Whole Life Carbon Net Zero Roadmap

A Pathway to Net Zero for the UK Built Environment

Draft for Consultation

July 2021

Contents

1. Introduction

In December 2020 the UK Green Building Council (UKGBC) announced the launch of the Net Zero Whole Life Carbon Roadmap project for the UK Built Environment. The Net Zero Whole Life Carbon Roadmap (hereafter known as the WLC Roadmap) aims to build a common vision and agreed actions for achieving net zero carbon in the construction, operation and demolition of buildings and infrastructure in the UK.

UKGBC is one of several European GBCs developing national WLC Roadmaps under the WorldGBC #BuildingLife project[1]. In the runup to COP26, WorldGBC has convened ten European Green Building Councils to galvanise climate action in the built environment through national and regional decarbonisation roadmaps. The Green Building Councils spearheading the project are Croatia, Finland, France, Germany, Ireland, Italy, the Netherlands, Poland, Spain and the UK. BuildingLife is accelerating ambitions in the building sector by creating the first region-wide response to the vision of a net-zero whole-life carbon built environment as set out in WorldGBC's 2019 report.

The UK already has a legal commitment to achieve Net Zero by 2050, with pathways and recommendations for how this could be achieved set out by the Committee on Climate Change (CCC) through their UK Carbon Budget analysis and reports. The WLC Roadmap highlights and provides focus to the emissions footprint specific to the UK Built Environment and presents a view of the specific actions and steps needed throughout the sector in order to reduce emissions, through the lens of whole-life carbon.

1.1. How to Provide Feedback

This consultation document presents an update on the Roadmap work completed to date, and seeks wider industry feedback on the current proposals. All built environment stakeholders are encouraged to participate in the consultation as the WLC Roadmap proposals are relevant to anyone involved in the delivery and management of the built environment.

Feedback from this consultation will be reviewed with the Task Groups and the Steering Group for consideration and incorporation into the final Roadmap to be launched in November at COP26.

The consultation is open from **Monday 26th July to Sunday 15th August**.

This consultation document includes the following sections:

- **Section 2: Project Overview**: An introduction to the Roadmap project and process
- **Section 3: Methodology:** The scope, definition and principles underpinning the Roadmap modelling
- **Section 4: Built Environment Carbon Footprint:** A snapshot of UK Built Environment GHG emissions
- **Section 5: Net Zero Scenario – Definition:** An overview of the references and inputs used
- **Section 6: Net Zero Scenario – Results:** Presentation of the trajectory to 2050.
- **Section 7: Observations:** The implications and meaning of the net zero trajectory
- **Section 8: Policy Recommendations:** Central Government and Local Authority recommendations
- **Section 9: Stakeholder Action Plan**: Key actions and milestones for built environment stakeholders

We are inviting feedback on the following sections:

5. Net Zero Scenario – Definition
6. Net Zero Scenario – Results
8. Policy Recommendations
9. Stakeholder Action Plan

To provide feedback, click on this **Survey Link** – all the questions are listed in the form.

Respondents do not need to provide feedback on all the questions. Reviewers who have expertise or interest in specific topics can respond to questions relevant in those topics only. At the end of the survey, respondents have the option to provide any additional feedback or comments.

[1] https://www.worldgbc.org/buildinglife

1.2. Summary of Consultation Questions

Section 5. Net Zero Scenario – Definition

The following question is repeated for each sub-section (numerically listed below):

Do you agree with the trajectory inputs described in this section?

- ***Agree***
- ***Somewhat Agree***
- ***Neutral***
- ***Somewhat Disagree***
- ***Disagree***

Please provide any further questions / feedback.

Domestic Buildings

5.2.1. Growth Rates – New Homes
5.2.2. Heating Technology Mix within Existing Dwellings
5.2.3. Heating Technology Mix within New Dwellings
5.2.4. Domestic Heating Technology Efficiencies
5.2.5. Proportion of Existing Housing Stock Retrofitted
5.2.6. Space Heating Demand (Existing & New Dwellings)
5.2.7. Retrofit Measures Performance Gap
5.2.8. Behaviour Change – Mean Internal Temperature
5.2.9. Behaviour Change – Hot Water Demand
5.2.10. Behaviour Change – Lighting Demand
5.2.11. Installed PV Capacity
5.2.12. Installed Solar Hot Water Generation
5.2.13. Domestic Cooking Energy Consumption & Fuel Mix
5.2.14. Domestic Appliance Energy Consumption

Non-Domestic Buildings

5.3.1. Non-Domestic Sectoral Growth & Demolition Rates
5.3.2. Non-Domestic Existing Building Heating Technology Mix
5.3.3. Non-Domestic New Building Heating Technology Mix
5.3.4. Non-Domestic Heating Technology Efficiencies
5.3.5. Non-Domestic Cooling Technology Efficiencies
5.3.6. Non-Domestic Existing Building Retrofit Measures – Performance
5.3.7. Non-Domestic Existing Building Retrofit Measures – Replacement Cycles
5.3.9. Non-Domestic Buildings – Installed PV Capacity
5.3.10. Non-Domestic Building – Unregulated Energy Consumption

Infrastructure

5.4.1. Infrastructure Spend Growth Projections
5.4.2. Change in demand - External lighting
5.4.3. Change in efficiency - External lighting
5.4.4. Water and wastewater
5.4.5. Construction & Demolition Waste – Destinations
5.4.6. Construction & Demolition Waste Arising per Unit Construction Value
5.4.7. C&D waste emissions intensity reductions

Capital / Embodied Carbon

5.5.1. Reduction Factors – Materials, Site & Transport
5.5.2. Industry Intensity Factors
5.5.3. Carbon Capture and Storage
5.5.4 Buildings Change-of-Use, Utilisation, and Material Re-use

Section 6. Net Zero Scenario – Results

6.1 UKGBC Scenario Trajectory (2 questions below)

With reference to the inputs and results shown in Section 6, do you feel the draft trajectory is:

- ***Too ambitious***
- ***Suitable***
- ***Not ambitious enough***

Please provide any further feedback / comments

Do you think the final residual emissions position for the Built Environment sector is an appropriate proportion of the UK total?

- ***No, not appropriate***
- ***Potentially not appropriate***
- ***Potentially appropriate***
- ***Yes, appropriate***

Please provide any further feedback / comments

Section 8. Policy Recommendations

The following question is repeated for each sub-section (numerically listed below):

Do you agree with the overall policy pathway laid out in this section?

- ***Agree***
- ***Somewhat Agree***
- ***Neutral***
- ***Somewhat Disagree***
- ***Disagree***

Please provide any further questions / feedback.

Buildings – Operational Carbon

8.1.1. Central Government Recommendations
8.1.2. Local Authority Recommendations

Buildings – Embodied Carbon

8.2.1. Central Government Recommendations
8.2.2. Local Authority Recommendations

Domestic Retrofit

8.3.1. Central Government Recommendations
8.3.2. Local Authority Recommendations

Infrastructure

8.4.1. Central Government Recommendations
8.4.2. Local Authority Recommendations

Section 9. Stakeholder Action Plan

The following question is repeated for each sub-section (numerically listed below):

Do you agree with the recommendations described in this section?

- ***Agree***
- ***Somewhat Agree***
- ***Neutral***
- ***Somewhat Disagree***
- ***Disagree***

Please provide any further questions / feedback.

9.1. NGOS / Trade Associations / Professional Institutions
9.2. Investors (banks, funders, etc)
9.3. Developers
9.4. Landlords / Owners
9.5. Occupiers
9.6. Facilities Managers / Maintenance
9.7. Contractors
9.8. Material & Product Manufacturers
9.9. Architects
9.10. Building Services Engineers
9.11. Structural Engineers
9.12. Homeowners and Civil Society
9.13. Infrastructure Clients
9.14. Infrastructure Owners
9.15. Infrastructure Designers

Additional Questions

Any further feedback or comments on the overall Roadmap?
In its current form, will the Roadmap assist you in your net zero journey?

2. Project Overview

2.1. Purpose of the Roadmap

The aim of the Roadmap project is to develop a roadmap of actions and secure the support of relevant market actors in delivering the decarbonization of the total impact (whole life cycle) of the built environment in the UK, as supported by the following objectives:

- Build consensus on a pathway to a net zero carbon built environment among businesses and industry bodies.
- Identify key interventions required and any critical interdependencies.
- Develop sectoral carbon targets.
- Set out actions, owners and processes to achieve these targets.
- Identify a range of policy recommendations to support, incentivise and where necessary regulate carbon reduction measures.
- Encourage and enable greater consistency between sector-based action plans that are published or in development.

2.2. Project Team

A key aspect of the project approach was that the proposals would be co-created with industry. To facilitate this engagement, in March 2021[2] UKGBC convened a project Steering Group, with input from professional institutions and key sector bodies, and four Task Groups formed of industry representatives capturing a range of stakeholder perspectives.

To deliver the above objectives, the four project Task Groups - New Build, Domestic Retrofit, Non-Domestic Retrofit, and Infrastructure - developed the proposals in the consultation document through a series of workshops. The industry-wide Steering Group provided strategic input throughout the process and acted as a reviewing body for the Task Group outputs.

2.2.1. Steering Group Participants:

- AECOM
- Association for Consultancy and Engineering (ACE)
- Better Buildings Partnership (BBP)
- British Retail Consortium (BRC)
- Buro Happold
- Chartered Institute of Building Services Engineers (CIBSE)
- Construction Leadership Council's (CLC)
- Construction Industry Training Board (CiTB)
- Construction Innovation Hub (CIH)
- Construction Scotland Innovation Centre (CSIC)
- Cundall
- Department for Education (DfE)
- Environmental Association for Universities & Colleges (EAUC)
- Future Homes Task Force
- Green Construction Board
- Good Homes Alliance
- Home Builders Federation
- Hoare Lea LLP
- Institution of Structural Engineers (IStructE)
- JLL
- Lloyds Banking Group
- Mott MacDonald
- NatWest
- NHS Improvements
- Office of Government Property (OGP)
- RetrofitAcademy
- RIBA
- RICS
- Skanska
- Tritax Big Box

[2] https://www.ukgbc.org/news/industry-comes-together-to-collaborate-on-whole-life-carbon-roadmap-project/

The steering group was also supported by representatives from the Department for Business, Energy and Industrial Strategy (BEIS) and the Ministry of Housing, Communities & Local Government (MHCLG)

2.2.2. Task Group Participants:

Task Group 1 - New Build

- AECOM
- Arup
- Atelier Ten
- Bennetts Associates
- Burges Salmon
- Buro Happold
- BRE
- Cundall
- ChapmanBDSP
- Feilden Clegg Bradley Studios
- Hilson Moran
- Igloo Regeneration
- Mott MacDonald
- Multiplex
- Perkins+Will
- Peel L&P
- SEGRO plc
- Sweco UK
- The Concrete Centre
- Thakeham Group
- Turley
- Willmott Dixon

Task Group 2 – Domestic Retrofit

- Active Building Centre
- Alliance for Sustainable Building Products (ASBP)
- Arup
- Dorrington PLC
- Energy Systems Catapult
- Essex County Council
- Federation Of Master Builders
- Grainger PLC
- Greengage Environmental
- Hoare Lea
- Knauf Insulation
- London Energy Transformation Initiative (LETI)
- Passivhaus Trust
- Pivot Energy Services
- SHAP (Sustainable Housing Action Partnership)
- South Yorkshire Housing Association
- Twinn Sustainability Innovation

Task Group 3 – Non-Domestic Retrofit

- Acclaro Advisory
- BDP
- Cundall
- Derwent London
- Elementa Consulting
- HawkinsBrown
- London Energy Transformation Initiative (LETI)
- MAPP
- Morrisons Plc
- Overbury and Morgan Lovell
- SOM
- The Carbon Trust
- The Crown Estate
- Tuffin Ferraby Taylor
- Verco
- WSP

Task Group 4 – Infrastructure

- BAM Nuttall
- BuroHappold
- CALA Group (CALA Homes)
- Chartered Institution of Civil Engineering Surveyors (CICES)
- dRMM
- High Speed Two (HS2)
- London Energy Transformation Initiative (LETI)
- Mott MacDonald
- National Grid
- Schneider Electric
- Skanska UK PLC
- Tarmac
- Tata Steel

2.3. Structure of the Roadmap

The Roadmap consists of four main elements:

1. A **Carbon Footprint** for the UK Built Environment defined on a consumption basis.
2. A **Net Zero Scenario** calculating an emissions budget and trajectory to 2050 for the UK Built Environment.
3. A suite of **Policy recommendations** for central and local government.
4. A **Stakeholder Action Plan** describing the specific actions for key stakeholder groups within the built environment required in order to deliver the Net Zero Scenario.

The Net Zero Scenario methodology builds on the work of the Green Construction Board's 2013 Low Carbon Route-map for the Built Environment[3]. The 2013 Route-map analysis model[4] has been updated to capture both historic emission data for the period 2013 – 2020 and incorporate key changes during this period (i.e. grid carbon factors).

The future trajectory was informed by data inputs from the Steering Group and Task Groups, setting out the required pace and scale of mitigation measures. Details on the methodology are provided in section 3.7.

The organisations listed above within Steering Group and Task Groups provided pro-bono support to the project through donation of time. This acknowledgement does not imply endorsement of every aspect of this report, which has been arrived at through a collaborative process. The proposals put forward in this report are draft for consideration and development with the wider industry. The proposals may not reflect the views of all participants.

2.4. Future Governance and Usage

The final WLC Roadmap will include an ongoing governance strategy covering the intended future usage of the Roadmap methodology and resources. The intention is utilise the methodology and data-sets going forward in order to track industry progress and update trajectories as appropriate.

It is envisioned that the Roadmap will be an important resource for built environment stakeholders as they manage their net zero transitions. The carbon reduction pathway as presented in the trajectory visualisation will enable sectors to review emission reduction progress and identify interim targets. The trajectory can complement other sub-sector roadmaps by providing the overarching carbon budget as context for individual sectors unique challenges and opportunities.

Stakeholders can use this report to understand the key actions, policies and milestones that need to be undertaken to deliver a net zero built environment, and how different interventions interact on the decarbonisation pathway.

[3] https://www.building.co.uk/download?ac=1753266

[4] https://scbrims.files.wordpress.com/2013/10/routemap-final-report-05032013.pdf

3. Methodology

3.1. A Carbon Budget for the Built Environment

Since the original publication of the Green Construction Board's Low Carbon Routemap in 2013, a new context has emerged for rapidly and aggressively addressing carbon emissions in the UK. Declarations of climate emergencies by Central and Local Government, ambitious target setting and increasing consensus around limiting warming to 1.5° frame a challenge of unprecedented scale for the Built Environment.

The CCC recommends emission reduction targets aligned with the UK's 2050 net zero goal, as defined by the 2015 Paris Agreement. In 2020, the CCC proposed a legally binding emission target for the period of 2033-37, known as the "Sixth Carbon Budget," which would commit the UK to lowering its emissions to 78% below a 1990 baseline by 2037. As of April 2021, the UK has adopted the CCC's recommendation as a legally binding target.

Emissions attributable to the UK Built Environment cut across several of the CCC emission categories, and the Sixth Carbon Budget therefore does not provide a clearly defined quantum of emissions for the built environment that align with the UK's overarching carbon budget.

One of the overarching objectives of this project is to identify and set out an emissions budget to 2050 for the built environment, consistent with the wider UK carbon budget, with a suitable system boundary. Emissions will be broken-down by sub-sectors and emissions categories relevant to the built environment to enable specific actions to be determined for responsible stakeholders.

The benefit of identifying carbon budgets is that they provide a ceiling for allowable emissions, whilst enabling choices within that budget around how emissions are allocated between sub-categories and different carbon emitting activities. Value judgements may be made around competing priorities and preferred pathways based on economic or technical considerations.

Determining and agreeing an overarching consumption-based carbon budget for the Built Environment will provide a top-down dataset from which to establish asset and project level targets.

3.2. Net Zero 2050 Target

The CCC 6th Carbon budget sets out a balanced pathway for carbon reductions across all sectors. Some sectors are projected to decarbonise completely, whereas other sectors, such as Manufacturing and Construction (which includes territorial embodied carbon emissions from buildings), are not projected to reach full decarbonisation, and are left with some degree of residual emissions.

Total residual emissions across all sectors are then proposed to be offset via both nature-based removals (i.e. land-use change, increased forestation, peatland restoration), and engineered greenhouse gas removals (i.e. Bioenergy with carbon capture and storage (BECCS), Direct Air Capture of CO2 with storage (DACCS) and increased use of timber in Construction) to permanently remove carbon from the atmosphere and achieve the UK's Net Zero target by 2050.

To align with a Net Zero UK by 2050, the UK Built Environment is therefore required to deliver significant decarbonisation, but not necessarily achieve absolute zero emissions. The residual emissions related to the Built Environment will however need to reflect a "fair share" of the available total UK removals budget as defined by CCC, in order to not exceed the sectors "allocation" of UK-wide natural and engineered carbon removals. Consumption emissions (embodied carbon from imported construction materials) should be reduced to as low a level as is practically possible.

This project proposes that the UK Built Environment Net Zero target therefore takes the form of a sector emissions budget, which aligns with the UK's Net Zero 2050 strategy, and identifies lowest possible residual consumption emissions.

3.3. Net Zero Modelled Scenario

To determine a carbon budget for the Built Environment, once boundary conditions have been established to identify the starting position, projections can then be made for the pace and scale of required carbon reduction interventions over time. The resultant projected emissions form the pathway, or emission trajectory, with the interventions forming the projected scenario.

Policy can then be identified to support and drive the interventions, via regulation, economic or fiscal incentivisation or other market drivers.

In this project the pace and scale of interventions have reference to the CCC's pathways analysis, but are primarily informed by latest industry thinking and research via the Task-Groups.

3.4. Net Zero Scenario Principles

The roadmap contains two scenarios; a Reference Scenario, and a Net Zero Scenario. Comparison is also made to the CCC balanced pathway for reference.

3.4.1. Reference Scenario

The reference (or business as usual) scenario is modelled based on the BEIS energy and emissions projections research and represents a forward "business as usual" scenario based on existing government policy outlook.

Each year BEIS publishes Energy and Emissions Projections (EEPs), analysing and projecting future energy use and greenhouse gas emissions in the UK. These projections allow BEIS to monitor progress towards meeting the UK's carbon budgets and are used to inform energy policy and associated analytical work across government departments.

The projections are based on assumptions of future economic growth, fossil fuel prices, electricity generation costs, UK population and other key variables regularly updated. They also give an indication of the impact of the uncertainty around some of these input assumptions. Each set of projections takes account of climate change policies where funding has been agreed and where decisions on policy design are sufficiently advanced to allow robust estimates of policy impacts to be made.

The roadmap trajectory modelling takes a simplified approach where-by the future emissions profile (curve shape) presented in the selected BEIS scenario will be applied from the baseline year of built environment emissions. As the BEIS data only projects to 2040, the scenario will utilise the profile data to 2040, with the trending line then extended to 2050.

This will therefore create a forward "business as usual" scenario based on government policy outlook.

3.4.2. Net Zero Scenario

For the UKGBC Roadmap Scenario, the pace and scale of carbon reduction measures applied was informed through research undertaken by the Task Groups and Steering Group, reflecting the latest industry thinking, research and publications.

3.4.3. Guiding Principles for the Roadmap Scenario

An overarching principle of the Roadmap project is that the UK Built Environment will seek progress towards *zero* emissions (including capital and operational emissions). Project team members thus considered which measures, interventions and solutions *should* be implemented in the drive towards Net Zero and in the context of the climate emergency, and with consideration of the following:

- Technological feasibility: Solutions and measures reflect what is currently considered to be *technically feasible*, as we look to the future. Technical feasibility of implementation is referenced through technical studies and background evidence, with the quality, transparency, objectivity, scalability and applicability of different resources considered throughout the process.
- Economic viability: The scenario includes measures which may not be currently viewed as *economically viable*, or do not have a positive return on investment (i.e. large scale retrofit of hard to treat domestic properties) and which would therefore require financial mechanisms, incentives or alternatively regulation to encourage or mandate adoption.
- Market viability: Measures proposed for implementation in the short and medium-term are cognizant of current market position and enabling actions required, i.e. unrealistic step changes should be avoided. Measures proposed further into the future are likely to increasingly rely on positive progressions in policy and market landscapes.

The project team also assumed the following direction of travel over the 30-year period from 2020-2050 for the Net Zero Scenario, Policy Recommendations and Stakeholder Action Plan:

- An overarching shift in national and local policy landscape towards Net Zero as part of a green recovery strategy.
- Increasing urgency for the implementation of Net Zero solutions, including fundamental changes in approach where necessary.
- Strong drivers toward Net Zero from both the investment community and occupiers.
- A responsibility, ownership and drive from within the construction industry and supply chains to accelerate change.
- Increasing consumer and societal pressure and appetite for climate action, and higher acceptance of disruption.

The Roadmap does not attempt to quantify, model or predict specific impacts related to the Covid-19 pandemic within the built environment, albeit some recent trends are captured within the projected growth rates for certain building sectors.

3.4.4. CCC Aligned Scenario

The intention of the CCC Aligned Scenario is to provide reference against the Balanced Pathway as published by CCC in 6th Carbon Budget report. The UKGBC Scenario is calculated on a consumption basis, including emission from imported materials, to account for all emissions for which the Built Environment is responsible. The CCC balanced pathway and the UK Net Zero target is based on domestic or territorial emissions, i.e. only those emissions arising within the UK. The approach taken for the purpose of comparison has been to present the UKGBC Scenario showing domestic emissions only, i.e. excluding imported emissions.

This comparison was established through dialogue with the CCC and its published work. The comparison maps the national emissions budgets established by the CCC, alongside the UKGBC Scenario, alongside emissions from the CCC balanced pathway relating to the built environment definition and scope as defined by the project.

3.5. Modelling Methodology

The objective of the Built Environment Net Zero Roadmap model is to provide a calculation platform that can be used to develop an emissions profile setting out the pace and scale of actions across the sector to support it to achieve net zero by 2050. This has been delivered through two key steps including:

1. Updating the 2013 Low Carbon Routemap model for the UK Built Environment[5]; and
2. Creating and then applying a net zero carbon scenario for the UK built environment to 2050.

Both these steps have been undertaken and supported through a detailed consultation and engagement exercise with UKGBC project task groups who have played a central role in bring forward data to inform the model as well as providing steer as to the pace and scale of actions it has applied.

3.5.1. Scope of the model

The scope of the 2021 Roadmap model includes new and existing buildings with detail of both domestic and non-domestic subsectors. It also covers infrastructure with a series of subsectors addressed. Across buildings and infrastructure, the focus is on Operational and Embodied carbon emissions. The model provides a timeseries approach to its calculations including historical outturn emissions from 1990 to a baseline calculation year of 2018 (the most recent year in which full emissions datasets are available); and then the ability to apply projected emissions scenarios to 2050.

3.5.2. Modelling approach

Model Structure

The structure and calculation methods of the 2021 built environment carbon Roadmap model are based on the 2013 Routemap project. The focus in 2021 has been to bring forward new data to update the existing calculation methods including re-baselining to the year 2018; alongside establishing, in selected areas:

- New calculation methods (to improve previous model approach);
- The inclusion of a number of additional modelled actions/interventions (not covered in the 2013 work), and which reflect current thinking for sector decarbonisation approaches.

In addition to the summary method description provided here, a more detailed technical addendum will be published to accompany the final Roadmap report, covering modelling approach and updates. This is designed to be read together with the original 2013 Low Carbon Routemap model technical report[6] much of which remains relevant because of the same structural underpinnings.

The calculation and analysis flow of the 2021 built environment carbon Roadmap model is shown in Figure 1.Here it can be seen that the model is based around a key number of calculation modules covering aspects such as historical outturn emissions, capital carbon and the use of the UKMRIO, and the building stock/and energy models for domestic and non-domestic buildings operational carbon. The calculation modules are driven by a wide range of specific datasets. In the cases of the baseline year and historical emissions this tends to be long running authoritative national sources, as for example is the case with using the Digest of UK Energy Statistics (DUKES 2020) for historic operational carbon emissions. When it comes to modelling the scenarios, this is made up of a more

[5] https://scbrims.files.wordpress.com/2013/10/routemap-final-report-05032013.pdf

[6] Ibid

varied mix of data requirements driven by different 'levers' in the model (for example, changes in heating technologies mix, building fabric standards, etc). The data for these defining the timing and scale of action has been taken from a diverse mix of references.

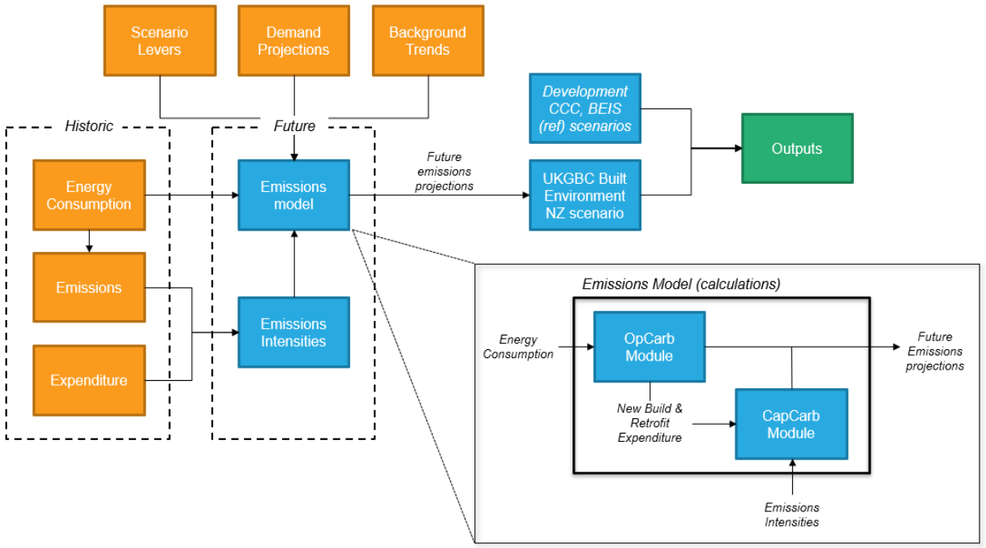

Figure 1: 2021 Built Environment Roadmap Calculation and Analysis Flow

Within the model update and development many different reference data-points are applied across a mix of calculation modules. A summary of the most important highlight a number of key model features.

Operational Carbon

Historic operational carbon emissions are primarily calculated from data for UK energy consumption sourced from the Digest of UK Energy Statistics (DUKES) developed by BEIS/ONS. This energy data has then been combined with GHG emissions factors to calculate the operational carbon contribution from various built environment sectors. For the modelling of future energy demand of domestic buildings, a hybrid approach is applied using a deconstructed version of the DECC 2050 Pathways Calculator. This has been modified with bespoke data for parameters such as electricity grid decarbonisation, heat delivery modes, and timeseries thermal loss profiles across both existing and new stock. For non-domestic buildings, a similar approach is applied, projecting sectoral energy demand based on future growth rates. Retrofit measures are introduced according to building and system lifecycles. The expenditure for new building and retrofit construction is estimated and imported into the capital carbon model.

Capital / Embodied Carbon

The capital carbon component of the model has been updated to use the 2021 UKMRIO model, incorporating data up to 2018 at a greater economic sector disaggregation (126 economic sectors) than used in the 2013 Routemap. The UKMRIO model links Greenhouse Gas Emissions with final consumption through understanding global supply chains. The University of Leeds uses this model of the UK's carbon footprint to provide consumption estimates to Defra (https://www.gov.uk/government/statistics/uks-carbon-footprint). The model uses a multi-region input-output (MRIO) model, to link the flows of goods and services described in monetary terms, with the emissions generated in the process of production. It is a sophisticated analysis model that can assimilate data on emissions and product flows from different countries and years in different classifications and valuations, dealing with the data gaps and reconciling inconsistencies.

This was combined with the UK Buildings and Infrastructure Embodied Carbon (UK-BIEC) model which can take the MRIO economic sector inputs and allocate them into the built environment subsectors that we are familiar with and apply in the Roadmap. An important part of updating the capital carbon model was also to include the latest updates from Defra's 2020 UK Statistics on Waste generation and treatment.

3.6. Scope of UK Built Environment Emissions

Within its analysis and reporting, the CCC splits UK emissions into the following categories or "sectors", with associated mitigation measures and recommended actions per sector. Figure 2 below shows the breakdown of UK emissions (2018 data):

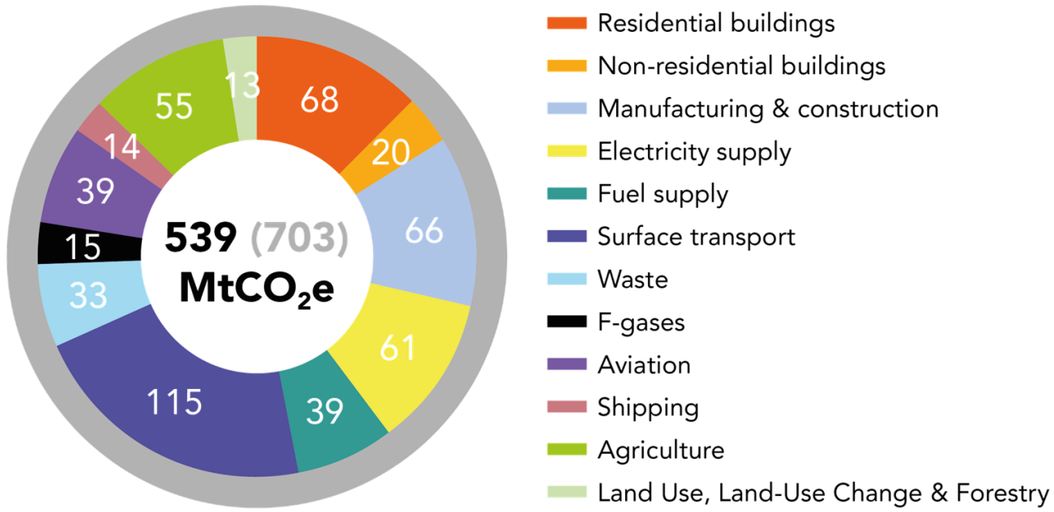

Figure 2: UK greenhouse gas emissions 2018 ($MtCO_2e$). Grey bubble represents consumption-based emissions (i.e. including imports and excluding exports).

Emissions related to the UK Built Environment cut across several of these CCC sectors, most obviously Buildings, but also elements of Manufacturing and Construction, Waste, Surface Transport, F-Gases and others. Furthermore, although a proportion of embodied carbon emissions from construction are captured within UK Manufacturing and Construction, a significant proportion (30-40%) relate to non-territorial emissions, i.e. construction materials and products produced overseas and imported to the UK.

Therefore, in order to accurately determine a carbon footprint for the UK Built Environment and identify tailored stakeholder actions, an appropriate system boundary and sub-categories are required. Sub-sector categories enable more effectively visibility of the degree of control or influence of each stakeholder group, and therefore allow for a more consistent roadmap of actions toward the end goal.

In first principle terms, the built environment encompasses all elements of man-made infrastructure and buildings. If the construction, operation and use of all these elements are included for foot-printing purposes, such as the supply and distribution of fuel and power, and all vehicle usage on our transport networks, the resultant quantum of emissions is nearly 70% of the UK emissions total based on 2018 data (see Figure 3).

A significant proportion of this is from the transport (vehicle usage), and energy (supply) sectors, and decarbonising these sectors is clearly critical in the context of the UK's Net Zero 2050 commitment. They are also integral parts of the wider Built Environment, and ultimately a systems viewpoint is required to evaluate the wider interconnected carbon impacts and reduction opportunities.

However in order to provide adequate focus and depth to the industry within the programme constraints, the focus of this report is on embodied and operational carbon of buildings and infrastructure, and excludes emissions related to surface transport and energy distribution (infrastructure user emissions).

For the purposes of this exercise the following scope of emissions and sub-categories have been determined to represent the UK Built Environment:

	Capital / Embodied Carbon	**Operational / Regulated Carbon:**	**User / Unregulated Carbon**	**F-Gas**
Domestic Buildings	Embodied carbon from Construction, Maintenance & Demolition. Both UK and international (imported) emissions.	Carbon emission from regulated energy uses within buildings: – Heating – Cooling – Ventilation & Pumps – Lighting – Hot Water	Carbon emission from unregulated energy uses: – Cooking – Appliances – Lifts – Small power / plug loads – IT / servers	F-Gas leakage from heat pumps and chillers within buildings
Non-Domestic Buildings				
Infrastructure		Carbon emissions from the operation of infrastructure: – Street & public realm lighting – Comms networks – Water supply & treatment – Waste treatment	Not in scope	Not in scope

Table 1. Emissions Scope for the UK Built Environment as defined for the Roadmap.

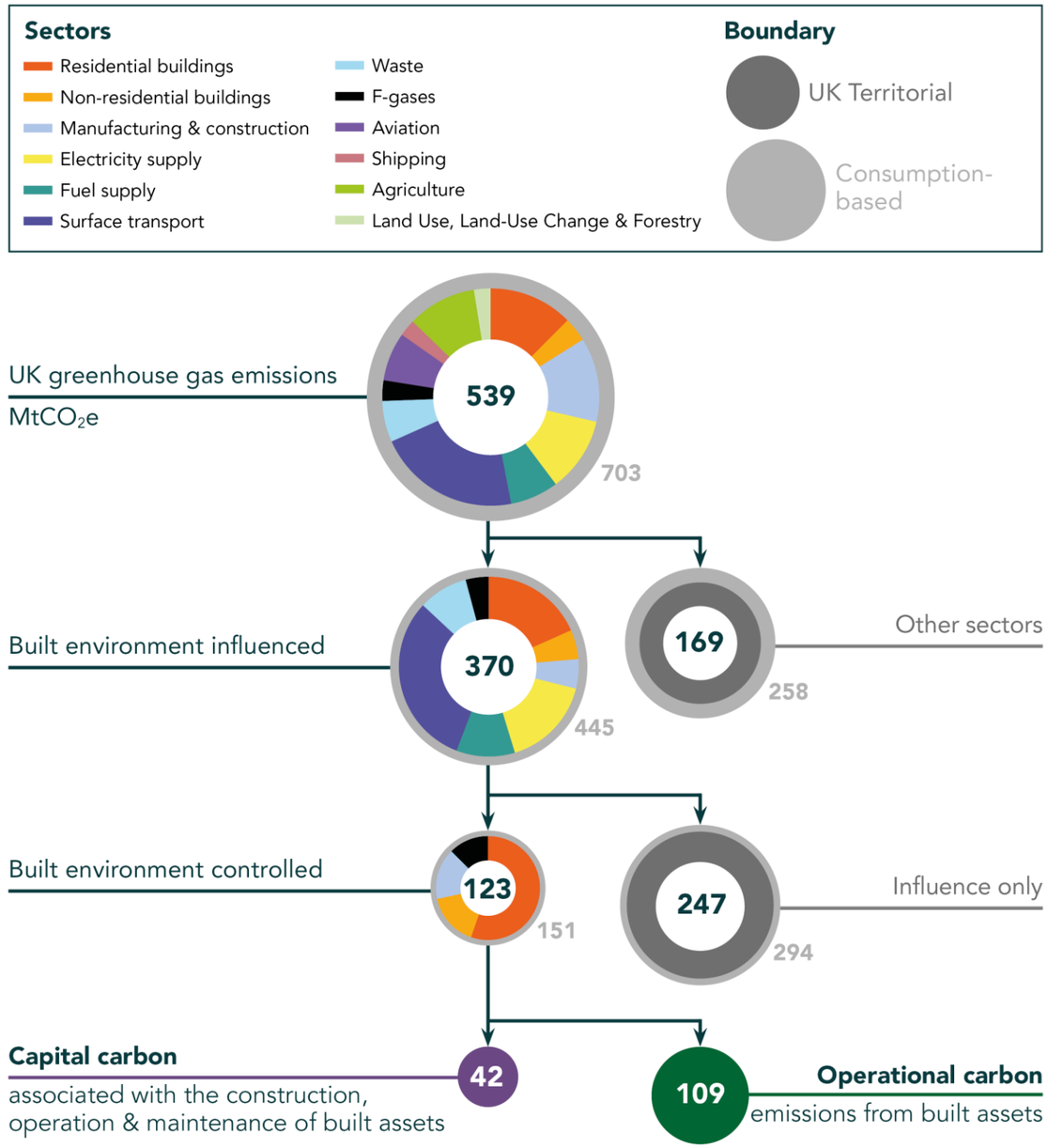

Figure 3. UK greenhouse gas emissions 2018 ($MtCO_2e$) showing influence and control of the built environment. Grey bubble represents consumption-based emissions (i.e. including imports and excluding exports).

3.7. Whole Life Carbon Emissions Categories

The vision for the Roadmap is to create a pathway to Net Zero for the built environment, including both buildings and infrastructure, and considering whole-life carbon emissions. That is to say greenhouse gas (GHG) emissions relating to the construction, operation and end-of-life processes for buildings and infrastructure assets.

Following this approach it becomes immediately apparent that differences exist in terminology and categorisation of GHG emissions between the buildings and infrastructure elements of the construction industry. This section briefly presents these alongside each other, to aid understanding of the terms used throughout this report, given that it is unlikely most readers will have an overarching understanding of all terminology used across all parts of the industry. This report does not take a view on the merits of the different terminology, but simply aims for clarity on what is described by the language used.

3.7.1. Infrastructure

PAS2080 (Carbon Management in Infrastructure) was produced in 2016 and shows how whole life carbon in infrastructure can be managed more rationally and strategically. PAS 2080 adopts the terms Capital, Operational and User carbon as follows:

- **Capital Carbon** - GHG emissions that can be associated with the creation, refurbishment and end of life treatment of an asset. This includes the emissions associated with materials, construction plant, transport of materials to sites, and will occur for all construction activities be they directed to new build, maintenance or refurbishment. Capital carbon emissions also arise at end of life associated with demolition, waste processing and any final treatment/disposal.

- **Operational Carbon** - GHG emissions associated with the operation of an asset. The origins of operational carbon emissions varies across infrastructure sectors due their different functions.

- **User Carbon** - GHG emissions associated with the users' utilisation of infrastructure (i.e. emissions arising from the user utilising infrastructure services). An example of user carbon emissions are emissions arising from vehicles utilising road infrastructure, as they represent the user utilising the infrastructure service provided.

PAS2080 states that the boundary on where to draw the distinction between operational and user carbon is not always clear. Therefore to differentiate between these, PAS 2080 uses the principle of control and influence, whereby asset owners who have a significant level of influence to reduce user emissions through their organizational activities, will be allocated the emissions (and hence they shall be termed operational emissions).

Figure 4 opposite shows an extract from PAS2080 (taken from BS EN 15978:2011 and adapted for PAS 2080 and infrastructure) which sets out the modular approach showing the life cycle stages and individual modules for infrastructure GHG emissions quantification. The colour coding across the modules show how the different categories of Capital, Operational and User emissions map across the various lifecycle stages.

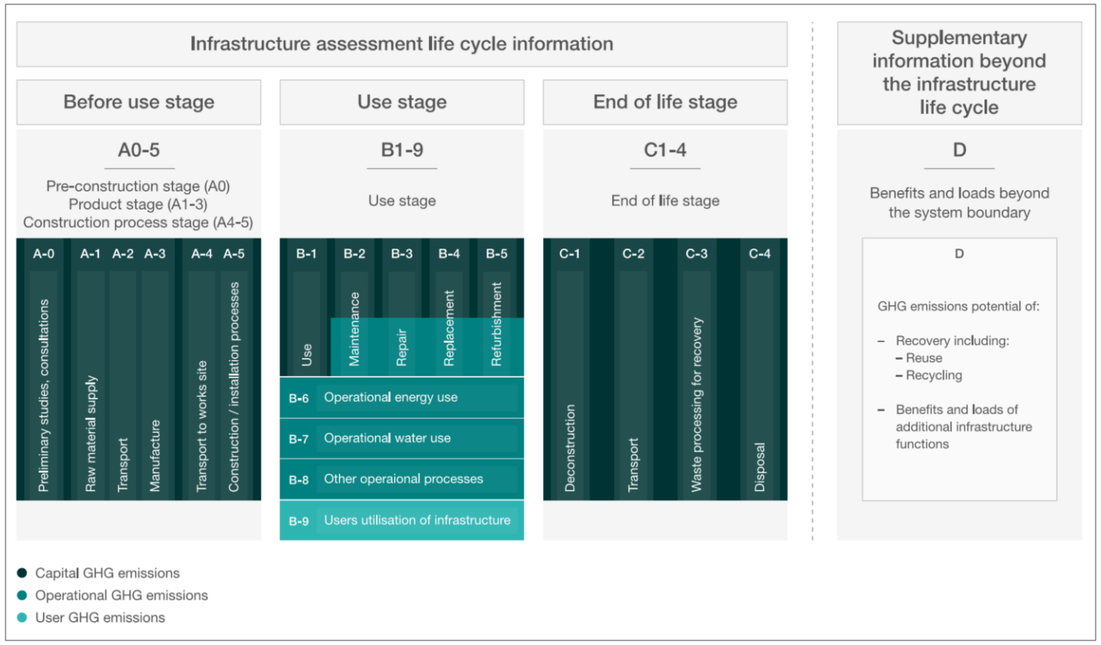

Figure 4: Extract from PAS 2080 showing the modular approach showing the life cycle stages and individual modules for infrastructure GHG emissions quantification.

3.7.2. Buildings

The RICS Professional Statement on Whole Life Carbon Assessment for the Built Environment was published in 2017 and was intended to standardise whole life carbon assessment and enhance consistency in outputs by providing specific practical guidance for the interpretation and implementation of the methodology in EN15978 in carbon calculations. The RICS Professional Statement categorises emissions across lifecycle modules, against a breakdown of building material categories.

Recently there have been efforts to provide a common set of definitions, developed by the Whole Life Carbon Network (WLCN) in collaboration with industry, and the publication of "Carbon Definitions for the Built Environment, Buildings and Infrastructure"[7]. This document sets out to achieve greater consistency across the built environment industry. Figure 4 below shows the summary of lifecycles modules and the various terms that are used. As can be seen, the key terms used are

- **Embodied Carbon** - Total GHG emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset (Modules A1-A5, B1-B5, C1-C4).

- **Operational Carbon** - GHG emissions arising from all energy consumed by an asset in-use, over its lifecycle, plus GHG emissions arising from water supply and wastewater treatment for an asset in-use, over its life cycle. For infrastructure assets this also includes GHG emissions associated with the operation of infrastructure, as required to enable it to operate and deliver its service.

- **User Carbon (Infrastructure only)** - GHG emissions relating to users' utilisation of infrastructure and the service it provides during operation.

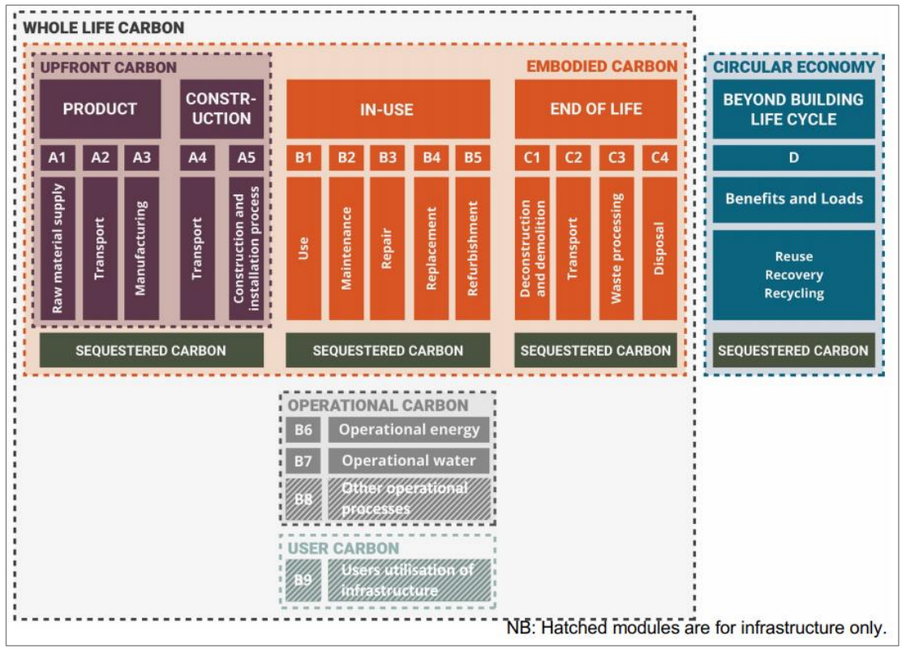

Figure 5: Life Cycle Modules adapted from BS EN 15978 and PAS2080 (for Infrastructure) with related terminology. Source: Carbon Definitions for the Built Environment, Buildings and Infrastructure, Version A, May 2021

3.7.3. Approach taken in this Report

This project builds on the work of the 2013 Low Carbon Routemap, which used the same terminology as PAS2080 of Capital, Operational and User carbon. In the context of buildings, the 2013 Routemap split Regulated and Unregulated energy usage into Operational and User emissions. This follows the logic contained in PAS2080 around control and influence, i.e. regulated energy uses (heating, cooling, lighting, ventilation, auxiliary) are directly within the control of building designers and operators, whereas unregulated energy uses (lifts, IT, plug loads, etc) relate more to building users, and therefore building designers / managers have less control of these elements.

As this project builds on the approach and model architecture of the 2013 Low Carbon Routemap, there is merit in retaining the categorisation and terminology used in 2013 in order to enable clear comparison of the datasets and evaluate progress to date.

Therefore, this report uses the term Capital Carbon within the carbon trajectory results, for consistency with how the datasets have been presented historically. However, within the narrative the term Embodied Carbon is used interchangeably with Capital Carbon, with no differential in meaning intended.

Unregulated energy usage of buildings has been included in the scope of this exercise, but to enable consistency with the previous 2013 Routemap, these emissions are categorised as User emissions.

[7] https://b80d7a04-1c28-45e2-b904-e0715cface93.filesusr.com/ugd/252d09_879cb72cebea4587aa860b05e187a32a.pdf

4. Built Environment Carbon Footprint (2010-2018)

4.1. Previous Projections

In 2015, the original Routemap was updated with 2012 data against its 1990 baseline, but no updates have been made since then. Tracking emission activity within the Built Environment sector is necessary for understanding where progress is being made and where further efforts are required.

In 2013, the GCB Low Carbon Route-map showed Built Environment emissions decreasing from a 1990 baseline of 209 $MtCO_2e$ to 191 $MtCO_2e$ by 2010 (measured data - see Figure 6 below). The Route-map then projected steep reductions through the 2010s, with emissions reaching 138 $MtCO_2e$ by 2018. Reduction profiles then tapered off, with overall emissions trending towards the 80% reduction target by 2050. It should be noted that this data did not include "User" emissions, and therefore the energy data is based on regulated energy uses only and excludes unregulated energy from buildings.

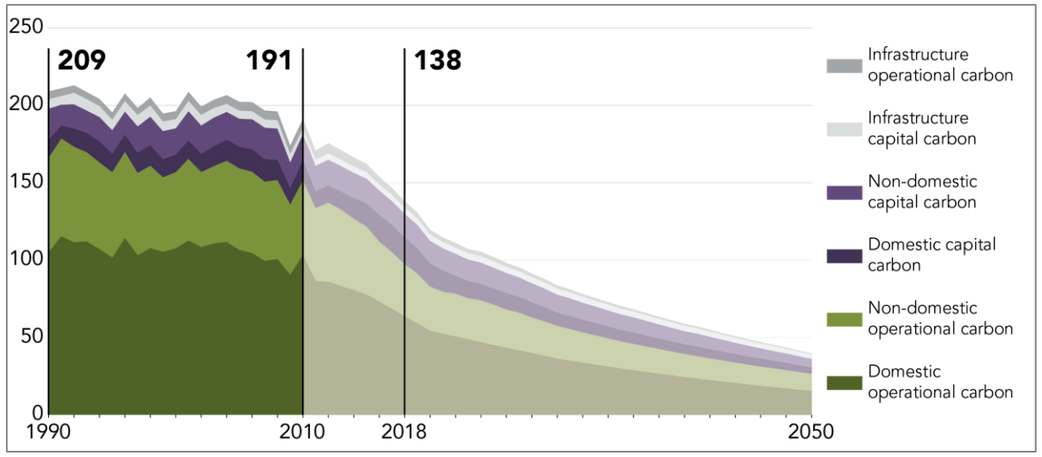

Figure 6: 2013 Route-map carbon projections ($MtCO_2e$ – excluding unregulated energy usage)

4.2. Progress in the last decade (2010 – 2018)

Updated analysis based on the latest available full datasets (2018) enables a comparison of actual emissions over the last decade versus the previous projections from 2013 (see Figure 7 below). It can be seen that total emissions during the period 2010-2018 are closely aligned with the previous projections. Total emissions in 2018 reach 143 $MtCO_2e$, slightly short of previously projected emissions by this point. This alignment is likely driven by the accurate representation of the pronounced grid electricity decarbonisation which occurred over this period (2010 – 2018). It should be noted that minor updates to historical data lead to a slight change in baseline position.

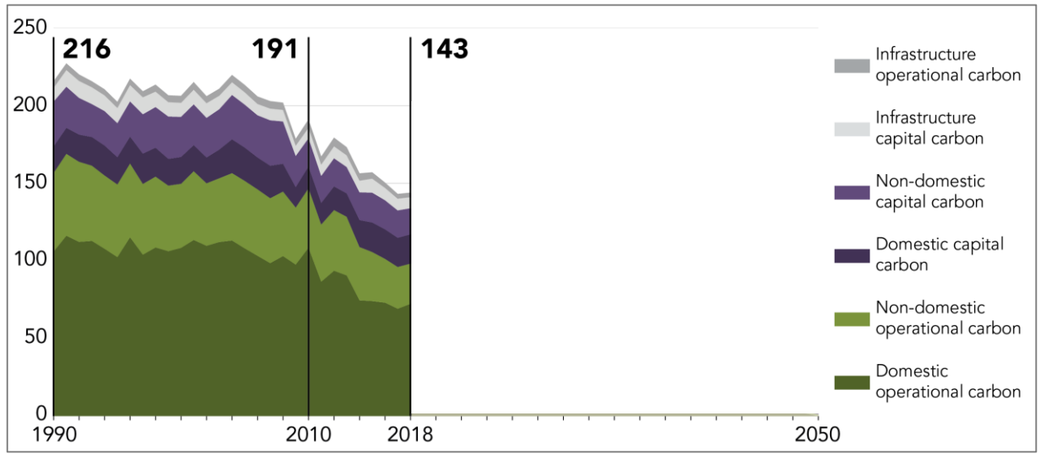

Figure 7: Actual emission data to 2018 ($MtCO_2e$ – excluding unregulated energy usage)

4.3. Analysis (2010 – 2018)

4.3.1. Grid Decarbonisation

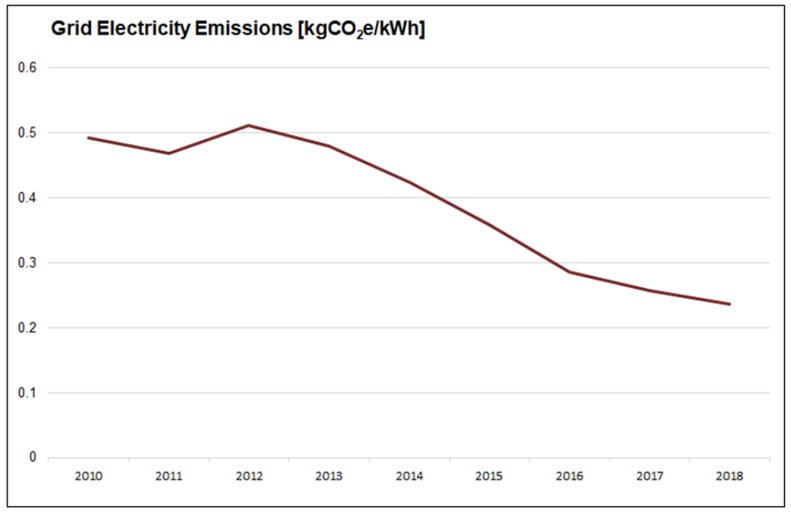

Figure 8: Grid Electricity Carbon Intensity (kgCO2e/kWh)

Grid electricity decarbonisation was pronounced between 2010 – 2018, with a 50% reduction in carbon intensity achieved largely as a result of significant expansion of the UK's off-shore wind capacity (see Figure 8).

4.3.2. Operational Carbon

Energy usage within buildings however remained largely static during this period, as can be seen in Figure 9.

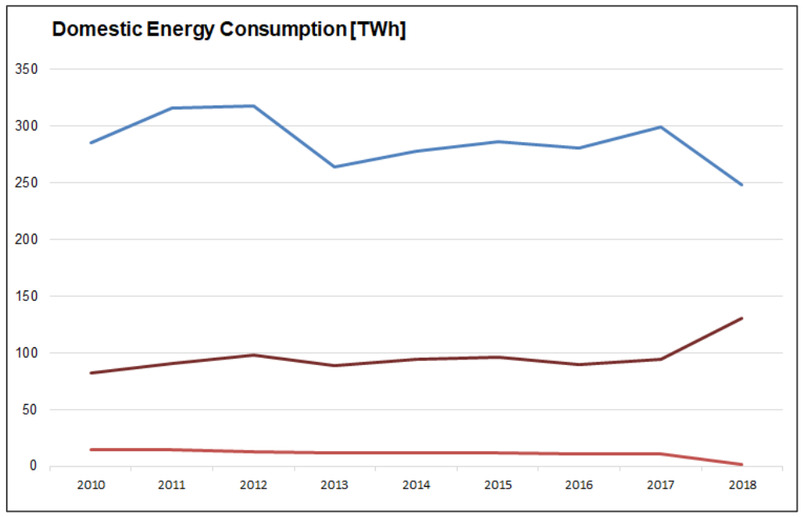

Figure 9: Domestic Energy Consumption

These two trends combined to result in a 26% reduction in operational carbon from UK buildings between 2010 and 2018 (see Figure 10), largely driven by grid decarbonisation and the resultant reduced emissions related to electricity usage in buildings.

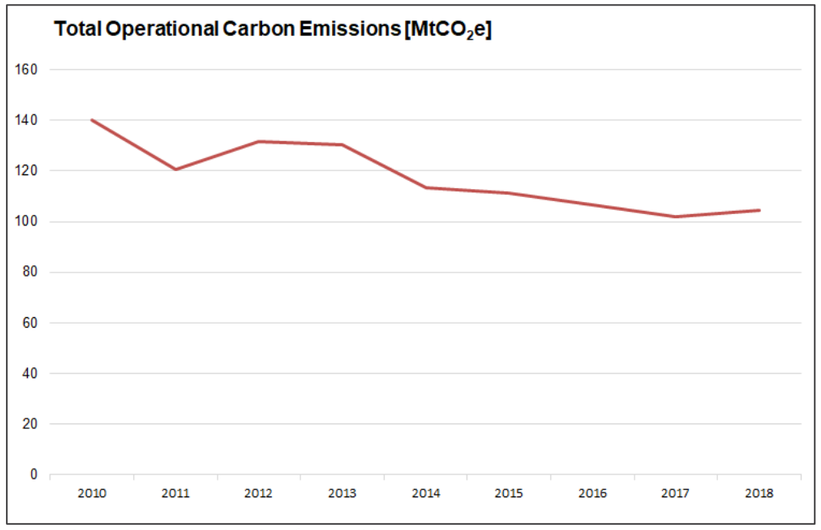

Figure 10: Total Operational Carbon from Buildings

4.3.3. Embodied Carbon

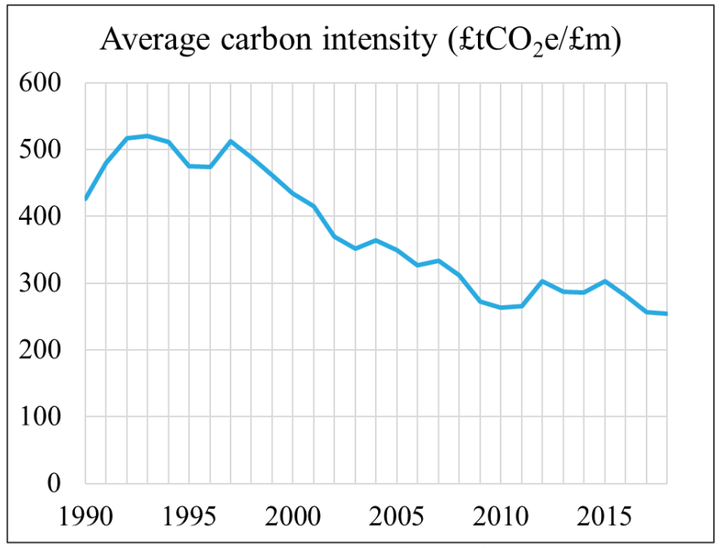

Figure 11: Average Carbon Intensity Construction (tCO_2e/£m)

Figure 11 shows the average carbon intensity of construction material supply chains. It can be seen that significant reductions (approximately 50%) have been achieved since the original 1990 baseline. However carbon intensity reductions have stalled in the period 2010-2018, which saw an initial increase in emission intensity, reducing from 2015 onwards, resulting in no meaningful change in the final carbon intensity of construction supply chains in 2018 compared to 2010. During the same period, demand for materials has continued to increase steadily, as can be seen in Figure 12 below which shows total UK construction spend expressed in £bn.

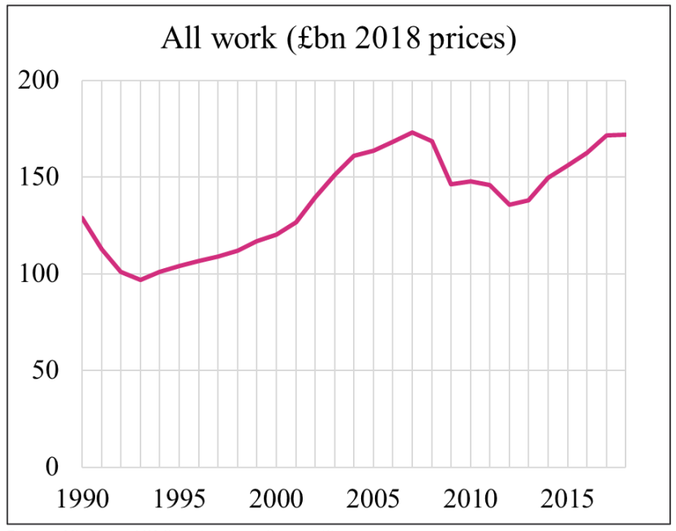

Figure 12: Total UK Construction Spend (£bn)

These two trends combine to form the overall profile for total embodied carbon shown in Figure 13 below. Embodied carbon has reduced by approximately 20% since 1990 levels, however since 2010, total embodied carbon has increased by approximately 12%, driven by increasing construction growth during this period.

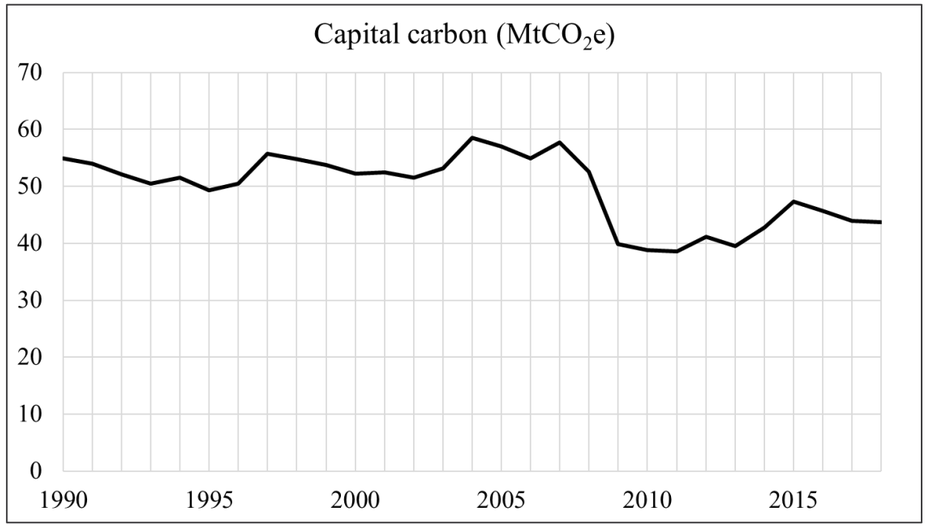

Figure 13: Total Embodied Carbon ($MtCO_2e$)

The data in Figures Figure 11, Figure 12, and Figure 13 indicates the challenge in decoupling embodied carbon emissions from economic growth. It is notable that the only period when significant reductions in embodied carbon within the built environmental have been achieved coincides with the most pronounced downturn in economic activity of recent times (2008 global financial crisis).

The historical data clearly illustrates that incremental improvements to business-as-usual approaches to material supply chains and design and construction are not compatible with the UK Net Zero target. Systemic change and national investment will be required to drive decarbonisation of materials on the supply side, whilst demand for materials must be significantly tempered with a transformative impetus across the entire industry to increase design efficiencies and prioritise re-use and circularity.

5. Net Zero Scenario – Definition

5.1. Scenario Definition

5.1.1. Grid Electricity Decarbonisation

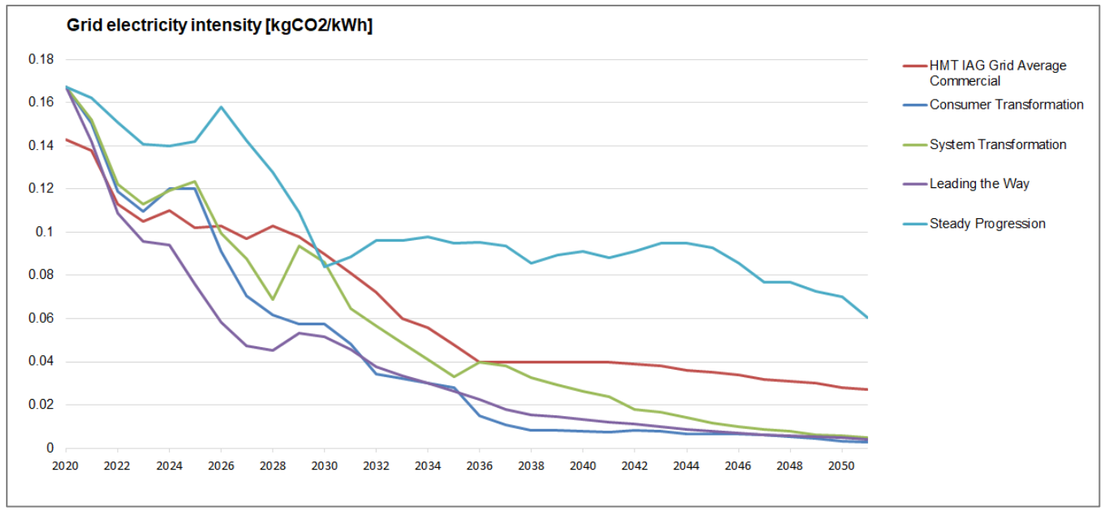

Figure 14: Grid Carbon Factors

Grid carbon factors are based on HMT IAG gird average commercial projections[8]. Projects are shown in Figure 14 alongside National Grid Future Energy Scenarios (FES) 2020[9] for reference. It should be noted that any benefits of Carbon Capture and Storage (CCS) or other carbon removals technologies are stripped out of all decarbonisation projections, in line with the overall approach of enabling comparison of final residual emissions with CCC projections for total removals potential by 2050 (and also to avoid the situation whereby negative grid carbon factors distort embodied carbon results).

[8] BEIS (2021). Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. Available here: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

[9] National Grid ESO (2020). Future Energy Scenarios (online). Available to download here: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

5.2. Scenario Definition - Domestic Buildings

5.2.1. Growth Rates – New Homes

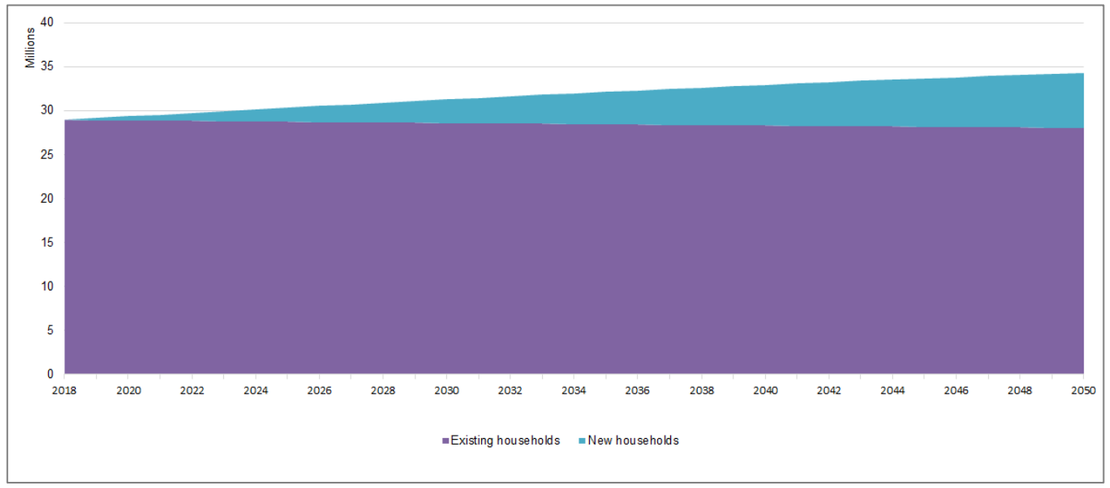

Figure 15: New homes growth rate

Growth rates for the residential sector, i.e. new homes, are based on Office of National Statistics (ONS) UK household estimates and projections for 2018 to 2039.[10] These are then linearly forecast through to 2050.

5.2.2. Heating Technology Mix within Existing Dwellings

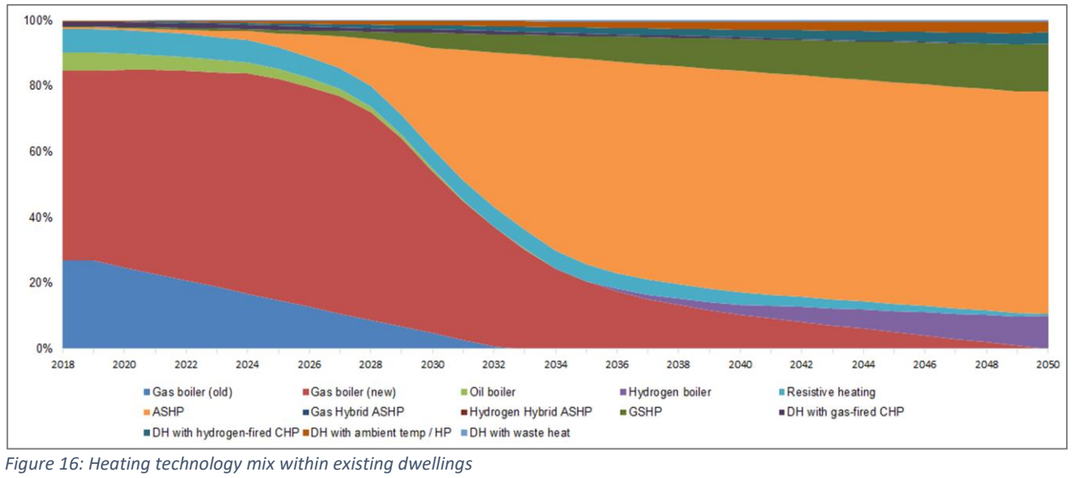

Figure 16: Heating technology mix within existing dwellings

[10] Office for National Statistics (2020). Household projections for England: 2018-based. Available here: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/householdprojectionsforengland/2018based

The 2020 heating mix for existing dwellings in the UK is based on the National Grid ESO Future Energy Scenario (FES) 2020.[11]

For the 2050 end point, hydrogen is assumed to align with the CCC 6th Carbon Budget Balanced Scenario with hydrogen accounting for 12% of the heating mix[12]. The split between hydrogen boilers and district heat with hydrogen was based on the assumption that 12% of suburban areas are reasonably close to hydrogen production and storage facilities, and the density should still be high enough to support the value proposition (using MHCLG English Housing Survey figures to establish split between Hydrogen Boilers and District Heat with hydrogen, based on proportion of houses that are classified as suburban[13]. The total number of houses on DH was also based on FES 2020 numbers.

Other key assumptions agreed included no gas boilers existing in the mix in 2050, and almost no resistive heating or storage heaters in existing houses as there are replaced by heat pumps, due to higher efficiency made possible by increasing thermal efficiency standards. The scenario is linked to a transformative domestic retrofit programme, with heat-pump roll-out aligned with the domestic retrofit profile, on the basis that heat pumps will be installed as part of wider retrofit measures (see Section 5.2.5). The split between ASHP / GSHP remains as per current proportions.

5.2.3. Heating Technology Mix within New Dwellings

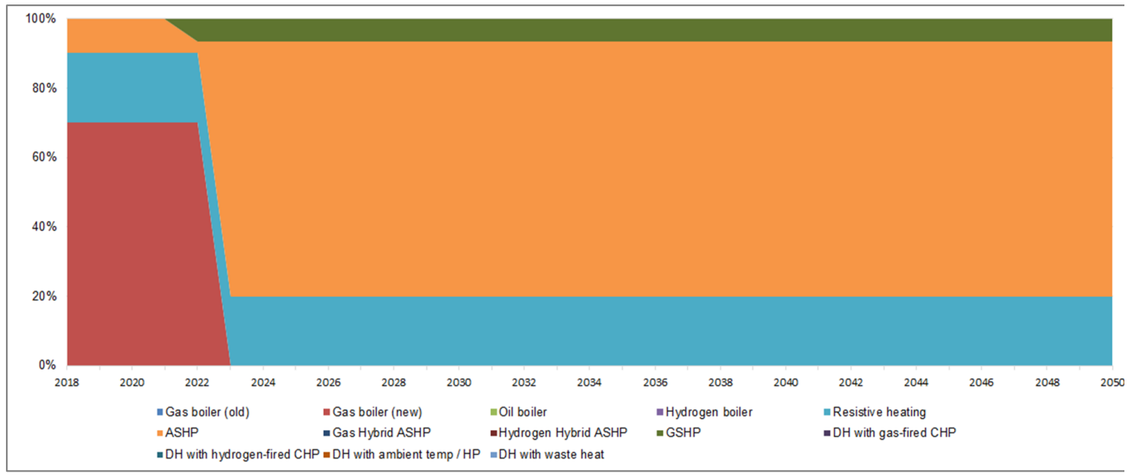

Figure 17: Heat technology mix - new homes

The basis for heating technologies in new homes assumes that the rate of current boiler installations continues, until the Future Homes Standard ceases further boiler installations in new houses (current boiler rollout in new houses are derived from annual changes in domestic gas meters from BEIS Postcode level domestic gas and electricity consumption[14]). From this point on, 80% of new houses benefit from Heat Pumps for space heating and hot water. The proportion of GSHP installations is assumed to be lower in new homes than in the existing stock. 20% of new houses are assumed to feature electric resistive heating, either due to very low heat demands due to size and heat loss characteristics (i.e. apartments), and installation challenges in some situations.

5.2.4. Domestic Heating Technology Efficiencies

Technology	Heating efficiency		Electrical efficiency	
	2018	2050	2018	2050
Gas boiler (old)	82%	82%	-	-
Gas boiler (new)	90%	97%	-	-
Oil boiler	65%	65%	-	-
Hydrogen boiler	90%	97%	-	-
Resistive heating	95%	95%	-	-
ASHP	250%	343%	-	-
ASHP domestic hot water	200%	250%	-	-
Gas Hybrid ASHP - Gas fuel	90%	97%	-	-
Gas Hybrid ASHP - Electricity fuel	313%	429%	-	-
Hydrogen Hybrid ASHP - Hydrogen fuel	90%	97%	-	-
Hydrogen Hybrid ASHP - Electricity fuel	313%	429%	-	-
GSHP	300%	393%	-	-
DH with gas-fired CHP	40%	40%	35%	35%
DH with hydrogen-fired CHP	40%	40%	35%	35%
DH with ambient temp / HP	300%	300%	-	-
DH with waste heat	40%	40%	-	-

Figure 18: Heating technologies efficiencies (current and future)

Efficiencies are applied within the model to the various heating technologies deployed. Efficiency data has been derived from a variety of sources, including:

- National Grid FES
- SEDBUK ratings for gas boilers
- English and Scottish housing surveys for boiler populations – numbers of old and new boilers.
- Scottish household surveys from the Scottish Government and the English Housing Survey from Ministry of Housing, Communities & Local Government (MHCLG)

In some cases indicating an expected efficiency improvement through to 2050 due to development and R&D. In other cases technology has as efficiency ceiling and no further improvements are expected. Heating efficiencies for old gas boilers are based on non-condensing boiler averages from MHCLG English Housing Survey averages, with no improvement factor to 2050 on the basis there will be no new installations of this technology type. Hydrogen boiler efficiencies are linked to gas boilers.

[11] National Grid ESO (2020). Future Energy Scenarios (online). Data workbook sheet - CV.10: Overall home heating technology mix in 2050: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

[12] CCC (2020). The 6th Carbon Budget – the UK's Path to Net Zero: https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

[13] MHCLG (2021) English Housing Survey: https://www.gov.uk/government/collections/english-housing-survey

[14] BEIS (2020). Postcode level domestic gas and electricity consumption: https://www.gov.uk/government/publications/postcode-level-domestic-gas-and-electricity-consumption-about-the-data/postcode-level-domestic-gas-and-electricity-consumption-notes

5.2.5. Proportion of Existing Housing Stock Retrofitted

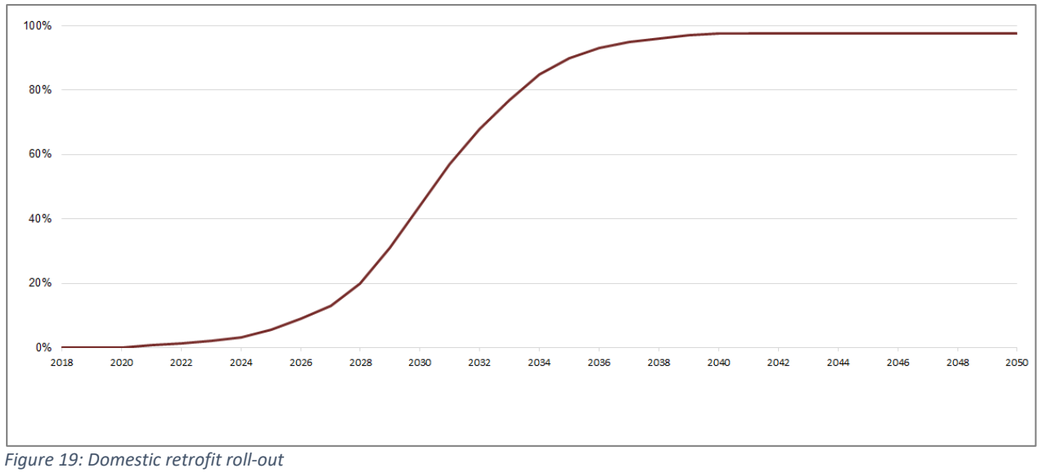

Figure 19: Domestic retrofit roll-out

The retrofit trajectory for existing domestic stock is based on the proposals set out in the Construction Leadership Council's National Retrofit Strategy[15] (CLC NRS - Dec 2020). The National Retrofit Strategy sets out a 20-year transformative plan for the energy efficiency retrofit of 97% of UK homes by 2040. The goal is to tackle the challenge systematically and pragmatically, establishing firm foundations for scaling up to meet the volume of work needed, whilst highlighting the resultant economic, social and environmental benefits.

The NRS retrofit roll-out profile is based on a slower start to focus on education of householders and upskilling of the wider industry, plus an intensive training programme for new entrants to the industry to build capacity. This is followed by a 'quick' middle period based on a mature supply chain eco-system and strong customer protections. Finally, there is a ramp down of pace toward the end to deal with very-hard-to treat properties, and a signalled ramp down helps the skilled workforce to shift to other sectors without a sudden shock.

The deployment profile applies to the whole UK housing stock. The trajectory is linked to the data-points set out in the NRS for number of houses retrofitted by 2021, 2024, 2030 and 2040, with interpolation between these to match the S-curve roll-out profile.

Estimated costs per dwelling are used to derive the capital carbon impact of the programme. Costs have been aligned with the CLC NRS value of £18,000 per dwelling.

[15] CLC (2020). Greening Our Existing Homes: National Retrofit Strategy. Available here: https://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2020/12/CLC-National-Retrofit-Strategy-final-for-consultation.pdf

5.2.6. Space Heating Demand (Existing & New Dwellings)

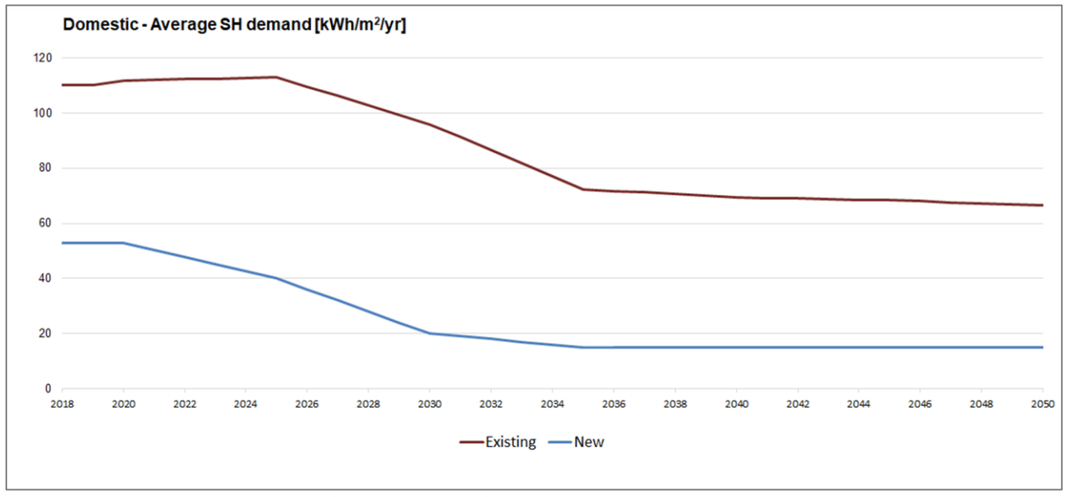

Figure 20: Average space heating demand (new and existing homes).

Energy efficiency measure and building fabric standards are expressed as a resultant space heating demand figure (kWh/m2/yr). For the retrofit roll-out as described in the previous section, an average design figure of 50 kWh/m2/yr has been established, aligning with the CLC NRS and the AECB retrofit standard target[16]. This figure represents an average figure representative of all dwellings and does not differentiate between easy-to-treat and hard-to-treat typologies. It should be noted that the space heating figures above are inclusive of performance gap allowances and anticipated behaviour change factors (see next sections).

For new dwellings, space heating demand projections are based on the following rationale:

- 53 kWh/ m^2/yr = current new-build dwelling average, based on EPB Statistics for 2020[17]
- 40 kWh/ m^2/yr = 20% reduction through 2021 Building Regulations Part L (FEES impact)
- 20 kWh/ m^2/yr = via 2025 Building Regulations Part L / Future Homes Standard uplift. This aligns with CCC assumptions (20-15 kWh/m^2/yr from 2025 onwards)
- 15 kWh/m^2/yr = via 2030 Building Regulations Part L update. Aligning with CCC, RIBA 2030, LETI & Passivhaus targets.

[16] AECB (n.d.). AECB Retrofit Standard: https://aecb.net/aecb-retrofit-standard/

[17] https://www.gov.uk/government/collections/energy-performance-of-buildings-certificates#2020

5.2.7. Retrofit Measures Performance Gap

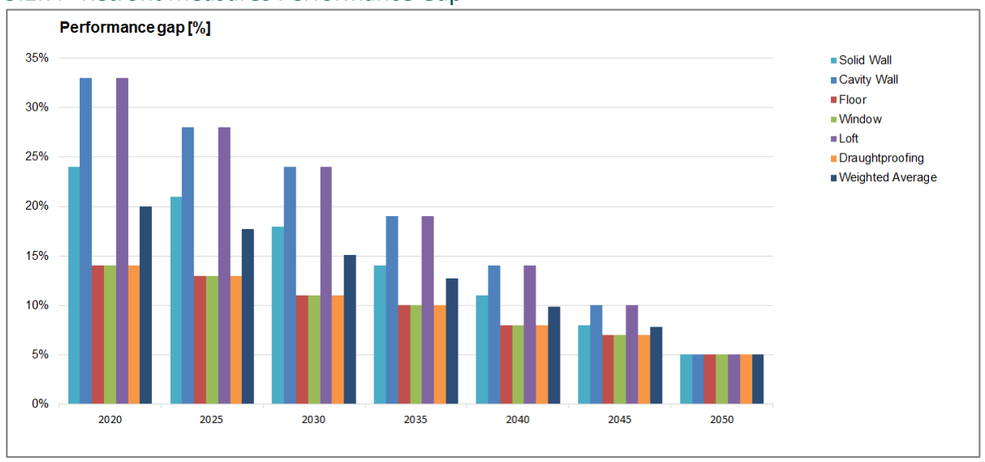

Figure 21: Retrofit Measures Performance Gap Factors

Within the model, additional factors are applied to retrofit measures to reflect the reality that design intent is not always fully realised by performance in practice. The model applies the factors shown in Figure 21 above to the retrofit target space heating demand. Assumptions for current performance of the retrofit measures in 2018-2020 were based on a review of numerous studies on the performance gap as well as data from heat flux texts in UK dwellings. It was assumed that by 2050, a clear focus on skills, quality and continuous improvement within the National Retrofit Strategy would result in performance gaps reducing to a similar level as Passivhaus outcomes.

- Department of Energy and Climate (DECC) (2012). How the Green Deal will reflect the in-situ performance of energy efficiency measures[18]
- Johnston, D.; Siddall, M. (2016). The Building Fabric Thermal Performance of Passivhaus Dwellings - Does It Do What It Says on the Tin?[19]
- Gupta, R.; Kotopouleas, A. (2018). Magnitude and extent of building fabric thermal performance gap in UK low energy housing.[20]
- BRE (2015). In-situ measurements of wall U-values in English housing.[21]
- Johnston, D and Miles-Shenton, D and Farmer, D (2015). Quantifying the domestic building fabric 'performance gap.'[22]
- Johnston D., et al. (2014). Bridging the domestic building fabric performance gap.[23]
- Marshall A., et al. (2017). Domestic building fabric performance: Closing the gap between the in situ measured and modelled performance.[24]
- Kragh J., et al. (2017). Possible explanations for the gap between calculated and measured. The 15th International Symposium on District Heating and Cooling energy consumption of new houses.[25]
- Wilde, P. (2014). The gap between predicted and measured energy performance of buildings: A framework for investigation.[26]
- Palmer, D., Godoy-Shimzu D, Tillson A, and Mawditt, I. (2016). Building Performance Evaluation Programme: Findings from domestic projects Making reality match design. [27]

5.2.8. Behaviour Change – Mean Internal Temperature

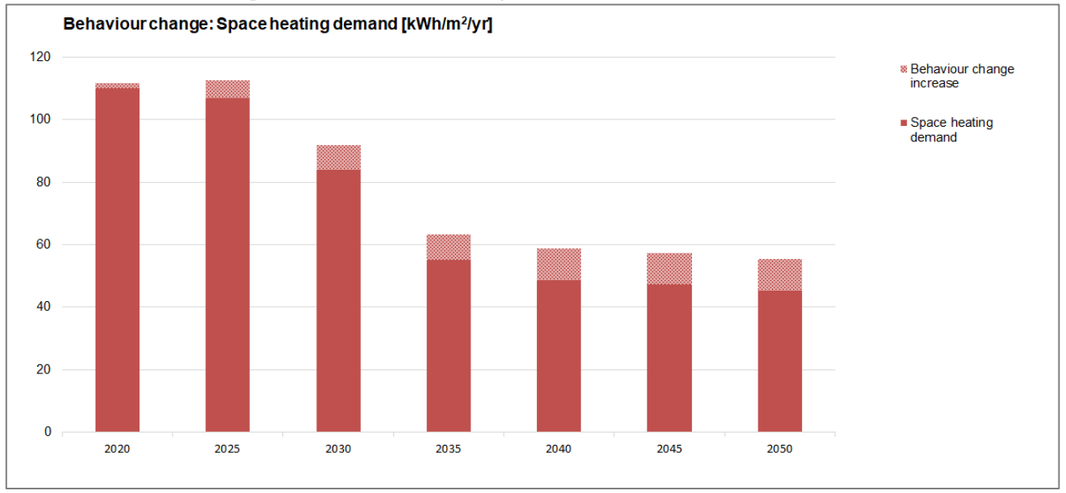

Figure 22: Domestic Behaviour Change Factors

Projections for changes to internal temperature are drawn from data on fuel poverty. It is assumed that those not in fuel poverty will not significantly alter their behaviour (in terms of thermostat set points) based on increases or decreases in heating costs. The latest statistics show 13.4% of homes are in fuel poverty[28] and it is assumed those homes are, on average, set to 14°C compared with an average of 19°C (the lower temperature being the threshold at which significant health issues become prevalent). It is assumed those in fuel poverty will raise their temperatures to the average as efficiency increases.

[18] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48407/5505-how-the-green-deal-will-reflect-the-insitu-perfor.pdf
[19] https://www.mdpi.com/2071-1050/8/1/97
[20] https://www.sciencedirect.com/science/article/pii/S0306261918304343
[21] https://www.gov.uk/government/publications/in-situ-measurements-of-wall-u-values-in-english-housing
[22] https://eprints.leedsbeckett.ac.uk/id/eprint/1054/5/BSER%252526T%20-%20Quantifying%20the%20domestic%20building%20fabric%20performance%20gap%20Dec%202014.pdf
[23] https://www.tandfonline.com/doi/full/10.1080/09613218.2014.979093
[24] https://eprints.leedsbeckett.ac.uk/id/eprint/3847/
[25] https://www.sciencedirect.com/science/article/abs/pii/S092658051400034X?via%3Dihub
[26] https://www.sciencedirect.com/science/article/pii/S092658051400034X
[27] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/497758/Domestic_Building_Performance_full_report_2016.pdf
[28] UK Government (2021). Fuel Poverty Factsheet: https://www.gov.uk/government/statistics/fuel-poverty-factsheet-2021

5.2.9. Behaviour Change – Hot Water Demand

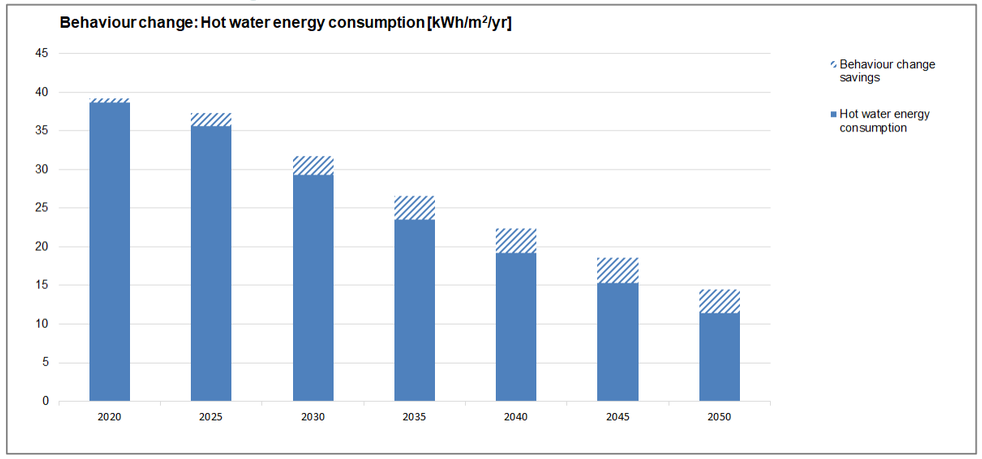

Figure 23: Domestic Behaviour Change Factors

Projections for reductions in water demand use 140l/p/d as a current baseline.[29] The Environment Agency has set a target of 110l/p/d by 2050 as being one that represents the changes most likely to be required in the long term and as being in line with their high ambition for environmental improvement.[30]

5.2.10. Behaviour Change – Lighting Demand

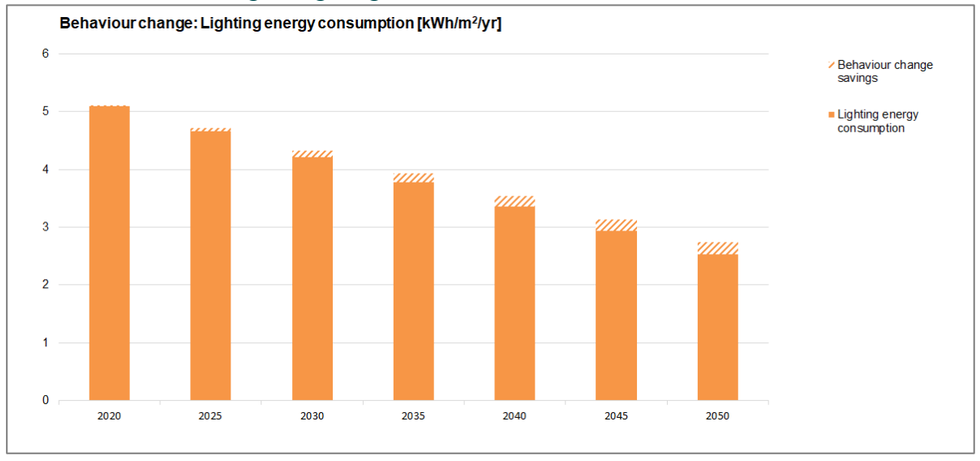

Figure 24: Domestic Behaviour Change Factors

Projections for lighting demand reduction are derived from the CCC's assumption that behaviour change can deliver annual savings of 0.4TWh by the 15 years to 2035.[12] It is assumed that not all behaviour change opportunities will be exhausted by then but that progress in the send 15 year period to 2050 will be half that previously seen.

5.2.11. Installed PV Capacity

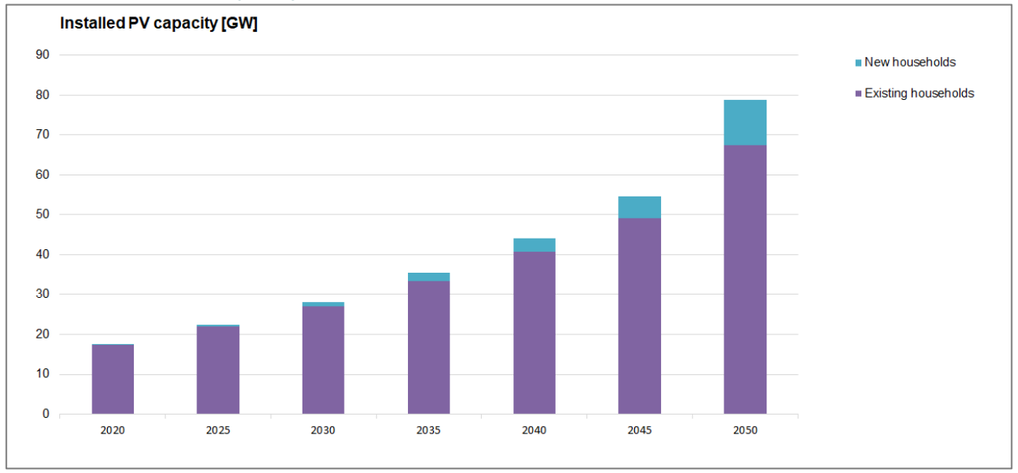

Figure 25: Installed PV capacity

Projections for photovoltaic installations are defined as installed kWp capacity, with an associated system efficiency. Currently efficiencies are around 19 -21%, with typical installations 3-3.6kW$_p$ for existing roofs and 4kW$_p$ for installations on new roofs. These efficiencies are improving according to NREL[31], with maximum laboratory measured efficiencies of over 40%. It is assumed that over the next 20-30 years due to continued R&D in emerging technologies that these higher efficiencies would mainstream. These higher efficiencies would allow installations of around 10kWp for new houses and 8kWp for existing properties. It is assumed that the uptake of solar PV will be around 80% of new properties, as most properties would be required to install PV to achieve future standards, although some roofs would not be possible due to local overshading. There is also the assumption that any capacity issues with the District Network Operators (DNOs) would be overcome and built in as required.

[29] Ofwat (2018). The long term potential for deep reductions in household water demand. Available here: https://www.ofwat.gov.uk/wp-content/uploads/2018/05/The-long-term-potential-for-deep-reductions-in-household-water-demand-report-by-Artesia-Consulting.pdf

[30] Environment Agency (2020). Meeting our Future Water Needs: a National Framework for Water Resources. Available here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/873100/National_Framework_for_water_resources_summary.pdf

[31] NREL (2021). Best Research-Cell Efficiency Chart. Available here: https://www.nrel.gov/pv/cell-efficiency.html

5.2.12. Installed Solar Hot Water Generation

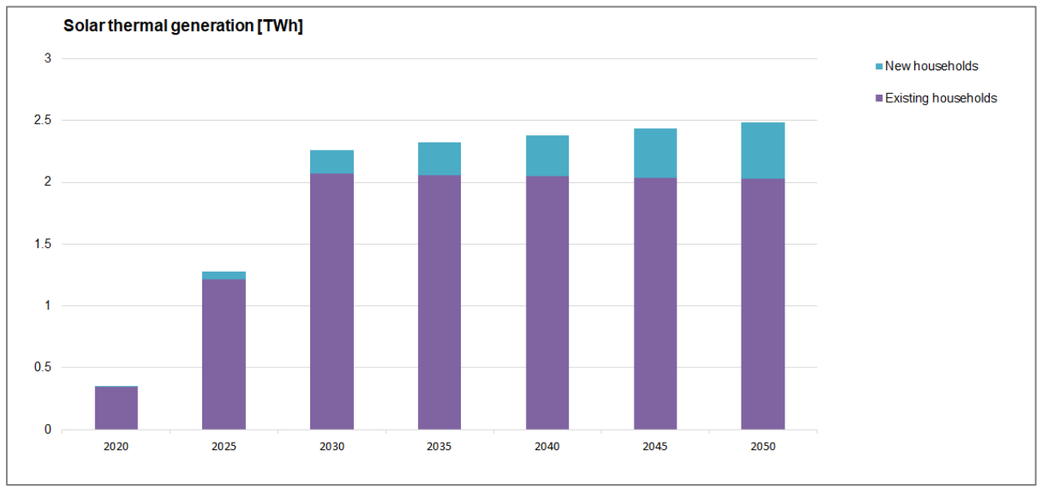

Figure 26: Installed SHW capacity

It is assumed that as PV becomes dominant due to potential integration with battery storage, the need for solar thermal will displace; there are also limits in terms of roof space (though it is acknowledged that they can be placed on external walls). It is therefore assumed that solar thermal is a cost-effective solution for properties where storing large amounts of hot water is feasible e.g. communal housing. It is assumed that there is large drive to install over the next 5-10 years while heat battery technology is establishing, with a slower uptake after that. $3m^2$ is the optimum area required and this remains static. Currently $0m^2$ is assumed as uptake is very low.[32] It is anticipated that solar thermal would be added to 5% of properties - this corresponds to the Committee on Climate Change scenario of 'achievable at a stretch' – 3-4% of properties will have solar thermal by 2035.

5.2.13. Domestic Cooking Energy Consumption & Fuel Mix

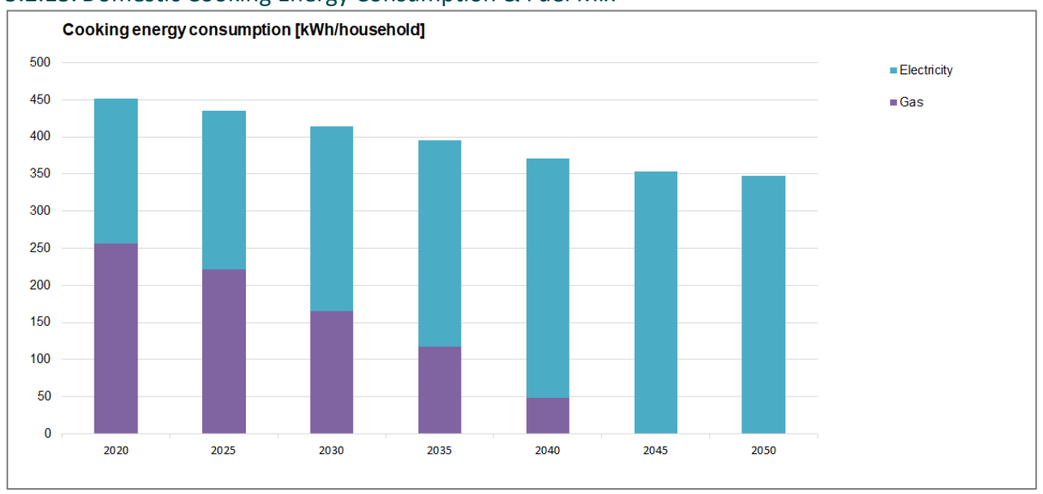

Figure 27: Domestic cooking energy usage

The number of homes in 2019 and 2050 is taken from FES2020 CV10[33] , with linear growth assumed across interim years. The number of gas boilers installed up to 2050 is taken from FES2020 CV15 'Leading the Way', from which the annual percentage reduction in installed gas boilers is calculated and used as a proxy for the reduction in gas cookers.[34] Total 2019 domestic gas cooking demand is taken from ECUK 2020 End Use Table U3 and converted from kilotons of oil equivalent (ktoe) to kilowatt hours (kWh).[35] The number of homes with an electric hob in 2019 is taken from ECUK 2020 Electrical Products Table A2, from which the number of homes with a gas cooker is derived by subtracting this value from the total number of homes in 2019.[36] Domestic gas demand for cooking across all homes up to 2050 (kWh/dwelling) is then calculated from the derived annual reduction in gas cookers, total 2019 domestic gas cooking demand, and number of homes up to 2050.

The projected increase in electric cookers is derived from the projected reduction in gas cookers. Total 2019 domestic electricity demand for cooking is taken from ECUK 2020 End Use Table U3 and converted from kilotons of oil equivalent (ktoe) to kilowatt hours (kWh).[35] The number of homes with an electric hob in 2019 is taken from ECUK 2020 Electrical Products Table A2, and the electric cooking demand in 2019 for homes with an electric oven is calculated.[36] The electric cooking demand projection across all homes (kWh/dwelling) is then calculated based on the projected number of homes, the annual change in the number of electric cookers, and total 2019 electric cooking demand.

[32] Element Energy, UCL and IEDE (2021). Development of trajectories for residential heat decarbonisation to inform the sixth carbon budget. A study for the Committee on Climate Change. Available here: https://www.theccc.org.uk/publication/development-of-trajectories-for-residential-heat-decarbonisation-to-inform-the-sixth-carbon-budget-element-energy/

[33] Future Energy Scenarios (FES) 2020 Data Workbook, CV10 Overall home heating technology mix in 2050

[34] Future Energy Scenarios (FES) 2020 Data Workbook, CV15 Number of gas boilers installed in homes ('Leading the Way')

[35] Energy Consumption in the UK (ECUK) 2020, End Use Table U3 Domestic; consumption be end use and fuel 1990 to 2019

[36] Energy Consumption in the UK (ECUK) 2020, Electrical Product Table A2 Number of appliances owned by households in the UK 1970 to 2019

5.2.14. Domestic Appliance Energy Consumption

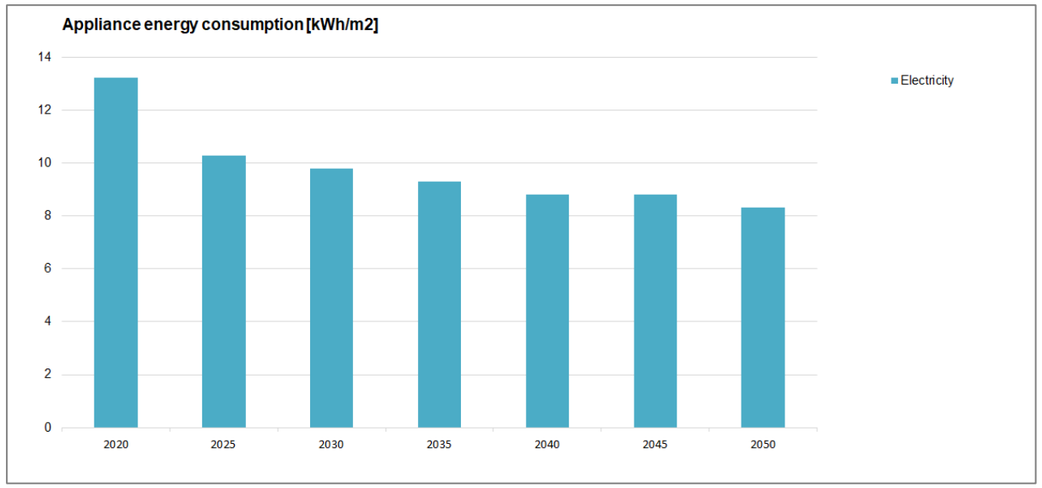

Figure 28: Domestic Appliance Energy Consumption

The number of homes in 2019 and 2050 is taken from FES2020 CV10, with linear growth assumed across interim years.[33] Annual domestic energy demand for appliances (GWh) is obtained from FES2020 CV18 Annual residential electricity demand for appliances 'Leading the Way'.[37] The average annual consumption per home (kWh) is projected, and the average annual consumption per m2 floor area calculated assuming an average dwelling floor area of 85 m2 taken from RIBA's The Case for Space (2011).[38]

5.2.15. New Dwellings Resultant Energy Use Intensity (kWh/m^2/year)

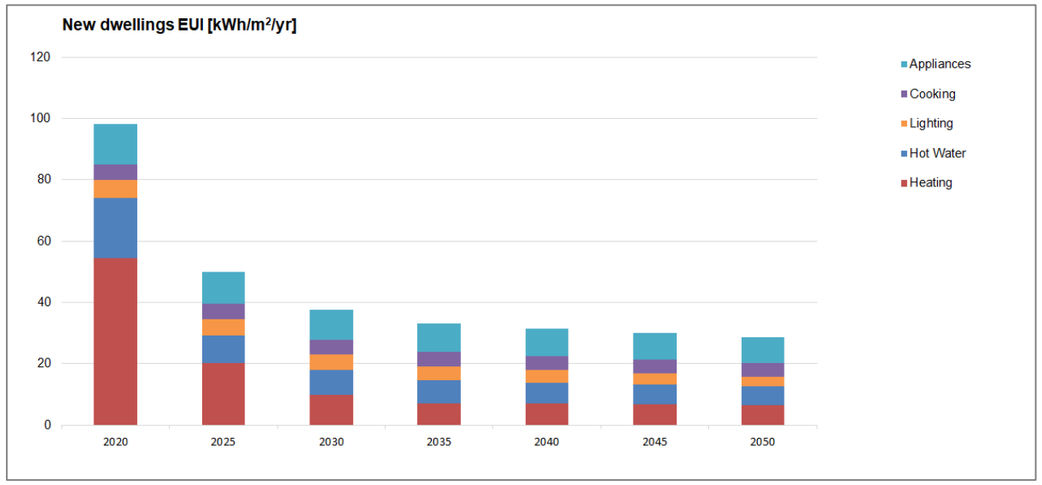

Figure 29: Resultant New Dwelling EUI (kWh/m^2/yr)

The energy use intensity of new and existing homes is an intermediate output step of the model, based on the inputs detail in the previous sections (space heating demand, behaviour change factors, heating technology mix and efficiencies, appliance and cooking energy, etc). Appropriate carbon factors are then applied to derive operation carbon emissions within the model. The projected energy use intensity data for new and existing homes is presented here in Figure 29 and Figure 30 for reference against industry guidance and benchmarks.

5.2.16. Existing Dwellings Resultant Energy Use Intensity (kWh/m^2/year)

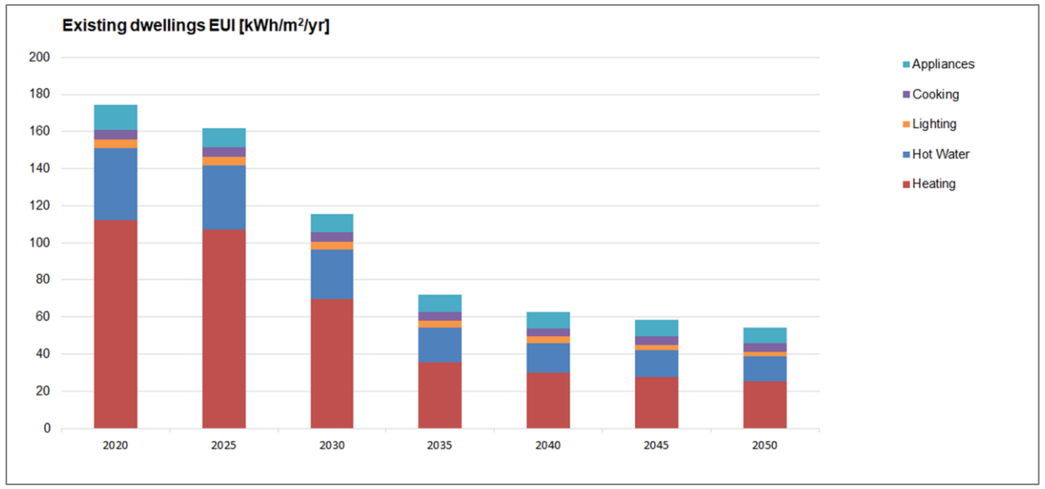

Figure 30: Resultant Existing Dwelling EUI (kWh/m2/yr)

[37] Future Energy Scenarios (FES) 2020 Data Workbook, CV18 Annual residential electricity demand for appliances ('Leading the Way')

[38] RIBA (2011) The Case for Space

5.3. Scenario Definition - Non-Domestic Buildings

5.3.1. Non-Domestic Sectoral Growth & Demolition Rates

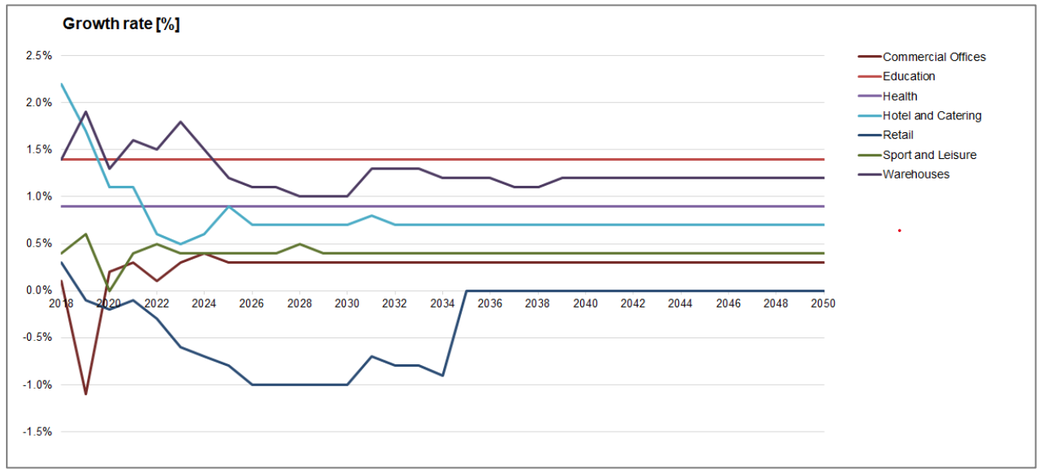

Figure 31: Non-domestic building growth rates

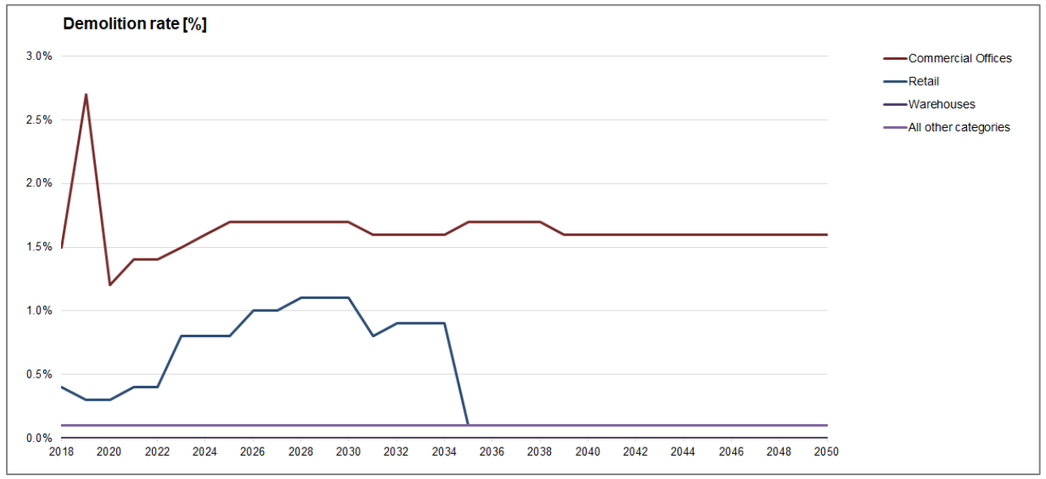

Figure 32: Non-domestic building demolition rates

Projections for non-domestic sector growth rates are derived from PMA UK Forecast Service Stock Projections which estimate growth rates until 2030.[39] PMA are a leading independent real estate research consultancy specialising in property forecasting. Projections post 2030 for commercial property and hotels and catering are based on historic rolling averages. Healthcare and education historic stock are estimated from rateable values, and forecast growth is projected to match the historic growth rate.

[39] PMA (2021), UK Forecast Service Stock Projections [Unpublished].

5.3.2. Non-Domestic Existing Building Heating Technology Mix

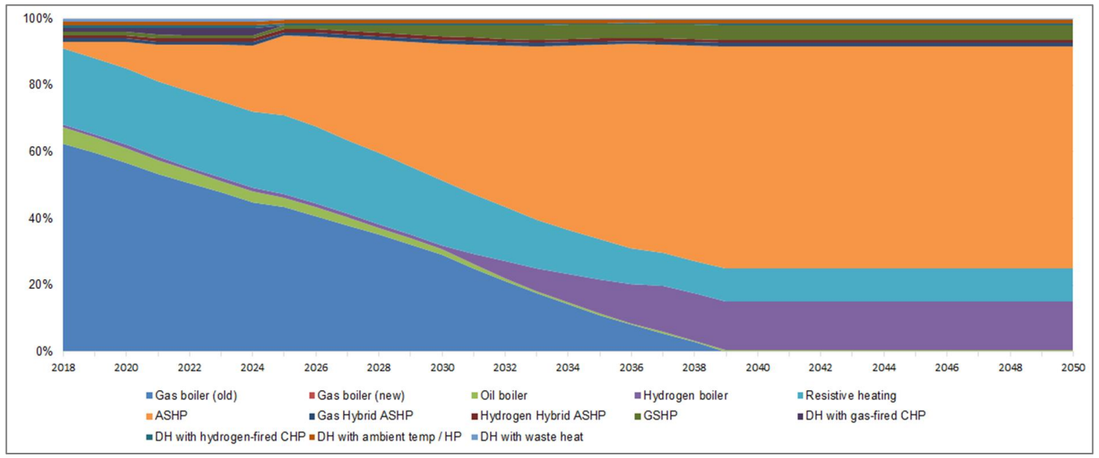

Figure 33: Non-Domestic Existing Building Heating Technology Mix

The projected heating technology mix for the existing non-domestic building stock was derived with reference to the Building Energy Efficiency Survey (BEES) research, based on coverage by total non-domestic stock floor area percentage[40]. The gas boilers are phased out by 2038, while oil boilers are phased out by 2032. Hydrogen boilers increase by 2% annually from 2030, while the remaining demand is met by ASHPS and GSHP. District Heating (DH) with gas-fired CHP is phased out by 2025, while DH with other fuel types is assumed to remain constant.

5.3.3. Non-Domestic New Building Heating Technology Mix

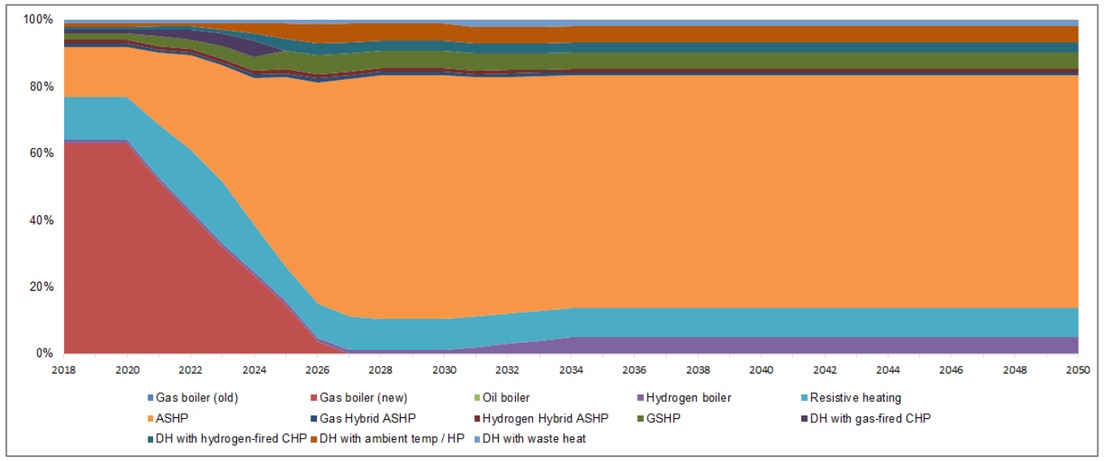

Figure 34: Non-Domestic New Building Heating Technology Mix

[40] BEIS (2016), Building Energy Efficiency Survey (BEES): https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees

Assumptions for the New Building Heating Technology Mix were determined through adjustments to the BEES research values for existing buildings[40]. No usage of oil boilers is projected, while gas boilers are phased out by 2025 with a shift to ASHPs, with a 5% increase from the switch away from direct electric to gas boilers, followed by a gradual decline due to policies phasing out gas boilers. Hydrogen boilers increase from 2030 as a by-product of industrial heat decarbonisation. ASHPs see a gradual increase up to 70% due to the switch from as boilers and direct electric, and additional 3% from switch away from oil boilers for off gas grid properties.

Electric resistive heating sees a 10% reduction compared with existing buildings, followed by an increase as gas boiler take-up drops off, followed by decline as heat pump gains market share. Gas hybrid ASHP/Hydrogen hybrid ASHP are assumed to remain the same as for existing buildings. DH is assumed to be the same as for existing buildings, followed by a gradual increase (2-5% dependant on type) as the as existing heat network pipeline is built-out with DH with gas-fired CHIP is phased out and switched to other fuels from 2025.

5.3.4. Non-Domestic Heating Technology Efficiencies

Technology	Heating efficiency		Electrical efficiency	
	2018	2050	2018	2050
Gas boiler (old)	84%	84%	-	-
Gas boiler (new)	86%	95%	-	-
Oil boiler	84%	84%	-	-
Hydrogen boiler	86%	95%	-	-
Resistive heating	96%	96%	-	-
ASHP < 750kW	250%	340%	-	-
ASHP domestic hot water	200%	250%	-	-
Gas Hybrid ASHP - Gas fuel	90%	97%	-	-
Gas Hybrid ASHP - Electricity fuel	313%	429%	-	-
Hydrogen Hybrid ASHP - Hydrogen fuel	90%	97%	-	-
Hydrogen Hybrid ASHP - Electricity fuel	313%	429%	-	-
GSHP	290%	423%	-	-
DH with gas-fired CHP	40%	40%	35%	35%
DH with hydrogen-fired CHP	40%	40%	35%	35%
DH with ambient temp / HP	300%	300%	-	-
DH with waste heat	40%	40%	-	-

Figure 35: Non-Domestic Heating Technology Efficiencies

Efficiencies are applied within the model to the various heating technologies deployed. Efficiency data has been derived from a variety of sources, including the Non-Domestic Building Services Compliance Guide[41] and ASHRAE HVAC Systems & Equipment (2020)[42]. In some cases the data indicates an expected efficiency improvement through to 2050 due to development and R&D. In other cases technology has as efficiency ceiling and no further improvements are expected.

5.3.5. Non-Domestic Cooling Technology Efficiencies

Technology	2018	2050
Standard Air Cooled Chiller <750kW	255%	450%
Standard Air Cooled Chiller >750kW	265%	500%
Absorption chiller	70%	70%
Standard Water Cooled Chiller <750kW	390%	550%
Standard Water Cooled Chiller >750kW	470%	600%
ASHP VRF/VRV	360%	550%

Figure 36: Non-Domestic Cooling Technology Efficiencies

Efficiencies for cooling technologies are applied within the model to the various technologies types deployed. Efficiency data has been derived from a variety of sources, including the Non-Domestic Building Services Compliance Guide[41] and ASHRAE HVAC Systems & Equipment (2020)[42].

5.3.6. Non-Domestic Existing Building Retrofit Measures – Performance

Name	Description	Change in energy end-use			
		Cool & Vent	DHW	Heat	Light
Improve solid element u-values	Increased / replace insulation to wall and roof areas	-5%	0%	30%	0%
Improve glazing u-values	Replace glazing for more efficient glazing	5%	0%	15%	0%
Improve glazing solar performance	Either as part of above or by adding solar film	25%	0%	-5%	0%
Voltage Optimisation and Power Factor Correction	Reducing building incoming voltage to European standard 220v, and applying power factor correction	5%	0%	0%	5%
Heat recovery ventilation	Improve the heat recovery within the ventilation systems	5%	0%	15%	0%
New lighting and controls		5%	0%	-5%	60%
Sub-metering & recommissioning	installation of sub-metering on all heating, cooling and power systems	10%	10%	10%	0%

Figure 37: Non-Domestic Existing Building Retrofit Measures – Performance

The performance impacts on building energy end-uses for different retrofit measures were estimated with reference to the 2013 Routemap Model and the Second Cost Optimal Assessment for the United Kingdom (MHCLG, 2019)[43].

[41] MHCLG (2014). Non-Domestic Building Services Compliance Guide. Available here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/453973/non_domestic_building_services_compliance_guide.pdf

[42] ASHRAE (2020. ASHRAE Handbook – HVAC Systems and Equipment. Available here: https://www.ashrae.org/technical-resources/ashrae-handbook/description-2020-ashrae-handbook-hvac-systems-and-equipment

[43] MHCLG (2019). Energy Performance of Buildings Directive: second cost optimal assessment. Available here: https://www.gov.uk/government/publications/energy-performance-of-buildings-directive-second-cost-optimal-assessment

5.3.7. Non-Domestic Existing Building Retrofit Measures – Replacement Cycles

Name	Description	Asset life		
		Slow	Med	Fast
Improve solid element u-values	Increased / replace insulation to wall and roof areas	55	40	25
Improve glazing u-values	Replace glazing for more efficient glazing	55	40	25
Improve glazing solar performance	Either as part of above or by adding solar film	55	40	25
Voltage Optimisation and Power Factor Correction	Reducing building incoming voltage to European standard 220v, and applying power factor correction	40	25	15
Heat recovery ventilation	Improve the heat recovery within the ventilation systems	40	25	15
New lighting and controls		15	10	5
Sub-metering & recommissioning	installation of sub-metering on all heating, cooling and power systems	40	25	15

Building Type	Asset Life Category
Commercial Offices	MEDIUM
Education	SLOW
Government	SLOW
Health	MEDIUM
Hotel and Catering	FAST
Other	MEDIUM
Retail	FAST
Sport and Leisure	MEDIUM
Warehouses	MEDIUM

Figure 38: Non-Domestic Existing Building Retrofit Measures – Replacement Cycles

Retrofit measures are deployed in the model at different time-steps as shown in Figure 38. Depending on commercial priorities, different sectors can be expected to replace their systems, fabrics, and indeed buildings on different timeframes. The selected lifecycles for this analysis were taken from the 2013 Routemap Model.

5.3.8. Non-Domestic Existing Building – Resultant Energy Intensities (EUI)

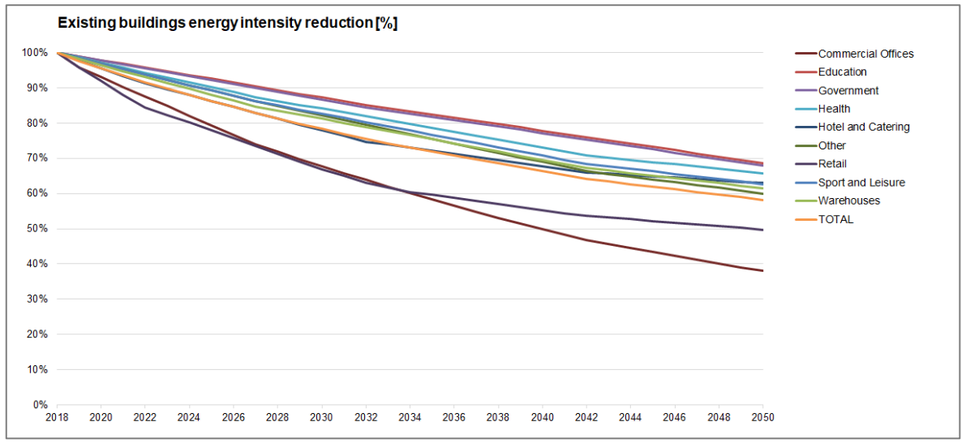

Figure 39: Non-Domestic Existing Building Energy Use Intensity Projections

The projected energy use intensity of the existing non-domestic building stock is an intermediate output step of the model, based on the inputs detail in the previous sections (heating and cooling technology mix and efficiencies, retrofit performance factors and replacement cycles per sector, etc). Appropriate carbon factors are then applied to derive operation carbon emissions within the model. The projected reductions from the 2018 baseline energy use intensity data for the existing stock is presented here in Figure 39. Uncertainty regarding existing stock floor area data and reconciling this with aggregate energy usage data per sector means that the projects are expressed as a percentage reduction from the baseline rather than absolute figures.

5.3.9. Non-Domestic Buildings – Installed PV Capacity

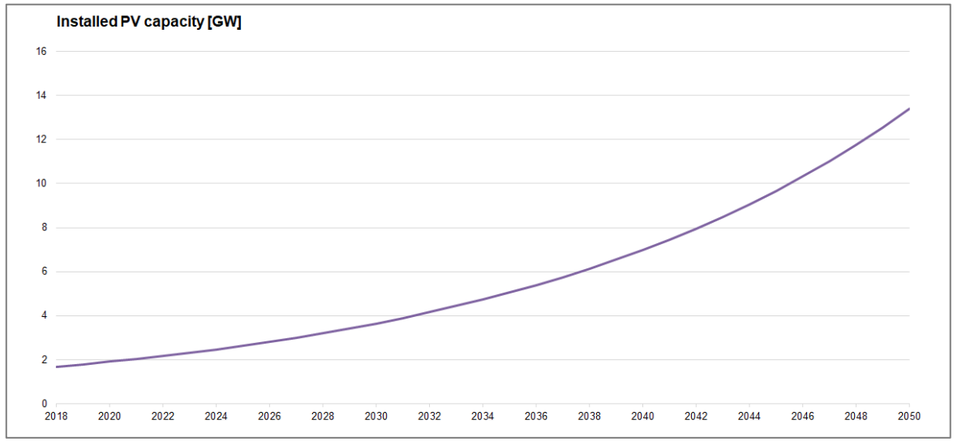

Figure 40: Non-Domestic Buildings – Installed PV Capacity

The installed PV capacity assumes an average annual increase of 6.71%MW, based on BEIS Solar Photovoltaics Deployment average annual system installation trends from 2018-2020. [44]

5.3.10. Non-Domestic Building – Unregulated Energy Consumption

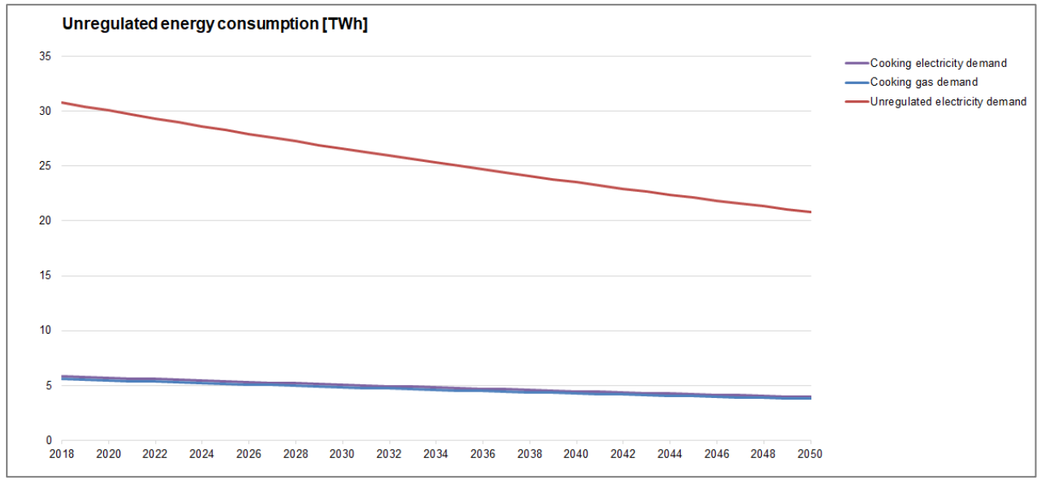

Figure 41: Non-Domestic Building – Unregulated Energy Consumption

Projections for unregulated or process energy loads within non-domestic buildings are derived with reference to the Building Energy Efficiency Survey (BEES) 2014-15 [45]. Trending information from 2015 - 2020 shows an average reduction of 1.22% annually for electricity consumption (taken from BEIS energy trends[46]) which is projected forward through to 2050.

5.4. Scenario Definition - Infrastructure

5.4.1. Infrastructure Spend Growth Projections

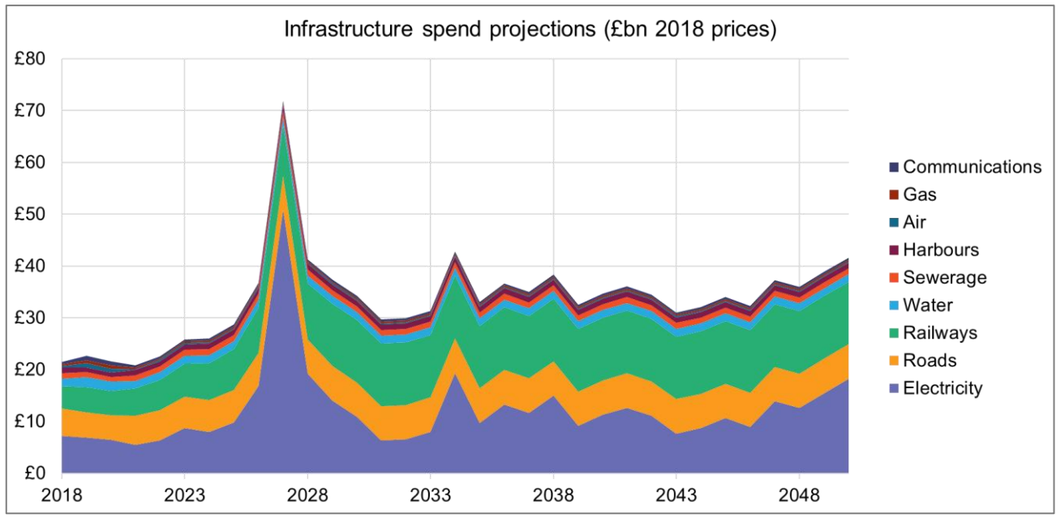

Figure 42: Infrastructure Spend Growth Projections

The infrastructure spend growth projections for listed sectors (excluding electricity and gas) are based on a Fitch Solutions Market Insights study which contains estimates based on ONS data and industry forecasts in relation to the expected growth rates in each sector up to 2029.[47] Sewerage, gas and communications are not explicitly itemised but can be inferred from the more general construction growth forecasts. The air forecast combines the CCC Aviation Summary growth projections for 2021 onwards blended with the Fitch report projections for 2018-2020[48]. The electricity projections are based on a Future Energy Scenario Aurora Research Report from the National Infrastructure Commission and assume the electrification of heating, 60% renewable production by 2050, and 2.9 MtCO2e by 2050.[49] The gas projections are based on the Pathways to Net Zero report from the Energy Networks Association and assumed a Balanced Future Energy Scenario with a 2020 baseline.[50]

5.4.2. Change in demand - External lighting

Following the 2013 Routemap Model, annual growth is assumed to be 0.1%. This does not allow for new technology and services provided through existing street lighting infrastructure.

[44] BEIS National Statistics (2021). Solar Photovoltaics Deployment. Available here: https://www.gov.uk/government/statistics/solar-photovoltaics-deployment

[45] https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees

[46] https://www.gov.uk/government/statistics/electricity-section-5-energy-trends

[47] Fitch Solutions (2019), Market Insights Report. [Unpublished]

[48] Fitch Solutions (n.d)., CCC Aviation Summary

[49] National Infrastructure Commission (2020): Aurora Research Report, Renewables Recovery and Reaching Net Zero. Available here: https://nic.org.uk/app/uploads/Final-Renewables-Recovery-Reaching-Net-Zero.pdf

[50] ENA - Pathways to Net Zero

5.4.3. Change in efficiency - External lighting

In 2014, 10% of UK streetlights were LED, with 89% penetration is expected by 2026. Analysis suggests that switching to LEDs saved 50% energy consumption, which increases to 80% when integrated with a central management system[51]. Interpolating for deployment by 2018 implies a further 68% reduction possible by 2050.

5.4.4. Water and Wastewater

Following the 2013 Routemap Model, the average historic energy use for water and wastewater was applied to population growth to project future energy use.

5.4.5. Construction & Demolition Waste – Destinations

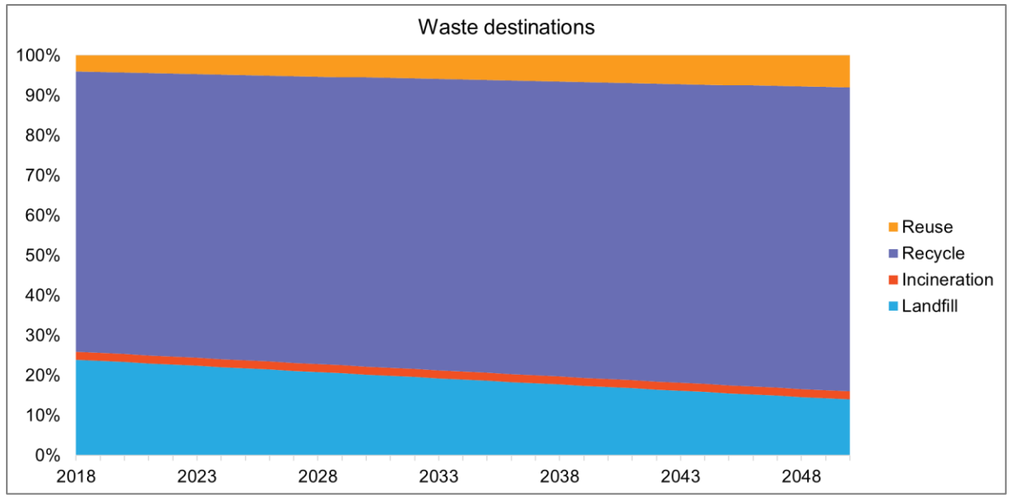

Figure 43: Construction & Demolition Waste – Destinations

Projections for construction and demolition waste destinations are derived from BRE's SmartWaste system, which is used on many construction projects.[52] KPIs and benchmarks are generated including for waste arisings (tonnes/£100k of project value) and diversion of waste from landfill. The task group made assumptions as to the change in % of different waste disposal routes in 2050 compared to SmartWaste figures and Defra historic data. Assumptions were based on a review of relevant industry literature and task group insights. Incineration was assumed to stay static at 2%, with any increase in rates of incineration offset by reduction in waste generation. Recycling rates were assumed to increase 6% by 2050 on the assumption of the best 10% of industry achieving a significantly higher rate than presently. Rates of reuse were assumed to double (4-8%) as an ambitious estimation, though this remains substantially lower than targets by industry groups like the Ellen MacArthur Foundation and C40 Cities, who propose reuse rates of 15-22%. Landfill was assumed to make up the remaining 14% of disposal routes at 2050.

5.4.6. Construction & Demolition Waste Arisings and Emissions Intensity

Figure 44: Construction & Demolition Waste Arisings (per Unit Construction Value)

Projections for construction & demolition waste figures are derived with reference to UK statistics on waste from DEFRA[53], with a 5% decrease projected by 2050[52]. A 2% figure for waste processing emission reductions was assumed based on DEFRA historical range of 1-8%.

[51] The Future of Street Lighting, IoT UK, 2017. Available here: https://iotuk.org.uk/wp-content/uploads/2017/04/The-Future-of-Street-Lighting.pdf

[52] BRE (n.d.), Smartwaste [data supplied for purposes of this project but available for fee on request] https://www.bresmartsite.com/products/smartwaste/

[53] DEFRA (2021), UK Statistics on Waste: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1002246/UK_stats_on_waste_statistical_notice_July2021_accessible_FINAL.pdf

5.5. Scenario Definition – Capital / Embodied Carbon

5.5.1. Reduction Factors – Materials, Site & Transport

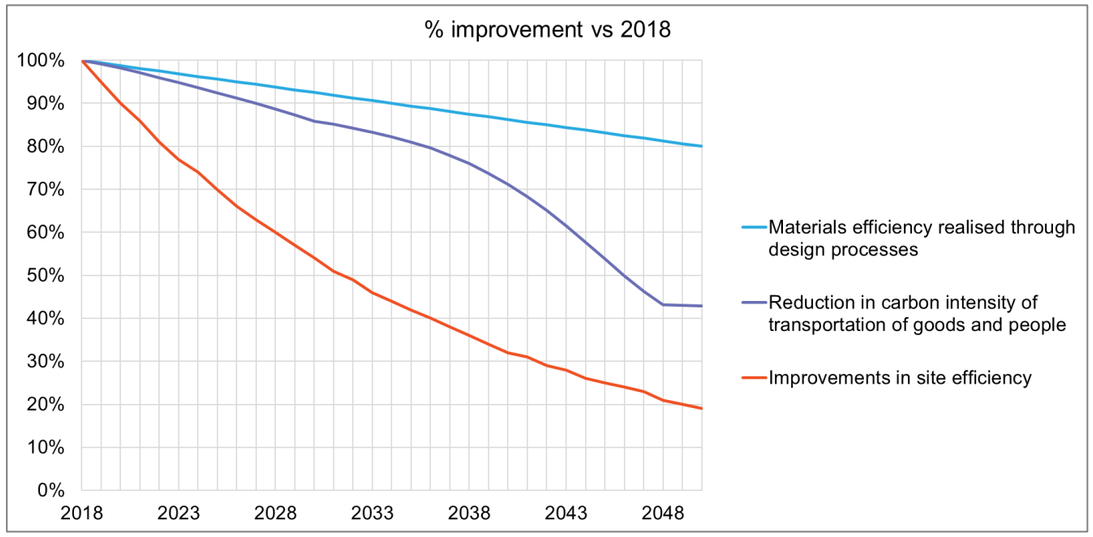

Figure 45: Improvements in design material efficiency, transportation of materials and construction site practices.

Transportation

For transportation, different modes of transport are decarbonising at different rates. For road freight, which is the largest mode used in construction, the significant milestones are the phase out of new petrol or diesel LGVs from 2030, and from 2035 all new HGVs must be zero emission (HM Government Ten Point Plan).[54] The National Grid Future Energy Scenarios was used for the trajectory and scaled to the relative reduction in internal combustion engines (as per Department for Transport data).[9] For rail, Network Rail's environmental strategy commits to net zero carbon emissions by 2050.[55] The trajectory was scaled in line with rail electrification targets. The International Marine Organisation strategy for shipping commits to a 40% reduction by 2030 and a 50% reduction by 2050 (from a 2008 baseline).[56] The trajectory was a linear interpolation of these targets.

Design Efficiency

Projections for improvements in design efficiencies are estimated based on a number of studies that give a wide range of predictions for possible design savings. The IEA predict an 11% saving for cement and 17% for steel by 2050 (pro-rated down from their 2060 figures)[57], whilst UNEP use a figure of 20% for reinforced concrete design and 15% for steel beams[58] (the UNEP report also noted that this "is somewhat lower than the assumption by Milford et al.")[59]. A study into steel frames published by Dunant et al showed potential savings of 40%[60], and a similar study for a single as-built project by Poole showed 34%[61]. On the basis of the range of available reference sources, an overall projection of 20% reduction of material usage through design efficiency was projected on a linear basis.

Site Efficiency

Data from major contractors (BAM Nuttall and Skanska) indicates that over the past 10-yrs on average, 5% construction phase carbon emissions reductions have been achieved.[62] This is as a result of continued technological developments that the industry has deployed over that time such as; optimising construction processes, digitizing construction operations and processes, value engineering, plant and equipment drive train technologies, electrification of site power supplies and some small plant, and training and behaviours pertinent to reducing carbon. The drivers for these measures have been largely commercial to mitigate the impact of increased fuel costs, carbon taxation and to comply with policies such as the Non-Road Mobile Machinery (NRMM) regulations and more recently the Ultra Low Emissions Zones (ULEZ) in London.

However, there is nothing currently that suggests this long term trend in carbon reduction will slow – in fact it is likely to accelerate should further punitive measures on carbon emissions be introduced, the ending of red diesel tax relief in April 2022 for example could have a dramatic effect on the financial case for electrification of plant and additionally drive the industry to more bio-fuel options. However, it seems sensible to remain conservative on projections of further efficiency gains that may come about in the near to medium term, as a result we concur that this lever should be set in line with the historically observed 5% annual emissions reduction trend.

It is worth noting however that the rapid transition from Gas Oil to the Biodiesel that is Hydrotreated Vegetable Oil (HVO) is expected to make a significant impact on reducing direct emissions from construction industry in the short term. However, in the medium to long term, HVO and other bio-derivatives need to be more robustly proven on their sustainability characteristics to ensure other aspects of sustainable development are not compromised. HVO for example is known to contain a small proportion of agricultural biomass from crops such as Palm Oil and proliferation of this crop for the purpose of fuel production is considered detrimental to forestry and biodiversity conservation. Hydrogen will very likely supersede HVO later in the 2020's but it's production equally needs to be demonstrated in a sustainable context.

[54] HM Government (2020). The Ten Point Plan for a Green Industrial Revolution: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf
[55] Network Rail (2020). Environmental Sustainability Strategy: https://www.networkrail.co.uk/wp-content/uploads/2020/09/NR-Environmental-Strategy-FINAL-web.pdf
[56] International Marine Organisation (IMO) (2018). IMO Action to Reduce Greenhouse Gas Emissions from International Shipping: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx
[57] IEA (2019). Material Efficiency in Clean Energy Transitions: https://iea.blob.core.windows.net/assets/52cb5782-b6ed-4757-809f-928fd6c3384d/Material_Efficiency_in_Clean_Energy_Transitions.pdf
[58] UNEP (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future: https://wedocs.unep.org/bitstream/handle/20.500.11822/34351/RECCR.pdf?sequence=1&isAllowed=y
[59] Milford et al. (2013). The Roles of Energy and Material Efficiency in Meeting Steel Industry CO2 Targets: https://pubs.acs.org/doi/pdf/10.1021/es3031424
[60] Dunant et al. (2021). Good early stage design decisions can halve embodied CO2 and lower structural frames' cost: https://doi.org/10.1016/j.istruc.2021.04.033
[61] Poole (2020). Rationalisation versus optimisation – getting the balance right in changing times: https://www.istructe.org/IStructE/media/Public/TSE-Archive/2020/Rationalisation-versus-optimisation-getting-the-balance-right-in-changing-times.pdf
[62] BAM (2021), 5 year CO2e comparison [Unpublished]

5.5.2. Industry Intensity Factors

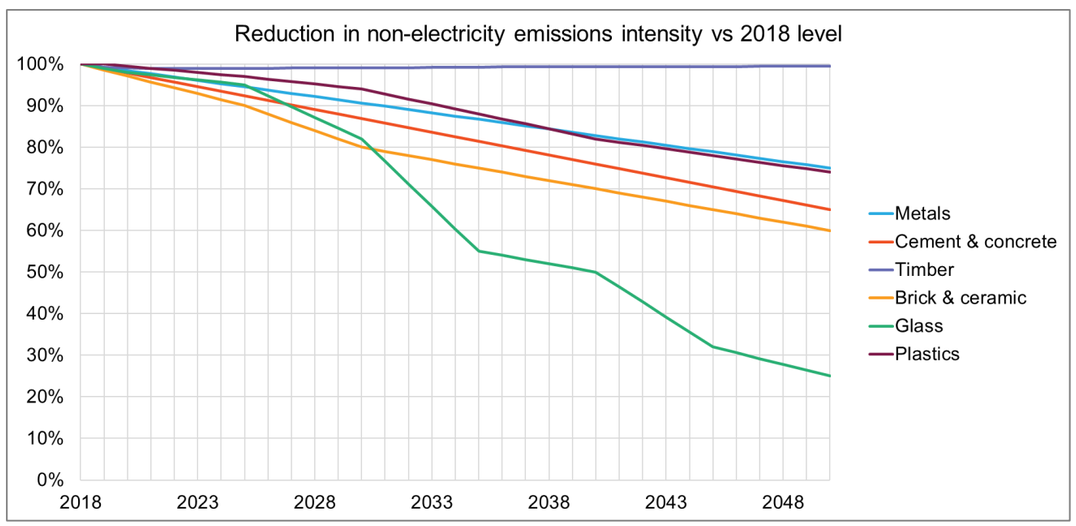

Figure 46: Carbon intensity (non-electricity emissions) per material category

Figure 46 above shows the non-electricity emissions intensities projected for the main construction material supply chains. Grid decarbonisation is applied separately to electricity usage (with any carbon removals technologies stripped out to avoid double counting). Carbon capture and storage (CCS) is applied separately.

Plastics

As no data could be found specific to the UK plastics industry, global chemical sector data was considered. The International Energy Agency (IEA) have estimated global CO_2 emissions reductions in the chemical sector between 2019 – 2070, and point to considerable emissions savings in the short to medium term (2020-40) through technology performance improvements and fuel switching. Technology performance data alone provides a 26% cumulative reduction in emissions between 2019 -2050. Given the chemical sector enables plastic production, the data has been deemed appropriate to apply. Other supporting references include:

- Julian Allowood and Jonathan M Cullen (2012), Sustainable Materials with Both Eyes Open[63]
- International Energy Agency (2020), Energy Technology Perspectives[64]
- International Energy Agency (2018), The Future of PetroChemicals[65]
- Intergovernmental Panel on Climate Change (2014), AR5 Climate Change 2014: Mitigation of Climate Change, Chapter 10 Industry[66]

Glass

The glass decarbonisation projection is based on the 'Maximum Technical Pathway Without CCS' model from the DECC/DBEIS 'Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050 – Glass' document[67]. The Maximum Technical pathway assumes an increased switch to electric melting, fuel switching to biogas and increased use of recycled glass in production, deployed as varying rates as per the descriptions in the Maximum Technical Pathway section of the aforementioned report. The decarbonisation closely follows the 'current trends' line in Figure 26 of the source document, but modified to remove impacts of grid decarbonisation, as previously mentioned. The source material is considered robust, as this is the source material for the glass sectors 'Industrial Decarbonisation and Energy Efficiency Roadmap Action Plan'[68].

Concrete

The projections for reduction in non-electricity emissions for cement and concrete is based on the MPA (2020) UK Concrete & Cement Roadmap to beyond net zero[69]. It reflects the implementation of some of the identified decarbonisation levers (for transport, low carbon cements and concrete and fuel switching) and is a continuation of significant decarbonisation initiatives demonstrated by the industry in the UK already.

Steel

Projections for the non-electricity emissions intensity for steel, and residual non-electricity emissions due to update of CCS for steel, are both taken from the Eurofer report "Pathways to a CO_2 Neutral European Steel Industry"[70]. From this report, Scenario 5 was seen as representing the 2050 scenario with non-electricity emissions reductions and CCS combined, with an 85% figure. The CCS figure is determined by the difference between Scenarios 2 and 3, giving a 60% reduction due to CCS. Therefore a 25% reduction excluding CCS was determined (85%-60%) for non-electricity emissions reduction. The 60% reduction due to CCS is only applied to the remaining 75% of emissions, and therefore an 80% reduction due to CCS is shown.

Brick and Ceramics

Data sources references included a variety of national strategy documents from the UK and Europe as well as manufacturer specific decarbonisation plans that were used to analyse whether the planned trajectories were being implemented in reality. It was noted the ceramic industry had more specific quantitative reduction pathways; for the brick industry it was narrative based aspiration rather than quantitative commitment. Where data was found a 40-60% reduction pathway to 2050 was considered realistic so a cautious view was taken in the figures put forwards. Supporting references include:

- Brick Development Association (2020). 2019 Sustainability Report.[71]
- Besier, D., Marsidi, M. (2020). Decarbonisation options for the ceramic industry in the Netherlands. MSc paper.[72]
- DECC (2021). Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 – Ceramic Sector.[73]
- Cerme-Unie – the European Ceramic Industry Association (2021). Paving the Way to 2050.[74]
- Ibstock (2019). Sustainability Report 2019.[75]
- Michelmersh (2020). Annual Report. [76]

[63] https://www.uselessgroup.org/publications/book/chapters
[64] https://www.iea.org/reports/energy-technology-perspectives-2020
[65] https://www.iea.org/reports/the-future-of-petrochemicals
[66] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter10.pdf
[67] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/416675/Glass_Report.pdf
[68] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/652080/glass-decarbonisation-action-plan.pdf
[69] https://www.sustainableconcrete.org.uk/MPA-ACP/media/SustainableCon-Media-Library/Pdfs%20-%20freely%20downloadable/MPA-UKC-Roadmap-to-Beyond-Net-Zero_October-2020.pdf
[70] https://www.eurofer.eu/assets/Uploads/EUROFER-Low-Carbon-Roadmap-Pathways-to-a-CO2-neutral-European-Steel-Industry.pdf
[71] https://www.brick.org.uk/admin/resources/2019-bsr-1.pdf
[72] https://www.pbl.nl/sites/default/files/downloads/pbl-2020-decarbonisation-options-for-the-dutch-ceramic-industry_4544.pdf
[73] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/416676/Ceramic_Report.pdf
[74] http://cerameunie.eu/topics/cerame-unie-sectors/cerame-unie/ceramic-industry-roadmap-paving-the-way-to-2050/?media=4249&f=Ceramic%20Roadmap%20to%202050%20EN.pdf
[75] https://www.ibstockplc.co.uk/sites/ibstock/files/Sustainability/Sustainability-Report-2019.pdf
[76] https://www.mbhplc.co.uk/wp-content/uploads/2020-Annual-Report-FINAL.pdf

Timber

Development of a Net-Zero Carbon Strategy for the Timber industry in the UK is in progress following the recent merger of the Timber Trade Federation (TTF) and Timber Research and Development Association (TRADA) into Timber Development UK (TDUK), in conjunction with other industry bodies. Ongoing initiatives to reduce emissions within the industry include measures to improve efficiency within forestry activities, plant and machinery, processing, and emissions from end of life processes. However currently no quantitative data is available to indicate the improvements expected through these measures.

5.5.3. Carbon Capture and Storage

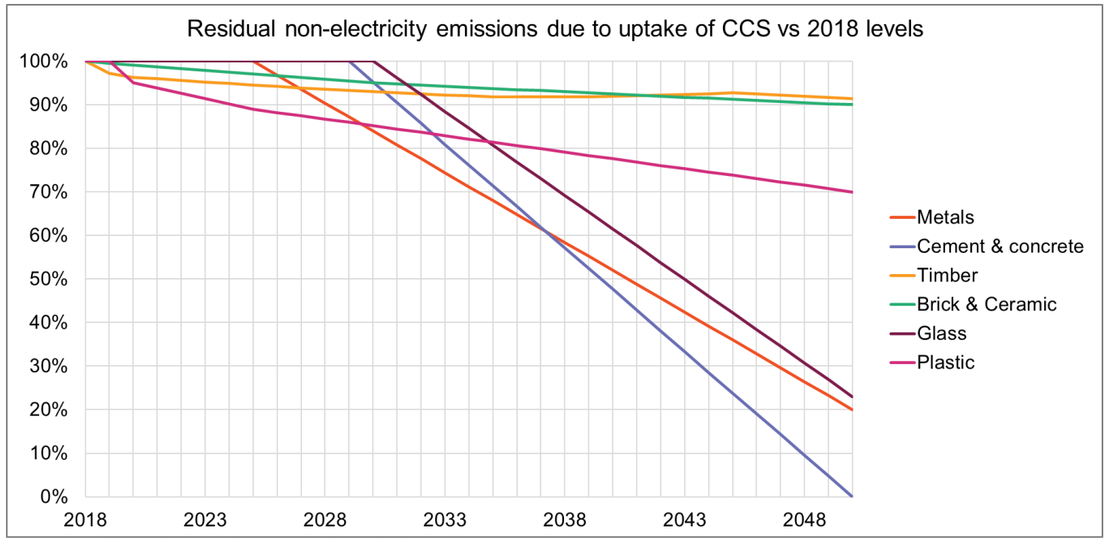

Figure 47: CCS uptake across key material supply chains

Steel

As detailed in section 5.5.2 above, projections for the emissions intensity, and uptake of CCS for steel are both taken from the Eurofer report "Pathways To A CO2 Neutral European Steel Industry"[70]. A 25% reduction due excluding CCS was determined for non-electricity emissions reductions, and therefore an 80% reduction due to CCS was determined.

Plastics

Commentary from Element Energy states similarity in CCS potential between UK chemicals and oil refining sectors[77]. Chemicals and oil refining sectors are likely to be most comfortable with capture separation technologies given the plants usually have high water availability required for these technologies. Given data specific to the plastics sector is not well documented, the oil refining and chemicals industries have been used. The data suggests a plausible sequence of CCS could reduce emission by 11% by 2025. Research from the International Energy Agency implies a linear increase in CCS uptake for the chemicals sector from 2030-2050 and plateauing thereafter, therefore, data from Element Energy has been extrapolated linearly beyond 2025 to 2050. Supporting references include:

- Element Energy (2014). Demonstrating CO2 capture in the UK cement, chemicals, iron and steel and oil refining sectors by 2025: A Techno-economic Study
- Element Energy (2014). Demonstrating CO2 capture in the UK cement, chemicals, iron and steel and oil refining sectors by 2025: A Techno-economic Study Appendix[78]
- Element Energy (2020). Deep-decarbonisation Pathways for UK industry[79]
- International Energy Agency (2020), Energy Technology Perspectives [64]

Concrete

The projected reductions in emissions for cement and concrete due to CCS are based on the MPA (2020) UK Concrete & Cement Roadmap to beyond net zero.[69] It reflects anticipated implementation of full-scale cement CCS in the UK commencing around 2030 following development of existing demonstration projects, assuming support from Government and other stakeholders to facilitate technology deployment. The use of carbon capture with a high proportion of biomass fuels means that there are no residual fossil emissions once other levers have been deployed.

Glass

The CCS model for glass is based on the 'Maximum Technical Pathway With CCS/U' model from the DECC/DBEIS 'Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050 – Glass' document.[67] As noted in the document it is only deployed at scale from 2035 onwards, to reach 75% deployment by 2050. There is still some industry uncertainty about the suitability of CCS deployment for the glass industry given the relative size of annual emissions compared to other industrial sectors, but as it is still a technically feasibly deployment its impacts are covered in this model.

Brick and Ceramics

The data sources were a variety of national strategy documents from the UK and Europe as detailed in section 5.5.2, as well as manufacturer specific decarbonisation plans that were used to analyse whether the planned trajectories were being implemented in reality. In regards CCS both the brick and ceramic industry highlighted issues with this being viable as the CO_2 is too hot and dilute so the reliance on this was considered minimal.

[77] http://www.element-energy.co.uk/wordpress/wp-content/uploads/2017/06/Element_Energy_DECC_BIS_Industrial_CCS_and_CCU_final_report_14052014.pdf

[78] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/312106/Element_Energy_DECC_BIS_ICCS_CCU_final_Report_Appendix.pdf

[79] https://www.theccc.org.uk/wp-content/uploads/2020/12/Element-Energy-Deep-Decarbonisation-Pathways-for-UK-Industry.pdf

5.5.4. Buildings Change-of-Use, Utilisation, and Material Re-use

Change of use

Conversion refurbishment projects which change the use of existing buildings rather than demolishing and rebuilding from scratch have the potential to temper the need for new construction and therefore embodied carbon. Recent changes in the planning system (permitted development rights) have increased the potential for such projects, and between 2015 - 2020 approximately 15,000 homes were delivered per year through PDR conversions[80]. 89% of these were office conversions[81], and proposed changes to the PDR legislation will increase the potential for such conversions in existing stock in other sectors. Asset level LCAs[82,83] indicate that embodied carbon of a buildings structure is typically 45-55% of the total.

On the basis that some degree of work will typically be required to modify existing structures, a reduction factor of 25% has been applied to the capital carbon intensity factor within the trajectory for 15,000 of the new build dwellings, to account for carbon savings via the retention of existing structure through PDR conversions. This factor is applied to 25,000 new homes per year from 2025 to represent the increased potential for this type of project.

Building Utilisation

Evidence from multiple sources suggests that over-supply exists within certain sectors of the current building stock, and that that potential also exists to better utilise floor area of the existing stock. Multiple sources have highlighted the current over-supply of retail floor-space in the UK. The Ellen Macarthur Foundation 2015 report ('Potential for Denmark as a Circular Economy[84]) estimates potential for reduction in demand for new floorspace of 9-10% between 2015 and 2035, assuming both improved office efficiency and home working, and increased sharing of residential space. The recent experience of mass home working during the Covid-19 pandemic is further evidence for the potential for home working. Policy Exchange research[85] indicates that the 2011 Census data suggests 12.4m under-occupied homes in England and Wales, with 1.1m homes with two spare bedrooms or more occupied by one person aged 65 or over living alone.

The wide potential for improved building utilisation through various opportunities has been represented in the trajectory by reducing demand for new office and residential by 10% by 2041 (allowing a 20-year period, as per research for Denmark), with a linear interpolation from 0% in 2021.

Material Re-use

The existing building stock is full of high value materials which have the potential to be re-used in new development through a circular economy model, dampening the demand for new materials. The C40 / Arup Buildings and Infrastructure Consumption Emissions report[86] referenced a study from Amsterdam (PUMA: Prospecting the Urban Mines of Amsterdam[87]) and set a target of 11% reduction in virgin metal and petrochemical-based materials by 2050, through circular re-use of existing building elements. The report notes that effective deconstruction requires preparation (so not always possible today) and an established market for deconstructed building components.

To represent this opportunity in the trajectory, demand for virgin metal and petrochemical-based materials has been reduced by 11% across all building sectors by 2041, with a linear interpolation from 0% in 2021.

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[80] MHCLG (2021). Supporting housing delivery and public service infrastructure. Available here: https://www.gov.uk/government/consultations/supporting-housing-delivery-and-public-service-infrastructure/supporting-housing-delivery-and-public-service-infrastructure

[81] Ibid

[82] UKGBC (2020), Building the Case for Net Zero. Available here: https://www.ukgbc.org/wp-content/uploads/2020/09/Building-the-Case-for-Net-Zero_UKGBC.pdf

[83] GLA (2020). Whole Life Carbon Assessments Guidance. Available here: https://www.london.gov.uk/sites/default/files/wlc_guidance_april_2020.pdf

[84] EMF (2020). Potential for Denmark as a Circular Economy. Available here: https://www.ellenmacarthurfoundation.org/assets/downloads/20151113_DenmarkCaseStudy_FINALv02.pdf

[85] Policy Exchange (2018). Building for the Baby Boomers. Available here: https://policyexchange.org.uk/wp-content/uploads/2018/11/Building-for-the-Baby-Boomers-Jack-Airey-Policy-Exchange-December-2018.pdf

[86] Arup (2019). Buildings and Infrastructure Consumption Emissions. Available here: https://www.arup.com/perspectives/publications/research/section/buildings-and-infrastructure-consumption-emissions

[87] AMS (2016). Prospecting Urban Mines of Amsterdam. Available here: https://www.ams-institute.org/urban-challenges/circularity-urban-regions/prospecting-urban-mines-amsterdam/

6. Net Zero Scenario - Results

6.1. UKGBC Scenario Trajectory

6.1.1. Total Carbon

Figure 48 below shows both measured historical emissions to 2018 (baseline year), and then resultant calculated emissions from the projections used, as described in the previous section 5.

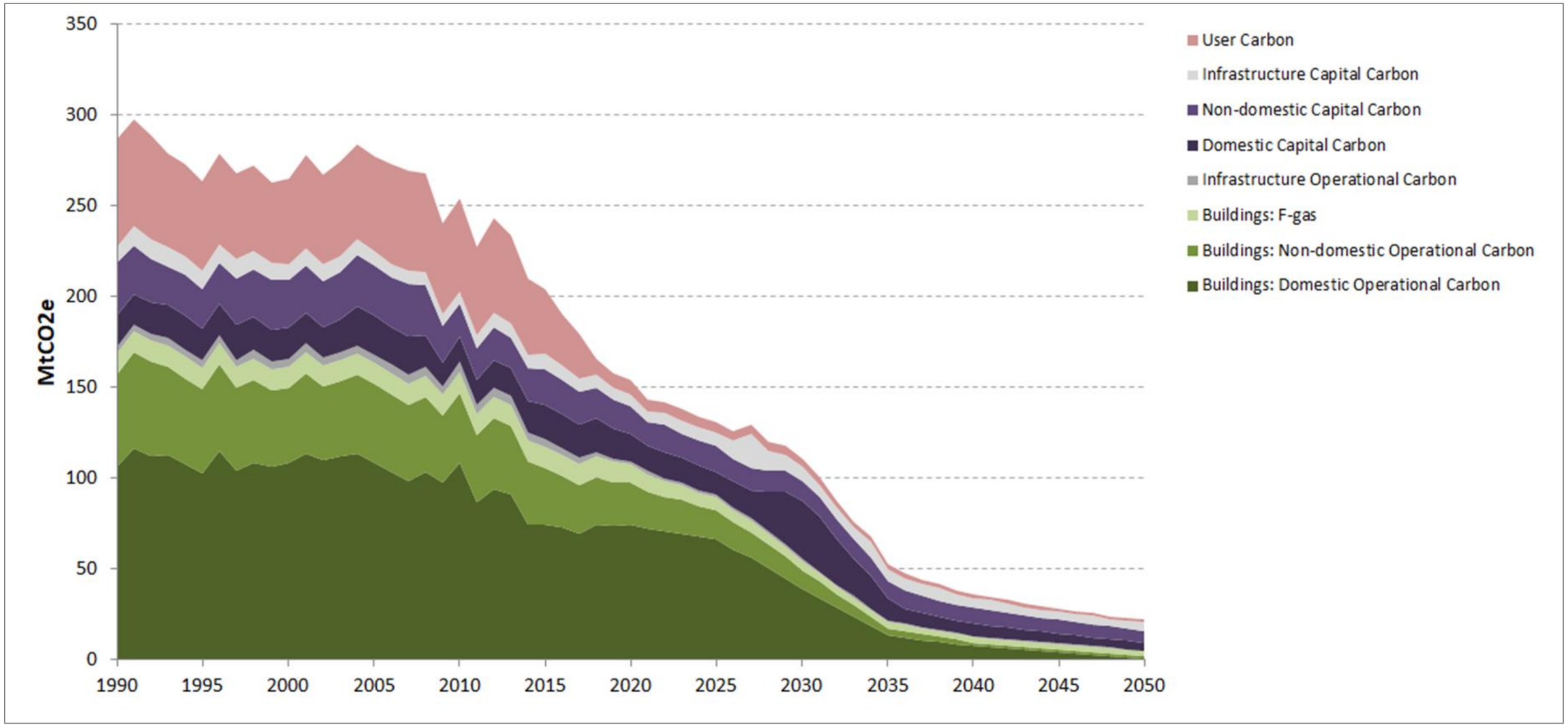


Figure 48: Overall Carbon Trajectory for the Built Environment (1990 – 2050)

Figure 49 below provides a more focused view of resultant projected emissions for the period 2018 – 2050, i.e. a zoomed in view of Figure 48 focusing on future emissions.

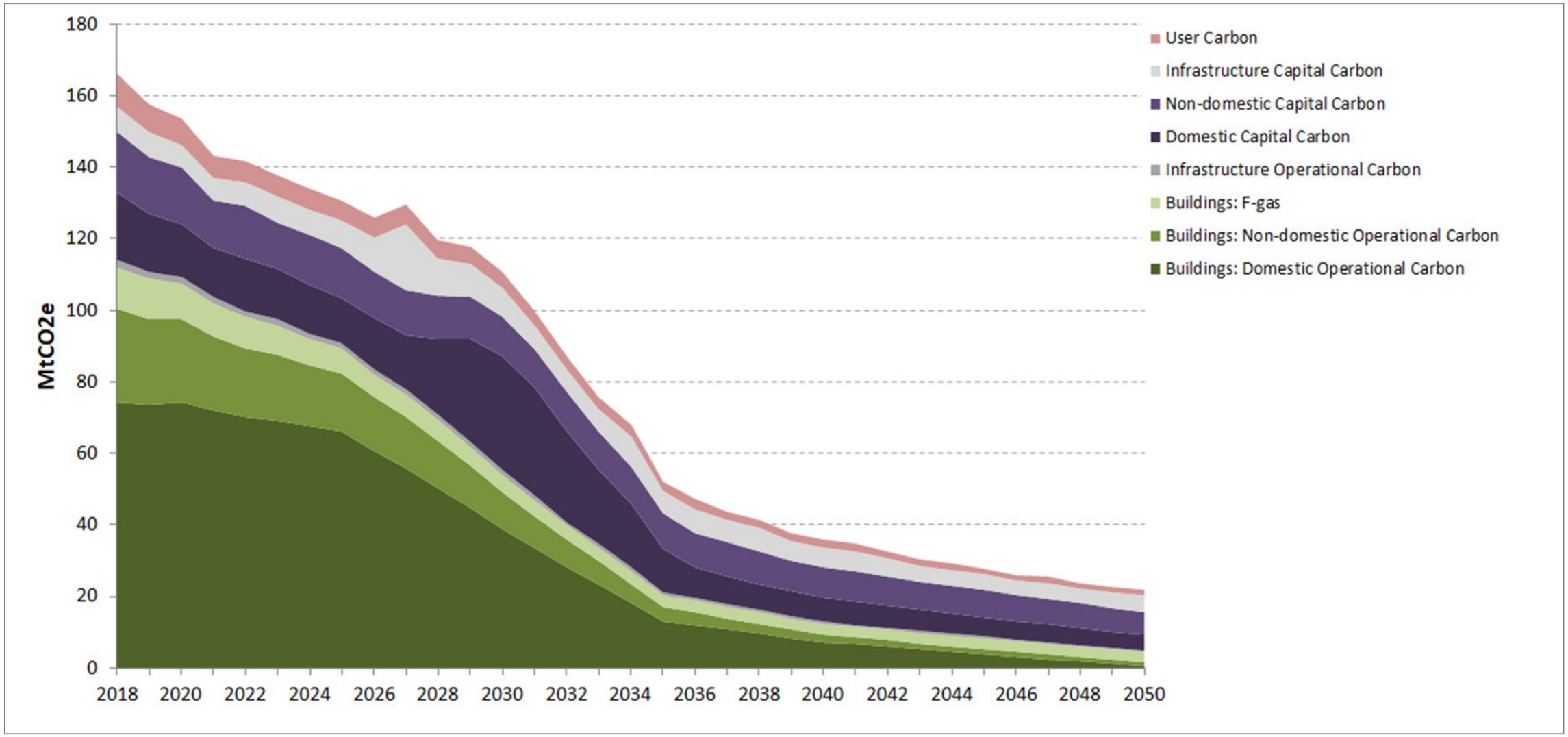


Figure 49: Overall Carbon Trajectory for the Built Environment (2018 – 2050)

6.1.2. Operational Carbon

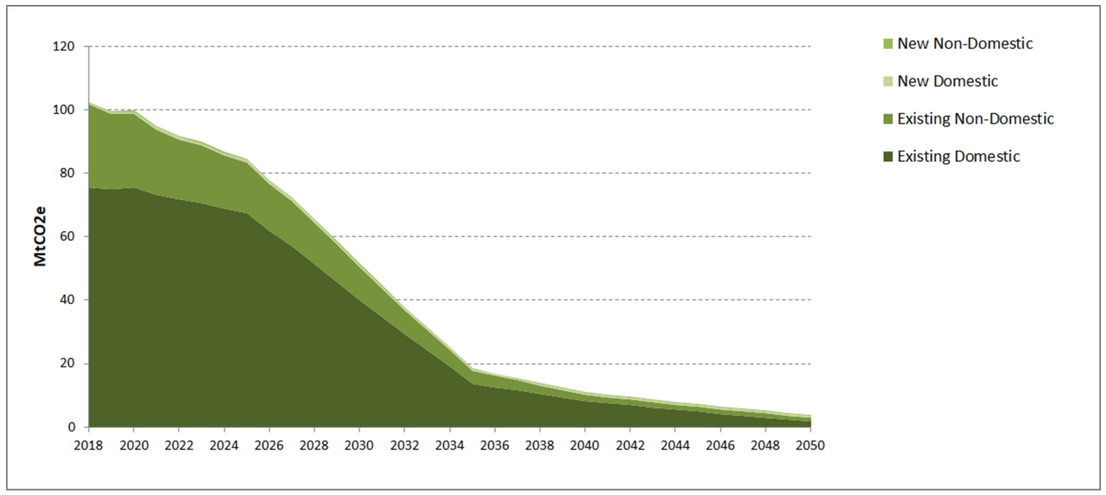


Figure 50: Operational Carbon of Buildings

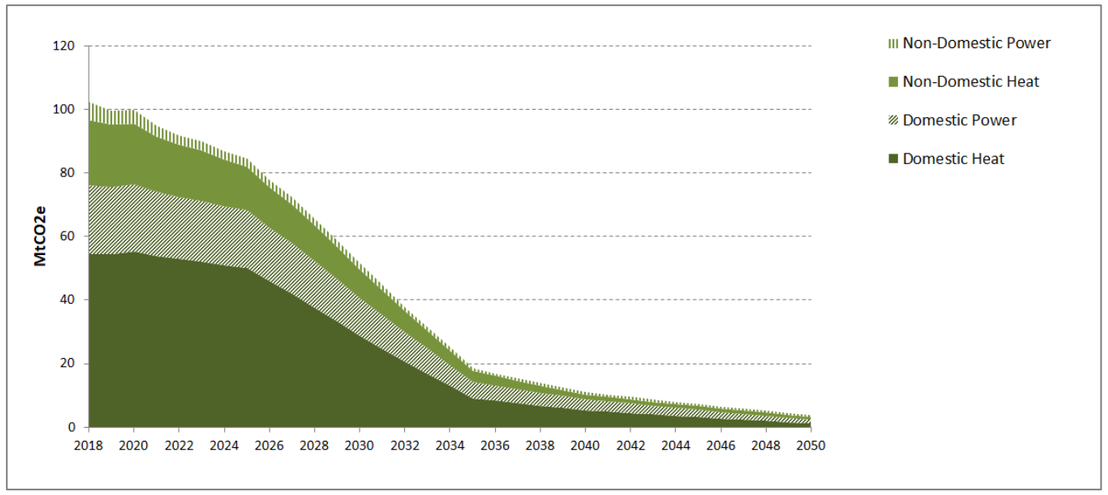


Figure 51: Operational Carbon of Buildings split by Heat / Electricity

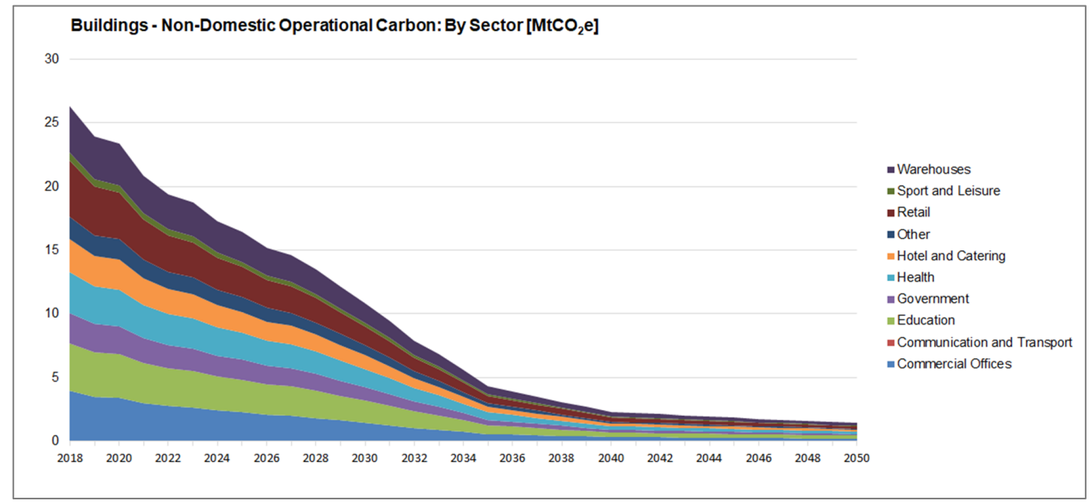


Figure 52: Operational Carbon of Buildings split by Sector

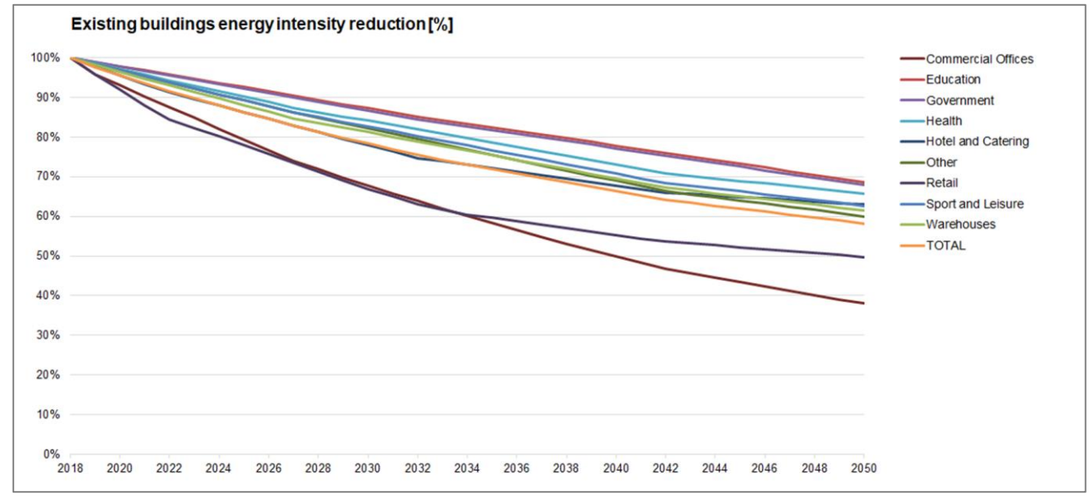


Figure 53: Energy Efficiency of Buildings split by Sector

6.1.3. Embodied Carbon

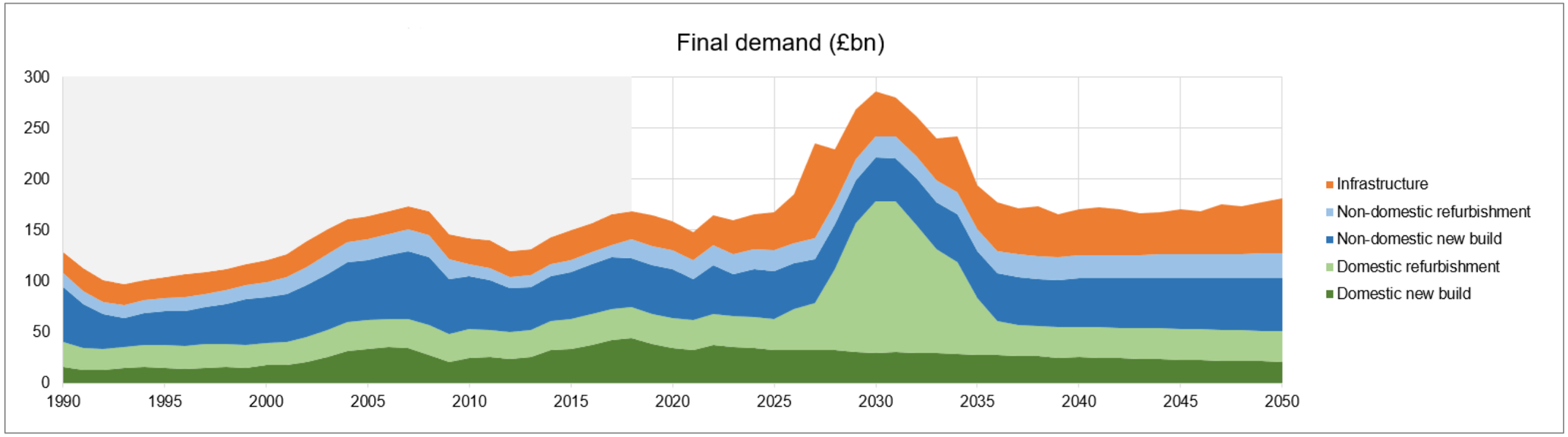
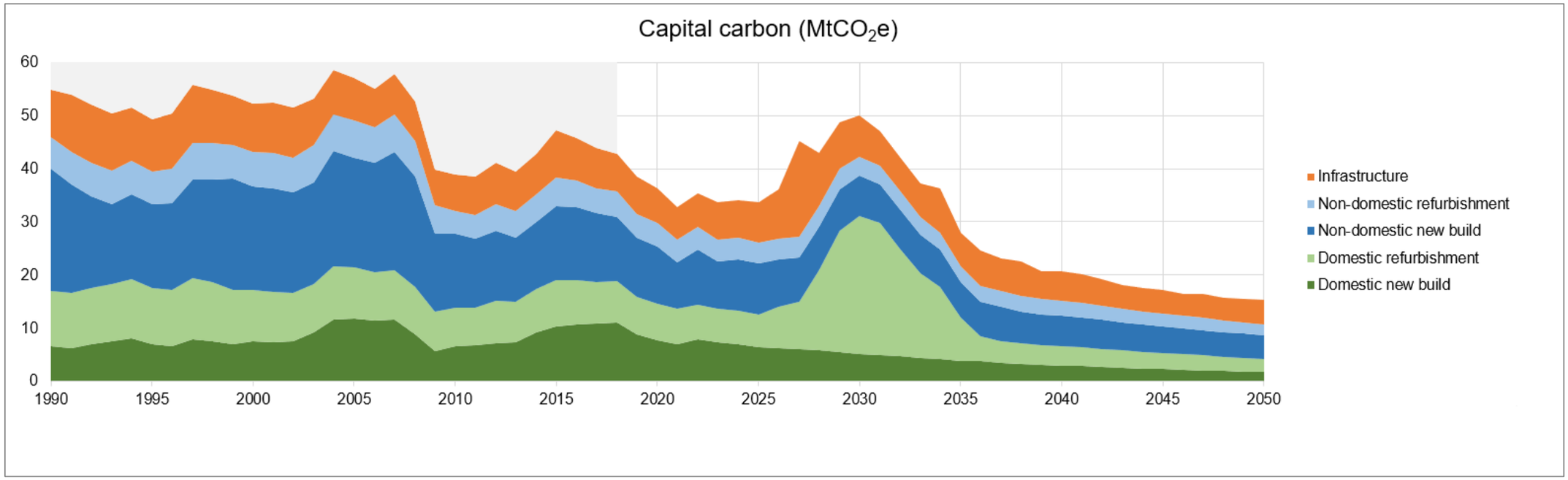


Figure 54: Total Construction Demand split by Buildings and Infrastructure

Figure 55: Total Capital Carbon split by Buildings and Infrastructure



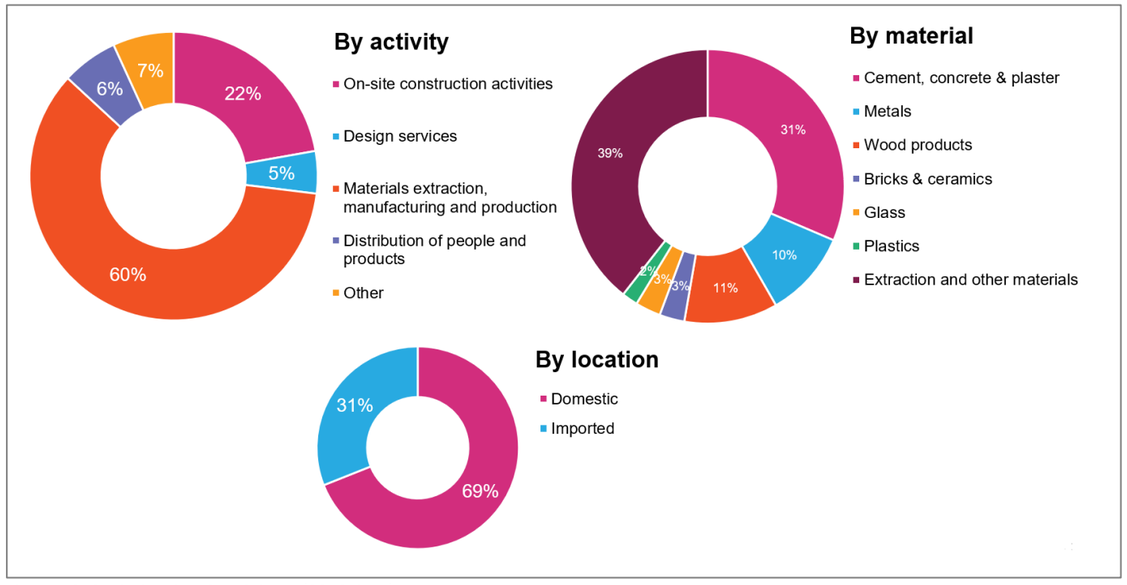


Figure 56: Capital carbon breakdown (2018 data)

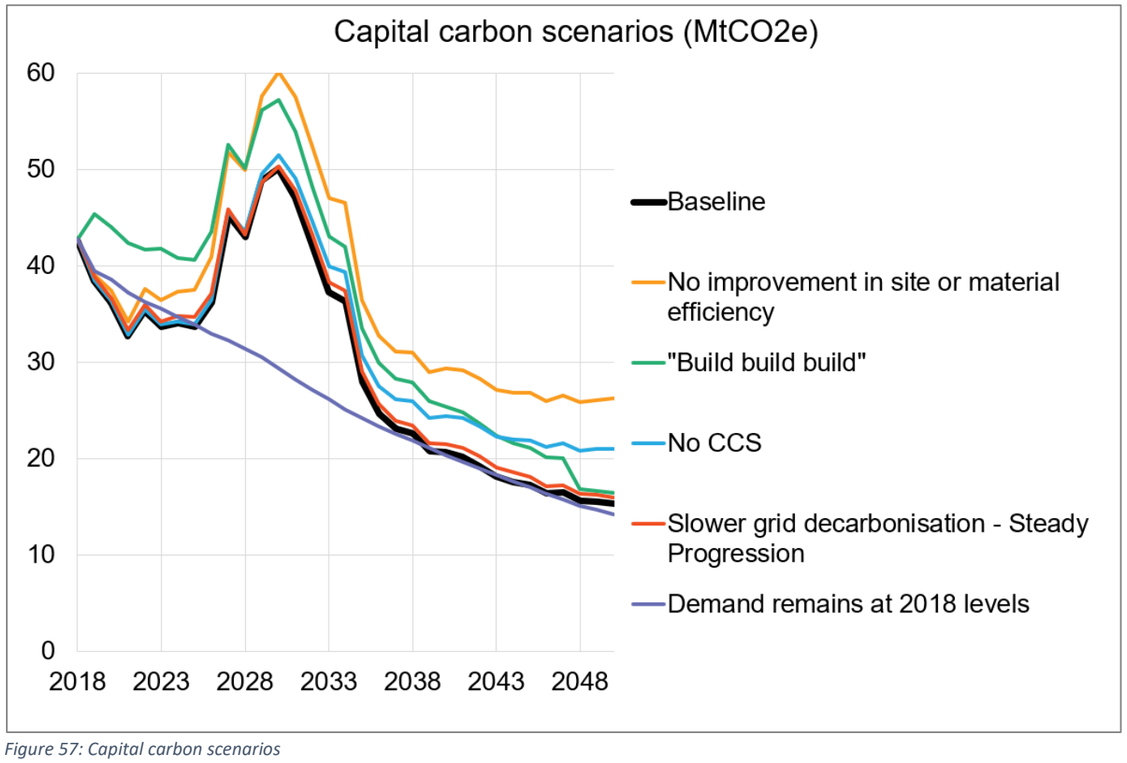


Figure 57: Capital carbon scenarios

6.2. Capital Carbon Scenarios

In addition to the main scenario described in this report, certain additional sensitivity analysis was undertaken to highlight the impact of key inputs on capital carbon, as shown in Figure 57. The scenarios considered are as follows, and the impact of each is shown separately, i.e. not cumulatively.

No improvement in site or material efficiency

In this scenario the improvements in site processes and material design efficiency described in section 5.5.1 (Figure 45) are discounted, and the current status quo projected to 2050 for these factors. It can be seen that this scenario has the highest impact.

"Build build build"

This scenario represents a situation of strong economic growth with heavy investment in the built environment. It is based on the construction of 300,000 new homes each year, with non-domestic new build and refurbishment activity consistently matching the highest level from last the 30 years through to 2050. Domestic refurb and infrastructure demand profiles are unchanged from the main scenario (as these already represent unprecedented levels). This translates into an average of £37bn a year extra of final demand.

No CCS

As the title suggests, this scenario represents no benefits from CCS.

Slower grid decarbonisation (steady progress)

This scenario shows the impact of the Nation Grid FES "Steady Progress" scenario for grid decarbonisation.

Construction demand as per 2018 levels

This scenario fixes construction demand at 2018 levels through to 2050, i.e. no growth in any sectors, and no mass domestic retrofit programme, as an alternative baseline.

6.3. Reference Scenario (Business as Usual)

As described in section 3.6.1, the reference (or business as usual) scenario is a projection based on the BEIS Energy and Emissions Projections (EEPs), which analyse and project future energy use and greenhouse gas emissions in the UK, to a create a forward "business as usual" scenario based on government policy outlook.

The EEP projections allow BEIS to monitor progress towards meeting the UK's carbon budgets and are used to inform energy policy and associated analytical work across government departments. The projections are based on assumptions of future economic growth, fossil fuel prices, electricity generation costs, UK population and other key variables regularly updated. They also give an indication of the impact of the uncertainty around some of these input assumptions.

Each set of projections takes account of climate change policies where funding has been agreed and where decisions on policy design are sufficiently advanced to allow robust estimates of policy impacts to be made.

The roadmap trajectory modelling takes a simplified approach where-by the future emissions profile (curve shape) presented in the selected BEIS scenario will be applied from the baseline year of built environment emissions. As the BEIS data only projects to 2040, the scenario will utilise the profile data to 2040, with the trending line then extended to 2050.

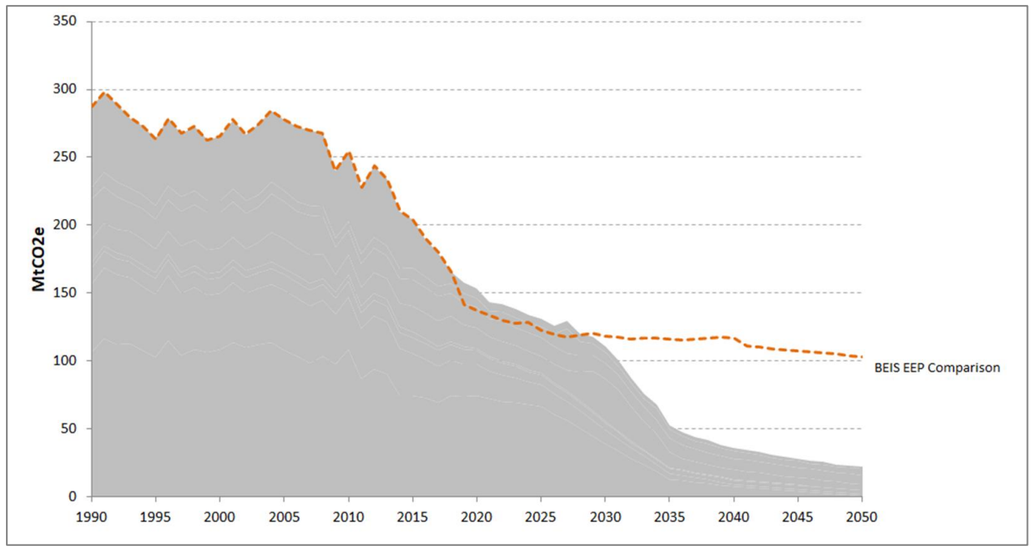


Figure 58: Reference Scenario (Business as Usual)

Figure 58 above maps the Reference Scenario results onto the UKGBC Scenario. As can be seen, the reference scenario initially projects slightly lower emissions than the UKGBC Scenario in the short term, however these quick tail off with a very shallow reduction profile forecast, leading to significant residual emissions in 2050 (approximately equal to the total residual emissions quantum for the UK forecast by CCC).

This indicates the transformative and systemic changes required in strategic policy and investment that will need to be brought forward in order to align with a forecast to Net Zero in 2050.

6.4. CCC Comparison

As described in section 3.6.4, the intention of the CCC Aligned Scenario is to provide reference against the Balanced Pathway as published by CCC in 6th Carbon Budget report. To enable comparison, it is necessary to align scopes. As detailed in this report, the UKGBC Scenario is calculated on a consumption basis, including emission from imported materials. The CCC balanced pathway and the UK Net Zero target is based on domestic or territorial emissions, i.e. only those emissions arising within the UK. The approach taken has been to present the UKGBC Scenario showing domestic emissions only, i.e. excluding imported emissions.

This comparison was established through dialogue with the CCC and its published work. The comparison maps the national emissions budgets established by the CCC, alongside the UKGBC Scenario, alongside emissions from the CCC balanced pathway relating to the built environment definition and scope as defined by the project.

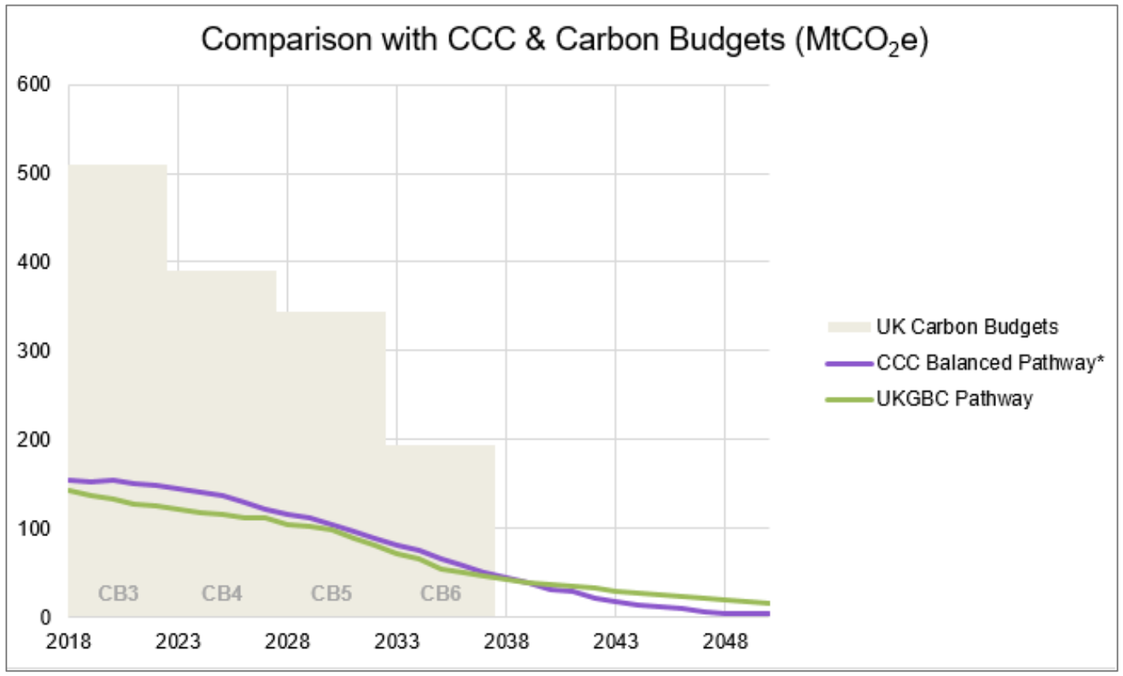


*Figure 59: Comparison of CCC Balanced Pathway and UKGBC Scenario (*note boundary differences detailed below).*

Although all efforts have been made to enable a like-for-like comparison, certain boundary differences remain which mean the comparison is imperfect. The purple CCC Balanced Pathway dataset includes the CCC's Residential Buildings, Non-Residential Buildings and the Manufacturing & Construction sector. However, not all Manufacturing & Construction sector emissions relate to the Built Environment, and hence the slight differential in starting point. Figure 61, Figure 62, and Figure 63 show a more detailed comparison of embodied carbon emissions, against a subset of CCC Manufacturing & Construction emissions which have been estimated as those which relate to the built environment.

Other scope boundary differences include the inclusion in the UKGBC Scenario of emissions from construction design services, and elements of surface transport which relate to the distribution of people and products related to construction in the built environment.

Other driving factors in the differences include the UKGBC projections for construction demand (see Figure 54) which show steady growth in almost all sectors in the years to 2050. Construction demand also factors in the anticipated domestic retrofit programme which creates a significant spike around 2030 as this transformative programme to retrofit 27m homes by 2040 enters its most accelerated phase between 2030-2035.

There are also differences in projected carbon intensities of material supply chains. UKGBC Scenario projections for material supply chain intensities are set out in Section 5.5. The main difference relates to projections for those materials included in the "other" category in Figure 56, which in our analysis benefit from the effects of grid decarbonisation and design efficiency improvements, but do not have any process efficiency improvements or CCS applied to them.

Within operational carbon of buildings there are numerous variations between the Balanced Pathway and the UKGBC Scenario, most notably a deeper and more accelerated domestic retrofit programme within the UKGBC Scenario, but with more conservative projections for domestic behaviour change.

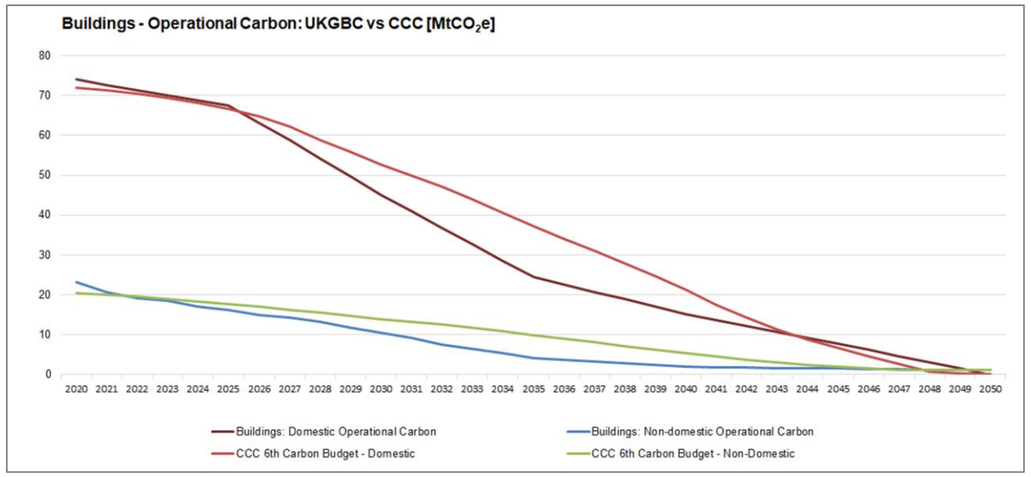


Figure 60: Comparison of CCC Balanced Pathway and UKGBC Scenario for Buildings Operational Carbon

Figure 61 shows the change relative to 2018 in the CCC's baseline emissions projections for the share of the manufacturing and construction sector that we estimate is attributable to the built environment. We estimate this share based upon the proportion of final output from these sub-sectors that is purchased by construction sectors (SIC 41-43) according to UK National Accounts for the most recent year. The UKGBC final demand profile is predicted expenditure on construction activity relative to 2018 levels.

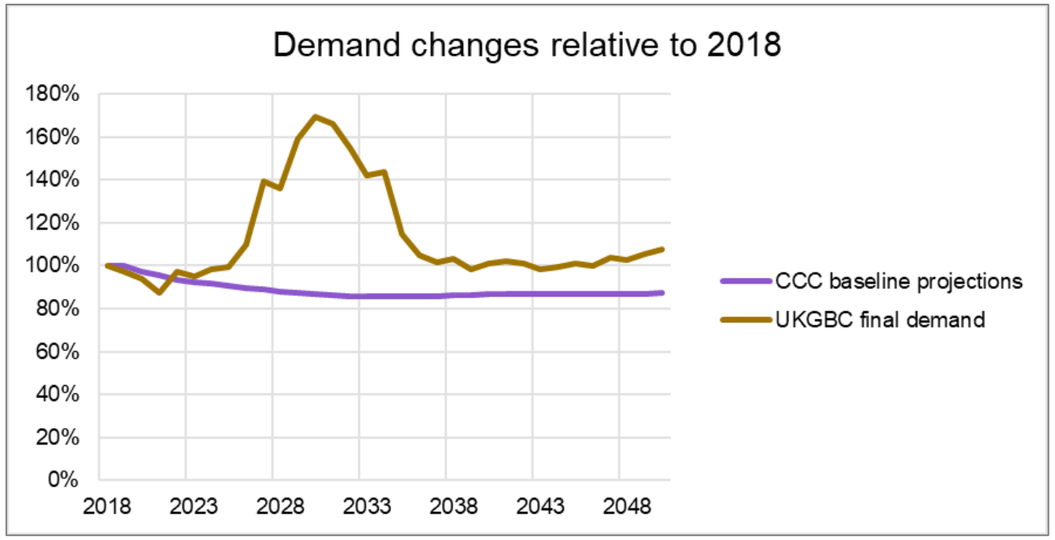


Figure 61: Comparison of CCC Balanced Pathway and UKGBC Scenario for Construction Materials Demand

Figure 62 below shows under the CCC's Balanced Pathway the relative change in emissions attributable to the share of the manufacturing and construction sector that we estimate is attributable to the built environment. It compares this with the relative change in the total carbon intensity (i.e. average capital carbon emissions per £ of spend) in the UKGBC pathway.

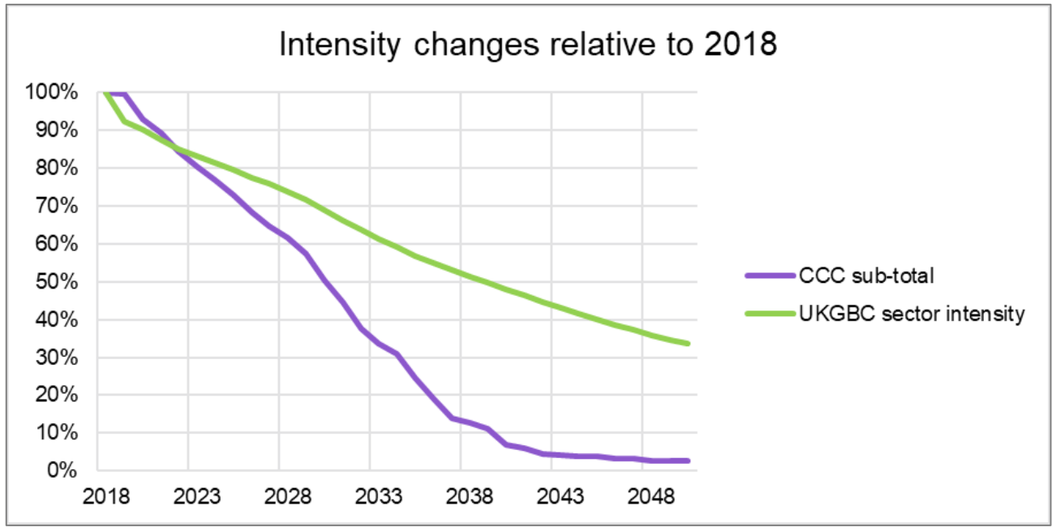


Figure 62: Comparison of CCC Balanced Pathway and UKGBC Scenario for Construction Materials Carbon Intensity

Figure 63 below compares the overall change in domestic (i.e. territorial) capital carbon emissions under the UKGBC pathway with the emissions under the CCC's Balanced Pathway from the share of the manufacturing and construction sector that we estimate is attributable to the built environment

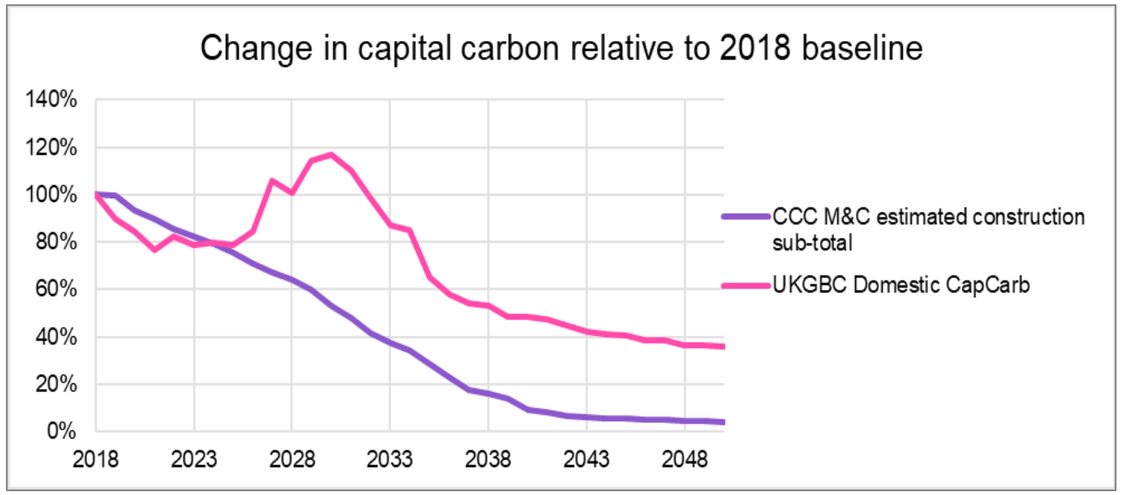


Figure 63: Comparison of CCC Balanced Pathway and UKGBC Scenario for Embodied Carbon attributable to the Built Environment

6.5. Final Residual Emissions

The carbon trajectory for the built environment created by this project is shown in Figure 64 below (see also Figure 48 for a larger version). Reductions in operational carbon accelerate in the period up to 2035, before tapering off in the period up to 2050. Embodied carbon emissions show a more steady reduction profile, with a noticeable increase in the period 2028-2032 during the most intense period of the national homes retrofit programme.

Operational emissions from buildings are reduced to zero by 2050, however a quantum of embodied emissions remain. The final residual emissions for the Built Environment resulting from the trajectory detailed in this report equates to **17.4 $MtCO_2e$** considering domestic (territorial) emissions, and **22.2 $MtCO_2e$** including all consumption emissions (i.e. imported materials).

These remaining emissions represent the built environments theoretical "allocation" of total UK residual emissions, which will need to be dealt with via both nature-based removals (i.e. land-use change, increased forestation, peatland restoration), and engineered greenhouse gas removals (i.e. Bioenergy with carbon capture and storage (BECCS), Direct Air Capture of CO2 with storage (DACCS) to permanently remove carbon from the atmosphere.

The CCC projection for total UK removals by 2050 is **97 $MtCO_2e$** (39$MtCO_2e$ from Land-based carbon sinks, 58$MtCO_2e$ from engineered greenhouse gas removals) as shown in green in Figure 65 from the 6th Carbon Budget report. This relates to territorial emissions only. Therefore the Built Environment's residual emissions equate to approximately **18%** of estimated available total UK removals (considering territorial emissions only).

This report provides a first attempt at defining this residual emissions position for the Built Environment, in order to open a conversation on whether, on the basis of the interventions proposed in the UKGBC Scenario, the final position reflects a "fair share" of the available total UK removals budget (as identified by CCC), and therefore whether this represents a suitable level of ambition for the Built Environment, relative to other sectors.

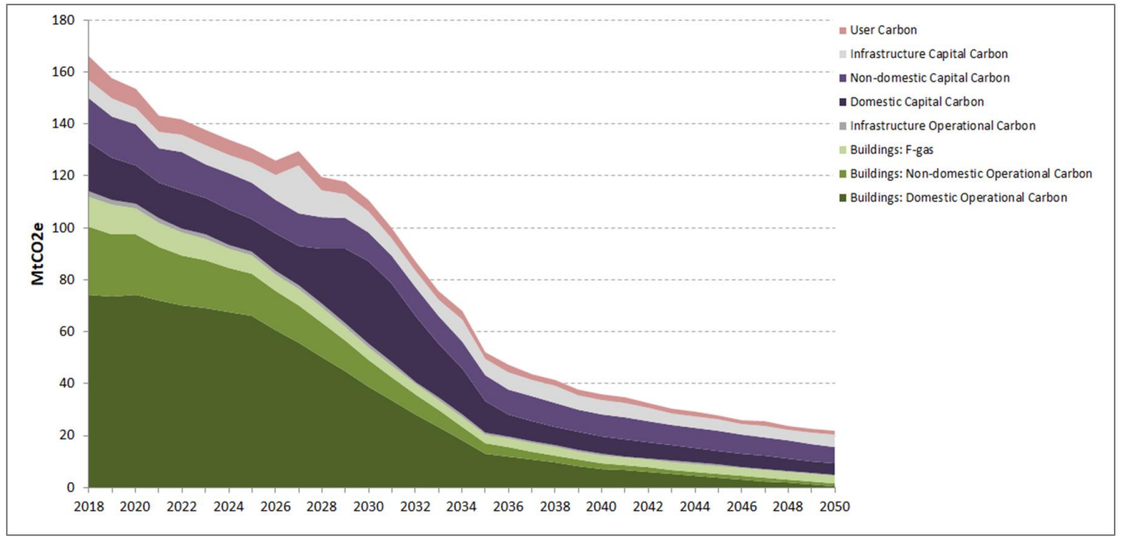


Figure 64: UKGBC Scenario Trajectory

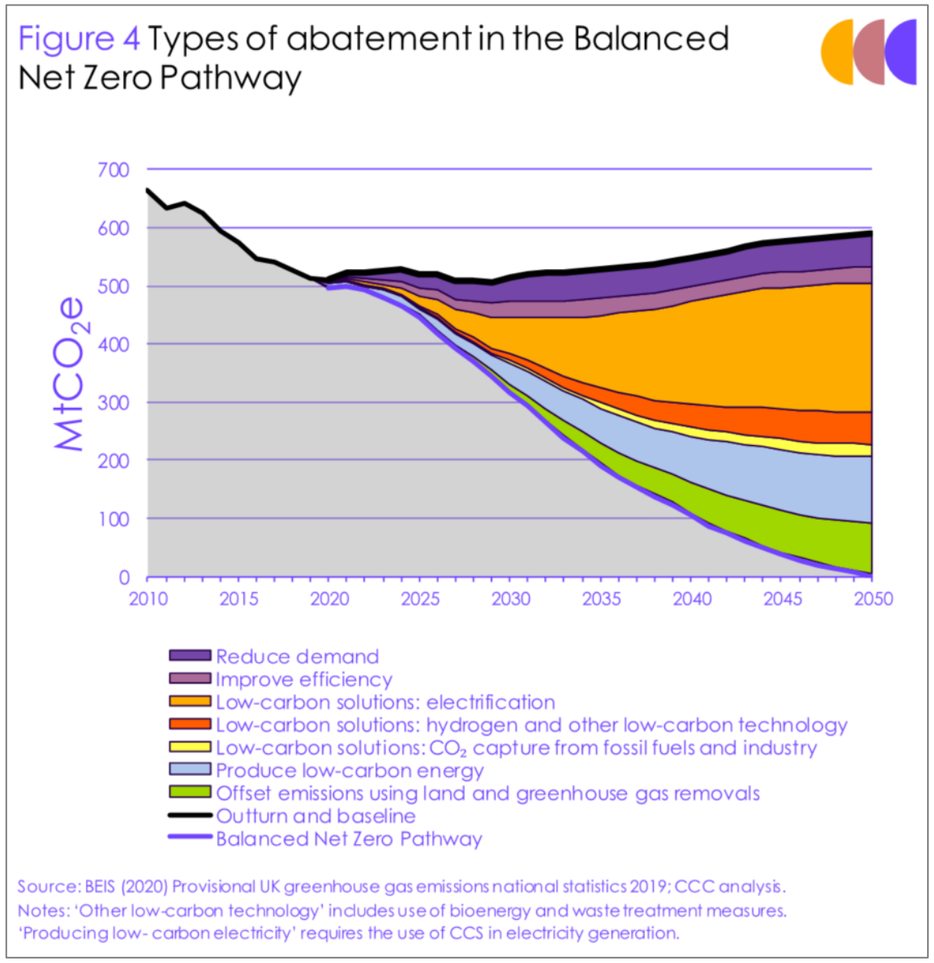


Figure 65: CCC Balanced Pathway showing carbon abatement types (Source: CCC 6th Carbon Budget Report, 2020)

7. Observations

This report establishes a carbon trajectory for the built environment through to 2050 based on projections for multiple interrelated factors and interventions across the sector. Within such an exercise there are naturally high levels of uncertainty in individual areas, but the process highlights some of the trade-offs and value judgements required between the different interventions that will be needed across the sector, within the context of an overarching carbon "ceiling" or budget.

Strategic judgements will be necessary to make the correct choices over the coming years to appropriately allocate the budget each year. For example, this may require critical review of the demand for new buildings and infrastructure in the short and medium term, whilst high carbon supply chains decarbonise. This may necessitate a re-thinking of how we meet society's needs, with an increased focus and incentivisation of circular materials and asset re-use.

Some of the key interventions put forward within the trajectory and important trends are summarised below.

Domestic Retrofit Imperative

The existing building stock is responsible for the vast majority of building operational emissions, with a large proportion of this related to the use of heat within buildings. One of the key interventions required is therefore the improvement of energy efficiency and critically, the reduction of heat demand in existing domestic buildings to enable the adoption of heat-pumps to electrify domestic heat. The scale and pace of the programme needed is unprecedented but would be transformative in terms of job creation and secondary benefits such as health impacts. Such a programme would need a coordinated effort with full government support and a key role for local authorities, which is explored further in the policy recommendations section. Mass domestic retrofit also requires investment in materials such as insulation and new heating systems, which will generate a knock-on increase in embodied carbon emissions, as can be seen in the results between 2028-2032. Further work is required to review the decarbonisation projections for key supply chains such as insulation and heat-pumps in order to to identify ways to minimise this impact.

Non-Domestic Building Energy Performance

Improvements in energy performance must accelerate across all non-domestic sectors, with the emergence of performance-based rating schemes and mandatory disclosure of energy performance key to sectoral improvements. Carbon reductions in recent years have been notable but largely driven by grid decarbonisation. The focus now needs to shift to energy use intensity of buildings, alongside a phasing out of fossil-fuel heating systems.

New Buildings

Although the relative impact of new buildings is minimal compared to the existing stock, all new buildings must be future-proofed to avoid the need for additional retrofit works prior to 2050. Design focus, regulation and standards must switch to energy performance in-use, with the use of suitable predictive methodologies to evaluate energy intensity and a design-for-performance approach forming a golden thread running through design, construction, and handover into operation. Future standards and regulation will need to introduce limits for peak demand reduction, space heating limits (thermal demand) and energy intensities.

Embodied Carbon

The embodied carbon from new construction and refurbishment of buildings and infrastructure is an increasing proportion of built environment emissions, with no simple mitigation option. By 2035, the trajectory results indicate that embodied carbon will form over half of all built environment emissions, with the domestic retrofit programme putting pressure on cumulative carbon budgets in the early 2030s.

Since 1990 the industry has only achieved a meaningful reduction in total embodied carbon emissions in the period following the financial crisis of 2008 (see Figure 48). Given the reductions required in the coming years, this suggests that the early 2020s is the period when regulation of embodied carbon of buildings will need to be introduced to embed consistent measurement and then introduce emission limits. The importance and opportunity from improving design efficiency is shown in the capital carbon sensitivities section (see Figure 57).

Alongside regulation at the asset level, strategic central investment is required in key material supply chains to support decarbonisation plans. If supply chain decarbonisation investments such as CCS are not planned for and delivered as projected, then other areas of the built environment will be required to deliver reductions to keep total emissions within budget.

The capital carbon results in the trajectory also highlight the fundamental influence of construction demand. Regardless of improvements in construction carbon intensity, if growth rates continue to surge then the benefits are negated and absolute emissions will be consistent or even increase. Carbon therefore needs to be at the forefront of infrastructure decision making, in the context of the overarching carbon budgets, with an understanding of the inter-relationship between capital, operational and user emissions for different infrastructure assets.

Growth within buildings requires a re-thinking of how to meet the fundamental need, with a focus on driving the circular economy, developing second-hand materials markets & increasing materials re-use. Strategic thinking on improved utilisation and change-of-use of the existing building stock has the potential to reduce embodied emissions, if an understanding of the true carbon value of existing assets becomes widespread.

The following sections set out the policy recommendations and industry stakeholder actions that have been identified by the project team to support the carbon trajectory.

8. Policy Recommendations – Central and Local Government

The following sections set out the policy recommendations and industry stakeholder actions that have been identified by the project team to support the carbon trajectory. Many of these are interlinked and interdependent, with specific policies or regulations required to drive the carbon reduction measures contained in the trajectory. Government policy is central to instigating significant change across industry, and this project is an opportunity for industry to set out specific recommendations.

Many Local Authorities are taking urgent action to address emissions from buildings, as they exert considerable influence through local planning policies and programmes, and are well-placed to implement emission reduction solutions that take into account local context.

The following policy recommendations have been developed by the Steering Group and Task Groups, building on existing UKGBC policy positions and proposals put forward by other cross-industry groups.

The Policy Recommendations are structured into the following sections, with recommendations for both Central Government and Local Authorities under each section:

- Buildings – Operational Carbon
- Buildings – Embodied Carbon
- Domestic Retrofit
- Infrastructure

While operational carbon and embodied carbon is relevant to domestic retrofit, the unique scale and challenges of policy needed to address domestic retrofit warranted a separate analysis. There are some overlapping elements between the three sections.

9. Stakeholder Action Plan

Alongside policy and regulation, all stakeholders in the built environment will have a role to play in the net zero transition. The purpose of the Stakeholder Action Plan is to identify the key actions that will need to be undertaken by built environment stakeholders to deliver the outcomes of the net zero trajectory. The actions are split across the following timeline:

- **Immediate Action**: actions that should be undertaken now to begin progressing the Roadmap's net zero ambitions and establish a supportive framework for the net zero transition at scale
- **Progress by 2025**: what progress or milestones should follow the implementation of the immediate actions
- **Progress by 2030**: what progress or milestones should follow the 2025 outcomes

This is not meant to be an exhaustive list to deliver net zero, but instead highlights key action required across industry. The focus is on the immediate action as this is the context best understood today and where practically achievable recommendations are clearest. Not all actions have an associated 2025 or 2030 progress indicator. Where certain actions form part of an overarching strategy from existing industry resources, an explicit reference to the strategy has been made.

The actions cover domestic and non-domestic buildings (new and existing), and infrastructure. While non-carbon elements such as social value, adaptation, and resiliency are critical in addressing the climate emergency, detailed consideration of these aspects are outside the scope of the current project. These elements are still touched on in some of the actions.

Policy Recommendations – Central and Local Governments

8.1 - BUILDINGS – OPERATIONAL CARBON

8.1.1 Central Government - Recommendations

Immediate Actions:	by 2025:	by 2030:
Non-Domestic Building Regulations Set out Building Regulations pathway to 2030, to include: - In-use energy evaluation (metrics consistent with Performance-based policy framework) - Thermal energy demand limits - Measures to limit peak demand. Include mandatory requirement for in-use energy evaluation (regulated and unregulated loads – total and EUI) within 2021 update to Part L for non-domestic buildings for all buildings. Ensure metrics are consistent with those within forthcoming Performance-based policy framework. Clearly signpost the link between in-use energy evaluation within 2021 Building Regulations, and forthcoming minimum performance-based standards for new office buildings (>1,000m2) in 2025 (see below).	2025 Building Regulations to include: - Alternative compliance paths based on in-use performance (switching from notional building approach to absolute kWh/m^2/yr targets) - Thermal Energy Demand limits (kWh/m^2/yr) for different building typologies - Peak Load prediction (and ability for load shifting) Clearly signpost the link between in-use energy metrics within Building Regulations, and the forthcoming minimum performance-based standards for new buildings in Phase 2 sectors from 2030 onwards (see below).	2030 Building Regulations to include: - Peak load limits demand limits (W/m2) for different building typologies. - Progressive tightening of energy targets based on asset level evidence base and updated sector carbon budgets.

Non-domestic Performance Policy Framework (In-use Energy)
 	
Complete and publish new Performance-Based Policy Framework for energy & carbon performance across non-domestic building types that integrates the relevant regulatory instruments and schemes, including trajectory for phased roll-out per sector and clear signposting of intention to progressively tighten performance requirements in line with sectoral carbon budgets.
 	
Implement Phase 1 of Performance Policy Framework:
 	
- Complete & publish industry-backed energy & carbon performance-based standard for all office buildings >1,000m^2
  - Launch scheme in April 2022.
  - Mandatory annual disclosure by April 2023
  - Signpost separate minimum standards for existing and new office buildings, and fiscal incentives, to be introduced in 2025 (if not sooner).
	Phase 2 of Performance Policy Framework implemented:
	
	– Performance-based standards for other non-residential building sectors launched, with suitable area thresholds (for example >1,000m^2) and mandatory annual disclosure.
	
	– Office performance-based standard area thresholds lowered (for example >250m^2) in order to include smaller office buildings in mandatory annual disclosure.
	
	– Minimum standards and fiscal incentives for existing office buildings >1,000m^2 introduced, aligned with sector carbon budgets.
	
	– Separate minimum standards for new office buildings >1,000m^2 introduced.
	
	– Ensure metrics are consistent with In-use energy requirements within Part L, to create a consistent transition of In-use energy evaluation from Part L (design and construction) into the performance-based rating system (operation).
	
	– Minimum standards for new buildings would apply within a 24-month post-completion window once suitable occupancy level are achieved (i.e. 75%) to allow for full commissioning and performance optimisation.
	
	– Signpost minimum standards and fiscal incentives for Phase 2 sectors, to be introduced in 2030 (if not sooner).
		Phase 3 of performance policy framework implemented:
		
		– Performance-based standards for any remaining non-residential building sectors established, with suitable area thresholds.
		
		– Area thresholds for Phase 2 sectors lowered (for example >250m^2) in order to capture smaller buildings in mandatory annual disclosure.
		
		– Minimum standards and fiscal incentives introduced for Phase 2 sectors and buildings (i.e. for example other sectors >1,000m^2 and offices >250m^2) aligned with sector carbon budgets.
		
		– Separate minimum standards for new buildings in Phase 2 sectors and smaller office buildings.
		
		– Signpost to progressively tightening of all minimum standards and fiscal incentives in future aligned with sector carbon budgets.

Immediate Actions:	by 2025:	by 2030:

Domestic Building Regulations
 	
– Alongside the 2021 update to Building Regulations / Future Homes Standard, set out the Building Regulations pathway to 2030, to include:
  ○ In-use energy intensities (kWh/m^2/yr)
  ○ Thermal energy demand limits (kWh/m^2/yr)
  ○ Measures to limit peak demand and enable load shifting.
 	
– Update the National Calculation Methodology (SAP) and the EPC methodology to create a fit-for-purpose predictive methodology for energy performance of dwellings, that better reflects in-use energy performance, and establishes total Energy Use Intensity (EUI) and Space Heating demand as key metrics.
 	
– Work with industry to confirm appropriate residential in-use energy intensity targets (kWh/m2/yr) for inclusion in 2025 update to Future Homes Standard.
 	
– Improve the enforcement of Building Regulations by implementing a suitably resourced enforcement and penalty regime, with significantly increased sanctions and penalties for non-compliance, ensuring transparency and consequences where organisations do not meet obligations.
 	
– Continue the work of the SMETERS project to develop mechanisms and tools working towards incorporating In-Use energy data into the EPC methodology so that they better reflect actual measured performance.
	– 2025 Building Regulations to include:
	
	  ○ Energy intensity targets (kWh/m^2/yr) for different building typologies
	  ○ Thermal Energy Demand limits (kWh/m^2) for different building typologies
	  ○ Peak Load prediction (and ability for load shifting)
	  ○ Minimum standards for currently unregulated key energy uses that particularly influence annual and peak demand:
	  ▪ Minimum performance for cooker hobs (induction typically 60% more efficient than gas) to drive peak demand reduction.
	  ▪ Minimum performance for showers (EWL green rating) as they are largest DHW demand (e.g. max flow)
	
	  ○ Introduce initial phased implementation of prototype SMETER solutions incorporating In-Use energy data into the EPC methodology to better reflect actual measured performance.
		- 2030 Building Regulations to include:
		
		- Progressive tightening of minimum standards aligned with sector carbon budgets.
		
		- Full roll-out of SMETER solutions incorporating In-Use energy data into the EPC methodology to better reflect actual measured performance.

Policies (All Buildings / Sectors) – Stamp duty rates should be adjusted in line with the energy performance of a property (as part of wider policy across the market - see Domestic Retrofit section). – Increased availability of green mortgages with reduced interest rates for the most efficient homes to stimulate market demand for future building efficiency standards (as part of wider policy across housing market - see Domestic Retrofit section). – Enable fast-track planning approval for early adopters of future energy efficiency levels with disclosure of performance on completion. – Review Landlord & Tenant Act 1954 to require by law that all new business leases include green lease clauses. – Support the development of the right market framework to enable financial incentives for individual consumers to trade energy flexibly and improve the route to market for pricing solutions such as flexible tariffs (eg. Time of Use (ToU)).		
Government Leadership		

– Government leads by example by embedding energy performance requirements throughout procurement, with adoption of future energy performance standards on all government projects. – By 2022 Government should require minimum performance-based standards for central and local government office buildings >1,000m^2. – Guidance such as the Construction Playbook and Treasury Green Book provide increased focus on how to optimise in-use energy performance through procurement of building projects.	– Government requires minimum performance-based standards for smaller central and local government office buildings (i.e. <1,000m^2).	

8.1.2. Local Authorities / Cities - Recommendations

Immediate Actions:	Progress by 2025:	Progress by 2030:
Elevate energy and carbon performance of new development to the top of the planning agenda where climate emergencies are declared and incentivise early adopters of future standards and best practice.		
Develop and introduce planning policy to focus on: <u>Reducing energy demand</u> (% carbon reductions and fabric standards - assessed via Building Regulation) - Require % reductions on Building Regulations Part L carbon emission rates, beyond minimum standards - Prioritise a fabric first approach, i.e. requiring that thermal performance of the whole envelope exceeds that of the Building Regulations Part L notional specification by 5%. <u>Reducing energy demand</u> (total energy performance and fabric standards - assessed via suitable predictive methodologies) – Require that new homes achieve a space heat demand of <15-20kWh/m2/year, assessed using suitable predictive methodologies – Require applicants to forecast total operational energy performance, expressed as an energy use intensity (EUI), using suitable predictive methodologies, and considering realistic information on likely use, occupancy, and operation of the building. – Adopt industry targets for total energy EUIs per building use type (i.e. including regulated and unregulated energy uses) <u>Reducing peak demand</u> – Require applicants to evaluate building peak demand (i.e. maximum instantaneous energy load), using suitable predictive methodologies, and require a demonstrable effort to reduce peak demand.	All LAs to have adopted planning policy and / or supplementary guidance to focus on: – Reducing Energy demand (via Building Regs) – Reducing Energy demand (Via Energy use intensities), – Peak demand reduction, – Measuring energy performance in-use.	Progressive tightening of local planning policy targets to reflect sectoral or local carbon budgets.

Measure In-use performance (energy in use, space heating demand, peak demand) – Require applicants to demonstrate that the principles of Soft Landings will be followed via a design for performance approach. – Require achievement of certified Performance Ratings as these become available (i.e. NABERS UK for offices, forthcoming Government performance-based rating schemes). – Utilise planning conditions to monitor performance through design, construction and into operation, i.e. require pre-commencement and post-completion updates to energy use intensity (EUI) assessments and new dwellings space heating demand via condition.	Measure In-use performance (energy in use, space heating demand, peak demand) – Require major non-domestic developments (>1,000m^2) to measure and report in-use performance for the first 5 years of occupancy, using Energy Use Intensity in kWh/m2/year – Local authorities to provide an open-source and public platform for sharing energy data reported for buildings. – Require domestic developments to put in place a recognised monitoring regime to allow the assessment of energy use for 20% of the dwellings (and 90% of common parts) for the first five years of their occupancy, and ensure that the information recovered is provided to the applicable owners and the planning authority.	
Low Carbon energy supply – Require all new developments to avoid onsite combustion of fossil fuel (unless demonstrated that there is no other viable alternative). – Require developments to assess viability of onsite renewables and target solar technologies equal to 40% of building footprint area (unless it can be clearly demonstrated that this is not practical). – Require large-scale major developments to consider the integration of energy networks (accounting for site characteristics and existing cooling, heat and power demands on adjacent sites and existing networks where readily available). Any new energy networks should prioritise non-combustible, non fossil fuel energy as the primary heat source. – Require existing district heat networks to publish credible decarbonisation plans showing technical feasibility and committed investment.		
Zero Carbon balance – Develop and integrate an appropriate administration process within the authority for effective delivery and monitoring of a carbon tax fund. – Where it is clearly demonstrated that net zero carbon cannot be fully achieved through on-site measures, all developments shall be required to make a financial contribution to the LPA's carbon tax fund equal to the residual regulated emissions at a determined rate (£X/tCO2) over 30 years (residual regulated emissions calculated using Building Regulation's Part L). Alternatively, developments can make up the shortfall off-site by funding a carbon reduction or removal project directly, provided the LPA has approved this approach.	– Where it is clearly demonstrated that net zero carbon cannot be fully achieved through on-site measures, all developments shall be required to make a financial contribution to the LPA's carbon tax fund equal to the residual regulated and unregulated emissions remaining at a determined rate (£X/tCO2) over 30 years. (residual regulated and unregulated emissions calculated using a predictive methodology). – Major developments shall be required to make a financial contribution to the LPA's carbon tax fund equal to the residual upfront embodied carbon (equating to the emissions covered by Modules A1-A5 of the RICS methodology) of the development at a determined rate (£X/tCO2) at the point of completion.	– Progressive tightening of criteria going forward for assessing eligible projects and evaluating the associated impacts from the funded projects.

8.2 - BUILDINGS – EMBODIED CARBON

8.2.1 Central Government - Recommendations

Immediate Actions:	Progress by 2025:	Progress by 2030:
Embodied Carbon Regulation – Development of a regulatory policy framework tackling embodied carbon in buildings, to be delivered in phases through the 2020s, including an implementation pathway and clear signalling to industry. **Measurement & Disclosure** – Support industry standardisation of methodologies, standards and datasets. – Support the development of a national asset and product embodied carbon database (Built Environment Carbon Database (BECD): www.becd.co.uk) to assist data collection and target setting across all typologies. – Develop a freely available national embodied carbon assessment tool. – Encourage & incentivise voluntary measurement and disclosure of upfront embodied carbon for new buildings and major refurbishments. – At the next update to building regulations (**2022**), introduce mandatory measurement and disclosure of upfront embodied carbon (A1-A5) for new buildings and major refurbishments >1,000m^2, to come into force in **2023**. **Limits** – Support industry in the development of embodied carbon benchmarks and best practice standards per building sector / archetype, through data collected via the BECD. – Support industry in developing competency standards and QA processes for the assessment of embodied carbon. – Publish embodied carbon benchmarks (using standardised methodology / carbon factors) and voluntary best practice standards by **2023**. – Signpost to forthcoming initial phase of minimum standards (limits) and fiscal incentives and penalties to be introduced in **2025**.	By **2025:** – Introduce mandatory measurement and disclosure of upfront embodied carbon (A1-A5) for ALL new buildings and major refurbishments through building regualtions. – Introduce minimum standards (limits) through building regulations, plus fiscal incentives and penalties for upfront embodied carbon for new buildings and major refurbishments >1,000m^2 in building sectors with greatest asset level evidence base. – Signpost timeline for expansion to all sectors, and progressive tightening of minimum standards, in line with carbon budgets.	By **2027:** – Introduce minimum standards (limits) and fiscal incentives and penalties for upfront embodied carbon for new buildings and major refurbishments >1,000m^2 in ALL building sectors. By **2030:** – Extend minimum standards (limits) to ALL buildings in ALL sectors. – Progressive tightening of minimum standards for embodied carbon in line with carbon budget trajectories.
Government Leadership – Government leads by example by embedding embodied carbon throughout procurement, with adoption of full whole-life carbon assessment, targets, and reporting requirements on all government projects.		

– Guidance such as the Construction Playbook and Treasury Green Book provide increased focus on how to minimise whole-life carbon through procurement. – Government / Homes England require embodied carbon assessment and target as a requirement for affordable housing grant.		
Industrial Decarbonisation – Implement Industrial Decarbonisation strategy, with strategic Government investment into key interventions required, such as initial CCS clusters. – Support, investment and incentivisation for construction supply-chain decarbonisation plans.	– Deliver two carbon capture clusters by 2025.	– Deliver two further carbon capture clusters by 2030.
Circular Economy – Support and incentivise the circular economy to drive an immediate increase in material re-use. – Reduce VAT in refurbishment projects from 20% to 0% to encourage in-situ fabric retention. VAT on newbuild could be proportionally increased to make this fiscally neutral. – Set out strategy for a nationwide second-hand construction materials market. – Government to require Home Warranty providers to support sign-off process for re-used materials.	– Build on city level second-hand markets to establish a nationwide second-hand materials database for construction sites to draw from to facilitate the re-use of materials. Support and enable associated logistics and storage facilities. – Require through the national planning process / NPPF, embodied carbon assessments on buildings before permissions granted for demolition	
EPD promotion – Introduce incentives and requirements for manufacturers to declare impacts of their products via EPDs (to EN15804 & 3rd party verified). Determine minimum thresholds and provide financial support for SMEs. – Government to provide grant funding and / or broker Venture Capital Fund for low embodied carbon materials to fund progression through BBA, Council for Mortgage Lender and Home Warranty certification process.		

8.2.2. Local Authorities / Cities - Recommendations

Immediate Actions:	Progress by 2025:	Progress by 2030:
Elevate embodied carbon performance of new development to the top of the planning agenda where climate emergencies are declared.	Incentivise early adopters of future standards and best practice.	
Develop and integrate planning policy requirements focussed on whole life carbon and upfront embodied carbon, re-use and circularity: **Whole-life and Upfront Carbon, Re-Use and Circularity:** – Require all developments to demonstrate design stage actions taken to reduce embodied carbon and maximise opportunities for reuse through the provision of a Circular Economy Statement – For application sites with existing buildings, use the Circular Economy statement review, and the determination process to critically appraise the need for demolition, and seek the re-use of foundations / superstructure to as great a degree as possible wherever feasible / viable (noting that sub/structure is typically c.50% of upfront embodied carbon). – Major developments (>10 dwellings or >1000m^2) shall calculate whole lifecycle carbon emissions (A-C) and upfront embodied carbon (A1-A5) through a nationally recognised Whole Lifecycle Carbon Assessment methodology (i.e. RICS PS Whole Life Carbon methodology) and demonstrate actions taken to reduce lifecycle carbon emissions. – Monitor any performance change via updated final As-Designed and As-Built embodied carbon assessments via the discharge of conditions, i.e. require pre-commencement and post-completion updates to embodied carbon assessments (via condition).	Adopt planning policy requirements focussed on whole life carbon and upfront embodied carbon, re-use and circularity: **Whole-life and Upfront Carbon, Re-Use and Circularity:** – All developments (>10 dwellings or >1000m^2) shall calculate whole lifecycle carbon emissions (A-C) and upfront embodied carbon (A1-A5) through a nationally recognised Whole Lifecycle Carbon Assessment methodology (i.e. RICS PS Whole Life Carbon methodology) and demonstrate actions taken to reduce lifecycle carbon emissions. – Adopt targets for upfront embodied carbon (A1-A5) per building use type, for major developments, and update as per industry targets.	Progressive reduction of development areas thresholds and tightening of local planning policy targets to reflect national embodied carbon regulations, and sectoral / local carbon budgets.
Contribute to the development of national embodied carbon assessment approaches and targets, linking to industry-wide datasets. Ensure locally applied approaches are aligned with national ones wherever possible to maintain consistency and familiarity. Coordinate and share knowledge with other LA's.		
Start developing a strategic approach to refurbishment and material re-use opportunities across the LA, through the lens of re-use, circularity and embodied carbon, to ensure most efficient use of existing assets (focusing on existing sub/structure) to dampen the demand for new build.	Drive the Circular Economy via enabling local distribution hubs / frameworks. Use planning process to identify opportunities for material re-use and connect local demolition projects with new development. Develop incentivisation policies to drive uptake.	

8.3 - DOMESTIC RETROFIT

8.3.1 Central Government - Recommendations

Immediate Actions:	Progress by 2025:	Progress by 2030:
Strategy – Develop a National Retrofit Strategy (NRS) by 2022, in partnership with local government and industry. This should form a clear national homes upgrade programme, including key decisions on required energy performance standards (kWh/m2/yr) to achieve Net Zero, heating technology mix, geographic split, and a strategy for embodied carbon. Building on proposals set out in CLC National Retrofit Strategy (Dec 2020). **Policy** Demand drivers and enablers that should be considered as part of a long-term strategy include: – Technical update to the EPC methodology to create a fit-for-purpose tool for predicting actual in-use energy performance of dwellings. This will enable EPC ratings to be used as a meaningful regulatory driver in reducing emissions via domestic retrofit over the next decade. Link to updated sizing and installation guidance (i.e. MCS) for heat pumps to optimise performance. – Development of standard package solutions to achieve required energy performance standards for main house architypes, indicating preferred cost-effective fabric measures and minimum sized heat pumps. – Continue the work of the SMETERS project to develop mechanisms and tools working towards incorporating In-Use energy data into the EPC methodology so that they better reflect actual measured performance. – A clear trajectory for improving the MEES for domestic rented sector to EPC C (or equivalent under updated EPC methodology) by 2030; – A clear trajectory and regulatory framework to introduce mandatory minimum EPC rating of C (or equivalent under updated EPC methodology), for owner-occupied homes at the point of sale (with suitable caveats) by 2028; – Signpost and then establish in law a phase-out of new natural gas boilers (replacement or first-time central heating) by 2030.	– As part of NRS, establish a Central Retrofit Agency - coordinating policy makers, local authorities, housing associations, community groups, local advocates, green finance and funding experts, industry bodies and regulators, private sector partners, and existing and future retrofit customers - to fund projects, track progress, share learnings, promote innovation, and broker partnerships.	– Introduce a mandatory minimum EPC rating of C (with suitable caveats) for owner-occupied homes at the point of sale.
Driving Refurbishment at Scale – Establish mass scale, cross-tenure retrofit pathfinder projects across England led by local authorities, to establish robust retrofit delivery solutions in line with PAS2035 and create self-sustaining retrofit markets (mirroring the Optimised Retrofit Programme in Wales). This should include cross tenure street and neighbourhood trial areas and be coordinated to allow full dissemination of lessons learnt. Use principle of doubling refurbishment numbers every year.	– Clear progress in capacity building and successful pathfinder projects with lessons learnt ahead of mass roll-out.	– Accelerate and broaden mass roll-out – Roll out continues with particular focus on harder-to-treat archetypes until 2040 completion.

Immediate Actions:	Progress by 2025:	Progress by 2030:
Fiscal Incentives Develop new fiscal structure to ensure funding comes from a variety of streams recognising potential for increased tax revenue from activities and wider secondary benefits such as reduced health expenses (potentially using social value metrics such as National TOMS framework). Incentives that should be considered to drive demand for more efficient homes include: – Variable stamp duty rates adjusted in line with the energy performance of a property. House buyers would receive a lower rate discount if a property is above a certain energy efficiency rating, and an increased rate for less efficient properties, designed to be fiscally neutral. – Remove VAT on refurbishment work (i.e. 0% VAT) where energy performance improvement targets are met. – Council tax reform considering variable rates / rebates dependant on energy performance. – Direct government grants for low income households. – Incentivise banks and lenders to offer low interest mortgage extensions and loans for retrofit for landlords and homeowners, where energy performance improvement targets are met. – Review the cost differential between the taxation of gas and electricity supply for domestic customers. – Enable mobilisation of Green Finance Institute recommendations – Utilise manifesto commitments on energy efficiency investment to drive the systemic changes needed to help mobilise capital, while policies and incentives bed in to support large scale retrofit with reduced subsidy. – Work with local and regional government and private sector to establish sustainable long term, government backed retrofit funding mechanisms for all tenures to ensure everybody falls into the 'able to pay' category. – Engage in a comprehensive engagement plan to ensure all households are aware of the funding and the benefits of taking action. Work with Local Authorities and other existing community structures to establish a network of 'enabling bodies' to facilitate action.	– Adjust the gas and electricity tax regime (which currently strongly favours gas) for domestic customers, to incentivise the shift to heat-pump technology, whilst mitigating risks to those in fuel poverty. – Update the Treasury Green Book to recognise the fiscal benefits of the impacts on society and the Treasury of a net zero carbon healthy housing stock. NHS costs, inward investment, increased tax returns from a new economic sector attractiveness of better housing, levelling up agenda etc. – Long term and binding energy efficiency funding commitments to 2040.	

Immediate Actions:	Progress by 2025:	Progress by 2030:
Skills and Businesses – Create a national retrofit training and skills strategy, scaling up rapidly to meet emerging demand, working with trade associations within the home repair, maintenance and improvements (RMI) market, local skills partnerships, and informed by the Government's Green Jobs Taskforce and the CITB work on Building Skills for Net Zero. – High profile promotion throughout the country with communications programme to inspire and recruit, targeting school leavers, those reskilling for career change in declining sectors and existing construction workers in need of upskilling. – Incentivise and enable routes into domestic retrofit for those with transferable skills, including into Retrofit Coordinator role. – Provide business and education support in the form of a guaranteed pipeline to enable the transition away from traditional approaches and rapid expansion of market delivery capability. Incentivise and support firms to take on new apprentices. – Update apprenticeship and training standards to align with the required the retrofit delivery programme, optimising digital skills.	– Provide necessary support to industry bodies to train and upskill workers in retrofit capacities.	
Building Renovation Plans – Support the development of digital building renovation plans or 'passports' (in conjunction with industry) that inform evidence-based, retrofit pathways for existing building stock varieties and are held within a central property database. Based on an agreed standard, these would contain survey information, EPC input data, energy in-use data, and other relevant data such as location, occupancy, ownership, etc.	– Rollout of building renovation plans across local and regional areas.	– Widespread use of building renovation plans for all existing building retrofits
	Whole Life Carbon – National Retrofit Agency to work with industry bodies to introduce measurement of WLC within domestic retrofit projects. – Introduce requirement in retrofit funding schemes (ECO etc) for EPD collection and / or embodied carbon assessment on installations. – National Retrofit Agency to evaluate retrofit packages per house architype to identify packages with greatest emissions reduction potential for further focus (i.e. insulation, heat-pumps)	– Introduce targets for whole life elemental carbon reductions (product level, standards)

8.3.2 Local Authorities / Cities - Recommendations

Immediate Actions:	Progress by 2025:	Progress by 2030:
Publish a comprehensive Local/Regional Retrofit Strategy, detailing how the National Retrofit Strategy will be implemented at local level, including local retrofit targets commensurate with overarching Local Authorities climate emergency targets.	Develop a range of financial 'offerings' to help fund the upfront cost of whole house retrofit, to cover all tenures (working with the private finance sector as necessary).	
Initiate local delivery programmes in conjunction with relevant stakeholders, developing area-based approaches for building retrofit capacity in a locally relevant way.	Develop / support One Stop Shops where multiple retrofit services are bundled together.	
Develop strategies to engage with householders & neighbourhood / community groups to deliver improvements at street / neighbourhood / community levels, putting them at the centre of all decision making based on a clear understanding of motivations.		
Undertake local area-based retrofit pathfinder projects to de-risk investment, win hearts and minds and provide exemplars to showcase.	Feed learning from pathfinder projects into continuous roll out of mass scale retrofits	
As part of pathfinder projects, develop regional upskilling programmes that apprentice young people and those moving from other sectors with trusted contractors to develop net zero retrofit skills. Include identifying gaps in education provision for those coming into trades from other routes.	Skills supply pipeline fully defined and operational.	
Deliver deep retrofit on social housing, developing ambitious targets (based on kWh/m2 space heating targets beyond EPC B) for local authority and registered provider owned social housing provides an opportunity to immediately stimulate the supply chain.		

8.4 - INFRASTRUCTURE

8.4.1 Central Government - Recommendations

Immediate Actions:	Progress by 2025:	Progress by 2030:
Strategy – As part of the National Infrastructure Strategy, develop a Net Zero Infrastructure Plan for transitioning the UK's economic infrastructure networks to net zero. – Mandate for PAS 2080 (or equivalent standard) to be fully implemented across all Infrastructure projects by 2025 – Develop an Infrastructure Skills Plan to ensure the UK has the capability within the built environment sector for the transition to net zero should be delivered – Set requirement for all regulators to develop an explicit first-order objective to support the transition to net zero by 2050.	– Create the role of a National Infrastructure Integrator to enable holistic decision-making across UK infrastructure planning with full visibility of carbon impacts – PAS 2080 (or equivalent standard) fully implemented across all Infrastructure projects by 2025 – Infrastructure Skills programme developed and agreed with industry and academia – 80% of all regulators to have developed first-order objective to support the net zero transition.	– 100% of all regulators to have developed first-order objective to support the net zero transition.
Policy – Review and reform the Green Book to better reflect the net zero target in project appraisals and assessments. – Review green book targets and new environment bill to encourage Nature Based Solutions for securing adaptation and carbon mitigation, and to deliver biodiversity gain within planning assessments. – Incorporate carbon accounting into the national planning policy framework (NPPF) to ensure net-zero is consistently included in all areas of national policy – Implement all 'no-regrets' actions which can be adopted immediately across all areas of infrastructure emissions impact (i.e. including transport sector user carbon). For example, adopt a zero-emission policy for vessels at berth in ports and harbours in the UK. – Support the collection and development of industry data for embodied and WLC carbon to be used across the infrastructure industry and allow a common reference for baseline and reduction targets on infrastructure projects (for example; Built Environment Carbon Database (BECD): www.becd.co.uk).	– Carbon explicitly accounted for in GreenBook review of major infrastructure schemes – Planning Policy guidance implemented nationally	

Procurement – The Infrastructure and Projects Authority (IPA) to commit to the CSIC Carbon Reduction Code which includes integrating carbon reduction targets and reporting commitments explicitly in all procurement documents from 2021. PAS 2080 (or equivalent standard) is to be used as the reference document for this. – The IPA sets out plans to meet net zero by 2045, including annual targets, recognising that the majority of reduction needs to be made by 2030. Plans to be published along with annual progress updates.	– To enable transparency and accountability across government, undertake and publish carbon emissions assessments for all public sector policies, including major infrastructure projects or investments. – Infrastructure and Projects Authority to review carbon reduction progress and trajectory towards 2030 target.	– Infrastructure and Projects Authority to reduce direct and indirect (Scope 1, 2 and where appropriate Scope 3) carbon emissions by at least 75% by 2030.
Immediate Actions:	**Progress by 2025:**	**Progress by 2030:**

Industrial Decarbonisation (CCUS & Hydrogen)
– Support the CCUS and Hydrogen strategies laid out in the Industrial Decarbonisation Strategy and Ten Point Plan for a Green Industrial Revolution.
 	
– Progressing a full-scale CCUS and hydrogen network must be a strategic Government priority to ensure competitiveness is maintained during the transition to net zero carbon material production. Government assistance should cover both capital and operational cost increases and progress via:
 	
  ○ Developing a supportive policy framework: To provide the right structure for inward investment.
 	
  ○ Eliminating the risk of carbon leakage: To ensure that the preferred option is local decarbonisation and not product imports.
 	
  ○ Choosing local: A market for 'carbon captured' products produced in the UK, through standards or Government procurement, will help drive investment.
 	
  ○ Accessible infrastructure: Access to CO_2 transport and storage (T&S) facilities for all industrial plants, including remote or isolated plants.
 	
– Support, investment and incentivisation for other construction supply-chain decarbonisation plans.
	– Hydrogen Hubs and Investment strategies identified strategic locations across the UK to enable CCUS, Hydrogen Generation and distribution networks to enable transition to low carbon fuels for infrastructure (in use)
	
	– Deliver two carbon capture clusters by 2025.
		– Deliver two further carbon capture clusters by 2030.

Research – Bring together public sector funders to develop a programme of public sector research and innovation investment to achieve net zero, including developing a living technology roadmap to set out which technologies are truly ready to deploy and how effectively they will reduce carbon emissions. This body should have a level of authority to influence spending decisions across departments, influence the strategic direction of UKRI programmes and set out opportunities for leveraging business activity	– Review funding marketplace – Influence marketplace to align with Net Zero Agenda – Advertise innovations – Greater uptake across industry	

Financing – Establish a national infrastructure investment bank (successor to the Green Investment Bank), with an explicit mandate to support the transition to net zero, to help manage risk, partner with the private sector, and bring down the cost of finance. This bank should be able to carry the risk of implementing immature net zero technologies where the client, designer, contractor, supplier may be unable to carry risk levels.		

8.4.1 Local Authorities / Cities - Recommendations

Immediate Actions:	Progress by 2025:	Progress by 2030:
– Introduce planning policy to ensure WLC impacts of infrastructure projects are quantified at planning stage		
– Prepare and publish Local Energy Plans with their Distribution Network Operator (DNO), neighbouring authorities and across their wider climate and energy partnership to assess an area's energy demands		
– Implement training and capacity building to deliver Net Zero within the local authority and with key suppliers and contractors. Make Climate Change central to Elected Member and Senior Director training		
– Conduct policy and service reviews to align policy, spending and functions with Net Zero, including developing project and financial appraisal systems that include WLC and climate impacts for assessing infrastructure projects, and standardised reporting		
– Local Plans and Transport Plans to introduce policies to support walking, cycling and public transport, including ensuring walking and cycling infrastructure are prioritised at the masterplanning stage, e.g. setting maximum car parking spaces, or introducing a workplace parking levy	– Implement Low Emission and Clean Air Zones and Air Quality Management Areas to reduce polluting traffic – Use parking powers (Traffic Regulations Orders) to repurpose parking spaces for car clubs, cycling parking and EV charging and scale parking charges to promote use of public transport – Prepare and publish a Local Cycling and Walking Infrastructure Plan that takes into account recommendations in the Gear Change report	

– Identify Low Emission and Clean Air Zones and Air Quality Management Areas, and develop an implementation strategy for incorporation		
– Use NDAs with private utilities to encourage data sharing and develop trust.		

Stakeholder Action Plan

9.1 - NGOS / Trade Associations / Professional Institutions

Immediate Actions:	Progress by 2025:	Progress by 2030:
Professional Institutions to: - Embed low carbon advocacy and competency across all current and prospective built environment professionals. - Work to agree a coherent approach to the development, adoption, approaches and methods for monitoring in-use performance of buildings - Introduce incentives and review professional requirements for their members to carry out in-use energy performance monitoring, evaluation, and reporting. - Support use of whole life carbon (and other environmental impacts) as design criteria and to drive design decisions. - Adopt and promote standard metrics for monitoring and reporting embodied carbon (for both buildings and infrastructure projects). - Establish a requirement for use of EPD databases in the design process (Built Environment Carbon Database (BECD)) - Integrate retrofit competency requirements within professional qualification criteria. - Work with wider industry to develop BIM-based building passports dealing with build quality, build standards, embodied and operational carbon.	Professional Institutions to: - Review accreditation of relevant degrees and training courses, and set core topics to be covered in each programme - Adopt and update CPD requirements for climate issues, net-zero skills and competences for their members. - Include threshold carbon literacy and carbon competence tests, entrance requirements & member assessments. - Agree and adopt a shared cross-industry Climate Framework Curriculum - Develop benchmarks and case studies to support the development of guidance and targets and to track progress. - Develop a performance and disclosure culture across professional service firms, their clients and supply chains. - Support the development of performance-based rating systems for in-use energy in buildings - Support the uptake of Building Passports.	Professional Institutions to: - Develop and progress professional requirements in line with requirements of sector carbon budget.
Establish a central database (Built Environment Carbon Database (BECD): https://www.becd.co.uk) for embodied carbon (asset and product level) to gather data across the industry, standardise inputs, and help set benchmarks and targets per sector.		
Set strategy for Net Zero Carbon verification and certification scheme	Certification scheme for net zero carbon buildings established, to include operational and embodied carbon performance standards.	Net Zero Carbon performance standards to be reviewed to ensure they align with sector carbon budgets.
Trade associations work with apprenticeship programmes to develop strategies to build capacity in order to meet significant increase in future domestic retrofit demand.	Trade associations developed skills base for domestic retrofit programme, via: retraining programs for gas fitters; PAS 2035 retraining programmes for project managers and cost consultants; ongoing incorporation into CPD programmes; wholesaler information provided for proper use of products, etc.	
Green Building Certification Schemes such as CEEQUAL and BREEAM update minimum standards for highest rating levels to align with industry NZC metrics for operational energy performance and embodied carbon (i.e. shift to absolute performance metrics instead of comparison studies).	Green Building Certification Schemes aligned with NZC targets.	
All industry awards to include disclosure of Carbon / Energy, with consideration as part of judging	All industry awards include carbon performance as key judging criteria	

9.2 - Investors (banks, funders, etc)

Immediate Actions:	Progress by 2025:	Progress by 2030:
Include energy performance-based rating system and upfront embodied carbon targets in project funding criteria	Mandate operational energy and embodied carbon assessments in project funding criteria	Project funding criteria based on validated past performance of projects, as well as targets for the project seeking funding
Require Climate-Related Financial Disclosure (TCFD) reporting	Recommendations from the BEIS consultation on mandatory climate-related financial disclosures are fully implemented	
Develop finance solutions and packages for accelerating domestic retrofit, informed by workshops with local authorities to discuss options for all tenure retrofit funding packages (drawing on recommendations the UKGBC GFI round table and Green Finance Institute)	Offer a range of finance solutions for domestic retrofit, suitable for different domestic tenures, including 'blended finance packages' which combine funding from private and public sector.	
Require all domestic loan scopes to cover whole house retrofits	Predicate home repair loans on energy efficiency improvements and performance	Work with domestic clients to assess actual energy performance of domestic buildings
Provide increased home mortgage lending for retrofit measures and reduced rates of interest for highly efficient properties	Offer preferential mortgage rates based on home energy efficiency for new and existing buildings	
Develop stricter guidance on what constitutes a net zero non-domestic building for the purpose of lending, based on the UKGBC Net Zero Carbon Buildings Framework Definition	Begin offering preferential borrowing rates for low to zero carbon retrofits that actively demonstrate how they reduce whole life carbon	
Institutional investors based in UK begin disclosing the operational energy and carbon performance of all held properties (at asset level) across their portfolios (Funds) in annual reporting	Investors to ask for Green Building Passports/and to engage with existing benchmarking frameworks as a requirement for assessing investment potential	All properties have building passports
Investors and lenders to align decision making with performance-based ratings for commercial buildings and away from EPCs		

9.3 - Developers

Immediate Actions:	Progress by 2025:	Progress by 2030:
Implement NZC skills and training plans to establish a baseline degree of carbon literacy across all staff	Maintain skills and training, and update where necessary to reflect evolving NZC requirements, to ensure all staff have high levels of carbon literacy	
Establish WLC as a first order consideration within initial site development appraisals (refurb / extend / new build)	Assess, as standard, development appraisals with WLC impacts as key determinant i.e. prioritise brownfield development, sustainable transport solutions, and local economies	
Establish a NZC client brief which: - Includes targets for energy intensity metrics for all projects in line with industry / sector targets - Embeds an outcome focused "design for performance" approach through design and procurement. - Includes embodied carbon targets (A1-A5 and A-C) and material re-use targets - Establishes WLC as a primary decision-making metric to be evaluated at each RIBA Stage	Set carbon performance KPIs across all RIBA Stages	
Work with contractors to set operational and embodied carbon reduction targets, procure materials with EPDs (EPD A-D to EN15804 & externally verified), require mandatory disclosure of supply chain data, and track construction site emissions	Aim for at least 40% of products and materials used in building projects to have EPDs,	100% of products and materials have EPDs

Engage contractors during the design phase so that the design team and supply chain can collaborate to develop cost-effective low-carbon solutions to embed into the project before procurement and construction commence		
Establish internal shadow carbon price mechanisms to embed climate risks within investment evaluations	Embed net zero metrics within corporate KPIs and executive remuneration mechanisms	
Share asset level WLC data via industry-wide central embodied carbon database (BECD) to expand datasets, evidence base, and support development of Embodied Carbon targets	All developers commit to industry-wide WLC reduction targets for majority of projects, based on accurate datasets	All new projects completed after 2030 are net zero carbon i.e. at least achieve energy intensity and WLC targets
Ensure carbon is evaluated alongside cost in all value engineering exercises		
Provide NZC pathways to demonstrate how projects can achieve future NZC performance standards (i.e. via tenant fit-out or building operation)		
Engage with local authorities to support city-level second-hand materials markets to drive circularity and material re-use		
Support industry, NGOS and central government in the development of energy performance-based rating systems		

9.4 - Landlords / Owners

Immediate Actions:	Progress by 2025:	Progress by 2030:
Commercial landlords to establish net zero carbon strategy for procurement and operation of commercial real estate, including base-build performance requirements, portfolio-wide strategies for transition away from fossil-fuels, and steps to reduce landlord energy usage		
Commercial landlords carry out POE on all projects delivered in last 5-years to evaluate performance, rapidly improve industry datasets, generate feedback loops and support the formation of new performance-based rating systems	Support development of improved industry datasets and evidence base for performance outcomes	
Commercial landlords to ensure plans are in place for in-use energy monitoring and reporting in entire building portfolio Commit to sharing energy data regularly and transparently with all tenants, and engaging and working with occupiers to minimise operational energy and disclose on an annual basis the operational performance of assets	Disclose servicing / maintenance arrangements by way of embodied carbon impacts (to better understand B1-B5 EN15978 module emissions) (to include refrigerant leakage) Clear asset plans in place to reduce operational energy usage	Provide annual carbon reporting for retrofit, replacement and maintenance work alongside operational energy / carbon reporting from 2025 onwards
Commercial landlords to work with industry bodies to develop/review existing green lease templates for all commercial sectors	Promote the uptake of green leases by working with potential occupiers to establish how the lease could benefit all parties; clearly demonstrate how the progress and outcomes of the lease will be followed up on during the occupier's tenancy	From 2025 onwards, green leases to be included as standard practice
Commercial landlords to start tracking buildings through green building passports to ensure they are working as intended	Work with professional bodies to promote the uptake of green building passports	By 2030, all buildings within commercial portfolios include building passports
Commercial landlords to include incentives for improved energy management within non-domestic FM contracts and require condition-based maintenance approach rather than standard PPM		

Social landlords to develop high level roadmap for decarbonisation of building stock that sets out financial provision and funding mechanisms for retrofits, engaging fully with local regeneration and housing decarbonisation opportunities provided by Local Authorities and Central Government	Have decarbonisation plan in place and first retrofit demonstrators completed, ready to implement lessons in further scaling up (note that this is strongly contingent on policy, regulatory, technology and funding mechanism provided by the Government & Local Authorities)	Retrofit programme ongoing
Social landlords to establish current carbon footprint, accounting for operational in-use and embodied carbon impacts (i.e. maintenance and repair)	Support decarbonisation business planning through technical assistance and clarity on finance models and recharge mechanisms	
Social landlords allocate a % of funds for establishing a new retrofit programme (funds could go nominating a responsible person in post for the decarbonisation of housing stock, contracting PAS2035 assessments as basis for surveying building stock retrofit needs, etc.)		
Social landlords to engage customers (tenants) in the retrofit imperative (including carbon literacy training for employees and setting up Tenants Working Groups)	Social landlords to work with local authorities to develop detailed retrofit plans by archetype, as part of area-based approaches to retrofit and 'One-Stop Shops'	Retrofit programme ongoing
Private rented sector (PRS) landlords allocate funds to assessing energy efficiency of property portfolio (using PAS 2035) and developing a medium-term improvement plan to meet EPC B. PRS landlords to engage with managing agents and leaseholders to develop and fully cost a block wide plan to improve every property to band B. PRS landlords to engage with managing agents and leaseholders to increase the use of green energy block wide and drive energy consumption reduction through resident action	Retrofit works on properties in full progress (doubling each year)	
PRS sector to work together to access 'trusted trader offer' for energy efficiency and low carbon technologies installs and repairs		
Landowners (MOD, NR, HE, Water utilities etc) set out plans to incorporate climate resilience / enhancements and carbon offsetting within the upkeep and operation of their estates to support their own Net Zero objectives		

9.5 - Occupiers

Immediate Actions:	Progress by 2025:	Progress by 2030:
Establish net zero carbon strategy for procurement and occupation of commercial real estate, including base-build performance requirements, moving away from fossil-fuels, and steps to reduce unregulated energy uses and embodied carbon of internal fit-outs	Make public commitments to only taking 'green leases' or occupying low carbon spaces (for instance, NABERS rated buildings, fossil fuel-free, provision of 100% additional renewable energy, etc)	
Establish an NZC occupier brief for all fit-out projects (and any new builds) including targets for embodied carbon and tenant energy intensity in line with industry targets	Commit to net zero fit out on all Full Repairing and Insuring leases	All fit outs are net zero
Ensure embodied carbon assessments are undertaken as part of an LCA on major Fit-out projects and internal works, and begin sharing embodied carbon data with industry carbon databases (BECD) to support development of industry targets	Provide embodied carbon assessment data for all projects to carbon database (BECD)	
Work with landlords to develop mutually beneficial green leases	Only occupy buildings with green leases	

All business occupiers commit to sharing energy data regularly and transparently with landlords Full Repairing and Insuring (FRI) building occupiers commit in aligning with the NZ pathway and operation of the building, as this is set-out by the asset-owner - on top of data sharing	Publish consumption rates and adopt targets for energy intensity in occupied spaces	Only occupy buildings that achieve net zero operational energy targets
Collaborate with landlords to shift to low-carbon heating technologies, install on-site renewable energy solutions (where possible) or procure 100% off-site renewable energy that creates additionality		

9.6 - Facilities Managers / Maintenance

Immediate Actions:	Progress by 2025:	Progress by 2030:
Implement skills and training plans for all students and staff to understand energy targets and plant maintenance requirements for net zero archetypes	Undertake accredited training for all staff to deliver optimal building service management	
Commit to assessing, monitoring, and implementing building performance plans, set against energy use reduction targets over time, including clear plans for ongoing engagement with end users/occupiers		
Incorporate data associated with operational carbon, embodied carbon, and building / infrastructure lifecycles within the ongoing management of existing / future assets to drive low carbon decisions	Managers adopt building passports	
Share learnings from maintaining / operating net zero assets to inform future projects and retrofits, including the submission of operational and embodied carbon data into a centralised data base to inform new projects		
Advocate for earlier involvement in the design and renovations process to ensure the project brief is informed by aftercare and vice versa	Managers are advocates for net zero carbon buildings	

9.7 - Contractors

Immediate Actions:	Progress by 2025:	Progress by 2030:
Develop and implement training and capacity building to deliver Net Zero internally and with key suppliers and sub-contractors, supported by Professional Institutions, covering all pertinent sources of emissions during the construction process - establishing baseline carbon literacy across staff - transport and site (modules A4-A5) & upfront carbon issues - closing the energy performance-gap - ensuring sub-metering is fully operational - processes for avoiding demolition and facilitating deconstruction to optimise reuse of materials	Contractors are carbon competent in delivering low carbon solutions, with knowledge embedded in CPD and training programmes	
All contractors track construction site emissions - measuring and monitoring all emissions from transport (A4), construction processes (A5), as well as materials quantities brought on to site and material wastage rates. Site carbon data should inform the project's carbon assessment and be fed into an industry database (BECD)	All contractors require at least 50% of on-site construction (construction vehicles and processes) to be fossil fuel free (transition to 100% by 2030), including elimination of use of red diesel onsite (use electric plant and equipment, hydrogen power or biofuel from waste)	Zero emissions from on-site activity / All construction sites are highly resource and energy efficient and, along with site-related transport processes, are powered by renewable energy (WorldGBC)
Work with supply chain to set operational and embodied carbon reduction targets, require mandatory disclosure of supply chain data, track construction site emissions, and request EPDs (EPD A-D to EN15804 & externally verified) from all supply chains (driving towards 40% of all products by 2025)	EPDs declared for 40% of construction materials and products used in supply chain	All contractors have declared 100% of supply chain products and materials via EPDs. i.e. 100% EPD by 2030
Include carbon reduction targets and reporting commitments explicitly in all documents, as a deliverable of the construction process, using PAS 2080 (or equivalent standard)	Share 'good/best practice' case studies from using PAS2080. 80% of projects achieve PAS 2080 verification (or equivalent standard)	100% of projects achieve PAS 2080 verification (or equivalent standard)

Increase investment (time and / or cost) in low carbon innovation, including role of MMC and DfMA approaches		
Ensure robust systems are in place to ensure quality standards and mitigation of performance gaps		
Carry out detailed pre-refurbishment and pre-demolition audits, to ensure that existing materials can be kept at their highest value. Provide material resource and disassembly plans for completed buildings.	Register of assets as material banks available and design for deconstruction common place	
Engage in the design stages to work with designers to de-risk low carbon designs, ensure buildability and optimise procurement		
Domestic contractors to assess existing retrofit capabilities and develop a skills training and recruitment plan for PAS 2030/2035 to guarantee retrofit supply chain capacity, including providing support for upskilling experienced tradespeople	Training and upskilling of employees in domestic retrofit is ongoing	All domestic contractors are retrofit-ready
Tier 1 contractors to achieve verification of their carbon management processes to PAS 2080, or have a verified carbon management and reduction plan accredited to ISO14064 or equivalent		

9.8 - Material & Product Manufacturers

Immediate Actions:	Progress by 2025:	Progress by 2030:
All manufacturers and suppliers commit to their specific industry roadmaps, or publish their own, which include carbon reduction targets, investment required, and timelines to NZC	Investment committed to major industry supply chain decarbonisation roadmaps	All electricity is from renewable or low carbon sources (manufacturing and transport)
All manufacturers begin developing EPDs for product portfolio, aiming for a minimum of A1-A5 + C + D (EN15804 and externally verified) and working towards 40% by 2025, with minimum thresholds and support and subsidies for SMEs	All manufacturers have declared the embodied carbon of the top 40% of their standard product portfolio by carbon footprint via EPDs	All manufacturers have declared their entire standard product portfolios via EPDs. i.e. 100% EPD by 2030
All manufacturers and suppliers to develop embodied carbon reduction plans for their products and operations, focusing on reducing materials and energy usage, manufacturing waste, packaging and transport needs	Increased availability and utilisation of take-back and refurbished product schemes	Re-used material usage widespread
Contribute to central industry database (BECD) capturing embodied carbon at product level through EPDs (EPD A-D to EN15804 & externally verified)	Develop material passport standards, tools and databases, with support of industry bodies	Material passports established and adopted by industry
Product suppliers to provide enhanced support, technical guidance and training for product installation to help ensure construction quality and overcome performance gap	Develop products to support the Future Building Standard (at a minimum) and embodied carbon reductions	
Key supply chains for domestic retrofit (heat-pumps, insulation) conduct market analysis (with support of newly formed Retrofit Agency and local delivery programmes) to better understand demand, forecast material needs, and guarantee capacity to scale up whilst minimising embodied carbon of expected products	Embodied carbon reduction plans established for key supply chains for domestic retrofit, minimising emissions from expected products.	Robust low carbon supply chains for domestic retrofit

9.9 - Architects

Immediate Actions:	Progress by 2025:	Progress by 2030:
Implement NZC skills and training plans supported by professional institutions to establish a baseline degree of carbon literacy across all staff	All qualified architects are carbon competent, with knowledge embedded in CPD and RIBA Membership criteria	All Architects are key change agents, challenging project teams and clients to achieve lowest carbon design strategy at each RIBA stage

Carry out high level WLC estimates as part of initial site appraisals (refurb / extend / new build), identify and advocate for lowest WLC option.	WLC assessments and carbon impacts used as the key driver to inform design strategies throughout the project lifecycle (RIBA stages 0-7). Provide clients with low carbon or net zero carbon design options as standard at early design stages	
Establish energy intensity and WLC targets in project briefs for all projects in line with industry / sector targets	Embrace new and innovative low carbon materials and processes to achieve WLC targets.	
Domestic architects assess existing retrofit capabilities to develop a skills training plan for PAS 2030/2035, including providing support for experienced designers to upskill	Use WLC results to inform decisions on material selection and specifications	All domestic architecture companies are trained in providing low carbon retrofits
Wherever possible, advocate and design for re-use and retention of existing building structure / substructure, including asking engineers to proactively propose lower carbon solutions	Achieve energy intensity and WLC targets for majority of projects, with as built verification in place to limit any performance gap.	'Retrofit first' mindset and prioritisation of material reuse becomes standard practice
Carry out POE on all projects delivered in last 5-years to evaluate performance, rapidly improve industry datasets and generate feedback loops		
Promote and learn from current pathfinder project adopting low carbon construction materials at scale.		

9.10 - Building Services Engineers

Immediate Actions:	Progress by 2025:	Progress by 2030:
Implement NZC skills and training plans supported by professional institutions to establish a baseline degree of carbon literacy across all students and staff	All Building Services Engineers carbon competent, with knowledge embedded in CPD and PI Membership criteria	
Build capacity in undertaking detailed operational energy assessments to elevate competencies and improve quality of energy assessments	Elevated industry competence and skills in operational energy forecasting, across all building types	Leading expertise in operational energy forecasting, across all building types
Proactively work with developers and building owners to carry out POE on all projects delivered in last 5-years to evaluate performance, rapidly improve industry datasets, generate feedback loops and support the formation of new performance-based rating systems	Support development of improved industry datasets and evidence base for performance outcomes	
Adopt and embed a "design for performance" culture across all project types and scales: - Work with developers to establish energy intensity targets in project briefs for all projects in line with industry / sector targets - Carry out operational energy assessments to an appropriate level of detail on all projects through all RIBA Stages, to inform design, procurement, handover and operation - Implement effective handover procedures on all projects in line with Soft Landings - Advocate for the measurement of in-use energy monitoring and performance and support initial optimisation of buildings in first 2 years post-handover	Publish results of operational energy and whole life carbon assessments on an anonymised basis; comparing design calculations with verified operational performance to support industry development	Performance gap eliminated
Improve understanding of WLC impact of typical MEP installations, build capacity in undertaking WLC assessments, and push supply chains to provide EPDs (EPD A-D to EN15804 & externally verified) and improved embodied and potential operational carbon data	Carry out embodied carbon assessments of building services systems on all projects through all RIBA stages, to inform design and procurement, and achieve industry targets for embodied carbon intensity	Low embodied carbon MEP design becomes the norm.

Adopt and support the development of industry project targets and commit to presenting design options for how these can be achieved on all projects	Ensure all designs are 'net zero ready' - with upgrade pathways identified to avoid significant future retrofit	
Commit to identifying the lowest Whole Life Carbon approach for every project	Champion the lowest Whole Life Carbon approaches on all projects	
Work collaboratively to challenge industry norms, reduce over-specification and enable leaner design	Improved industry specifications and standard practices.	

9.11 – Structural Engineers

Immediate Actions:	Progress by 2025:	Progress by 2030:
Implement NZC skills and training plans supported by professional institutions to establish a baseline degree of carbon literacy across all staff	All structural engineers carbon competent, with knowledge embedded in CPD and PI Membership criteria (i.e. structural engineers able to offer low carbon solutions as part of a standard scope of works)	
Build capacity in undertaking whole life carbon assessments using industry tools to elevate competencies and enhance quality of structural WLC assessments	Elevated industry competence and skills in WLC assessment of structural designs across all building types.	
Undertake and present WLC estimates for different structural solutions at concept design stage on all projects	Embodied carbon assessments carried out for structural design on all projects through all RIBA design stages as one of the primary decision tools in design and procurement.	
Promote and learn from existing pathfinder projects adopting low carbon construction materials at scale	Innovate structural design to embrace low carbon construction materials. Support industry to work through delivery challenges in order to mainstream adoption	
Enable market circularity through training structural engineers in conducting pre-demolition audits, identifying re-use and retention opportunities, and designing for disassembly (i.e. the future re-use of building products and materials	On all projects, proactively identify opportunities to utilise re-used structural elements and design for disassembly, and advocate for maximum re-use of existing building structure / substructure. (if structures must be demolished, advocate for controlled deconstruction over demolition to maximise reuse potential of structural components)	Re-used material usage widespread
Work collaboratively to challenge industry norms, reduce over-specification and enable leaner design. Proactively propose solutions to the design team and client, that maximise efficiency of structural configuration (well-proportioned beams, short spans, direct axial load paths, etc) on all projects.		

9.12 - Homeowners and Civil Society

Immediate Actions:	Progress by 2025:	Progress by 2030:
Engage with the retrofit agenda and advocate for local authorities to develop local/regional retrofit strategies	Work with LAs to set up/run 'One Stop Shops' where bundles of retrofit services and information are available in one place	Act as net zero champions and promote One Stop Shops within communities
Local groups work with LAs and local stakeholders to drive demand for area-based approaches to retrofit, prioritising integrating efficiency works with any other repairs and renovations	Each LA area has a coherent decarbonisation hub led by civic society and other retrofit industry partners, providing trusted advice and signposting	
Adopt user centric approach to building community awareness, capacity to engage in decision-making and ability to then finance and deal with installation and ongoing maintenance/repair		

9.13 - Infrastructure Clients

Immediate Actions:	Progress by 2025:	Progress by 2030:
Commit to relevant industry roadmaps, or publish their own, which includes Science Based Targets in line with 1.5 degree pathway, investment required and timelines to NZC for both new and existing assets		
Include carbon reduction targets and reporting commitments explicitly in all procurement documents, as a deliverable of the procurement process Use PAS 2080 (or equivalent standard) as the reference document for this	All clients to achieve PAS 2080 verification (or equivalent)	
Provide a carbon baseline for all projects by adopting PAS 2080 and set targets for carbon reduction against these, which will drive innovation. Include, where appropriate, financial incentives to ensure targets are met	Implement approaches to improve capabilities to measure and reduce embodied and operational carbon over the whole lifecycle of the asset and ensure carbon reduction targets remain progressive over time with industry advancements	
Provide supply chain with performance/ outcome-based specifications and commercial arrangements, where possible, ensuring outputs are not constrained to current thinking but encourage low carbon innovations	Require strategic suppliers to have science-based carbon reduction targets in line with 1.5°C net zero pathway	
	Make a public commitment via SteelZero to procuring, specifying or stocking 100% net zero steel by 2050 and an interim commitment to procuring, specifying or stocking 50% of its steel requirement by 2030	As per SteelZero commitment, 50% of steel requirements procured, specified, or stocked at net zero
Share carbon data openly via industry-wide central embodied carbon database	Commit to using an agreed industry-wide set of carbon emission factors for construction products and buildings materials that are used consistently across all infrastructure projects	

9.14 - Infrastructure Owners

Immediate Actions:	Progress by 2025:	Progress by 2030:
Owners of existing assets to commission studies on how they might best reduce operational carbon, recognising that in many cases (e.g. roads) it is the users of those assets who produce most emissions	Commit to, and disclose science-based targets in line with 1.5°C net zero pathway	
Ensure operational investment plans align with the national net zero carbon obligation, including retrofitting decarbonisation to existing asset operations and their use		
Include carbon reduction targets and reporting commitments in project briefs as deliverables of the design. Use PAS 2080 (or equivalent standard) as the reference document for this	80% of projects achieve PAS 2080 verification (or equivalent standard)	100% of projects achieve PAS 2080 verification (or equivalent standard)
Develop net zero strategies for asset system maintenance, refurbishment and low-cost upgrade (i.e. not major project), including identifying big-ticket actions for targeting reductions	Implement approaches to improve capabilities to measure and reduce embodied and operational carbon over the whole lifecycle of the asset and ensure carbon reduction targets remain progressive over time with industry advancements	
Share carbon reduction data openly via industry-wide central embodied carbon database for the purposes of benchmarking and performance improvement, and commit to sharing own best practice across the supply chain / sectors and learning from and adopting others best practice where possible	Commit to using an agreed industry-wide set of carbon emission factors for construction products and buildings materials that are used consistently across all infrastructure projects	

9.15 - Infrastructure Designers

Immediate Actions:	Progress by 2025:	Progress by 2030:
Develop and implement internal training and capacity building to deliver Net Zero as a core design and/or consultancy service		
Proactively recommend and adopt carbon measurement and carbon reduction methodologies in all projects for both design and construction, regardless of whether clients are requesting them. Use PAS 2080 (or equivalent standard as the reference document)		
Conduct Whole Life Carbon assessments for all projects above £10m	Conduct Whole Life Carbon assessments for all projects above £10m	Conduct Whole Life Carbon assessments for all projects
Include carbon reduction targets and reporting commitments explicitly from the client, as a deliverable of the design. Use PAS 2080 (or equivalent standard) as the reference document for this	80% of projects achieve PAS 2080 verification (or equivalent standard)	100% of projects achieve PAS 2080 verification (or equivalent standard)

Contribute carbon reduction data to an industry-wide central carbon database for the purposes of benchmarking and performance improvement, and to sharing own best practice across the supply chain / sectors and learning from and adopting others best practice where possible		
Actively instigate early collaboration with the client and across the value chain, including with product manufacturers and the O&M team to deliver on the carbon requirements, and inform the development of approaches and standards		
Automate production and delivery of CO_2e information through design and construction by using integrated approaches to data creation and management. This will inform optimal solutions through the build phase and streamline delivery of information to clients		