

Part of the conference series
Breakthrough science and technologies
Transforming our future

Unlocking building sustainability

Held on 1 – 2 September 2021

Conference report

Supported by AstraZeneca

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SOCIETY**



Introduction

In September 2021, this Royal Society meeting gathered key stakeholders from across the construction, energy, and materials sectors to discuss the technical, regulation, supply chain, and economic issues associated with achieving net-zero targets for buildings by 2050.

Speakers examined how the industry is functioning, explored systems-based approaches to building sustainability, highlighted existing and emerging solutions for new buildings and retrofitting existing buildings, and examined the path to unlocking building sustainability in the UK.

The meeting forms part of the Society's wider Transforming our Future series, supported by AstraZeneca, and was organised by Dr Fiona Riddoch, Royal Society Science Industry and Translation Committee, Adam Locke, Laing O'Rourke, and Professor James Durrant FRS, University of Swansea.

Each conference in the Transforming our Future series brings together key stakeholders from across a sector to address a major scientific and technical challenge of the next decade. The series is organised through the Royal Society's Science and Industry programme which supports the Society's commitment to integrate science and industry across its activities, and to promote science and its value by building relationships and fostering translation.

This report is not a verbatim record, but a summary of the discussions that took place during the day and the key points raised. Comments and recommendations reflect the views and opinions of the speakers and not necessarily those of the Royal Society.

Executive summary

Our homes and the buildings frame the majority of how we spend our lives. To keep these spaces comfortable and healthy takes energy for heat, light and appliances. The UK Parliament Energy Select Committee in 2019 stated “The widespread deployment of energy efficiency measures across the UK’s buildings will be a key pillar of any credible strategy to meet net zero greenhouse gas emissions by 2050”.

To reduce the carbon emissions associated with buildings’ energy consumption we can do two things. First massively improve the energy performance of the buildings themselves and secondly replace the fossil fuel used in buildings with renewable fuel making the renewable energy we generate go further. Making both existing buildings and new builds more energy efficient also makes for a more comfortable indoor environment and reduces energy bills.

The Royal Society Meeting in September 2021 identified existing barriers to decarbonising the UK’s building stock. Presentations highlighted emerging solutions in the new build and retrofit sectors and outlined the interventions necessary to meet net zero. The discussion showed that there is a lot to do but also that much of the technology exists to do it. There was a strong call across speakers for the industry to step up to lead the needed change and for finance and government to play their parts.

Key findings were:

Adopt a systems approach:

- The buildings sector should adopt a whole life embodied carbon approach to accurately measure its carbon impact.
- To maximise the energy efficiency of a building, its components cannot be considered in isolation. Buildings should be designed and constructed in ways that reduce their embodied carbon as well as their operational carbon.

Highlight the opportunities associated with decarbonising the UK’s building stock:

- Decarbonising the UK’s building stock will benefit the consumer. The associated opportunities should be better advertised to incentivise decarbonisation.

Industry changes:

- The building sector must develop industry-wide collaboration on net zero along the supply chain and encourage government to work with it to take a systems approach in its net zero strategy. The construction industry must address its historical resistance to change, improve work practises and develop new business models to deliver the co-operation that is needed to get to net zero.
- The construction workforce needs to upskill to better understand how their work interacts with the decisions of other trades and how it directly influences the energy performance and the safety of a building.

Market changes:

- The housing market is very fragmented and new financial instruments should be considered to create a just transition to net zero in which all citizens can participate.
- The market for energy efficient buildings is still immature and an initiating or enabling policy framework is needed to create an attractive low risk market for investors and Financial Institutions (FIs) to invest in.
- Solutions need to be designed, prototyped and piloted at scale to prove that they are economically viable and can be widely commercialised.

Policy and regulation changes:

- To enable a safe and effective transition to high energy efficiency in buildings, the UK should introduce multifaceted performance criteria that assess buildings as a whole. This would replace the existing regulation approach of individual performance areas such as safety, energy performance and ventilation.
- Policy and regulations must be simple, consistent and transparent to achieve the strategic level push required across the sector.
- Regulations should be designed to reward best practice in the construction industry to disincentivise corner-cutting and encourage a culture of innovation in the sector. The sector needs to be incentivised to learn from past mistakes and scale up the rate of delivery of net zero.

“There is a big upside for the building industry to get off the blocks and provide solutions to lower the energy consumption of buildings. There is clearly a demand for low energy, warm homes across the UK. I hope the industry takes the lead and that government responds with a policy environment that supports scaling up in both new build and retrofit. The time to act is now.”

Fiona Riddoch, Royal Society Science Industry and Translation Committee

Racing to net zero carbon: route ahead for the built environment

Julie Hirigoyen, CEO of The UK Green Building Council (UKGBC), spoke about the NGO's mission to radically accelerate the sustainability of the built environment and the launch of their whole life carbon net zero roadmap.

The UKGBC's vision is a built environment that mitigates and adapts to climate change; maximizes resource efficiency; embraces or even restores nature; promotes biodiversity; optimizes the health and wellbeing of people and ultimately improves quality of life or creates long term value to our society. As part of this mission, the UKGBC in collaboration with over 100 organisations have developed a whole life carbon net zero roadmap identifying how to decarbonise the built environment sector.

Current state of the sector

The built environment is responsible for a significant 25% of the UK's carbon footprint. Of that, 20% are embodied emissions from buildings, associated with the manufacturing and transportation of construction materials and onsite activities; 74% are operational emissions from buildings, and 6% are from operational and embodied infrastructure. The carbon footprint of imported products (i.e. consumption emissions) is not always accounted for but totals c30% of embodied carbon.

Built environment emissions have reduced by c30% over the last two decades. The majority of this reduction occurred after 2010 and is largely due to a decrease in operational emissions driven by grid decarbonisation¹. While further decarbonisation of the electrical grid is expected, progress is slowing with energy use in buildings remaining constant and energy efficiency retrofit measures dropping in the last decade. Domestic energy consumption figures illustrate that roughly 62% of operational emissions derive from heating homes, 85% of which is from gas boilers. This suggests that the biggest challenge to the sector is the decarbonisation of heat within existing buildings.

Embodied (capital) carbon

The average carbon intensity of construction products and materials have decreased by half since 1990, but that rate of reduction has slowed in recent years. What's more, final demand for carbon intensive products and materials have increased due to increasing construction growth. Using the latest available figures from 2018, the total embodied (capital) carbon in the sector is predicted to be around c43 mega tonnes of CO₂. Despite being a c20% reduction from 1990 levels, it masks a troubling 12% increase in embodied emissions since 2010. In keeping with the delivery of new homes and further economic growth, the sector's embodied carbon is expected to continue to increase.

UKGBC's UK Whole Life Carbon Roadmap Trajectory

The UKGBC's Whole Life Carbon Roadmap maps the sector's trajectory and has developed science-based decarbonisation targets to mitigate emissions. Its data-backed predictions show the progress that each stakeholder group must make if the industry is to meet the 2050 net-zero target.

The report makes series of informed predictions based on current technologies, existing strategies, published documents, emerging policies and commitments from the industry to determine the pace and scale of mitigation measures that must be taken. It then develops a series of tailored action plans for each stakeholder and profession in the sector. It also outlines a series of policy recommendations for central and local governments that focus on tackling domestic retrofit, non-domestic building energy efficiency, new buildings and embodied carbon. The roadmap is designed to be co-owned by government and industry to encourage a coherent approach and the development of complementary policies, fiscal instruments, lending products and consumer campaigns.

1. Net Zero Whole Life Carbon Roadmap Technical Report, November 2021, UKGBC Last accessed 04/2022

Next steps

The UKGBC predicts that it is possible for the built environment sector to cut carbon emissions to 7 mega tonnes of CO₂ by 2050, or 9 mega tonnes of CO₂ when including consumption emissions. The CCC projection for remaining UK emissions in 2050 that will need to be offset is 97 mega tonnes of CO₂ (excluding consumption emissions). This means the built environment’s residual emissions in 2050 equate to 7% of the residual carbon emission levels that the Climate Change Committee (CCC) predicts the UK can and should reach.

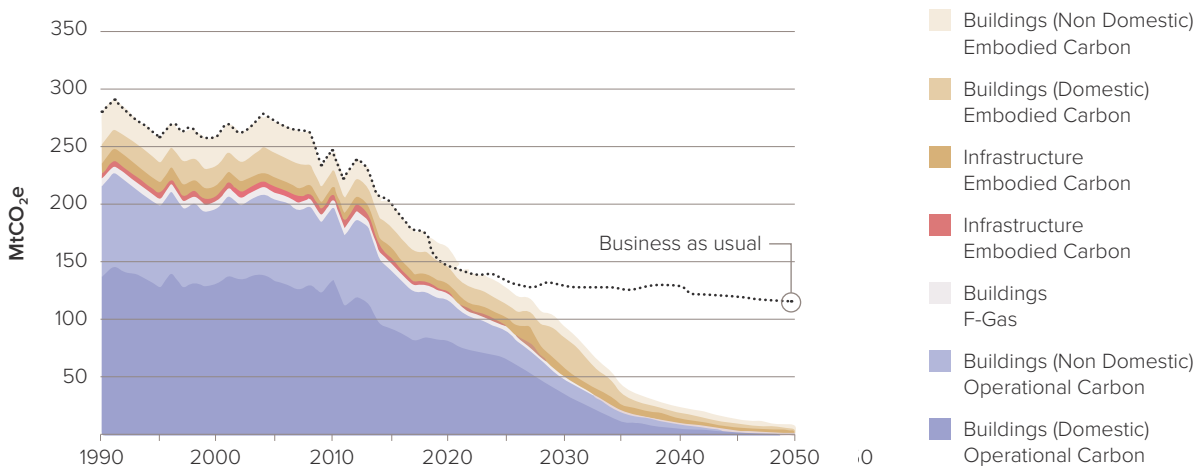
Recent months have seen a major uptake in ambition in this area. If the UK building sector is to reach its goals, it must convert that ambition into action. As an immediate action, the UKGBC recommends joining the CCC-backed Race to Zero² campaign. This is the most ambitious climate net zero campaign to date and is open to every business and professional working in the sector.

“After all the talk, it’s time for action. The UK Government’s Heat and Buildings Strategy is a step in the right direction but fails to address several key priorities that this analysis clearly demonstrates are non-negotiable to achieving a net-zero carbon built environment by 2050. The Net Zero Whole Life Carbon Roadmap pulls together disparate strands of recent policy and action into one coherent pathway, with clear recommendations for National Government and Local Authorities, as well as the private sector and the wider industry. We urge policy-makers and industry to embed these recommendations into policies and strategies to make good on the promises and commitments of COP26.”

Julie Hirigoyen, CEO, UKGBC

FIGURE 1

UK Whole Life Carbon Roadmap Trajectory



2. Net Zero Whole Life Carbon Roadmap Technical Report, November 2021, UKGBC Last accessed 04/2022

The systems approach to building sustainability

Dervilla Mitchell, Deputy Chair of Arup spoke about viewing buildings as a whole system to meet sustainability challenges in the sector.

Achieving net zero demands the most comprehensive transformation the construction industry to date and it will create a fundamental shift in the planning, design, delivery, and operations of buildings as well as the infrastructure they rely on. Choices made by engineers, architects, constructors, and suppliers about materials used for new and refurbished buildings have significant implications for carbon emissions. Good decisions can reduce a building's embodied carbon significantly as well as its future operational carbon emissions.

Embodied carbon key learnings:

- Embodied carbon accounts for up to half of a building's whole life carbon emissions; most embodied carbon is created during the manufacturing of materials and the construction process.
- The manufacture of six materials accounts for approximately 70% of the global buildings sector's embodied carbon emissions: steel, concrete, aluminium, steel reinforcement, glass, and raised flooring.
- Embodied carbon associated with maintenance and refurbishment projects account for approximately 20% of a typical building's whole lifecycle carbon emissions.

Buildings should be designed and constructed in ways that reduce their embodied carbon as well as their operational carbon, which is one reason why building components need to be reused and reclaimed wherever possible. Taking a 'circular' approach to materials as part of the journey to net zero will allow the construction industry to become a driving force within the circular economy. Circular economy and net zero goals support each other, and a systems approach creates ways of achieving progress in both.

Overcoming industry barriers

An industry-wide agreement on what net zero means for buildings is a critical requirement as it will set the parameters to work within. Any agreement should include a valid offsetting solution for the sector's residual emissions. In parallel, a consistent method of measuring and reporting carbon emissions across buildings' full lifecycles is needed, based on existing whole lifecycle

carbon assessment techniques. This will give the industry analytical capability, allowing better comparison between projects and the transparency of data at an industry level. The industry must be prepared to experiment as it develops solutions.

Overcoming industry barriers requires:

- Immediate action: Easy and immediate changes include prioritising the design of passive systems, prioritising energy efficiency and being proactive in the management of buildings. These approaches will reduce buildings' operational emissions.
- Longer-term changes in attitude and approach: The industry should strive to build less, refurbish more, and reuse materials wherever possible. In addition to reducing embodied carbon significantly, these changes could act as a strong driver for further innovation within the industry.
- The final step: Once the industry has minimised its emissions, it must also offset residual emissions credibly and transparently.

Every business and stakeholder seeking to contribute to net zero should:

- Adopt whole lifecycle carbon assessments for all buildings projects, measuring every source of emissions at all stages of a project. Widespread use of whole lifecycle carbon assessment will create a consistent methodology to allow the sharing of comparative data. In turn, this will create a body of evidence to foster the sharing and learning required to move the industry forward faster.
- Develop consistent and transparent carbon intensity certification for all building components, systems, and materials.
- Promote industry-wide collaboration and a systems-wide approach across the whole buildings value chain and between governments, businesses, and academia alike.

Learning through case studies

Arup worked with the World Business Council for Sustainable Development (WBCSD) to identify case studies demonstrating current best practices and key levers to drive decarbonisation for the built environment. One case study is the refurbishment of 1 Triton Square, a London office building built in the 1990s. Its refurbishment focussed on reuse of materials to minimise new embodied carbon emissions arising from high carbon intensity materials being introduced as part of the building's renewal. Large elements of the building, including its superstructure and original façade, were renewed and retained. This approach to refurbishment saved more carbon than the building will release during its next 20 years' of operations.

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“Viewing buildings as a system is the only way forward. We need to act together and decisively to accelerate the design and construction sector's progress toward net zero. Let us really come together to demonstrate that our industry can lead. We need to address embodied carbon and to invest in research and development and knowledge sharing.”

Dervilla Mitchell CBE FREng, Deputy Chair, Arup Group

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FIGURE 2

Recommended policy changes to increase demand and uptake of net-zero carbon buildings

Reduce embodied carbon

- Building regulations requirement for whole life carbon assessments of new buildings and major renovations
- Requirement through NPPF for whole life carbon assessments of new buildings and major renovations
- Extension of Local Plan 'zero carbon' requirements to cover whole life carbon, including offsetting of these impacts

Reduce energy demand

- Mandatory disclosure of operational energy performance rating for all commercial buildings (with delineation between landlords and tenants where applicable)
- Transition to using operational energy ratings as the basis of minimum base building energy efficiency standards for commercial rented properties

Increase renewable energy supply

- National planning Policy Framework (NPPF) 2018 Planning Practice Guidance (PPG) on Climate Change to require 'net zero' for all new developments
- Recognition of off-site renewable energy procurement as carbon abatement measure within Building Regulations

Offsetting

- Infrastructure Act 2015 provision on allowable solutions mechanism
- National offset framework or fund in line with Infrastructure Act provisions
- Consistent national framework for local offset funds to improve consistency and transparency

UKOBC Net Zero Carbon Buildings Framework

Unlocking building sustainability: the role of value-based decision making

Keith Waller, Programme Director at Construction Innovation Hub focussed on how to create the right enabling framework and conditions for technology solutions to succeed. The Value Toolkit identifies approaches that maximise value across the life-cycle of a project.

The current political and regulatory environment in the construction sector is complex and evolving but there is increasing demand for better value investment. Driving better value involves delivering on multiple interdependent priorities around social value, cutting waste, reducing carbon, and improving the performance of buildings.

Despite a broad array of policy reports advising procurement and project delivery, clients in the public and private sector often struggle with the complexity, breadth, and depth of the guidance available. Complicated and inconsistent advice prevents effective delivery of the wider social, economic, and environmental market ambitions required for a sustainable construction sector.

Establishing priorities

Clear priorities are needed to deliver the sector's policy goals and values. There are several key areas where the construction industry currently falls short and needs new solutions.

- Industry lags on productivity and its approach to R&D investment.
- Construction generates too much physical and process waste.
- Buildings often fail to deliver on expected performance.
- Energy use during construction and operation is unsustainable.

The Construction Innovation Hub, in collaboration with 600 stakeholders from across the supply chain, has developed a value toolkit that works from the sector's objectives and helps people to make decisions that deliver better value across the whole life-cycle of a project. The toolkit is designed to help establish which interventions in a project or process will drive the greatest social, economic and environmental value from investment in the built environment. By focusing on value, the toolkit advises the stakeholder how to best manage the multiple and often competing requirements of the industry at every stage of the lifecycle process from business, design, delivery and operation.

The toolkit is aligned with the government's Construction Playbook³ and Transforming Infrastructure Performance programme⁴, the toolkit can be used widely and with confidence by clients and advisors alike. It enables clients to demonstrate that they are delivering the value profile and objectives of their project. Similarly, the public sector needs to demonstrate that policy is being translated into meaningful action. In the private sector, the increasing role of ESG is driving the need to demonstrate the delivery of broader outcomes beyond traditional cost, time and quality.

The value toolkit is currently in its pilot phase, funded through the construction sector deal, and is being tested on live programmes and projects. At the end of the pilot phase, it will be launched as a freely available web app tool.

3. The Construction Playbook, Version 1.0, December 2020, HM Government Last accessed 04/2022

4. Transforming Infrastructure Performance, December 2017, Infrastructure and Projects Authority

FIGURE 3

The Value Toolkit has 5 key streams of activity:

- 1. Value definition** stream develops and refines a unique *Value Profile* for a project, programme or portfolio, enabling clients and their stakeholders to articulate what is important to them – their core values and drivers.
- 2. Risk** stream helps clients to identify and create a *Risk Profile* for the project.
- 3. Client Approach** stream helps clients to select a *Delivery Model* and build a *Commercial Strategy* which best fit the Value Profile of a project. It focuses on how clients work with the market to effectively deliver value and to address risks in an effective way.
- 4. Measurement & Evaluation** stream builds on the Value Profile to develop a project or programme-specific *Value Index*.
- 5. Appointments** stream helps the client build a team of highly motivated individuals and organisations that will deliver all phases of a project – from the validation of the business case through to the operation of the asset.

“It’s about delivering value for money. But that’s not the same as delivering cheap. If you buy cheap, you get rubbish. We need to think about value in a much broader lens than just the capital cost of construction.” -

Keith Waller, Programme Director,
Construction Innovation Hub

The role of active buildings in a low-carbon built environment

Joanna Clarke, Design Manager at SPECIFIC focused on the use of active buildings to help reduce carbon emissions from the built environment and be the stepping-stone for getting new technologies to market.

The concept of an 'Active Building' was developed by the SPECIFIC Innovation and Knowledge Centre based at Swansea University. These buildings would combine locally generated renewable energy technologies and smart control strategies to create an integrated system for heat, power and transport. The buildings are designed to be mostly self-sufficient and could sell back to the grid if surplus energy was created.

Active Building demonstrators

SPECIFIC have built a series of real-world demonstrators that are used to test and validate combinations of technologies, de-risking their use in other projects. The demonstrators collect significant data on their operation to:

- Test and optimise the integration of new technologies with building services instead of in isolation.
- Generate performance data that can be fed back to partners for optimisation of products.
- Demonstrate how different control strategies affect the operational carbon of new technologies.

The Active Classroom, SPECIFIC's first building demonstrator, was developed to enable the trialling of cutting-edge technologies on the market, such as aqueous hybrid ion batteries, and novel building approaches, such as an offsite panelised construction system. It also allowed the testing of pre-commercial products and prototypes such as NSG Pilkington's photovoltaic windows and a building integrated photovoltaic (BIPV) system. Testing these novel products and technologies on real building demonstrators has provided performance data and feedback on factors such as their aesthetics, installation methods and maintenance, which has helped product development. The BIPV roof, for example, is now available as a commercial product and has been deployed on many buildings since the Active Classroom. The manufacturers of the offsite panelised system made adjustments to their product based on their experience of building the classroom and feedback SPECIFIC were able to offer them.

The Active Office demonstrator

Their second demonstrator, the Active Office, utilised less experimental technology, but with more sophisticated testing techniques. An energy dashboard allows time-specific monitoring of the energy generated and consumed by the building, its carbon usage, how the energy is being used and the state of charge of the energy storage system. Several key data collection sources include heat meters on the building's distribution pipework to allow tracking of energy consumption and any faults to be detected, located, and quickly fixed. Sensors in all rooms monitor variables such as occupancy, temperature, air quality and light levels thereby giving an accurate depiction of how the building's systems perform. There are two primary means to tackle carbon intensity in use for buildings.

- Reducing energy use: making data-backed decisions, SPECIFIC were able to obtain an 11.5% reduction in energy usage over 1 year, taking the building to ~ 61 Kilowatt Hours per metre squared. Energy generated by the building nearly matched consumption.
- Reducing the carbon intensity of the energy used: Maximising solar energy usage and minimising grid energy usage reduces the carbon intensity of the cumulative energy used. Relating energy consumption with energy type used over 30-minute intervals, SPECIFIC demonstrated an 18% reduction in carbon emissions for the first quarter of 2020. Active and accurate energy monitoring also allow SPECIFIC to take more active control of its batteries, determining when to charge or discharge them according to the carbon intensity of the grid at any given moment.

SPECIFIC anticipate that a further one megawatt hour of energy reduction is achievable by examining the building's lighting and the hot water generation. Accurately measuring energy consumption also enables the tracking of small power usage, which can be sizeable and is often not considered in operational energy consumption. SPECIFIC has worked in collaboration with Measurable.energy to monitor small power usage and identify opportunities for savings. Being able to monitor and display the energy usage of a building is also an effective tool for improving energy literacy of building occupants and visitors.

The Active Building Centre

The Active Building Centre, established in 2018, is led by Swansea University and funded through the Transforming Construction Challenge within the UK government's industrial strategy. Its focus is on enabling the mass adoption of the Active Building concept in building projects across the UK.

The Active Building Toolkit

SPECIFIC have developed a toolkit, which includes a series of case studies, manuals and guidance documents. It highlights technologies that are available for use in Active Buildings and is updated as new technologies emerge.

Leading transformation at scale

Sam Stacey, Challenge Director for the Transforming Construction programme spoke about Innovate UK's work to transform the construction industry.

In 2013 the Construction Leadership Council and BEIS were involved in setting targets for the construction industry for 2025: reducing whole-life construction costs by two thirds; halving emissions from the built environment; achieving 50% faster delivery; a 50% improvement in the balance of trade; and 15% improvement in productivity. Since then, Innovate UK have demonstrated that these targets are achievable.

To unlock the potential of the sector and encourage stakeholders to commit to change the Transforming Construction Challenge has taken a three-step approach to laying the foundations for rapid and effective change:

Step 1: Defining value drivers and the platform approach

The industry's key value drivers were defined in a Value Toolkit. This is a series of integrated activities supported by tools, resources, and guidance. The goal is to help make project decisions, guide best procurement methods and support groups to find capable partners to help deliver their goals according to the value profile of the project.

Step 2: Proving platform methods

Over 50 projects were funded to pilot and de-risk their respective sustainable construction approaches. Such approaches included product-based building systems, the kit of parts approach, digital twins, off-site manufacturing, automated construction, data collection during the construction process and rapid intelligent decision making. Examples of the projects include:

- AI Enabled Automated Costs and Carbon Estimated project: led by Skanska, this platform is being piloted on HS2 and links carbon emissions with their cost effect. The project aims to reduce embodied carbon by 30%, operational carbon by 10% and project costs by 13% across the whole life cycle.
- HIPER Pile project: led by Keltbray, the project trials the use of hollow piles that integrate with building components to help generate, manage and store energy. The approach requires fewer piles, less material and uses light-weight cement-free concrete thereby significantly reducing embodied carbon whilst also allowing for heat exchange with the ground.
- The Active Office project: The SPECIFIC demonstrator building shows the energy savings that active buildings can achieve and proves that they are economically viable and capable of achieving economies of scale. It builds the business case for technologies that can capture, store and control green energy.

Step 3: Shifting public procurement with the construction playbook and procurement of assets

By ensuring a large enough order book, the rapid scale-up and adoption of the techniques will be much easier to achieve at the pace required. Examples of large-scale implementation projects include

- Ties living lab project: Making transport infrastructure smarter, greener and better value for money. It has adopted the use of AI and sensors to monitor and inform the production process and is standardising technologies that have potential for cost and efficiency savings, such as cooling systems for underground stations.
- Challenging Space Frontiers in Hospitals: Adopting techniques used in the space industry to produce operating theatres more effectively with up to 50% fewer emissions.
- GenZero: Developing a prototype system for producing net zero schools in both urban and rural settings. It employs generative design, the platform approach and active building technologies all configured using artificial intelligence tools to develop the optimal solution for any given school.

Next steps

The Transforming Construction programme has established a model for enabling leadership and innovation in the sector. They have laid the foundation for the system, piloted, de-risked and funded a big portfolio of projects, and proven that platform approaches such as kits of parts, configuration, digital models and digital twins work. They have shifted public procurement in line with their industry recommendations stimulating the market as a result and shown how to embed whole-life carbon value in the decisions made through the whole project life cycle. Industry must now seize the opportunity to commit to and invest in these changes.



“This is not all about pain, there is a lot of gain to be had.”

Sam Stacey, Challenge Director, Innovate UK



Sustainable chemistry: a question of scale

Professor Peter Licence, University of Nottingham, spoke about the design, construction and use of a new chemistry laboratory that is carbon neutral from design to use.

The GSK Carbon Neutral Laboratory is the first attempt to deliver a carbon neutral science facility. It is now a fully functioning space with all the equipment required to deliver high-quality, world-leading science. Sustainability has been achieved in the construction and the design of the building, even the researchers within the building now avoid using environmentally damaging chemicals.

Maintaining sustainability in construction

The materials used prioritised sustainability at every level. The procurement process involves analysis of embodied carbon emissions, transport associated carbon, recycled content and where available, each material's Environmental Product Declaration at every stage of construction. Timber was the primary construction material chosen, with small amounts of steel used in complex joints. Walls were a combination of timber stud and solid cross laminated timber. Cladding was made from once fired terracotta tiles, substantially reducing the embodied carbon of traditional tiles that are twice fired. High fly ash concrete used for footings and foundations were sourced from a local power station.

The building is designed in an aerofoil shape to allow natural wind assisted ventilation of the labs. On the light side of the roof, translucent photovoltaic roof panels are used to power the building and provide light, whereas on the dark side, the roof has been covered with the earth removed during construction. This process has improved the building's insulation whilst also increasing biodiversity and reducing the transportation carbon associated with removal of the soil. The entire building was constructed in parts offsite and brought to site for assembly. This modular approach significantly reduced construction time.

The carbon mortgage

During the project, carbon cost was counted alongside financial cost. As such, it was possible to accurately record where and how much carbon was invested at each stage of the project. The CO2 mortgage of the building was quantified and is to be paid back to the environment over the building's lifetime. The building does this through the generation of its own sustainable energy, using a model that compares the generation of energy with consumption. As with a typical mortgage, the target is to repay the debt within 25 years.

Additionally, chemical labs are energy intensive, yet the design and materials used in the building mean that the lab uses 32% of the energy of a traditional facility of equivalent size with no compromise to the quality of the science performed within it. It has achieved impressively low levels of embedded carbon and has reduced water consumption by 45% through smart management of use.

By continually collecting and monitoring the building's performance data, the facility managers are also able to identify where the building is underperforming and iterate and adjust its operation accordingly.

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“When we're pressurized and made uncomfortable, we evolve and when we evolve, we make big changes.”

Professor Peter Licence, University of Nottingham

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Passivhaus design methodology at scale

Hannah Jones, CEO and founder of Greengauge spoke about the Passivhaus solution to sustainable construction and her experience of delivering sustainable domestic housing at scale.

The Passivhaus methodology focuses on designing for simplicity and delivering thermally comfortable buildings which are affordable in delivery and operation. A successful Passivhaus focuses on optimising both comfort and energy efficiency.

Comfort and energy efficiency

Comfort as a concept revolves around air tightness and a constant surface temperature. Controlling air movement through a space reduces heat loss and provides better control of moisture, humidity, and volatile organic compounds. In public buildings, good ventilation design can also be used to control the spread of infectious diseases. A stable internal surface temperature with shifts of less than 4°C, delivers a significant level of thermal comfort. The management of summertime overheating must also be considered and this requires a physics-based, whole house approach. As a standard for Passivhaus, space heating demand must be below 15 kW hrs per m² per year and a primary energy demand of 120 kW Hrs.

Passivhaus buildings are simple, robust and long lasting, thereby making them easy for homeowners manage. The Passivhaus calculation methodology is a valuable tool for designers to accurately design and optimise buildings based on real-life scenarios rather than nominal targets.

Scaling delivery

Greengauge worked with architect Mikael Riches and the designers at Warm to deliver 93 Passivhaus dwellings as part of a social housing project in Norwich funded by the city council. The Goldsmith Street project was the largest deployment of social housing using Passivhaus methodology to date. A key goal for the council was to minimise fuel costs for residents.

The key learnings from the project were:

- The greater the simplicity of the design, the more flexible the project is and the easier it is to address unexpected issues as they arise during construction and operation.
- The design of the building, its form, and the materials used play an important role in achieving the goals.
- Manufacturing the frame off-site allows for a high level of control, although this reduces flexibility to adapt the design during construction.
- The methodology and strict adherence to guidelines are a priority at every stage of the project for every stakeholder from design to delivery.
- A Passivhaus consultant is needed to support the design team and a certifier is needed to act as an independent body, checking and supporting the design process and ensuring that it will meet certification requirements once delivered.
- For a Passivhaus project to be a success, the client and whole design team must commit to the challenge and make sure they work as a team to deliver it.

Circular building in construction: the K-Briq

Professor Gabriela Medero, Heriot-Watt University spoke about material innovation in the sector and the development of the K-Briq.

Material challenges facing the construction industry

The UK's construction industry produces over 100 million tonnes of waste per year, accounting for over one third of the nation's total waste produced. This is detrimental not just in terms of carbon emissions produced but also valuable virgin resources such as sand and clay exploited and sent to landfill. New laws trying to address this have recently set targets for 70% of all construction demolition waste to be recycled with none going to landfill.

Not only is there significant waste, but there are also material shortages. The UK imported 500 million bricks in 2019 and used 2.6 billion; during the pandemic this figure is estimated to have risen dramatically. Shortages of construction materials means that bricks are being imported from as far as Ukraine. Such transportation distances add greatly to the carbon footprint of bricks.

Despite challenges, there is urgent pressure on the government to build more homes, having now set targets of an additional 200,000 new homes per year.

A new brick made from the old

Bricks have been used in construction for over 9,000 years. The first bricks were made of mud and hardened in the sun. The current standard, the fire clay brick, goes through multiple stages; recovery of raw clay, preparation of clay, moulding, drying, and firing. Whilst the steps required to prepare the clay are relatively extensive, the bulk of the energy used (approximately 90%) comes from the firing of the brick.

As an alternative with 10% of the carbon footprint, Professor Medero at Heriot-Watt University has developed the K-Briq, which is made of 90% recycled content. By removing the need to fire the brick, the energy consumption is greatly reduced. Additionally, cement is not needed in the mixture, further reducing processing energy. Due to its ingredients, the K-Briq has a cyclical life cycle, providing reduced energy benefits. It still meets the most stringent building standards globally, however, being comparable to the high performance of traditional brick in terms of strength, durability and benefits additionally from double the insulation properties.

To keep embodied carbon minimal, K-Briq factories and production plants can be built next to demolition recycling plants and in areas of high demand for bricks. By doing this, brick mileage and associated carbon from transportation of the product can be dramatically reduced.

The K-Briq has already been patented in the UK and the US (and later stages with Canada and Europe). The development was funded by Scottish Enterprise (High Growth Spin-Out Programme), the Royal Academy of Engineering, Construction Scotland Innovation Centre and Zero Waste Scotland. Scale up of production is underway with a target of producing 3 million bricks per year. The K-Briq has been used in a number of small scale projects; including a demo-wall for COP26 and Hampton Flower Show.

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“With the K-Briq, we are developing a blueprint for necessary change in the current approach to brick manufacture. We hope that waste handling facilities around the UK will work closely with us and existing brick manufacturers to replicate this circular economy approach, removing the need for imported bricks entirely.”

Professor Gabriela Medero, Heriot-Watt University

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Delivering and scaling sustainable new build projects

Chaired by Adam Lock, Partnership and Innovation Leader at Laing O'Rourke, this panel comprised of Sam Stacey, Challenge Director for the Transforming Construction programme; Professor Gabriela Medero, Heriot-Watt University; Professor Peter Licence, University of Nottingham and Hannah Jones, CEO and founder of Greengauge.

When will we begin to see the impact of the innovations that are being developed and supported?

- Inevitably there is a lag between the procurement of technologies and approaches and seeing the finished buildings, however, the buy-in from both the private and public sector means that changes are in the pipeline. Procurers and designers are already beginning to incorporate sustainable and modern techniques into their work and there is activity from both the private and public sector.
- Developers and clients remain nervous of being stuck with stranded assets, so it is important that the industry rewards those making bold and progressive moves with consistent advice and regulations. It is also important that regulations are as strict and strictly enforced as possible so that there isn't an opportunity for people to continue to deliver buildings at lower capital costs and higher environmental costs. Sustainable construction is financially viable but there can't be an opportunity for people to cheat.

What is the best approach for dealing with multiple and sometimes competing drivers for a project?

- This issue of dealing with multiple priorities for a project is a matter of determining key drivers. Any building must be functional as well as environmentally good. Developing a tool that serves its purpose to a high standard is critical. 'Carbon cost' is a universal parameter that is easy to understand however the key and underlying priority is ensuring material and energy efficiency.
- Because there are multiple priorities and drivers, it is vital to understand the process and consider all parameters at every stage of a project from design to delivery. It is also important to continually monitor and adapt at every level of the building's life-course.

How to balance fabric versus active control systems of the building. Is the fabric first approach always right?

- An efficient building is one that can balance its thermal gains against its losses. In the 1970's, the focus was placed on reducing energy demand in buildings, which resulted in a heavy reliance on solar and led to buildings that were uncomfortable and prone to overheat. By adopting a fabric first approach to achieve building features such as natural ventilation and air tightness, the resulting reduced reliance on energy control systems such as renewable systems and energy storage systems means that fewer valuable materials are used overall.
- Overall, resource efficiency is key to achieving more sustainable resources. An ideal technology or building material is one that considers the environment not only in terms of its short-term effect from production but also its whole life cycle. It should also be flexible to the changing demands of the construction industry.

What is the most important action to scale up the impact of any innovation developed?

- We must re-educate ourselves to accept change because resistance to change is the biggest challenge.
- We must commit to business change and to doing things differently. We have to commit to modern methods of construction and learn from people and business in the area that are already adopting them.
- We need the education, training and skills within the construction industry to be able to deliver the collaborative effort that's required to deliver low energy buildings effectively and efficiently. We must change the way our workforce operates.
- We need the user pull. We need to educate users and to grow their appetite for solutions so that they are open to adopt the solutions on offer.
- Facility managers must be trained how to get the best out of the building. That is a slow process, because skills rarely change rapidly enough when we're innovating with function.

The green homes revolution: The need for a national retrofit strategy

Brian Berry, CEO of the Federation of Master Builders (FMB), spoke about the National Retrofit Strategy and the need to improve the UK's existing building stock to achieve net zero.

The UK's existing building stock currently consumes 35% of national energy generated and is responsible for a fifth of carbon emissions. An estimated 85% of the nation's existing housing stock will be in use in 2050, of which 28 million homes require energy efficiency retrofitting. Retrofitting will also benefit the estimated 2.5 million people living in fuel poverty in the UK.

Existing barriers for change: Industry and consumer challenges

Despite the clear need to retrofit buildings, there has been a 95% decline in installation of domestic energy efficiency measures since 2012, with only a tenth of households undertaking standalone efficiency works.

Current barriers to retrofitting for the consumer include the fact that there is little financial incentive or awareness of the benefits. Energy efficiency measures increase property values by around 2% and if property owners do decide to retrofit, they struggle to find accurate information and support. Lack of regulations or quality control means that consumers are also concerned about the poor quality of retrofit work. The industry is currently fragmented and difficult to navigate. There is also a substantial skills gap with no recognised training or qualification focussing on low carbon retrofit. Finally, there is a lack of clear pipeline of work which disincentivises investment in retrofitting.

An overarching barrier across the sector is the short-term thinking and temporary nature of policies made by successive Governments, which result in a lack of clear vision and leadership. The implementation and subsequent termination of schemes such as the Green Homes Grant has had a negative impact on credibility and confidence across the building industry.

Actions for change

The FMB's *Building on our Strengths*⁵ report proposed the following actions to aid the transition towards a zero carbon economy

- Update the Building Regulations to mandate more energy efficient properties;
- Cut VAT on all home improvement works to 5% to reduce the cost of building works.
- Introduce a licence to trade for building firms to increase consumer confidence and promote high-quality construction;
- Incorporate a foundation course on buildings and energy into all construction training;
- Introduce 'building renovation passports' to enable householders to understand and to better assess what changes are needed to make their homes more energy efficient; and
- Intervene in the market to make retrofitting affordable and accessible for the homeowner.

The National Retrofit Strategy

The FMB has worked with the Construction Leadership Council (CLC) to develop the *National Retrofit Strategy*⁶. It is 20-year roadmap to retrofitting the UK's building stock that co-ordinates actions to increase consumer awareness, provide financial incentives and scale up industry capacity in four phases. It identifies 8 interdependent deliverables that must be considered together for their roadmap to succeed⁷.

Phase one would focus on increasing awareness through a communications campaign and addressing the current skills gap through investing in training. Phase two would increase output and establish clear consumer protection mechanisms. Phase three would see rollout of retrofit meet its maximum speed. The final phase of the strategy would focus on properties that are harder to retrofit.

Next steps

The National Retrofit Strategy has been developed to align with political incentives and other programmes such as the Construction Leadership Council's Construct Zero Campaign. The strategy requires a funding of just over £5 billion to kickstart the retrofit market – but it will save £1.4 billion for the NHS within four years and significantly reduce carbon emissions. Within ten years, an estimated 100,000 additional jobs will be created. The National Retrofit Strategy is backed by over 50 organisations across the built environment sector.

“We will only achieve a green industrial revolution if we have a green homes revolution. And we won't get to that unless we have a national long-term retrofit strategy to transform the homes we live in.”

Brian Berry, CEO, Federation of Master Builders

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5. Building on our strengths: A market transformation approach to energy retrofit in UK homes, July 2021, Federation of Master Builders and the Centre for Research into Energy Demand Solutions Last accessed 04/2022
 6. Greening our existing homes: national retrofit strategy, Construction Leadership Council Last accessed 04/2022
 7. Page 8 of the national retrofit strategy

Overcoming challenges to energy renovation of buildings

Adrian Joyce, Secretary General of EuroACE, focused on the technical challenges of retrofit and highlighted examples of approaches that are working across Europe to effectively mitigate climate change and reduce the impact of the climate sector.

Together, the heated and conditioned indoor floor area of the UK plus EU building stock is roughly equivalent to the size of Belgium. Of those buildings, 75% are residential and only 3% have reached an energy label 'A' as defined by the Energy Performance of Buildings Directive in 2002⁸.

The EU context

Through its Climate Law, the EU has committed to become the first climate-neutral region in the world. Its Renovation Wave Strategy⁹, set out by the European Commission (EC), will help to achieve this by deeply renovating 35 million buildings and reducing the overall energy demand from buildings by 14% by 2030.

Technical challenges ahead

Lack of financing and low consumer demand are typically cited as the greatest challenges for achieving widescale energy renovation. The EC proposes to address these through the upcoming Minimum Energy Performance Standards, which will define minimum-term targets and oblige owners to energy renovate. Technical challenges relating to the scale of the challenge, including a lack of capacity, skills shortages, and a traditionalist attitude to on-site works, must also be addressed.

- The rate of deep energy renovation in the EU is currently below 0.2% of the building stock per year. This must increase by a factor of 10 within the next few years if the EU is to reach its climate targets in the sector.
- The workforce in the construction sector is not trained to understand fully how to achieve a deep energy renovation. Typically, the importance of precision work when installing insulation and achieving necessary air-tightness detailing is poorly understood.

- The workforce is ageing at a time when there are already not enough workers in the industry. The construction industry is not perceived by young people as an attractive career option, although this may change as the industry adopts more digital approaches.
- The speed at which on-site works take place is still too slow in most cases. Industrialised and prefabricated approaches to renovation can help this.

The Work of EuroACE

EuroACE has recently extended its call for the decarbonisation of buildings in use, through a combination of achieving high energy efficiency and the use of renewable energy sources for buildings. The organisation believes that the technologies and approaches required to transform Europe's buildings are already available in the market today. The challenge, however, is their rapid and widescale deployment. To prove that the methods already exist, EuroACE have highlighted a series of 23 projects and programmes across the EU that exhibit best retrofit practices. The projects include:

- Bordeaux, France: A social housing complex consisting of 530 dwellings that was saved from demolition as part of the regeneration of the "Cité du Grand Parc" in Bordeaux.
A prefabricated modular approach was used for construction. This kept disruption to a minimum and enabled the tenants to remain living in the building throughout the renovation. Despite a 50% increase in habitable space, rent for the occupants remained the same. The overall energy performance of the building was improved by 60% and the construction costs were just €500 per m².

8. Directive 2002/91/EC of the European Parliament and of the Council. A revised version of the EPBD was published in 2018 (Directive 2018/844/EU). Last accessed: 04/2022.8.

9. A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives, 10/2022, European Commission. Last accessed 04/2022

- Bratislava, Slovakia: An 88-apartment block that had been poorly constructed in the 1980's and poorly maintained since achieved a 74% reduction in energy demand through the City of Bratislava's participation in an EU-funded project, EU-GUGLE¹⁰. Residents own their flats, but no-one is responsible for the common areas and shared technical systems. Any energy renovation must be unanimously agreed by all owners of the building – meaning that the larger the living complex, the more difficult renovation becomes.
- Portsmouth, UK: A social housing complex consisting of 107 homes dating from the 1960s, where residents experienced high heating bills, with most of them suffering from serious fuel poverty as well as mould, damp, and condensation, which had adverse health effects. Good advance planning meant that the renovation works were performed while the residents were living the building. The deep renovation reduced energy demand by 90% and the building now meets standards for energy efficiency that are equivalent to Passivhaus standards. Residents now only use active heating systems for a few hours each winter. The living conditions and well-being of residents has improved dramatically.

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“Looking ahead to the time when energy renovation activity in the EU will reach the levels that match our climate ambitions, we can expect that there will be more quality jobs of a more diverse nature in the construction sector. This will stimulate our economies, increase revenues for public finances and dramatically improve the quality of life of our citizens who will be living and working in more comfortable, healthier buildings.”

“The products, equipment, and technologies needed to transform Europe's buildings are available in the market today. The challenge is to deploy them at scale in all countries in a short timeframe.”

Adrian M Joyce, Secretary General, EuroACE

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10. TH EU-GUGLE project, <http://eu-gugle.eu/> Last accessed 04/2022

Developing a UK net zero market

Emily Braham, Head of Strategy and Operations at Energiesprong UK, spoke about the company's approach to scaling retrofit solutions.

The Energiesprong model makes buildings more energy efficient by insulating them in scalable off-site manufactured insulating shells, and installing smart heating solutions with vastly reduced energy consumption. Energiesprong UK works with suppliers and clients to create a market, runs pilots to remove existing barriers to scalable retrofit and feeds its project learning and recommendations back to policy makers.

Solutions must enable occupiers to live in comfort for the same cost or less than they paid before the retrofit; the design must be attractive, appealing and desirable to the consumer, performing in the way in which it is intended to; installations should also cause minimum disruption to the consumer. This objective is best achieved by digitalising processes and maximising off-site manufacturing to reduce the time required on-site. Compared to traditional on-site manufacturing processes, an industrialised off-site manufacturing approach increases quality, drives down waste and facilitates the more rapid scale-up of a given technology- thereby making the solution more affordable in the longer-term.

At present Energiesprong UK is working with landlords – who hold significant volumes of homogenous stock – to advise and unite them to generate a large enough demand to stimulate the supply chain and lay the path to wide-scale renovation.

Pilot projects

Retrofit projects can differ dramatically according to the task and requirements of the consumer. Fabric-first retrofit solutions put a full wrapper around a building, changing its exterior. On the other hand, technical retrofit solutions can be used to make a building more energy efficient without altering its aesthetics.

- **Fabric innovation case study: Structural wrapping**

The manufacture and installation of off-site façades is an industry in its infancy in the UK. In Nottingham, Melius Homes are working to design and produce a structural wrap for buildings. They have now set up their own factory to manufacture façades with fitted windows off-site, and on-site construction time has been reduced to two weeks per property.

- **Technology innovation case study: The Communal Energy Centre**

Melius Homes were tasked with developing a strategy to heat and power 39 homes without exceeding the tenant costs set by Energiesprong.

A communal energy centre was installed, consisting of a heat pump, thermal and battery storage systems. The system optimised the energy produced on-site and distributed it between the houses as needed via private wire, thereby minimising the amount bought from the grid at a greater price. This reduced bills, which enabled the landlord to collect more from the tenants to help pay for the cost of the retrofit work.

Maintenance could be centralised and accessed without needing to obtain permission to enter each tenant's property. One drawback, however, was the energy centre's technological complexity, and determining responsibility for its upkeep. One approach would be to have service providers in place to maintain the systems.

Communal energy centres are difficult to install retrospectively, working best for new builds. For retrofit, a preferable solution may be energy pods for each tenant – such as those created by Ventive¹¹ – which are heat pumps with hot water, ventilation, cooling and controls all integrated into one box. As one relatively simple system, they can be manufactured off-site and installed in a day. Such energy pods are also self-optimising, as they can interact with the grid in a smart way to buy energy at off-peak times and store it until it is required by the tenant.

11. Ventive Limited, <https://ventive.co.uk> Last accessed 04/2022

Energiesprong UK pilot studies learning:

- Products to retrofit whole houses are not yet available to buy. Procurements should be structured as a partnership to develop prototypes, which can then be scaled.
- Every property differs slightly, and one retrofit solution does not fit all. To effectively scale retrofit, it is essential to get the digital process correct, from scan to manufacture.
- Innovating within grant-funded project timescales is challenging. Products should be prototyped before the project delivery starts so that they can be fed into a project and scaled up at speed.
- New materials and façade approaches may be required to deal with hard-to-access and unusual types of property.
- Energy efficient buildings are becoming machines, which will have to be serviced and operated. The industry must be careful not to just focus on the initial retrofitting stages, but also on maintenance, operation and optimisation once fitted.
- Collaboration is key. Solving the challenges that arose during Energiesprong UK's pilot projects depended on partners working together.

Bringing storage to heat: a scalable solution to sustainable retrofitting

Andrew Bissell, Founder & CEO at Sunamp Ltd, spoke about the company's work to bring better storage to the heating sector.

Heat is 46% of final energy demand in the world. With the UK rapidly decarbonising its electricity grid and supply, Sunamp's goal is to provide effective compact thermal storage to facilitate the effective electrification and decarbonisation of heat energy.

A good quality gas boiler of over 90% efficiency will burn gas with about 200 grams of CO₂ per kilowatt hour of heat. Electrifying space heating and hot water can improve on this, with even poorly performing heat pumps capable of halving the carbon emissions of gas.

Heat batteries

Sunamp's heat batteries can be a quarter of the size of equivalent hot water cylinders and can store energy from a wide variety of sources, releasing it for space heating, cooling, and hot water on demand. The technology platform uses a phase-change material that has up to four times the energy density of water over useful temperature ranges. It relies on the principle of latent heat: the idea that the process of melting or freezing stores a lot of energy.

The heat battery is low cost, built from sustainable sources and has a high cycle stability, meaning that there is no significant degradation in thermal energy capacity over 10,000 cycles as validated by RAL PCM – the equivalent of 13 years' normal use. Sunamp internal testing shows very limited degradation <5% to 40,000 cycles equivalent of over 50 years normal use.

The heat battery is simple to install, thereby working to address current industry skills gaps and increase the speed of installation.

Piloting the battery

The Gentoo housing association project in Sunderland was designed by Engie (now known as Equans) and delivered by Kensa Group, with the Sunamp heat batteries as a key enabling technology. The aim was to deep retrofit a set of 364 apartments. The project replaced the gas combination boilers by putting in a borehole field, tapping underground heat and using a shared ground loop to bring renewable heat to each apartment. A small Kensa 'shoebox' heat pump in each apartment meant that each tenant had their own electricity bill to run their own heat pump. Sunamp heat batteries were then placed where the combination boilers had been previously. The batteries were charged by the heat pump, delivering hot water on demand with lower heat loss, no legionella risk, lower fire risk and no carbon monoxide risk and higher flow rate than the combination boilers had been able to deliver.

Each apartment retrofit took 1 day to install (avoiding the need and cost of alternative accommodation) and resulted in an estimated saving of £200 per annum for each household. Over the lifetime of the project, CO₂ emissions will be cut 70%.

The Klimaatmissie refurbishment modules in the Netherlands also utilise Sunamp heat batteries. These modules, consisting of air source heat pumps and heat batteries, are designed to fit with the local outdoor architecture and supply heat to nearby buildings.

Finally, heat batteries can also be used in tandem with air and ground source heat pumps, operating on off-peak electricity eg at night or when the wind is blowing, opening up opportunities to take energy from the grid when it is cheapest and store it until it is required.

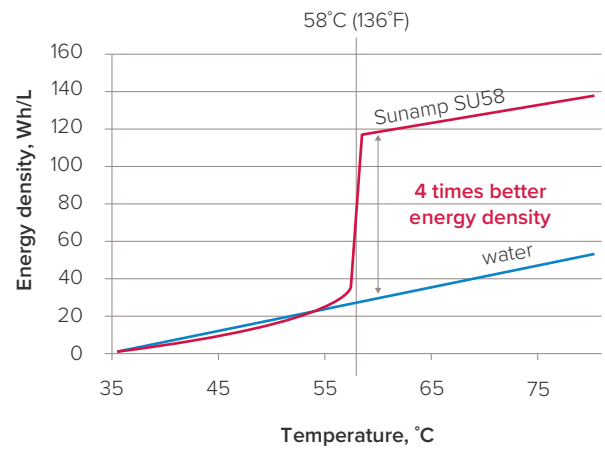
Next level systems approach:

As part of the refurbishment process, low carbon modular energy systems have the potential to improve properties that require retrofitting but do not meet the criteria for deep retrofit. This technology solution can bridge the gap where a fabric-first approach isn't viable or where a building doesn't need a deep retrofit but can be made more energy efficient.

Sunamp is currently working with finance partners and manufacturing partners to roll out their batteries at a global scale.

FIGURE 4

Sunamp's heat batteries use the principle of latent heat to store energy.



Scalable solutions to sustainable retrofitting

How can we overcome the scale-up problem?

- Every property is different but the more standardised the approach the more cost-effective the method. One approach, is to build scale of demand by first tackling homogenous building stock to kick-start the market. Once an industry has been kick-started, the cost comes down and then it can be applied retrospectively into the private sector and heterogeneous building stock.
- There are serious shortages of key materials in the construction industry. Without demand, there isn't supply. A market needs to be created to supply the certainty of material supply, up-skill the sector and establish a pipeline.
- There are products that can work across new build and retrofit, combining these markets in some cases will help increase the volume of demand.
- Innovation is still required to develop scalable retrofit solutions for more complex properties such as Victorian Terraces.
- Policy needs to sit behind progress, but brave moves are required from people and industry to give government the opportunity to support initiatives and invest in scalable solutions. Solutions need to be designed, prototyped and piloted at scale to prove that they are economically viable and can be commercialised en masse.

What are the necessary interventions?

- The market needs to be kickstarted with the help of government incentives eg by cutting VAT or offering low-interest loans or grants. Capital value of a building and its energy ratings need to become better linked so that people consider the energy rating of a home before they buy it. When this point is reached, the government can pull back its support of retrofit as it will then be market led.
- An economically viable model could be one where the tenant energy savings bill and owner maintenance savings are capitalised into the upfront investment budget. Solution providers and design teams need to innovate to reduce the cost. Policy instruments should be structured to cover that gap until products can be manufactured in cheaper ways. This approach proved successful in the electric vehicle market.
- All trades need to up-skill and better understand how their work interacts with others regarding the energy performance of a house.
- A hub or agency should be created to co-ordinate and monitor all components of a retrofit strategy. This would help to address the current authority gap that is prohibiting progress. The hub would be responsible for the delivery of energy passports, ensuring that qualifications in the industry are sufficient and accredited, and monitor conformity and uniformity across the country.

“It is really encouraging to see the progress that there has been and the ongoing work by individual companies, businesses and the sector as a whole.”

Fiona Riddoch, Royal Society Science Industry and Translation Committee

“The challenge for Government is to create a national infrastructure strategy that is long term and cross party. Without political consensus or leadership, you won't get certainty or confidence of consumers, suppliers and installers to invest in the market. At the moment, we're seeing a stop-start approach.”

Brian Berry, CEO, Federation of Master Builders

Is the 'fabric-first' approach best?

- A 'fabric first' or 'energy efficiency first' approach should be the core and guiding principle in the sector. Driving down energy demand makes a building more cost efficient, decreases the maintenance required, reduces the materials needed and makes it easier to supply energy through renewable sources. Politicians tend to see greening the supply as the silver bullet for the sector, however, this doesn't bring the additional benefits of better indoor air quality, higher comfort level, increased productivity and better health within buildings that decreasing energy demand does.
- A fabric first approach should be the key strategy, but equipment-first and technological intervention is also needed to meet the necessary targets. A fabric-first only approach only might not decarbonise our building stock fast enough. There needs to be a strong synergy between fabric fixes and technology fixes to bridge the gap between deep retrofit and making an already energy efficient home more efficient.
- Collaboration across sectors is vital. Sharing information, work and ideas with others in the sector will take the market forward. Trade secrecy and guarding information isn't important as there is enough opportunity in the area for all to benefit.

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“We need everything, there's no silver bullet. We need the right balance of all the different products and equipment coming together within projects to deliver the best result. We need everybody- otherwise we won't get there.”

Adrian M Joyce, Secretary General, EuroACE

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“Inertia in government leads to inertia from people buying products. Success stories help people make the decision to act instead of just waiting for the government to make their decision on a long-term strategy.”

Emily Braham, Head of Strategy and Operations, Energiesprong UK

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“Alliances are vital. We should double-down with the bits we do well in, but in partnership with others.”

Andrew Bissell, Founder and CEO, Sunamp Ltd

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Creating the right framework to deliver outcomes – from prescription and compliance to leadership and responsibility

Dame Judith Hackitt is chair of Make UK and an independent advisor to the UK Government on building safety. She spoke about the principles arising from her independent review of building regulations and fire safety and how they are linked to the challenge of building sustainability.

Changing the regulatory framework to drive a shift in responsibility and culture

High guidance and regulation levels do not guarantee compliance or desirable outcomes. The level of prescription in the industry's regulatory system has resulted in a situation where assessing what is compliant is solely the responsibility of the regulators and policymakers. A framework should be established whereby industry is responsible for demonstrating to the regulator that their buildings are safe, effective and to the necessary standard across design, build and management. This will encourage a culture shift towards accountability over blind compliance.

Quality assurance for materials

The features which are designed into a building need to work to the standard promised when the build is constructed. Whether for fire safety or energy efficiency, the materials used must perform as intended. Product and systems testing need to relate to how a material performs in practice and in tandem with other parts of the building.

Systems thinking and a multi-faceted approach to delivery

Our current systems and processes fail to recognize the need for a multi-faceted performance criteria approach across every building stage that ensures that every need is met simultaneously. Improving the construction industry cannot allow trade-offs where one requirement, such as safety, overrides another, such as sustainability. Sustainability is vital but it should not be the only priority. Buildings will only be truly sustainable if they perform in a way that they're intended to perform in every respect.

At present, the guidance underpinning building regulations is siloed, with one set of guidance on fire safety, another on energy performance and another on electrical safety. Such features of a building are interdependent and interconnected and must be treated as such. A holistic systems approach should be used to evaluate whether a building meets the required criteria, rather than if its independent parts behave effectively in isolation.

Skills

Even with the right materials or product, a qualified and upskilled workforce is essential to install and maintain the building. This is true for safety and sustainability measures. Those working on a building need to not only have the skills but also understand and care how their work interacts with all the other features of a building. This will help ensure that a building has integrity in all dimensions.

Enabling innovation

Too prescriptive regulations lead to the downward spiral of industry waiting to be told what the new standards are and then working to them. This impedes the level and rate of innovation that is required to meet our safety and sustainability targets.

There is no simple or single answer to many questions in the construction industry. If policymakers set only black and white goals or regulations, they will stifle industry and limit opportunities for impactful innovation. Truly innovative solutions will arise from a regulatory framework that is performance-based and set around desired outcomes rather than limits. Having been open with their regulations, policymakers should expect industry to demonstrate that any innovation preserves the integrity of the building system and will deliver the required outcomes.

Incentivising good behaviour and re-building trust

Those who take responsibility and lead in safety and sustainability should be rewarded with reputation and market advantage. This will be achieved by establishing a regulatory system whereby those who deliver poor performance by seeking to meet minimum standards at minimum costs will suffer.

This shift to rewarding quality will also help to restore trust in an industry that is currently distrusted by residents, investors and policymakers alike.

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“Whether driven by the need to improve safety, sustainability or greater quality assurance, I am sure that the opportunities for innovation in process and materials are very high. But we need a tough regulatory regime in place that places responsibility to deliver the right outcome, not one that stops the industry innovating by overprescribing, or one that stops them feeling responsible for delivering good performance.”

Dame Judith Hackitt DBE FREng, Chair, Make UK and Independent Advisor

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Making the energy transition work for energy consumers: the challenge for policy

Joanne Wade, Chief Strategic Advisor at the Association for Decentralised Energy, outlined the need for both policy makers and the industry to make a transition to a net zero energy system that suits the energy consumer.

The Climate Change Committee estimates that around 62% of the changes needed to deliver net zero involve people changing the way they do things. This includes using newer, less familiar, low-carbon technologies. The Association for Decentralised Energy (ADE) represents over 130 organisations in the decentralised energy supply chain that use low-carbon technologies that directly impact the life of the energy user.

Transitioning the current housing stock to low-carbon technologies will require an investment of around £65 billion. To effectively engage energy users and encourage them to make such an investment, the energy systems created need to not only work for the users but work better than their old systems.

Delivering what is required

Those involved in redesigning the system, including the policy and regulatory elements that surround the physical energy system, should think about the system itself but also about what energy users want from it. A successful energy transition will be able to meet the needs of the user, as well as the needs of the environment and system itself. Regulation of the energy system to date has prioritised affordability. Meeting other customer concerns, however, has typically been left to service providers. To effectively engage energy users in the transition to net zero, new energy technologies must show that they also meet consumer requirements such as appearance, cosiness and ease of use. In many cases, the new technologies available already deliver on these fronts but this has not been communicated effectively to consumers.

The future home

Future homes will work differently to current ones and inhabitants may have to adjust their lifestyle to use their home to its maximum potential. Smart appliances or heating systems might, for instance, require adjustments to the pattern of daily life. For example, while gas central heating is designed to function in short bursts of heat, heat pumps work best when run at the same temperature over a long period of time. Any successful home renovation needs to help the inhabitant understand how their home works and how to best manage it.

In addition, some aspects of the energy transition might involve people ceding control of certain features of their home eg choosing their heat network or when their smart appliances run. This could become a major barrier and regulators and policy makers will need to build trust in renovation and technology options so that people are happy to relinquish control if necessary. The idea that the energy transition will demand a change in the consumer's living pattern is often portrayed as a major obstacle to progress but this need not necessarily be the case as people change their lifestyle when they move house with little dissatisfaction.

Decarbonising 29 million homes in the UK

For some householders an improved energy system is one that requires less input from the user while for others, it will be one that allows them to engage and become more active participants in its functioning. Embedding flexibility into the retrofit process so that each consumer's personal demand can be met is vital to achieve widescale decarbonisation of homes.

There also needs to be more effective consumer advice and support available to those deciding to undertake a retrofit. Any change that householders make during the transition- from replacing a single electric heater for a better option, to fully refurbishing an old property- will involve decisions about unfamiliar technologies. The householder needs to be confident that the changes made to their house are high-quality and will suit them. Improvements must also be made to the repairs and maintenance supply chains so that a house remains as energy efficient as it can be throughout its lifecycle.

Policy changes

A systematic approach to energy renovation is needed that values longevity and consistency. This will depend on having an educated picture of the future.

Creating a trajectory of minimum energy performance standards for existing buildings will help to identify areas for improvement. By using zoning for heat decarbonisation (based on building stock, natural resources, local economy, and preferences of the local population) it would also be possible to identify the most appropriate heat supply fuels and energy systems for any given area.

Tackling the politics & the policy of UK building decarbonisation

Nick Mabey is Chief Executive and co-founding director of E3G, a climate think tank operating to accelerate the global transition to a low carbon future.

Systematic policy change is needed to drive the level of public and private investment required to deliver decarbonisation

Net Zero requires investment in the built environment. Increasing energy efficiency must be an infrastructure investment priority and a strong infrastructure plan and adequate capital funding is needed. The Energy Efficiency Infrastructure Group (EEIG) is an alliance of businesses and non-governmental organisations that has identified the sectors and constituencies that need to work together to deliver Net-Zero. They have identified a series of structural, industrial and governance reforms to drive investment.

Pump-priming the market:

Short term financial incentives, such as the recent Green Homes Grant, have failed to deliver the kind of up-take necessary to address the problem of carbon emissions from UK housing. Long term policies create certainty for financial institutions and citizens to invest and innovate. Furthermore, public investment is needed to decarbonise low-income houses and to leverage private investment. There is significantly more private investment available in the sector than public, however, it first needs to be unlocked with public investment and incentivising policies

To establish a desirable market, policy levers need to be put in place to level the playing field, support the market and get it to scale. Such levers include long-term grants for all tenures, 0% VAT for home retrofit, a Green Stamp Duty and a UK Infrastructure Bank that offers 0% loans. Once to scale, the initial levers can be removed, and focus placed on establishing a self-sustaining market for green home retrofits. Policy levers for this include green mortgages and loans, property linked finance, demand aggregation financing and affordable comfort-as-a-service schemes. An example of where the above approach has worked previously is the Green Investment Bank's early support for the offshore wind industry.

Political headwinds and tailwinds

Public polling shows consistent support for further and faster climate action. The net zero transition is not a divisive subject and consensus should be able to be reached across all parties and groups. A clear government strategy is necessary to maintain confidence and conviction in the area. Fairly allocating costs and shielding low-income and vulnerable houses will be critical.

Learning from neighbours

No country has yet successfully delivered the scale of action needed for home renovation. The UK has multiple strengths which it can build on such as its financial innovation capacity, energy efficiency policy experience and track record of delivery through supplier obligations. It can, however, still learn from its neighbours. France has an effective stimulus and recovery investment approach, Germany has successful deployment methods and the wider *Fit for '55'*¹² scheme can teach the UK how to navigate political landscapes while trying to balance social justice within and across areas.

The structural pillars needed to ensure a rapid, just and opportunity-maximising transition

- Devolution: Align governance with new distributed, integrated and smart systems, giving powers and budgets to cities, regions and nations on energy, infrastructure and resilience.
- Delivery Support Institutions: Support decentralised action with a transformational UKIB, devolved and city banks and a National Climate Transition Agency with a core just transition and levelling-up mission.
- Regulatory Reform and Innovation to get financial levers in place: Make a UK model for integrated and strategic regulation of smart, green and resilient infrastructure systems and markets. Work with EU to integrate power and digital networks to gain the full benefits of access to EU grid opportunities and stability.

12 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, 07/2021, European Commission Last accessed 04/2022

- **Transparent Governance:** Have a climate change committee focused on delivery to avoid the policy and pilot failures of the past. Enhance transparency and parliamentary scrutiny.
- **Whole of Society Action and Permission:** Build public support and engagement in deep and rapid decarbonisation by incentivising and engaging core civil society institutions to debate, own and deliver their transitions.

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“Everyone knows the economics works: we can afford this and we have the technology. The question is can we build the politics and the structures for government delivery to get it out the door fast enough to meet our targets? If we can do it, there’s a huge prize, if we can’t then we’re in a very hard place.”

Nick Mabey, Chief Executive and co-founding director, E3G

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FIGURE 5

Policies needed to drive investment. A policy framework from the Energy Efficiency Infrastructure Group.

Governance

- Reflect updated climate targets and carbon budgets
- Establish governance, delivery arrangements and architecture that support a locally led approach
- Institute a fabric and energy efficiency first principle
- Support a flexible, smart and efficient system
- Initiate establishment of a Heat Pumps Sector Deal

Regulation to drive demand

- Minimum Energy Efficiency Standards: stretch ambition for PRS, equivalent for social housing, and introduce for owner-occupiers
- Set a trajectory for the phase-out of fossil heating system sales
- Set roadmap for a phased introduction of Future Homes Standard from 2023

Public capital

- Confirm total investment requirement to meet 2030 targets, including for a further £8.2bn of public capital for energy efficiency
- Confirm full manifesto pledges to underpin rapid decarbonisation of housing
- Connect public capital with the green finance agenda

Local and fair delivery

- Set out long-term successors to the local authority delivery scheme
- Build investable local propositions through UKIB and local energy hubs
- Coordinate local delivery in close alignment with the updated Fuel Poverty Strategy
- Put forward an update of consumer protections

‘Able-to-pay’ incentives

- Establish successor arrangements for the Green Homes Grant voucher scheme
- Establish long-term arrangements through Clean Heat Grant and Green Homes Grant, including support for heat
- Use behavioural science approaches to promote action and take-up

Advice and standards

- Ensure EPCs are fit for purpose through the EPC action plan
- Roll out the remainder of the Each home counts and Hackitt reviews’ recommendations
- Boost innovations, supply chains and skills
- Drive digitalization forwards through real energy performance and building renovation passports
- Connect adaptation, resilience and circular economy agendas

How finance can unlock building sustainability: six financial levers to accelerate the decarbonisation of the construction and operation of European buildings

Peter Sweatman, Chief Executive at Climate Strategy & Partners discussed unlocking building sustainability through policy intervention, finance innovation and de-risking.

Background

Half of the EU population's life savings are invested in buildings, nearly all of which will require refurbishment to deliver a net zero emissions economy by 2050. To reach climate targets, renovation rates must triple to over 3% annually.

Financial levers to unlock building sustainability in Europe

Financial constraints are cited as the top reason for not renovating so financial and investment levers are vital to overcome the current barriers.

'Buildings' can be split into 5 different sub-sectors: 'Owner Occupied Residential', 'Private Rental', 'Social Housing', 'Commercial Real Estate' and 'Public Buildings'. Financial institutions (FIs) are among the most powerful stakeholders in real estate and exert substantial leverage as owners, mortgage lenders, investors in building renovation and providers of finance for construction. From assessing which financial levers will be effective in which sub-sectors (see figure 6), some immediate conclusions that can be drawn.

FIGURE 6

An assessment of which financial levers are effective in each building sub sector. A green circle signifies that the financial lever (leftmost column) can work in the column where it appears. A red tick means the lever works weakly in that column's segment. Empty means no leverage.

	Owner occupied residential	Private rental	Social housing	Commercial real estate	Public Buildings
1. Financial institutions as building owners		⊗		⊙	
2. Banks as mortgage lenders	⊙		⊗	⊙	⊗
3. Investments in building renovations	⊙	⊗	⊗	⊙	⊗
4. Finance for construction	⊙	⊙	⊙	⊙	⊙
Public finance (e.g. Recovery funds)	⊙	⊙	⊙	⊙	⊙

⊗ Limited lever, as the market conditions do not allow to amplify returns on investment

⊙ Array of different instruments is suitable to lever investments

- Finance for construction is a big point of leverage across all building segments;
- Public finance can play a role decarbonising all buildings;
- Financial actors hold all the cards in commercial real estate;
- Owner occupied residential is a big opportunity for using financial levers;
- Public finance can be used a financial lever across the board to stimulate and de-risk renovation and new build.

By identifying clusters of effective financial leverage points, the following six strategies to accelerate the decarbonisation of the building sector appear:

Strategy 1: Targets and pathways

Financial asset owners have high leverage in commercial real estate, which can be activated by giving each building a science-based decarbonisation trajectory, leading to a Building Renovation Plan.

The commercial value of real estate is at risk from physical climate changes, carbon taxes, Emissions Trading System extensions, minimum energy performance standards and stranding in the transition to a net-zero emissions world. To protect their assets, owners can pledge to set a series of real estate portfolio targets. To help them, the EU has funded a building-level tool called CRREM, the Carbon Risk in Real Estate Monitor. The CRREM can define science-based decarbonisation pathways for individual or portfolios of buildings to manage stranding risk and renovation strategy.

Strategy 2: Minimum safeguards for all new buildings

The only effective financial lever for new build is construction finance. Due diligence is the legal process through which providers of construction finance check the technical details of the buildings that their clients build. Embodied carbon can be effectively embedded into construction finance due diligence using Environmental Product Disclosure documents (EPDs). EPDs enable standardised disclosure of the life-cycle environmental impacts of products in an independent, transparent and credible way and can effectively ensure mandatory supply chain due diligence.

Strategy 3: Mortgage alignment with the Paris agreement

Mortgages are the most important financial lever on homeowners and home renovation, with lenders being uniquely placed to sway clients toward improved energy performances at critical points such as home purchase, renovation and re-mortgage. Mortgage Portfolio Standards (MPS) let lenders volunteer to meet a specified energy standard portfolio average which is determined through the collection of energy performance certificates and real energy consumption data for each property.

Nationwide, the UK's second largest mortgage lender, has attached Energy Performance Certificates (EPCs) to 64% of its mortgage portfolio and pledged to ensure that half its mortgage book has an EPC rating of C or above by 2030. To incentivise clients to own energy efficient properties, it offers cashback to properties bought with EPC rating B or above.

Strategy 4: Strong FinTech

Renovation requires consideration and planning from cost benefit analysis, identification of reliable contractors, quality assessment and licence requesting. Within academia, these are referred to as 'transaction costs' and can account for 10-30% of renovation costs. FinTech can be used to improve data transparency thereby driving down renovation finance transaction costs. It has the potential to improve sustainability at every level from consideration and planning to decision making and execution.

Strategy 5: Renovation loans

To increase the rate at which private homeowners renovate, attractive long-term funding should be offered in the form of a UK Renovation Loan (URL). This will provide fair and cheap renovation funding for all homes. A Government backed; pre-qualified by the Bank of England; open market and acquisition-ready UK renovation loan would provide fair, accessible and cheap finance for the millions of deep renovations required in the next decade. The URL should be 30-year, zero-coupon, junior to the existing mortgage and repayable upon sale of the building. They should be extended automatically to all UK homeowners to borrow against their home to deeply renovate it, with the interest rate set at the level at which the UK Treasury borrows.

Assuming the value of a property goes up, the URLs are a win for citizens, banks and the climate alike.

Strategy 6: Customer empowerment

FIs are expert at client handling and can drive down the cost and complexity of the renovation process if they have a big enough stake in their customer's renovation journey. To achieve the greening of mortgage portfolios at scale, renovation needs to be economically attractive to both the client and the bank.

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“Once the construction sector sees that there is money available and that every building owner knows that just at the push of a button they can get the amount of money needed at government rates on a zero-coupon basis, the game changes”

Peter Sweatman, Chief Executive, Climate Strategy & Partners

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Policy agenda and de-risking technical uncertainties in the industry

How can a co-ordinated approach be achieved?

- Inspiration should be taken from the offshore wind industry. Through clear government ownership, engagement with participants, structured objectives and the commitment of the financial sector and global stakeholders, offshore wind became an affordable and attractive energy option. A structured industrial and corporatist approach rapidly set up subsidies, drove down costs, increased market competitiveness and set quality targets for industry.
- The vital need to renovate shouldn't be used to scare the homeowner, but instead renovation should simply deliver a better home that has the impact of saving the climate.
- Creating trust between the sector and consumer is vital but it must be earned through demonstrating good political ownership and leadership. Renovators need to deliver against performance and cost, and banks need to lend against good jobs only. The media is also important to building trust for the sector.
- Decisions need to be made at the appropriate level of Government. Power needs to be devolved to the homeowner. The challenge is too complex to be run from Whitehall only.
- Value chains to the construction sector and the sector itself needs a set of precise objectives if it is going to deliver the required level of renovation.
- By making Finance zero-coupon in nature, cost-benefit analysis will be less of a barrier for the homeowner. Retrofit loans that are payable when the building is sold and valued at the government's borrowing costs (meaning there is no subsidy) would be no immediate cost to renovation for the homeowner. Zero-coupon finance means that every benefit delivered from a retrofit would be from a positive baseline.
- The UK is uniquely transparent about its buildings information. It has publicly available building energy performance certificates and a proficient SAP scoring mechanism to provide a more granular, numerical set of data that can be used to accurately measure buildings performance.
- Non-governmental stakeholders such as the finance and business sector have already converged and established objectives. The finance and skills are available to enable scale-up, and the public are receptive to change. The core barriers to change are now policy and politics. A sense of ownership from within government and strategic level push is needed achieve coherence across the sector. Necessary changes include devolving power, increasing funding from the treasury and reframing the challenge to be part of a broader 'what Britain do we want?' question rather than 'how do we renovate buildings?'

“While there appears to be limited progress at the moment, there is certainly a lot of serious action and serious thought. I can see a change in ambition, but the actions are still a step down the timeline.”

Fiona Riddoch, Royal Society Science Industry and Translation Committee

“Renovation for the homeowner should be like seatbelts for the passenger. They are required because they are for benefit to the user.”

Peter Sweatman, Chief Executive, Climate Strategy & Partners

What incentives are necessary to up-skill the construction sector?

- The same equipment can vary widely in performance according to the fitter. The performance of retrofit organisations needs to be better sampled to address this.
- Currently, it is seen as too risky to do energy retrofit because there isn't a market for it. This can be tackled through a combination of professionalising the building sector and providing a strong pipeline of work.
- Consumer service offerings could package renovation programmes to include energy renovation within the work. As a result, builders would be incentivised to learn how to energy retrofit so that they could then bid for the available work.
- The buildings market is fragmented. Incentivising inter-company trade and services would create a single market approach that will help drive up quality and scale.
- There is already the capability in the UK as shown by the number of start-ups in the sector. What is required is the opportunity and trust. One way to create a market and incentivise up-skilling would be to offer all of the finance needed to retrofit the UK at the point that it is needed to all households at once. That would create a market that would then self-rationalise.
- There needs to be an audited system that allows performance quality to be demonstrated. There also needs to be a set of accredited codes of safety and sustainability that constructors can sign up to.
- Rather than incentives, it should be made a requirement to be the adequate level of qualified.

“We have the methodologies to demonstrate intention, we now just need to make sure they match up with reality and delivery.” -

Dr Joanne Wade OBE, Chief Strategic Advisor,
The Association for Decentralised Energy

“This is more of an organisational challenge than it is a ‘can it be done?’ challenge.”

Nick Mabey, Chief Executive and co-founding director, E3G

- Careers in the sector need to be more visible and exciting to young people. The building sector should learn from the technology sector in how to achieve this.

What actions need to be taken urgently to accelerate progress?

- The more sustainability and safety are brought together as joint activities rather than competing priorities, the better for everyone.
- Renovation should be proposed not as a sacrifice to homeowners but a benefit. Successful innovation and services should excite the consumer.
- Consumers should be engaged with in ways that are meaningful to them.
- Powers and money should be devolved. Energy renovation strategies could be developed for every local area which then has money and power linked to them.
- A joint task force should be created between the Treasury, Bank of England and BEIS to study the UK Renovation Loan within the confines of government. Making a renovation fund available for every building would resolve the pipeline issue and kick the negative spiral into a positive one.
- With a history of stop-start policies, underperforming funding schemes and one-off pilot projects, structural changes need to be made to the UK's institutional and policy delivery landscape to deliver an effective transition to a low carbon building economy. A successful policy framework must actively manage the issues of public consent and service quality to meet emissions targets on time and prevent backlash from the public.

“The UK has all the ingredients necessary to be a leader in this space. It has a uniquely old and inefficient building stock, is sufficiently far north to have high enough energy bills and has the lion-share of start-ups.”

Peter Sweatman, Chief Executive, Climate Strategy & Partners



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