury could be deployed to respond to the climate and biodiversity crisis with a transition to a fair and sustainable built environment (275).

11 Cities and regions have a powerful role to play and many have already made ambitious commitments such as the C40 Net Zero Carbon Buildings Declaration (264), the C40 Clean Construction Declaration (265)and the state and regions Under2 coalition (241).

12 For example, UK FIRES show that introducing a recondition specialist into the UK steel supply chain would be a powerful intervention to improving steel reuse (36).

13 Examples include the World Green Building Council's Net Zero Carbon Buildings Commitment (160), the World Resources Institute's Zero Carbon Building Accelerator (278), and C40 Cities' Net Zero Carbon Buildings (264) and Clean Construction Declarations (265).

14 In the UK, retrofit strategies have been characterised by stop-start funding that led to boom and-bust cycles, ultimately leaving the largely SME suppliers of construction for retrofit with unsustainable business models. If these poor outcomes are to be avoided in the future, the government will need to bring forward a National Retrofit Strategy, i.e. a long-term policy and investment programme for upgrading the energy efficiency of a nation's housing stock with the genuine involvement of all stakeholders to realise social benefits and reduced energy consumption simultaneously.

15 Engaging residents in decisions about changes to the built environment is crucial and has resulted in successful refurbishment of several social housing properties (195).

16 The informal settlement of Mukuru in Nairobi suffers from repeated flooding, prevalence of mosquito-borne diseases and property destruction. A local women-led movement worked closely with the community to strengthen neighbourhood associations, build residents' capacity, and engage local government. This led to the formal designation of the settlement as a Special Planning Area, and the pipeline of climate actions including improved waste management, cooler housing, and more green spaces. (269)

The government of New South Wales, Australia has adopted the following commitment, which is being incorporated into planning policy: 'Through our projects, we commit to helping support the health and wellbeing of Country by valuing, respecting, and being guided by Aboriginal people, who know that if we care for Country – it will care for us.' (276).

17 The team for Colma Creek (98) worked closely with community, government agencies and stakeholders to empower decision-makers with a vision for a restored creek and instilled in the community not only a desire to see change, but also building capacity for nature-based climate adaptation.

18 In Guadalajara, tree planting, green corridors and public gardens are being introduced to cool down the city and provide shade and leisure space. The city is also funding courses to train gardeners and tree technicians and providing workshops for residents on caring for trees and gardens. (266) (267)

19 There is a real risk that flagship urban 'regeneration' projects can alienate local communities, contribute to massive area gentrification, and divert funds from grassroots/community-led projects. This is hard to avoid where high costs of flagship projects are considered to need private housing to pay back on investment (246). Conversely, land use strategies and requirements, when well-managed, can be successful in supporting affordable housing (247).

20 Sustainable new buildings reduce building operation costs, which should reduce tenants' operational and fuel costs, particularly where micro renewables provide power. However, this depends on any increased production costs not being passed on to tenants (29).

21 Regenerative design is a system of technologies and strategies, based on an understanding of the inner working of ecosystems that generates designs to regenerate rather than deplete underlying life support systems and resources within socio-ecological wholes (245).

22 Examples of these principles are set out in the SER Guidelines for Developing and Managing Ecological Restoration Projects Commission on Ecosystem Management (103).

23 Extended Producer Responsibility (EPR) is a policy approach under which producers are given a significant responsibility – financial and/or physical – for the treatment or disposal of post-consumer products (248).

24 Retrofit and restoration projects can integrate strategies to increase resilience of built spaces, with toolkits available that provide climate-specific design advice such as the Climate Responsive Design for Low Carbon Architecture by CRTKL (249).

25 Green infrastructure can mitigate surface water run-off and flood risk, reduce the urban heat island effect, encourage local food production, and improve air quality and wellbeing (40).

26 Municipal zoning authorities can support designation of zones and by-laws (56).

27 Multidisciplinary frameworks exist to facilitate these considerations (250).

28 There are examples of government stimuli unlocking private capital. For example, in Germany in 2016, their national infrastructure bank, KfW, invested €1.7 billion to incentivise energy efficient renovation through interest rate and capital subsidies. These incentives led building owners spending €8.4 billion. In other words, for every €1 invested, building owners were motivated to borrow and spend €6. The resultant VAT on these revenues alone (€1.6 billion) nearly covered KfW's own costs. Larger subsidy levels were dependent on achieving higher energy performance, which are more expensive to achieve, which in turn requires building owners to spend more. These measures, coupled with low-cost borrowing, incentivised building owners to spend six times more than the government investment (272).

29 The UK produces 200 Mt of waste per annum. Around 63% of this is construction, demolition, and excavation waste, in part due to the 50,000 existing buildings that are demolished each year. Retrofit campaigns, such as the Architect's Journal's RetroFirst, champion more reuse in the built environment. AJ's campaign proposes a major reduction in use of new materials and energy through adoption of circular economy principles, which makes (low-carbon) retrofit the default option. It also seeks to reform current UK policy, which in its current state provides a financial incentive for new build housing. (The current UK system charges 20% VAT on retrofit and refurbishment, and 0-5% VAT on building new, thus favouring the latter) (167).

30 Adaptation pathways are developed to design adaptive policies to handle climate change uncertainty.

31 Building Renovation Passports are digital tools to help property owners access decision-useful information to retrofit their home. They provide information on the current energy performance of a property, past renovations. They are underpinned by a long-term retrofit roadmap that identifies future decarbonisation measures, along with links to contractors and finance options (7) (106).

32 Form factor is the ratio of heated floor space to heat loss envelope (ground, walls, and roof) (114).

33 Reclaimed materials are any materials that have been used before either in buildings, temporary works or other uses and are re-used as construction materials without reprocessing. (233)

34 It is estimated that 20-80 Mt CO_2e could be avoided globally through replacing concrete floors with mass timber and steel composite structures (124).

35 Introducing measures at the earliest decision gateways helps to prevent lock-in to orthodox practices and processes (36).

36 Closing the feedback loop in the built environment requires acknowledging the relevance of every case study (274).

37 Austin, Texas in the USA requires efficiency improvements to be made on low-performing multi-family buildings (277).

38 Typically, a corporate power purchase agreements will set a long-term power pricing mechanism (some are for 25 years+) between the generator and customer. This allows the customer to procure renewable energy, while also providing certainty and transparency over the wholesale price element of its delivered energy costs (251).

39 The WELL Building Standard is a vehicle for buildings and organizations to deliver more thoughtful and intentional spaces that enhance human health and well-being.

40 Mechanical ventilation with heat recovery (MVHR) works by extracting air from inside a building and supplying treated outdoor air. The system uses the heat from the outgoing air to warm the incoming air (252).

41 Effective public engagement encourages uptake of sustainable practices and products, improves public perception around net zero buildings and motivates behaviour change (7).

42 See the evolution of the multi-disciplinary 'Climate Framework' (173) for example, or the development of Arch4Change's digital architecture curriculum (161).

43 Other examples of academia's impact on moving the industry forward include C40's Students Reinventing Cities competition (253) and the University of Melbourne's project to identify opportunities to facilitate climate action through built environment professionals (254).

44 In partnership with Construction Declares, Open City have launched the Open City Stewardship Awards, recognising the importance of both caring for, improving, and enhancing existing places, and challenging the assumption that new is always better (255). RICS is also developing standards and indicators to facilitate reliable measurement of the industry's response to climate change, demonstrating the industry's commitment to embedding the measurement and monitoring of climate impacts in professional practice (270). NABERS is an international rating system that assists in accurately measuring, understanding, and communicating the environmental performance of buildings while identifying areas for cost savings and future improvements (151).

45 For example, London Plan Energy Monitoring Reports published annually present outcomes secured by the implementation of the London Plan energy policies through the planning system for planning applications referable to the Mayor (101).

46 For example, UK FIRES show that computer modelling large numbers of preliminary structural designs can help designers to make better-informed decisions about reducing carbon emissions and costs, despite the one-off nature of most building projects (36).

47 The Living Building Challenge (LBC) that comes from the International Living Futures Institute offers a strong framework for regenerative design. It suggests that 'every act of development should be positive and regenerative, not less bad but actually good.' With hundreds of buildings around the world registered and certified to some degree, it is a poetic and inspiring approach to design for the future. It also requires teams to publish their work so future projects can benefit (256).

48 Some insurers currently view feedback processes as a source of risk, whereas they should be seen as a mechanism for reducing liability risks (149).

49 There are two criteria for a household to be categorised as fuel poor. First, it must have heating costs that place it above the national median, and second, meeting those costs will put the household below the poverty line.

50 Cost savings, reduction in fuel poverty, better quality of homes (219) and (258).

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Royal Institute of British Architects
66 Portland Place,
London W1B 1AD
Tel: +44 (0)20 7580 5533
Email: info@riba.org

RIBA
Architecture.com