NATIONAL ENGINEERING POLICY CENTRE

Royal Academy of Engineering

Decarbonising construction: building a new net zero industry

Four missions to transform and decarbonise the built environment

Executive summary

The construction industry is a crucial contributor to the UK economy responsible for creating, operating and maintaining the building blocks of our communities and society. However, despite reductions in greenhouse gas emissions since 1990, the sector still requires urgent transformation if it is to successfully contribute to the UK's net zero target.

This report focuses on four interconnected missions that cut across the whole of the construction sector that require urgent attention to achieve net zero.

1 product outcomes

2 design and specification

3 construction and reuse

4 changes to procurement

Executive summary

Missions, recommended actions, desired outcomes and systems levers

On 23 June 2020, the **National Engineering Policy Centre (NEPC)** convened a workshop of 50 consultants, client organisations, policymakers, academics and others with expertise relating to the construction sector. The workshop focused on the transformational changes needed to achieve a low carbon-built environment. The aim was to identify the principal areas for change, referred to as '**missions**' in this report, and agree priority actions. A summary of the workshop can be found here.

Since the initial workshop, the findings and recommendations have been further developed and refined, via desktop research and interviews with stakeholders, into a set of specific **recommended actions** for different stakeholders, these are listed under each mission in section 3 of this report. We have presented **desired outcomes** to these recommended actions in **Annex A**.

We have also drawn together the recommended actions into six '**systems levers**'. These overarching levers are areas where action taken now will result in rapid decarbonisation of the construction sector. These are set out and described in **Annex B** at the end of the report.

In addition, we have begun to sequence all the individual actions set out in this report into a sequencing framework that breaks these down in those actions that can be taken **now (in 2021)**, **next (by 2025)** and **in the future (beyond 2025)** (see **Annex C**). This will help to develop a shared understanding of how to address the issues that exist across the sector being clear about what actions need to be taken to decarbonise the construction sector in the short, medium and long-term.

Contents

Section 1: introduction

Decarbonising construction: the scale of the net zero challenge

If urgent action is not taken at pace and at scale, the construction process will jeopardise attempts to meet the 2050 net zero target. The World Green Building Council has stated that buildings and infrastructure around the world can reach 40% less embodied carbon emissions by 2030 but that this can only be achieved through urgent transformation.[1] The construction sector has already made progress; the concrete and cement industry has already delivered a 53% reduction in absolute CO2 emissions since 1990, faster than the UK economy as a whole.[2] However, more still needs to be done to meet the UK's targets of 68% emissions reduction by 2030 and 78% by 2035, compared to 1990 levels, and ultimately to meet net zero by 2050.

This net zero transformation, although challenging, presents a massive opportunity for the sector, a chance to make a fundamental change in its ambitions, processes and social contribution. Immediate action by government, standards bodies, the construction sector and the engineering profession is required. Actions need careful planning and implementation, with correct sequencing of strategies for what needs to happen now, next and in the future. **Annex C** of this report makes recommendations for what must occur now, next and in the future across the four missions that are described in **section 2**.

Existing government support to decarbonise the construction sector

Government, as a major client of the construction sector, has a central role to play in mandating the sector's action to ensure decarbonisation takes place at speed and scale.

Government has signalled its support for change in terms of investment in research and innovation, learning from other sectors, adopting emerging technologies and providing guidance on the sourcing and contracting of public projects and programmes as part of the Construction Playbook.[3] Improving the efficiency and productivity of the construction industry has also been the aim of multiple initiatives in the past 20 years, including *Construction 2025*[4] and the *Construction Sector Deal*.[5] More recently, the Construction Leadership Council published its *Roadmap to Recovery Plan*[6] for the construction sector, which sets out the urgent need for transformation and the Construction Industry Council published its carbon zero climate action plan which identifies the actions needed to decarbonise the construction industry.[7]

Despite these initiatives, challenges remain. The construction sector is currently lacking clearly mandated emission reduction targets for the construction process, material extraction and operational carbon. In addition, there is no roadmap that outlines the actions needed to decarbonise the sector which clearly defines the role and obligations of different actors in the sector.

To stimulate change in the industry, judicious interventions by government and industry are needed urgently across the four missions described in **section 2**. These will need to be progressive, with universal application and fixed time horizons, and will require cross-party support to enable the industry to appropriately plan and invest to achieve them.

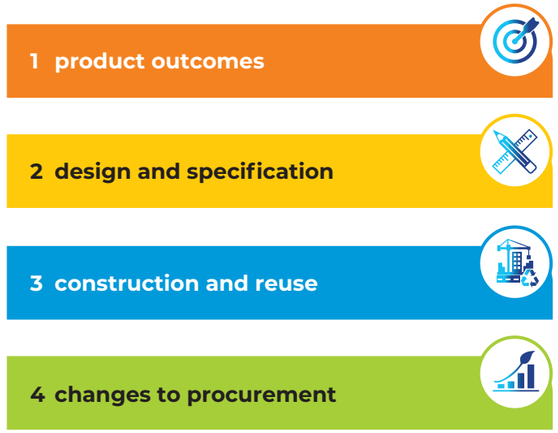
Taking a systems perspective can ensure that these interconnected missions work together towards the common goal of net zero emissions. This approach, described in the paper Net zero: a systems perspective on the climate challenge, was taken as part of a virtual workshop hosted by the NEPC in June 2020 which provided many of the key actions for stakeholders presented in this report.

The benefit of taking a systems approach is that it leads to a 'big picture' view of a policy problem and how it might be tackled. The UK government faces the challenge of designing and implementing policies across different government departments and all economic sectors, including the construction sector, that must work together to achieve net zero. Any changes introduced to decarbonise construction will impact on the energy, transport and manufacturing sectors, and similarly changes in those sectors will impact construction. Taking a systems approach will improve the ability of policymakers to avoid siloed thinking, unlock co-benefits such as health and safety, assess effectiveness of policy across different sectors, provide an effective feedback loop and identify potentially unforeseen consequences.

Section 2: missions

This report focuses mainly on key areas to decarbonise the construction sector and the built environment that it is a significant component of, as stated in the recent cross-sector Vision for the Built Environment report. While construction is a discrete phase in the lifetime of the built asset, decisions made in the earliest stages of project inception, procurement, design and specification are key in determining the embodied and operational carbon of the built environment. Given this, instead of focusing on the construction phase alone, this report focuses on outlining the mission of decarbonisation across four fundamental and interconnected areas of the construction industry that are crucial for an effective net zero transformation.

These are:



These missions provide a framework for understanding what changes are required to reach net zero by 2050, while continuing to provide the sector's societal function.

Each mission requires urgent change to achieve net zero with increasingly ambitious emission reduction targets over time. This report will examine each of these missions and provide tangible recommendations for how each area can be transformed to put the construction sector on track for net zero by 2050.

It is important to stress that the construction industry also requires transformation outside of these four missions. Areas such as digitalisation of the sector, the extraction of raw materials required for steel and cement, and the use of transport in the construction process will all require decarbonisation if the construction sector is to contribute to meeting the net zero target. These areas are, however, not covered within the scope of this report.

Section 2: **missions**

Mission 1: product outcomes

This refers to the objectives and goals of products produced by an industry or business. The construction sector's objectives and goals will shape the embodied and operational carbon performance of our built environment. Current objectives do not prioritise decarbonisation which results in an increase in whole-life carbon. Changing the goals of infrastructure with a focus on decarbonisation is important to reducing whole life carbon.

While some progress has been made in changing how the construction sector evaluates the outcomes of construction projects, such as the IPA's Transforming Infrastructure Performance report,[8] more still needs to be done. This must include a joint government and industry vision for net zero, which covers changing demand, outcomes-based decision making and developing a roadmap to 2050.

Mission 2: design and specification

This refers to the technical design of the building or infrastructure and specification for how needs are going to be met. The values and judgements involved in design and specifications have a significant impact on carbon emissions. This includes determining the products and materials that are used in the construction process and how a piece of built infrastructure is to be operated or used. Key structural design decisions at the earliest stages of a building project effectively 'lock-in' both the embodied and operational carbon. For net zero transformation of the sector, the availability and specification at design stage of low-carbon materials, lean low-carbon design, embracing digital technologies, decentralised energy generation and nature-based solutions are all vital.

Mission 3: construction and re-use

The current linear economy (take, make and throw away) operated by the construction sector is unsustainable, and increasing the reuse of materials in construction is urgently required. This will involve moving the construction sector towards a circular economy that minimises extraction and reuses waste.

The action or practice of reusing materials, whether for their original purpose or to fulfil a different function, will minimise extraction and waste. It should be distinguished from recycling, which is the breaking down of used items to make raw materials for the manufacture of new products. It is vital that all stakeholders work to transform the sector into a circular economy with reuse of materials as standard.

Beyond material reuse, this mission also covers wider decarbonisation of the construction process, such as the electrification of on-site plant and machinery.

Mission 4: changes to procurement

This mission covers changes to the procurement of goods, services and works, and the business models and supply chains involved. It also includes leadership since a change in the culture and behaviour of the construction industry will be required.

Procurers, such as government, must change their approach to procurement to reflect whole-life carbon performance. Procurers can use their purchasing power to stipulate carbon performance through specification and the requirements that are set out in both public and private contracts. Procurement practices are therefore a key driver of carbon performance within the construction sector.

Section 3: recommended actions for each mission

The NEPC decarbonising construction workshop, held in June 2020, acted as a starting point to identify important policy interventions and actions that are urgently needed to drive the net zero transformation of the construction sector. Since the workshop, specific actions for different stakeholders have been developed through desktop research and interviews with stakeholders. These specific actions for different stakeholders are presented in this section and sequenced later in **Annex C** of this report.

Mission 1: product outcomes

Recommended actions for key stakeholders

Actions for government:

- In government, the built environment falls within the remit of many different departments, and this can prevent the built environment from being treated coherently as a whole system. A joined-up response across government departments would lead to a set of aspirations and policies that are consistent and coherent, lower costs and greater value for money, and which have potential to deliver other co-benefits. As described in a cross-sector Vision for the Built Environment, the current construction system is resource-hungry and wasteful, vulnerable to economic, environmental and social pressures and system-wide shocks. The construction sector must become more sustainable, secure and resilient. Adopting systems-based policies can facilitate this transformation.

Why?

Urgent action is required from decision makers to decarbonise the sector at pace and scale is needed if the sector is to play its role in meeting the 2050 net zero target. Decision-making considerations must now go beyond financial outcomes to ensure a just transition of the construction sector. By taking a holistic [systems] approach, as set out in Net zero – a systems perspective on the climate challenge, decision makers can address carbon and broader social, environmental and economic factors as well as avoid unintended consequences that can result from siloed thinking.

Shared actions for the construction sector and government:

- The construction sector must demonstrate how approaches to decarbonisation fit within new models of economic growth that minimise resource use, reverse ecological damage and contribute to the net zero target. This will be aided by using the updated tools and guidance set out in HMT Green Book.[9]

Why?

The decarbonisation challenge cannot be successful if there is confusion of purpose, or unresolved tension between competing aims such as between the aims of financial and environmental sustainability. The construction sector needs to be guided and incentivised to reduce emissions. The guidance in HMT Green Book has recently been updated so that all interventions that are aimed at moving the UK towards the net zero target are first appraised in terms of their contribution to the net zero target.

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It is now vital that actors in the construction sector follow this guidance as an important step towards decarbonising the sector.

- Government and industry can learn from and propagate examples of best practice. This includes other countries, such as Denmark and the Netherlands, and other sectors, such as the UK's energy sector, which are setting targets and developing new processes to drive better carbon performance. For the construction process, material extraction and imported materials, increasingly stringent carbon reduction targets should be introduced that, over time remain in line with overall UK carbon emission reduction targets of 68% by 2030 and 78% by 2035 compared to 1990 levels. More stringent targets for the operational carbon of the built environment are required to achieve net zero.

Why?
Several European countries are leading the way in driving improvement procurement practices. In both the Netherlands and Denmark (see case study one), tools and initiatives have been developed that have driven decarbonisation projects in construction. It is important that the UK learns from and, as a minimum, keeps apace with these examples of best practice, implementing similar targets. Reducing operational carbon to zero is key to accelerating this decarbonisation. Technologies, such as electrified heat and natural air flow, already exist to reduce operational carbon but adoption must now be accelerated and scaled up.

- Net zero and sustainability principles and practices must be a mandatory inclusion in engineering education, continuous professional development and upskilling.

Why?
Increasing the understanding and skills needed for net zero is required to both enable good decision-making for net zero and for having the skills needed to implement these decisions.

Achieving a net zero transformation through a vision for net zero

Public attitudes and expectations towards achieving net zero have changed. With the new legal context around the 2050 target, carbon targets will play a key role in delivering change, but they will be most effectively accepted and implemented if the public have a deeper appreciation of why these changes are needed. Part of this is increasing public understanding of what net zero means. To do this, the NEPC has published an explainer on net zero.

Both industry and government have a key role in nurturing greater public awareness of energy use and carbon emissions throughout infrastructure lifecycles and informing the public of the changes needed to mitigate the effects of climate change. Government must ensure that an understanding of climate change and carbon emissions is embedded in all stages of the education pipeline, along with broader sustainability considerations such as ecological regeneration opportunities. Within relevant further and higher education courses, accreditation bodies should require training in carbon accounting, low-carbon construction techniques and energy neutral design.

Key enablers such as changing demand, product outcomes, culture, and standards will play an important role in delivering the net zero transformation of the construction sector. These are discussed in more detail in the following sections.

Changing demand

Changing the demands of customers of the construction industry, including government and private sector procurers will play a key role in delivering the sector's net zero transformation. A greater appreciation of the degree to which resources are limited, and how our actions impact the sector's ability to achieve net zero, must be embodied into decision-making.

Decision-makers, including government, procurers, regulators, end-users, and investors, need to change what they demand of the construction industry so that net zero can be achieved. They must also tap into the growing community of financial institutions taking action and demonstrating leadership on climate change. Some institutions are allocating capital and steering financial flows towards more low-carbon and climate-resilient activities. Others are taking steps to change corporate behaviour and collaborating with policymakers so that greater participation in the transition to a low-carbon economy is encouraged in the finance sector.[10] Decision-makers must also counter perceptions among private and public sector clients that low-carbon construction is more expensive and emphasise that design for net zero is cheaper in the long term.

Government must lead the way to incentivise this change in demand so that other clients follow. Government should define and mandate a set of procurement targets that get increasingly challenging up to 2050. Recognising the longevity of buildings and infrastructure and the more immediate opportunities for decarbonising operational performance, targets should differentiate between carbon in construction and carbon in the operation; and having more stringent targets for operation in the short term so that there is better operational performance of the infrastructure that will still be in operation in 2050. Government can lead the way in incentivising this change and driving up best practice and standards through its procurement standards. The important role of government in driving change is apparent in examples outside the construction sector. For example, when it intervened in the car industry to mandate a ban in sales of new petrol and diesel cars in the UK by 2030 thereby accelerating the development and roll out of electric vehicles and an electric charging network.

If actions such as these do change demand, much will need to be updated both rapidly and regularly: from updating out-dated contracts, to adding to the new guidance in HMT's Green Book, and from updating the planning system, to reshaping engineering education and training. The advice and tools in HMT's Green Book must be reviewed and updated to reflect the steps needed for the construction sector to reach the 2050 net-zero emissions target. The construction sector must work alongside economists and HMT to make possible new models of economic growth that minimise resource use and reverse ecological damage. The industry must help government demonstrate how infrastructure system solutions fit within these models.

Outcome-based decision-making

It is vital that considerations within decision making go beyond financial outcomes, whether at project, company or government level, in order to achieve the net zero transformation. In December 2020, the UK government published its Construction Playbook[11] to set clear and outcome-based specifications that are designed to drive improvement and innovation in the construction sector including enabling the sector to take strides towards the 2050 net zero target. However, to achieve this ambition more is required.

By taking a holistic systems approach at a project level, decision-makers can address carbon and broader social, environmental and economic factors. Some progress is being made in this space by both government, such as the IPA's Transforming Infrastructure Performance,[12] and industry, such as the industry-led Project 13[13] which seeks to develop a new business model to improve whole life outcomes in operation and to support a more sustainable, innovative and highly skilled industry. It may also be necessary for designers and others commissioned through construction to have a revised approach to their terms of appointment. If these were extended beyond the point of project completion, then there would be increased accountability and commitment to improved performance. The number of projects organised in this way needs to increase.

Previous work by the NEPC has mapped the system of housing and infrastructure planning and delivery and the diverse perspectives of the actors involved, including the public. Key factors impacting on the quality of the outcome included the transparency of developer incentives and of their role in the planning

Section 3: **recommended actions for each mission**

and construction process.[14] Meaningful community engagement, co-design and co-creation can improve social outcomes and enable reduced carbon impacts. The construction industry needs to move beyond its traditional role in technical delivery to engaging with third sector organisations, all levels of government (central, devolved and local government) and the community to help shape outcomes and secure buy-in.

Driving culture change and capability in the industry

A change in culture across the industry is needed, moving from compliance to focus on performance and outcomes to achieve the sector's net zero transformation. This requires an industry that is collaborative and competent. Engineers working in the industry must be able to address complexity and generate creative solutions to problems.

A change in mindset is needed around business growth, moving away from the assumption that building more reflects business success. Principles of ecological economics that enable growth in prosperity without increasing resource use must be embodied in construction. This will require the construction industry to work closely with economists and those engaged in advancing new, more circular models of resource consumption. Committed leadership will be required to drive changes to culture and capability.

Ratings schemes such as BREEAM,[15] CEEQUAL[16] and Environmental Product Declarations[17] (EPDs) have a role in improving carbon performance, and BREEAM ratings have a positive impact on the market value of buildings. However, they are not sufficient to drive the scale of performance change needed. On occasion the system can be 'gamed' to ensure a project achieves a high rating.

There is a role for building standards, enforced through building control, to improve whole-life carbon performance from material extraction and the construction process through to operation. Building regulations have driven reduced operational carbon emissions, and they can do the same for embodied energy and carbon emissions. Unregulated energy sources could in future also be included.

There is also potentially a role for more top-down measures, such as carbon or energy budgets that are cascaded down from national to local scale through local plans. Local plans can also set their own requirements, as the London Plan[18] is doing. Planning permission could be granted according to whether new buildings can meet carbon and energy budgets. Carbon would then become an important metric underpinning decisions about whether to build new zero carbon buildings or refurbish existing buildings.

Government's role

In government, the built environment falls within the remit of many different departments. Responsibility for procurement and delivery is separate and split across departments, for example with environmental issues (in Defra), transport (in Department for Transport) and safety (new building safety regulator in HSE) separate again. Without joined up thinking, it is not possible to address the built environment coherently as a whole system. A coordinated approach across government departments would lead to a set of aspirations and policies that are consistent and coherent, lower costs and greater value for money, and which have potential to deliver other co-benefits. HMT must take a lead in introducing incentives for low-carbon projects, which would need to be accompanied by culture change across government.

Towards a roadmap

An action plan for the sector, would set out what needs to happen over the next few years if the construction industry is to reduce its carbon impact. This report has attempted to start this process by organising its recommended actions into a 'now, next, future' framework in **Annex C**. Targets need to be accompanied by incentives, that drive change across all areas of construction including both the supply and demand sides.

CASE STUDY 1

LEARNING FROM EXAMPLES OF BEST PRACTICE

Several European countries are leading the way in driving improved procurement practices. In the Netherlands, the 'CO_2 Performance Ladder'[19] has been developed, initially in the Dutch rail sector. It is a management tool that helps organisations reduce their carbon emissions within the organisation, on projects and across an organisation's supply chain. The ladder is also increasingly being used as a procurement tool by both national and local public clients in the Netherlands. If organisations have a certificate on the ladder, they are at an advantage when they tender for a project. Efforts are rewarded with a concrete advantage in the tendering process in the form of a discount on the registration price. Furthermore, Amsterdam has adopted Doughnut Economics Principles, turning them into a tool for transformative action for the city.

In Denmark, where the Fehrmarn Belt project[20] is currently underway, low-carbon procurement is strengthened through initiatives such as the Partnership for Green Public Procurement and the Forum on Sustainable Procurement. For the construction sector, the direction of travel is towards mandated carbon reduction targets for particular construction projects. Once a contractor has been awarded tender for an infrastructure project, they are tasked with reducing embodied carbon in the design by a certain percentage relative to the original design. Currently, carbon reduction is a 'nice to have' rather than being a contractual requirement, but in future it is likely that carbon reduction targets will be mandated, with penalties if targets are not reached.

Denmark has also introduced a strategy for a circular economy, which includes an initiative to improve procurers' capability to use circular economy principles in procurement, to share best practice between organisations and public clients, and to gather evidence on the environmental and economic benefits of the circular economy. In London, the Greater London Authority is preparing its *Circular Economy Statement Guidance*[21] which requires planning proposals to set out core circular economy principles.

The London 2012 Olympic Delivery Authority's (ODA) stated aim was to reduce greenhouse gas emissions by 50% compared with standard practice.[22] As part of this aim, the ODA used its purchasing power and prestige status to develop 'sustainable concrete', using recycled aggregate and batched on site to reduce both transport emissions and supply risk. This demonstrates the importance of mandating carbon reduction in ensuring that action is taken.

Mission 2: design and specification

Recommended actions for key stakeholders

Actions for the construction sector:

- Practical and user-friendly tools to enable consistent assessment of carbon performance of built environment systems, and not just individual components, need to be developed and embedded within design and procurement. This can be achieved through the increased use of data and digital technologies to assess carbon performance and opportunities for decarbonisation.

  Why?
  Practical tools for understanding and designing for carbon performance are required. Data and digital technologies, such as digital twins, can be used to improve modelling tools to reduce uncertainty and drive efficiency in design. Data can help to guide decisions about choosing low-carbon materials and processes, enabling better understanding of the carbon impacts at the project level.

- More holistic design approaches for the built environment must be implemented. This can be achieved through choice of design practices and driving more efficiency within designs as well as requiring more, materials reuse within specification, design and construction.

  Why?
  The design approach has a significant impact on carbon emissions even before a building is completed as decisions made at this first stage can lock carbon into design. Changed design practices can drive improvements in carbon performance, part of which should include enabling the reuse of materials.

Actions for government and standards bodies:

- Design and performance standards should be updated to include new approaches to risk that will improve the material efficiency and carbon performance of buildings and infrastructure, including the reuse of materials and components. This can be achieved through updated standards that set out more efficient design practices to enable greater material efficiency and reuse and greater consideration for the life expectancy of materials. This may require cutting down the last few percent of performance confidence. To drive change in practices in material reuse across all projects, designers should be required to consider the reuse of materials, including the reuse of building foundations, and when constructing from new materials, evidence must be presented to show that constructing from reused materials is not possible.

  Why?
  Current standards are not designed for net zero. Design and performance standards must be urgently updated as infrastructure built now will remain operational in 2050 and will impact the future infrastructure built around it. In addition, updated design and performance standards are key to nature-based solutions in construction and moving towards a circular model of material use within the sector. There will be some difficult trade-offs for example around risk and performance.

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Actions for the engineering profession:

- Engineering education must change to include continuous professional development and upskilling in net zero technologies and the tools and frameworks that enable the assessment of carbon performance. The engineering profession must prioritise a pipeline of transferrable STEM skills from primary education through to higher education, reviewing future skills needed to complement a net-zero roadmap for the sector.

Why?

This will prepare the sector to use tools and frameworks that enable assessment of carbon performance and guide them in how to make decisions that will enable the construction sector's net zero transformation. The project-driven nature of construction makes reskilling and upskilling a challenge. There is a role for professional bodies, working alongside the relevant training boards, trade associations, unions, training providers, skills accreditation bodies, and industries to raise awareness of the value of reskilling and upskilling, and improve access to skills provision.

Shared actions:

- Government, supported by industry, must introduce a certification process for all materials used in the construction process. This should be supported by regular inspection to enforce the use of low-carbon materials and supply chains.

Why?

There is currently no clear certification or enforcement process for materials used in the construction sector. This results in businesses having limited information on the embodied carbon of their supply chains. Introducing an accreditation scheme for the materials supply chain can bring transparency on carbon performance. It would incentivise the sector to buy low-carbon materials, such as recycled steel and low carbon concrete and drive the adoption of low-carbon processes within the supply chain, such as the use of electrified plant in mining. This action would drive the production of low-carbon products as well as the market for them.

Achieving a net zero transformation through design and specification

Design and specification is the most important stage for determining the carbon performance of buildings and infrastructure, even before they are completed. Key structural design decisions at the earliest stages of a building project affect the amount of material that will be used and how a building or structure will be used, and hence the embodied and operational carbon. Decisions made at this first stage, can 'lock-in' carbon into design. This may be in the architecture, the function or the materials.

The UK government's overall strategy for decarbonising the construction sector should include a strategy for decarbonising design and specification through a series of key enablers to maximise the opportunity to reduce carbon. These are outlined below.

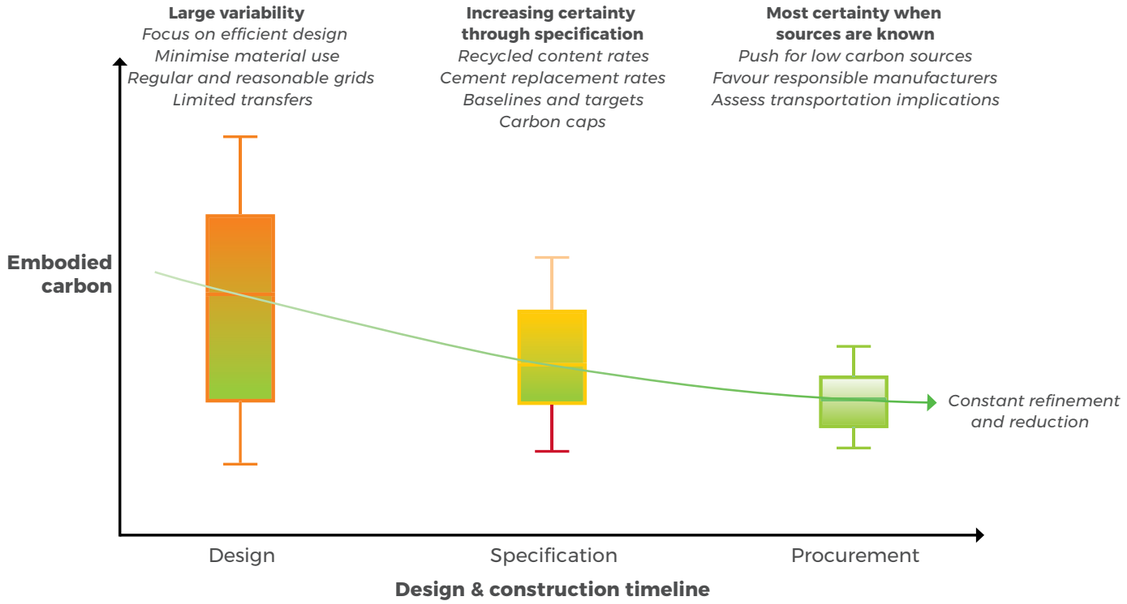

Figure 1: Graph of embodied carbon levels at each stage of the construction process

Key enablers for decarbonising design and specification:

Low-carbon materials

Carbon emissions associated with construction materials arise from several sources, including the energy used to extract and process them, emissions from their use, and emissions associated with their transport and disposal. The use of steel and cement dominates the construction industry. These materials have high emissions arising from their production and transportation, which are difficult to avoid. No single new material provides a silver bullet, instead a whole range of novel materials will need to be deployed to reduce emissions. Low-carbon alternatives include Portland cement-free concrete, recycled steel, the use of stone and timber if they can be locally sourced, and low-carbon glass. It will be important for government to provide an enabling environment, for example through incentives and standards for rapid innovation, certification and testing of new materials, including understanding their safety, resilience and public perception.

To incentivise the use of low-carbon materials government, supported by industry, must introduce a certification process for all materials used in the construction process. There is currently no clear certification or enforcement process for materials used in the construction sector. Introducing an accreditation scheme for businesses in the construction sector can incentivise the sector to buy low-carbon materials and adopt low-carbon processes and will drive the market for those producing low-carbon products.

Government, working with standards bodies must urgently update current design and performance standards to facilitate greater innovation and the reuse of materials, including the foundations of

existing buildings and infrastructure. The use of new materials should be a last resort, and these should be low carbon. To drive change in practices in material reuse across all projects, designers should be required to consider the reuse of materials, including the reuse of building foundations, and when constructing from new materials, evidence must be presented to show that constructing from reused materials is not possible. The engineering profession must begin continuous professional development and upskilling so that engineering professionals are trained in the use of low-carbon materials and materials reuse.

Improved use of data and digital technologies
To enable a net zero transformation across the construction industry, a better understanding of the carbon performance of built environment systems is urgently required. The use of data and digital technologies can help the construction sector accomplish this. Data and digital technologies can be used to improve modelling tools, reduce uncertainty and drive efficiency in design including carbon performance. Data can also help to guide choices on low-carbon materials, enable better understanding of the carbon impacts at a project level, and ensure that emissions associated with the supplied building materials are transparent.

To assess carbon performance and opportunities for decarbonisation, new frameworks and tools that incorporate data and digital technologies are urgently required. For example, the UK Green Building Council's *net zero framework definition*[23] currently aims to provide the industry with clarity on how to achieve net zero, and to inform the development of tools, policies and practices to enable this. They and other leaders in the construction sector must continue to develop user-friendly tools to enable consistent assessment of carbon performance of the whole built environment.

Rethinking design standards
Updating design standards has the potential to drive improvements in carbon performance. For example, it would be possible to achieve an acceptable level of an infrastructure asset's performance by cutting down the last few percent of safety and reliability performance confidence through changes to design standards.

This presents a serious challenge for engineers whose training embeds a risk-averse approach to design that can lead to overspecification within design. Therefore, an entirely different way of analysing risk is required that relies on continuous analysis and monitoring rather than over-specifying the building. Assessment of design risk is also critical. Societal acceptance of different performance levels, such as thermal comfort or energy availability, may also be needed. As a result, a more holistic approach to the design of the built environment is needed and engineering education must change to include continuous professional development and upskilling that will prepare the sector for the net zero transformation.

It is also important that updated design standards for net zero are developed in such a way that is consistent with indoor air quality and making buildings resilient to spreading infection.[24] It is feasible to achieve an indoor environment that can mitigate transmission of infection within an energy-efficient building. With appropriate technology and effective management, the need for appropriate ventilation and indoor air quality in a building is compatible with strategies to reduce carbon emissions and attain net zero. This will require proactive action to integrate thinking on infection control into the sector's approach to net zero.

Mission 3: construction and reuse

Recommended actions for key stakeholders

Actions for the construction sector:

- Industry must begin to demonstrate best practice by considering materials reuse as standard and it must be made a requirement to provide a justification for when materials are not reused. The sector should also measure and articulate the benefits of reuse and address the risks associated with reuse using tools developed with the support of engineers, scientists and economists.

  Why?
  The construction sector currently operates as a linear economy. This is unsustainable if global targets on greenhouse gas emissions reduction and biodiversity protection are to be met. The construction sector must manage resources in a more efficient manner; scale up the use of recycled materials, creating a more circular economy and building the supporting evidence base as it proceeds.

- The sector must take action to use only non-fossil fuel powered plant and equipment to eliminate carbon emissions from sites and reduce materials wastage during construction.

  Why?
  Non-fossil fuel powered plant and equipment is becoming available on the market and requires rapid adoption to decarbonise the on-site construction process.

Actions for government:

- Government should ensure that building planning and consent stages take better account of both the carbon performance and the potential co-benefits, such as improved health and job creation, that can be achieved through retrofit options as opposed to building new. This requires a systems approach to decision making.

  Why?
  In many cases options for retrofit may perform better in carbon terms than new build options. There will also often be added societal benefits and economic opportunities associated with reuse, for example through the creation of jobs and supply chains around maintenance and retrofit activities. However, the benefits of retrofit options are often not properly considered at scoping and design stage. Taking a systems approach in decision making will help to identify and realise these benefits.

Achieving a net zero transformation through a vision for net zero

The construction sector operates as a mostly linear economy – for example it relies on material extraction from the environment, it processes and utilises those resources, and ultimately, they are disposed of into the environment in ways that prevent reuse. Broadly, a model of take, make and throw away. This is unsustainable as a practice, so the construction sector must manage resources in a more efficient manner and by reusing waste, creating a more circular economy.

Moving towards a circular economy that minimises waste will also be key in delivering co-benefits such as health improvements and quality of life. The activity of open burning of construction and demolition waste is widespread which results in the emission of a wide range of potentially hazardous substances that are classed as persistent organic pollutants, carcinogens, mutagens, cause immunological and developmental impairments; and may lead to reproductive abnormalities.[25] Demolition activities also result in an increase in concentrations of silica dust. Silica dust exposure is increasingly a public and occupational

health issue and is known to cause silicosis, a fibrotic disease of the lung. Silica dust is also linked to lung cancer and pulmonary tuberculosis.[26]

There has been some progress in recent years: the Waste and Resource Action Programme (WRAP) estimates that 20% of the construction industry is already circular,[27] and since 2010 the industry has nearly halved the amount of waste it sends to landfill or incineration. But there is much further to go. A fully circular economy might not be feasible, but government and industry can do more to embed practices that accord with government's published waste hierarchy (2011).[28] This includes setting very ambitious targets, along with implementing enablers such as incentives and enabling regulation, to encourage the required step-change through existing technology and innovations in 'urban mining'[29] and the recycling of materials and building.

Every actor in the sector should develop processes for being efficient resource managers and applying circular economy principles in their work. This may require an enabling economic environment, such as incentives and enabling regulations, and intervention and co-operation by government, private procurers and the construction industry.

Important aspects of waste reduction and circularity in the built environment including the extension of

Exterior of Circl ABN AMRO's sustainable pavilion.
Photo credit: Duncan Baker-Brown, University of Brighton

life, the reduction of materials use, waste reduction, the use of recycled materials, and sustainable design will all play a very significant role in enabling a net zero transformation.

The value of, and identifying opportunities for, reuse

In many cases, options for retrofit and reuse may perform better in carbon terms than new build options. There may also be added societal benefits and economic opportunities associated with retrofit and reuse, through the creation of jobs and supply chains around maintenance and retrofit activities. However, the benefits of retrofit options are often not properly considered at scoping and design stage. Taking a systems approach in decision making will help to identify and realise the available benefits and carbon savings and this is needed at the building planning and consent stages. This should map the consequences of decision making on other interconnected sectors and include assessment of whether better outcomes including improved health and job creation are achieved through retrofitting or building new.

Government, as a procurer, must be clear about how it will evaluate projects, products and companies with this value of reuse in mind. Clarity about what 'good' looks like in terms of the circular economy will act as a driver for improvement. Industry must begin to build the evidence base and articulate and measure benefits of reuse, using tools developed with the support of its engineers.

Interior of Circl ABN AMRO's sustainable pavilion.
Photo credit: Duncan Baker-Brown, University of Brighton

Industry and government must now take steps to identify opportunities for reuse. Reuse is possible at different scales, from component and material level to neighbourhood and systems level. For example, at a neighbourhood level, there may be opportunities to reactivate redundant buildings with associated benefits to the local community. Consumer appreciation of the value of a neighbourhood and the potential to explore and identify co-benefits has deepened because of COVID-19, and the opportunity exists to build on that.

Carbon savings can be achieved by ensuring new buildings are robust, future-proof and adaptable, so that they last longer in the building stock rather than being demolished. This requires a careful choice of design life so that carbon impact is also minimised in the critical short term. A key to design is also to make the built environment flexible to enable change of use, so that buildings can reach their life expectancy through being repurposed.

Challenges to reuse in the construction sector

Projects such as Circl, ABN AMRO's sustainable pavilion in Amsterdam's financial district[30] and the Brighton Waste House[31] help to demonstrate the circular economy in construction in practice, as well as the surrounding co-benefits. The challenge now is to remove barriers and create incentives so circular economy principles are scaled up across the whole industry.

Concerns about the legal and insurance ramifications of such changes are common in the sector. Insurers have tended to be conservative in the past, relying on risk history, and therefore struggle to price risks associated with forward-looking innovative approaches, inhibiting innovation in the sector. There is a need to learn from those who have overcome contractual barriers and dealt with liability issues successfully. The rapid rise of future scenario planning and climate related financial disclosures is likely to have a significant impact by ensuring that climate risks are referenced in investment decisions. This opens new funding opportunities linked to improved resilience, working with the insurance industry and mobilising resilience bonds. The consideration of this type of risk will help drive forward the decarbonisation of construction, as long as a systems approach is taken

to cover the performance of the whole system over its entire lifetime.

There may also be technical risks in some instances. For example, requirements in relation to steel strength were lower in past decades than at the current time. Issues with timber products may occur when the product is taken out of a building or asset because of contamination or use of coatings. There may also be safety concerns in relation to the use of innovative materials and to reusing foundation materials, which must be overcome through innovations in material reprocessing.

There may be ways of introducing improvements without creating additional risks; for example, using existing materials more efficiently. Testing is one way to mitigate risk and to allow low carbon products to be marketable. Government support, backed by the certification process proposed previously in this report (see page 15), for development and testing of low-carbon materials would increase interest from manufacturers and drive the market for low-carbon building products, increasing their speed of development and availability.

Exterior of Brighton Waste House. Photo credit: Duncan Baker-Brown, University of Brighton

Mission 4: changes to procurement

Recommended actions for key stakeholders

Actions for the construction sector:

- Industry needs to embed low-carbon design and implementation rapidly and at scale over the next five years so that infrastructure products are performing adequately by 2030. This can be achieved through committed leadership to drive change, both within organisations and across the supply chain.

Why?
Committed leadership in organisations and across the supply chain is needed to drive improved practices and culture change. Certain pathways to improvement could be followed to ensure that the building process is more effective and efficient, while ensuring co-benefits such as freeing up capital and reducing resource wastage are maximised.

Actions for government:

- Government must urgently change approaches to procurement, at central, devolved and local levels to reflect broader definitions of whole-life value, including whole-life carbon performance, and not just short-term cost. Government can achieve this by using its purchasing power and the requirements that are set out in public contracts to drive better carbon performance.

Why?
Procurement is an important lever in delivering the net zero transformation of the sector. Government must now change its approach to reflect whole-life carbon performance. Government can use its position to stimulate the construction sector to change its culture from one of short-term targets to one that is focused on the whole-life value. This change is vital for the net zero transformation of the construction industry.

- For the construction process and material extraction, increasingly stringent carbon reduction targets should be introduced over time. These targets should include embedded carbon in imported construction materials[32] and be in line with the ambition of UK emission reduction targets of 68% reduction of carbon emissions by 2030 and 78% by 2035 compared to 1990 levels. For operational carbon of the built environment, which partly results from decisions made in earlier stages of the construction process (e.g., design and specification), more stringent targets are required as new infrastructure will continue to be in operation beyond 2050. This can be achieved by working in close partnership with the construction sector and applying targets immediately to the infrastructure that is currently being procured, as part of the National Infrastructure and Construction Procurement Pipeline[33] as well as to publicly procured buildings. Private clients will look to government for guidance and follow suit.

Why?
Setting increasingly demanding, but realistic whole-life carbon targets will encourage the industry to think creatively and deliver innovative solutions. This needs to be done in close contact with industry to provide leadership and support government in setting out realistic expectations of how the sector will achieve its net zero transformation.

Shared actions:

- Government and industry need to take a different approach to productivity performance and risk to foster innovation and collaboration across the supply chain, if the industry is to create the innovative solutions needed to meet carbon targets. Digitalisation across the sector will be a key enabler.

Why?
Current profit margins in the construction sector are not suitable for achieving the net zero transformation, failing to encourage both innovation and decarbonisation. Future business models need to take a different approach to productivity performance and risk to stimulate greater innovation in the sector which can in turn stimulate decarbonisation.

Achieving a net zero transformation through changes to procurement and target setting

It is vital that both government and industry set challenging but clear targets that deliver the net zero transformation at pace and at scale. Government, as a major client of infrastructure and building projects, must now change its approach to procurement, to reflect whole-life carbon performance.

It is important that government uses its purchasing power to stipulate carbon performance through specification and the requirements that are set out in public contracts. This will act as a key stimulus in securing the net zero transformation of the construction sector. To support this change to procurement, government must work in close partnership with industry leaders. Industry can provide leadership to support government in setting out realistic expectations of how the sector will achieve its net zero transformation.

To achieve the net zero transformation, carbon targets must be outcome-based, with government specifying the expected level of performance rather than specifying solutions. This will allow the industry to create solutions and innovate in the delivery of these outcomes. Outcomes-based targets need to be meaningful and make a material difference at the procurement stage. Carbon impacts need to be tracked for all construction contracts, including embedded carbon emissions and those associated with construction and operation.

It will be crucial to transfer learnings from other sectors on different business models, supply chains and sector leadership to help transform the construction industry.

Key enablers of change for government procurement

Business models and supply chains

Current business models are not suitable for achieving the net zero transformation, with some contractors in the sector typically working on very low profit margins. This often leads to a conservative approach to innovation, including innovation for decarbonisation. Future business models will need careful thought to not only stimulate the decarbonisation of the sector but also necessitate sustainable profit margins that protect jobs in the long term.

A rethink about productivity performance and how risk is shared across the supply chain is needed to counter the risk-averse nature of the industry, which can hold back innovation. Digitalisation can play a key part in improving productivity and performance. For example, new business models might be supported by digital technologies, drawing on learning from sectors that do this well such as the manufacturing industry.

Supply chains and leadership

There is potential to reduce carbon emissions from the construction sector through good supply chain management, creating products that are deemed necessary or reducing other supply chain activities that produce carbon. Three potential areas for improvement are:

- Improving the flow across the supply chain with an end-to-end supply chain perspective, and a more strategic approach. This would require a very different approach to supply chain management in the construction industry and learning lessons from other sectors such as energy (see case study two).

- Identifying ‘economies of repetition’, where a programme of repetitive projects enables the supply chain to plan over a longer time period and become more efficient, with the potential to simplify contracts and provide headroom for innovation.

Section 3: recommended actions for each mission

- Developing new responsible and sustainable business models that allow firms to make money from responsible consumption and production practices.

The head of the supply chain, often the main contractor, sets the tone for the rest of the chain. However, committed leadership in organisations across the supply chain will be needed to drive improved practices and cultures. There are certain incremental improvements that could be followed, for example around supply chain planning and coordination. This would make contractors more effective and efficient, with benefits such as increased margins, freeing up capital and reducing resource wastage, resulting in reduced carbon emissions.

CASE STUDY 2

LEARNING FROM OTHER SECTORS

The construction sector has much to learn from the energy sector, which reduced the carbon intensity of its power supply without a mandate from government. Instead, government put in place targets and incentives, which led to renewable sources of energy such as solar and wind power becoming economically viable. National Grid, in its role as buyer of services, required its supply chain to explain the carbon intensity of their materials and processes, and this was priced into the bidding structure so that the selection was based on carbon performance, rather than purely on price. The partnership across the supply chain was a key component. The regulator’s role in mandating continuous improvement was another factor.

Section 4: conclusions

There is an urgent need for change across multiple interconnected areas if the construction sector is to decarbonise. The challenge is to define and scale up best practice rapidly so that it is applied to every new build and refurbishment project by 2025.

Committed leadership and partnership is required from and between government, industry, standards bodies and the engineering profession. An ambitious but achievable roadmap must be agreed, with increasingly stringent carbon reduction targets over time linked to incentives. With clarity about the required performance, the industry will innovate and develop new approaches toward risk to deliver the roadmap.

Given government's role as a major client of infrastructure and building projects, procurement must play a key role as a lever for driving change, working alongside changing attitudes to investment and insurance. Opportunities to drive economic growth while minimising resource use and delivering other benefits should be captured.

Decision-makers will need to take a systems approach to recognise broader definitions of value that consider carbon impacts and other social and environment factors beyond short-term economic cost, if infrastructure and building projects are to be shaped to take into account their impact on future generations. A clear vision of what a net zero future looks like is needed to make the actions needed more accessible and understandable to the public.

The recommendations presented in this report are primarily based on discussions made in the NEPC decarbonising construction workshop of June 2020. This has limited the scope of this report and therefore, other actions for government, industry, the engineering profession and other stakeholders may have been overlooked. As such, this set of actions is a work in progress and, for this reason, we would like to develop this framework further with the help of stakeholders. We would like to invite interested stakeholders to help us develop it and test it further. Please contact NEPC@raeng.org.uk if you are interested.

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Annexes

Annex A: desired outcomes from the recommended actions

To achieve a decarbonised construction sector, we have presented **desired outcomes** which arise from the **recommended actions** presented in section 3, and which link to systems levers presented in Annex B. They cover the following broad categories:

- The construction sector should adopt the same carbon emission reduction targets as the national targets of 68% and 78% by 2030 and 2035 respectively, compared to 1990 levels. These recommended percentage reductions should include embodied carbon of built infrastructure, including that of imported construction materials, not just the scope of emissions included in the UK carbon budget. More stringent targets for operational carbon of the built environment are also required to achieve net zero. Responding to these targets, government and industry must jointly introduce an ambitious but achievable decarbonisation roadmap to 2050 guided by a vision of a net zero future, that covers changing demand and outcomes-based decision making.

- The construction sector must support the implementation of the updated guidance for appraising environmental impacts defined in HMT Green Book[34] which is aimed at ensuring that interventions are first appraised in terms of their contribution to the net zero target. This should include adopting the principles outlined in the Transforming Infrastructure Performance[35] report by the IPA.

- Current design and performance standards need to be immediately and continually updated. This should enable more holistic design approaches for the built environment that support efficient design and material reuse. In addition, the updated standards must ensure that all future projects, including those that are part of the economic stimulus following the COVID-19 pandemic, are obligated to contribute to meeting net zero. It is important that proactive action in design is taken to integrate thinking on infection control and energy efficiency to prevent increasing susceptibility to infection and other health risks as the UK moves towards the net zero target.[36] These updated standards for design and construction will need to be accompanied by subsequent assessments of performance in use of completed projects.

- Government and the construction sector must rapidly define and scale up best practice in low-carbon construction and procurement, applying it to all new build and refurbishment projects by 2025. This must be underpinned by a different approach to productivity performance and risk, with digitalisation a key enabler.

- To achieve a shift in culture in the construction sector, net zero and sustainability principles and practices must be a mandatory inclusion in engineering education, continuous professional development and upskilling. Increasing the understanding and skills needed for net zero is required to both enable good decision-making for net zero and for having the skills needed to implement these decisions.

- Government should apply a systems approach[37] to ensure that total emissions from construction are minimised. Net zero emissions will not be achieved solely by building less and retrofitting existing building stock. Radical new systems need to be created that enable us to undo the last 200 years of fossil fuel dependency. By employing a systems approach, policies for the built environment and construction can maintain consistency, join up and coherence across national, local and devolved government and have clear co-benefits that place social, economic and environmental outcomes at their heart. This includes addressing any conflicts between net zero and infection resilience, particularly ventilation.

Annex B: systems levers

Drawing together the detailed actions set out throughout this report, we have identified six over-arching recommendations which form 'systems levers' where action taken now will result in rapid decarbonisation of the construction sector. In addition, we have drawn together all the individual actions set out in this report into a sequencing framework that breaks these down into those actions that can be taken now (in 2021), next (by 2025) and in the future (beyond 2025). This represents a comprehensive set of actions for the construction industry, government, the engineering profession and other stakeholders across the four missions outlined in this report to put the construction sector on the path to net zero. This will help to develop a shared understanding of how to address the issues that exist across the sector by being clear about what actions need be taken to decarbonise in the short, medium and long-term.

- **Setting and stipulating progressive targets for carbon reduction**
- **Embedding quantitative whole-life carbon assessment into public procurement**
- **Increasing design efficiency, materials reuse and retrofit of buildings**
- **Improving whole-life carbon performance**
- **Improving skills for net zero**
- **Adopting a joined up, systems approach to decarbonisation across the construction sector and with other sectors**

Annex C: now, next, future framework

What has to happen...

Mission Area	Outcome	Now (in 2021)	Next (within the next four years to 2025)	In the future (beyond 2025)
Design and specification	Setting progressive targets – a government/industry partnership improving skills for net zero	Design and performance standards should be updated to include new approaches to risk that will improve the material efficiency and carbon performance of buildings and infrastructure, including the reuse of materials and components. This can be achieved through updated standards that set out more efficient design practices to enable greater material efficiency and reuse and greater consideration for the life expectancy of materials. This may require cutting down the last few percent of performance confidence. To drive change in practices in material reuse across all projects, designers should be required to consider the reuse of materials, including the reuse of building foundations, and when constructing from new materials, evidence must be presented to show that constructing from reused materials is not possible. The construction sector must begin to employ more holistic design approaches for the built environment. This can be achieved through choice of design practices and driving more efficiency within designs as well as requiring more materials reuse within design and construction. Engineering education must change to include continuous professional development and upskilling in net zero technologies and the tools and frameworks that enable the assessment of carbon performance. The engineering profession must prioritise a pipeline of transferrable STEM skills from primary education through to higher education, reviewing future skills needed to complement a net-zero roadmap for the sector.	Practical and user-friendly tools to enable consistent assessment of carbon performance of built environment systems, and not just individual components, need to be developed and embedded within design and procurement. This can be achieved through the increased use of data and digital technologies to assess carbon performance and opportunities for decarbonisation. Government, supported by industry, must introduce a certification process for all materials used in the construction process. In tandem, government must carry out regular inspection to enforce the use of low-carbon materials and supply chains.	

Annexes

		What has to happen...		
Mission Area	**Outcome**	**Now (in 2021)**	**Next (within the next four years to 2025)**	**In the future (beyond 2025)**
Changes to procurement	Embedding quantitative whole-life carbon assessment into public procurement	For the construction process and material extraction, increasingly stringent carbon reduction targets should be introduced over time. These targets should include embedded carbon in imported construction materials and be in line with the ambition of UK emission reduction targets of 68% by 2030 and 78% by 2035 compared to 1990 levels. For operational carbon of the built environment, which partly results from decisions made at the earliest stages of the construction process, more stringent targets are required as new infrastructure will continue to be in operation beyond 2050. This can be achieved by working in close partnership with the construction sector and applying targets immediately to the infrastructure that is currently being procured, as part of the National Infrastructure and Construction Procurement Pipeline as well as to publicly procured buildings. Private clients will look to government for guidance and follow suit.	Industry needs to embed low-carbon design and implementation rapidly and at scale over the next five years so that infrastructure products are performing adequately by 2030. This can be achieved through committed leadership to drive change, both within organisations and across the supply chain. Government and industry need to take a different approach to productivity performance and risk to foster innovation and collaboration across the supply chain, if the industry is to create the innovative solutions needed to meet carbon targets. Digitalisation across the sector will be a key enabler.	Government must urgently change approaches to procurement, at central, devolved and local levels to reflect broader definitions of whole-life value, including whole-life carbon performance, and not just short-term cost. Government can achieve this by using its purchasing power and the requirements that are set out in public contracts to drive better carbon performance.
Construction and reuse	Increasing design efficiency, materials reuse and retrofit of buildings	Industry must begin to demonstrate best practice by considering materials reuse as standard and it must be made a requirement to provide a justification for when materials are not reused. The sector should also measure and articulate the benefits of reuse and address the risks associated with reuse using tools developed with the support of engineers, scientists and economists. Action must also be taken by the sector to use only non-fossil fuel powered plant and equipment to eliminate carbon emissions from sites and reduce materials wastage during construction. Action must be taken by the sector to use only non-fossil fuel powered plant and equipment to eliminate carbon emissions from sites and reduce materials wastage during construction	Government should ensure that building planning and consent stages take better account of both the carbon performance and the potential co-benefits, such as improved health and job creation, that can be achieved through retrofit options as opposed to building new. This requires a systems approach to decision-making.	

Annexes

		What has to happen...		
Mission Area	**Outcome**	**Now (in 2021)**	**Next (within the next four years to 2025)**	**In the future (beyond 2025)**
Product outcomes	Improving whole-life carbon performance	In government, the built environment falls within the remit of many different departments, and this can prevent the built environment being treated coherently as a whole system. A joined-up response across government departments would lead to a set of aspirations and policies that are consistent and coherent, lower costs and greater value for money, and which have potential to deliver other co-benefits. As described in a cross-sector Vision for the Built Environment, the current construction system is resource-hungry and wasteful, vulnerable to economic, environmental and social pressures and system-wide shocks. The construction sector must become more sustainable, secure and resilient. Adopting systems-based policies can facilitate this transformation. Net zero and sustainability principles and practices must be a mandatory inclusion in engineering education, continuous professional development and upskilling.	The construction sector must demonstrate how approaches to decarbonisation fit within new models of economic growth that minimise resource use, reverse ecological damage and contribute to the net zero target. This will be aided by using the updated tools and guidance set out in HMT Green Book. Government and the industry can learn from and propagate examples of best practice. This includes other countries, such as Denmark and the Netherlands, and other sectors, such as the UK's energy sector, which are setting targets and developing new processes to drive better carbon performance. For the construction process, material extraction and imported materials, increasingly stringent carbon reduction targets should be introduced which, over time remain in line with overall UK emission reduction targets of 68% reduction by 2030 and 78% by 2035 compared to 1990 levels. More stringent targets for the operational carbon of the built environment are required to achieve net zero.	
Adopting a systems approach (cross-mission area)	Adopting a joined up, systems approach to decarbonisation across the construction sector and with other sectors	The construction sector must begin to employ more holistic design approaches for the built environment. This can be achieved through choice of design practices and driving more efficiency within designs as well as requiring more, materials reuse within design and construction. Government must adopt different approaches to decision making that enable consistent and coherent policies across different government departments, local government and devolved administrations. As described in IPFA's Vision for the Built Environment, the current construction system is resource-hungry and wasteful, vulnerable to economic, environmental and social pressures and system-wide shocks. The construction sector must become more sustainable, secure and resilient. Adopting systems-based policies can facilitate this transformation.		

Annex D: glossary

Term	Definition
Construction and re-use	This is the action or practice of reusing materials, whether for its original purpose or to fulfil a different function. It should be distinguished from recycling, which is the breaking down of used items to make raw materials for the manufacture of new products.
Design and specification	This refers to the technical design of the building or structure and the needs which it fulfils. This includes the products and materials that are required at the start of construction, and the values and judgements involved in design choices.
Embodied (or capital) carbon	In the building life cycle embodied carbon is the carbon dioxide equivalent (CO_2e) or greenhouse gas (GHG) emissions associated with the non-operational phase of the project. This includes emissions cause by extraction, manufacture, transportation, assembly, maintenance, replacement, deconstruction, disposal and end of life aspects of the materials and systems that make up a building.
Government procurement	The procurement of goods, services and works on behalf of a public authority, business models, supply chains and leadership.
Mission areas	Missions are the fundamental and interconnected components of the construction industry landscape that will require urgent change to achieve the net zero transition while continuing to provide the same societal function.
	The mission areas analysed in this report 1. product outcomes, 2. design and specification, 3. construction and re-use, and 4. choices of projects and procurement to achieve their objectives.
Nature-based solutions	The international Union for the Conservation of Nature defines nature-based solutions as actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.
Operational carbon	In the building life cycle, operational carbon is the CO_2e or GHG emissions associated of with the maintenance and operation of the building. This includes emissions from heating, cooling, powering and providing water.
Product outcomes	These are metrics that help to understand and monitor whether the product of a business or industry is helping that business or industry is on track to meet its goal.
System levers	Instruments that can be adjusted by key systems actors to lead to system wide change.
User carbon assets	User carbon describes emissions from the end-users of an infrastructure.
Whole-life carbon assessment	The whole-life carbon of the building is both the embodied carbon and the carbon associated with operation. An assessment of this aims to understand the relationship between embodied and operational carbon, which can assist in determining the overall optimum carbon reductions.

Annex E: audience

This NEPC paper is aimed at policymakers in central government and other organisations that work across a range of net zero policies for example in government procurement, infrastructure and the built environment. It is aimed at those responsible for driving forward the industry transformation including construction industry leaders and the engineering community.

Annex F: NEPC Decarbonising Construction Workshop

On 23 June 2020, the NEPC convened 50 consultants, contractors, clients, policymakers, academics and others with expertise relevant to the construction sector to identify the areas of change and agree priorities for action. The workshop was co-chaired by Dervilla Mitchell CBE FREng and Dr Mike Cook FREng.

The workshop focused on the transformational changes needed in the construction industry to achieve a low-carbon built environment, with the aim of identifying principal areas for change and agreeing priorities for action. The question at the heart of the workshop was: what needs to be done NOW to accelerate the rate of transition of construction to a zero-carbon industry to best serve the needs of the nation?

Workshop attendees heard presentations from invited speakers in four areas of the construction industry landscape and debated immediate priorities for action. These are introduced in **section 2** and discussed further in **section 3**.

Further information on our work in decarbonising construction can be found on our website.

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NATIONAL
ENGINEERING
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Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

TALENT & DIVERSITY

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.
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We are a unified voice for 43 professional engineering organisations, representing 450,000 engineers, a partnership led by the Royal Academy of Engineering.
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