

Building on the Paris Agreement: making the case for embodied carbon intensity targets in construction

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CIEMAP

Our mission

- » *Working closely with government and industry, CIEMAP conducts research to identify all the opportunities along the product supply chain that ultimately deliver a reduction in industrial energy use*
- » One of 6 RCUK funded centres focussing on end use energy demand in the UK
- » Interdisciplinary team from the universities of Leeds, Bath, Cardiff and Nottingham Trent, plus contributions from the Green Alliance



Centre for Industrial Energy, Materials and Products

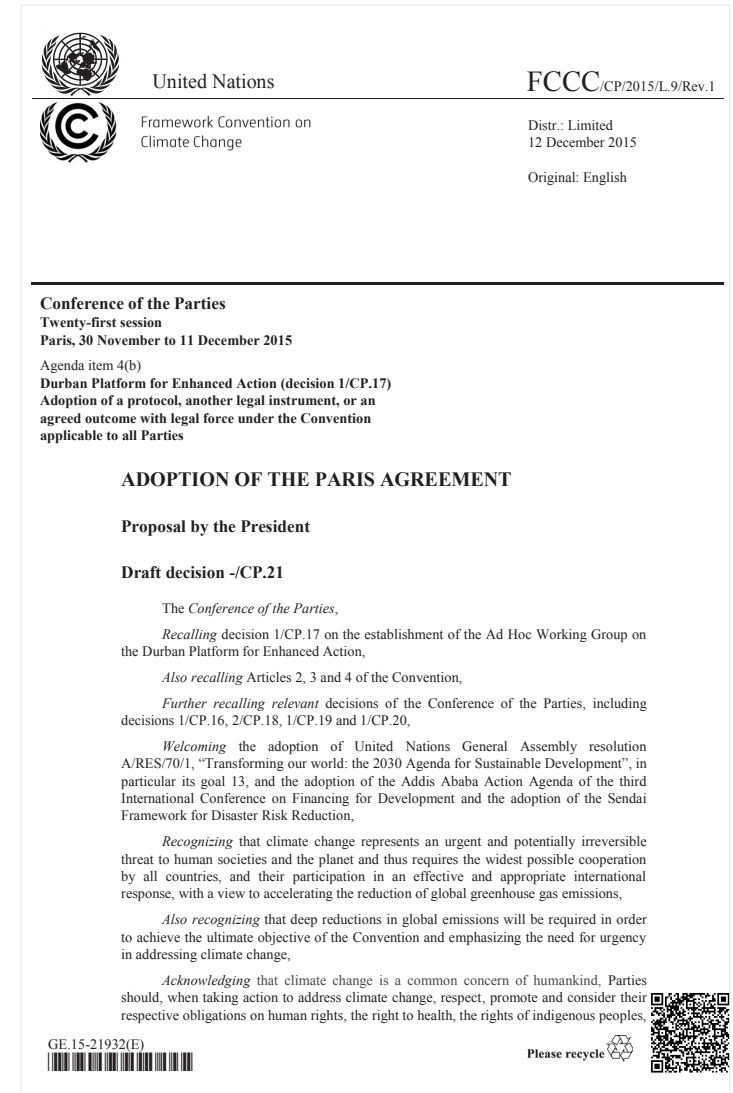
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Paris Agreement on climate change

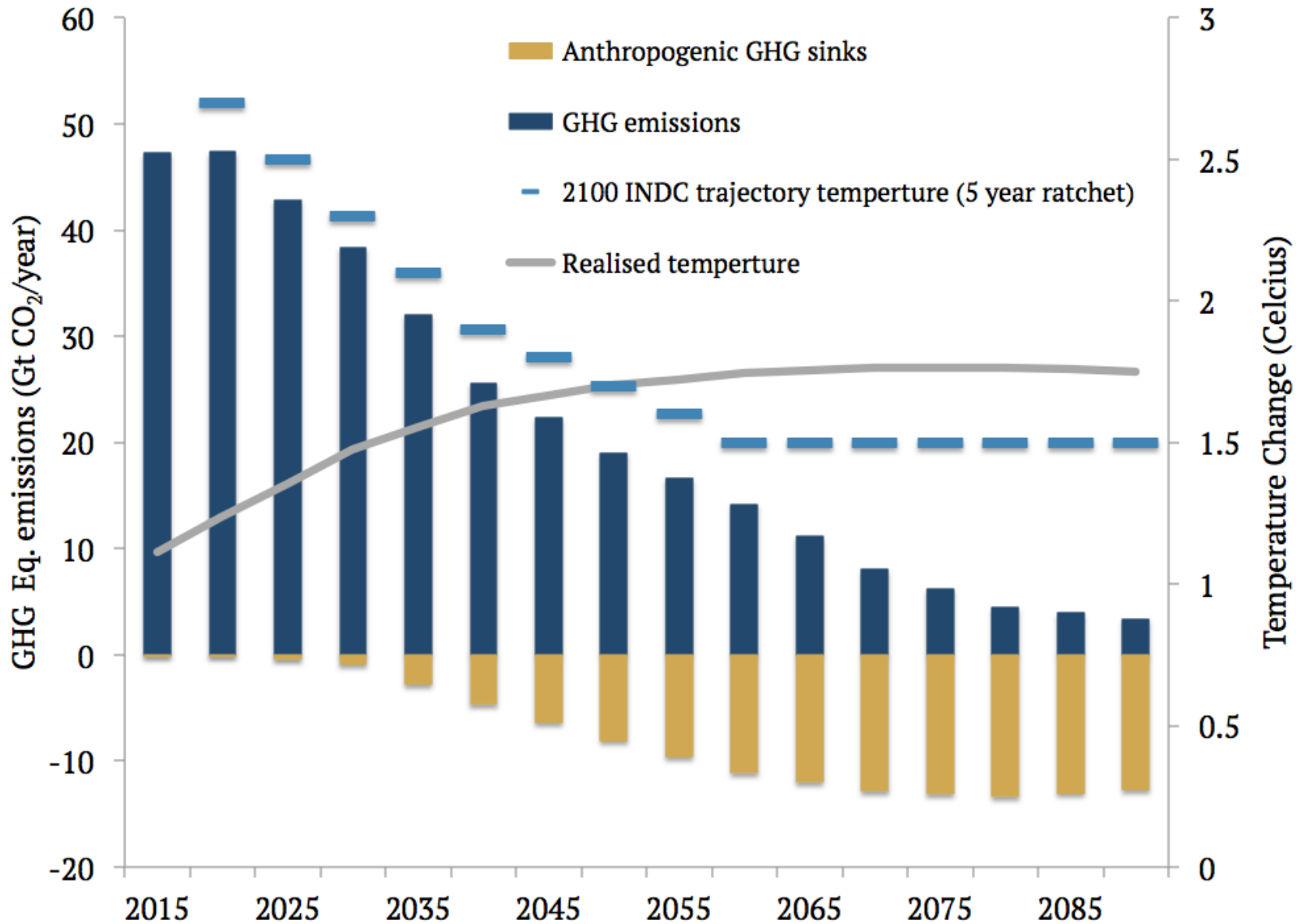
Global agreement in December 2015

- » Commits to *“holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels”*
- » With goal of achieving *“a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century”*
- » Commits parties to global stock-take and ratcheting up of ambitions every 5 years
- » Signed by 180 parties, ratified by 26 so far (representing 39% of global emissions)



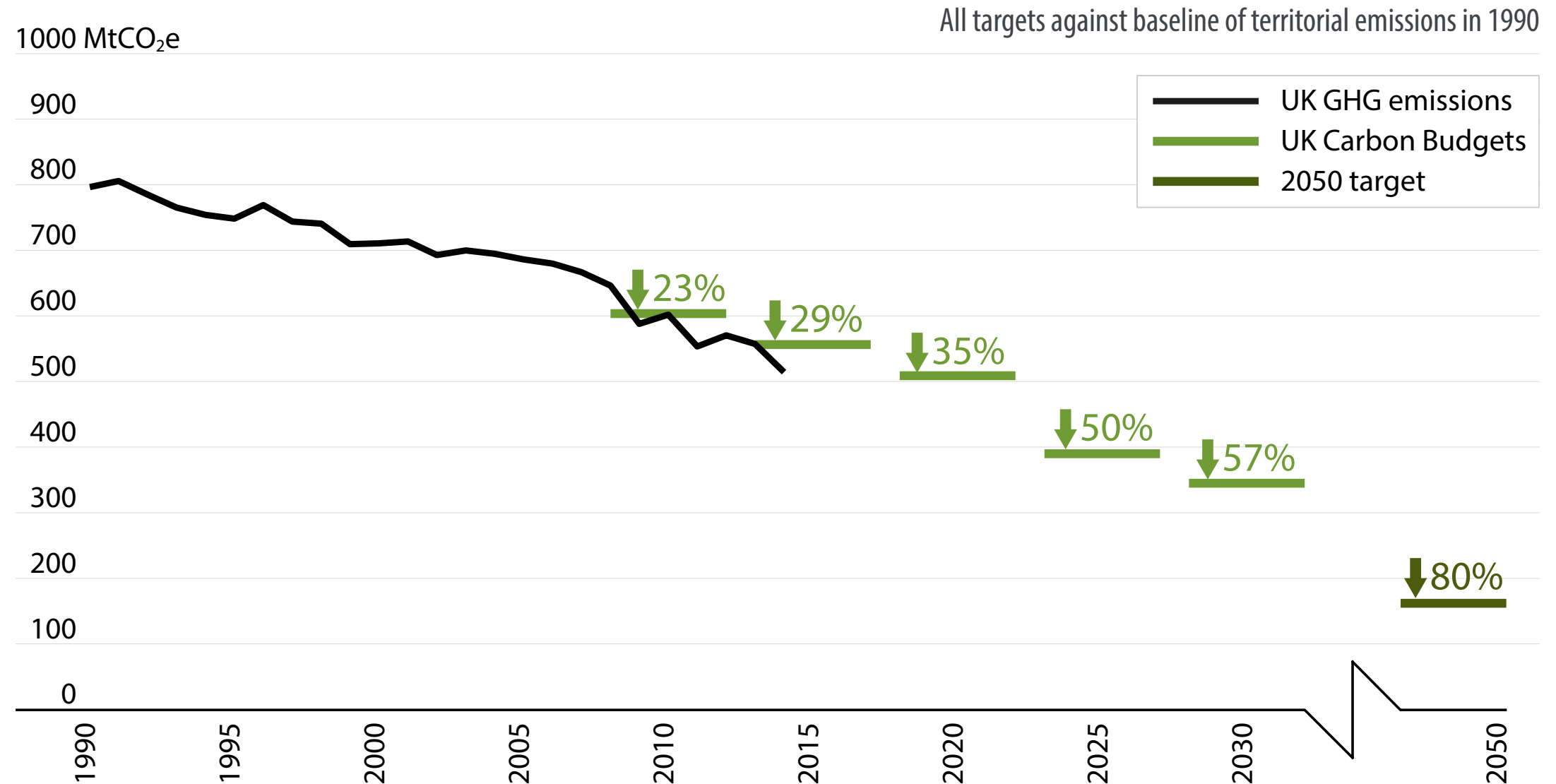
What might this look like?

One potential pathway



Interim targets for the UK


Based on series of legally binding 5 year budgets



Construction 2025

Targets 50% reduction in GHG emissions in the built environment

» Envisages a sustainable industry that *“leads the world in low-carbon and green construction exports”*

 HM Government

Industrial Strategy: government and industry in partnership





Construction 2025

July 2013

EXECUTIVE SUMMARY | CONSTRUCTION 2025 5

Lower costs 33% <small>reduction in the initial cost of construction and the whole life cost of built assets</small>	Faster delivery 50% <small>reduction in the overall time, from inception to completion, for newbuild and refurbished assets</small>
Lower emissions 50% <small>reduction in greenhouse gas emissions in the built environment</small>	Improvement in exports 50% <small>reduction in the trade gap between total exports and total imports for construction products and materials</small>



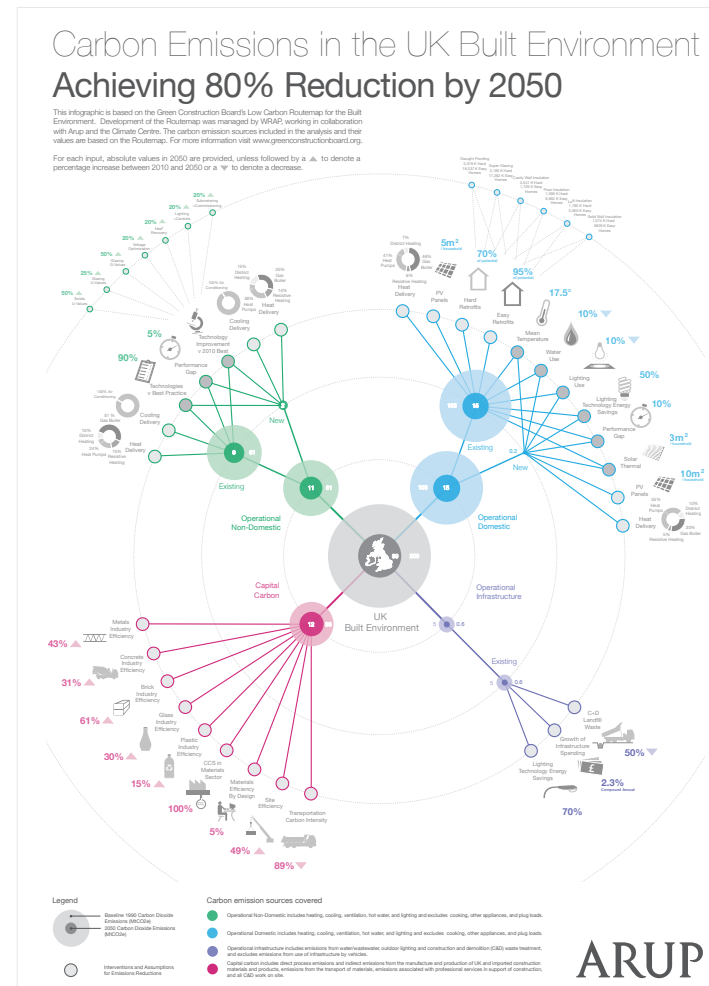
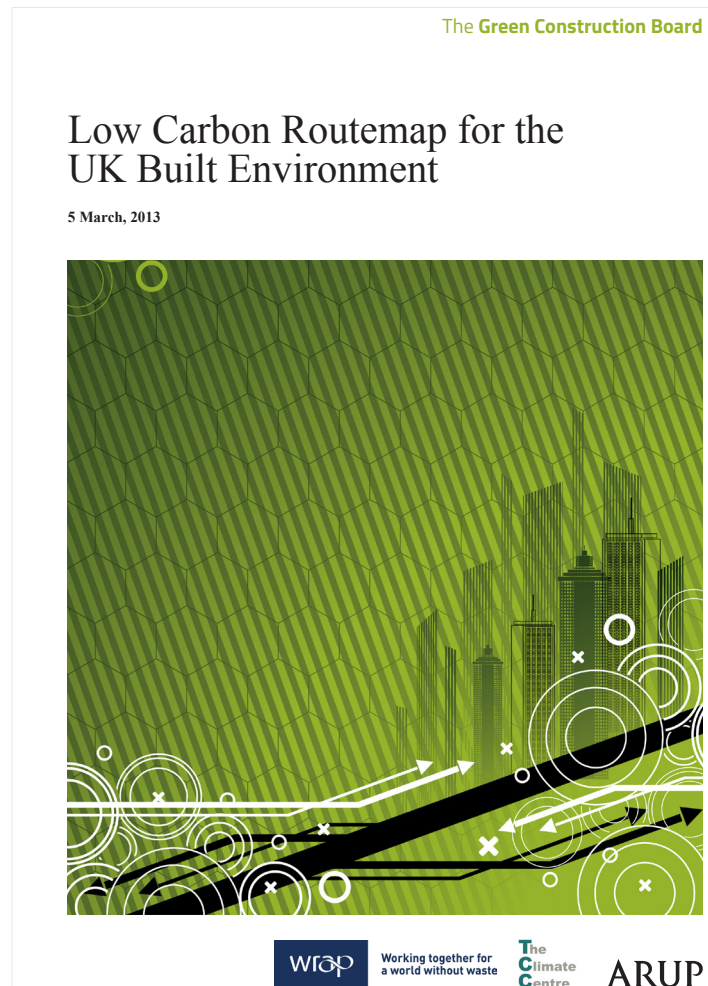
The global construction market is forecast to grow by over 70% by 2025.

Global Construction 2025; Global Construction Perspectives and Oxford Economics (July 2013)

Low Carbon Routemap

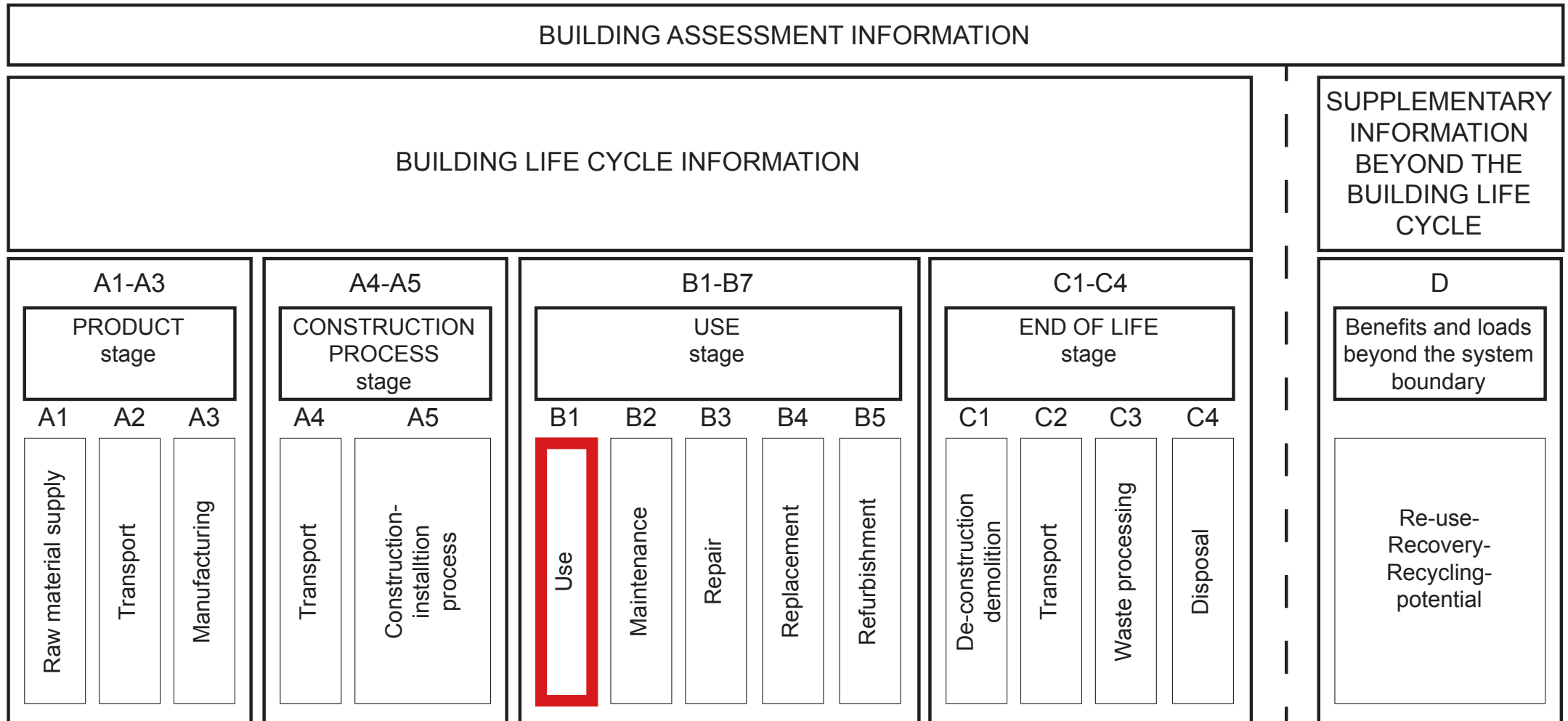
Initial report set out target trajectory to 2050

- » 2013 routemap showed substantial reductions in capital carbon required **in addition to** operational reductions



Life cycle emissions

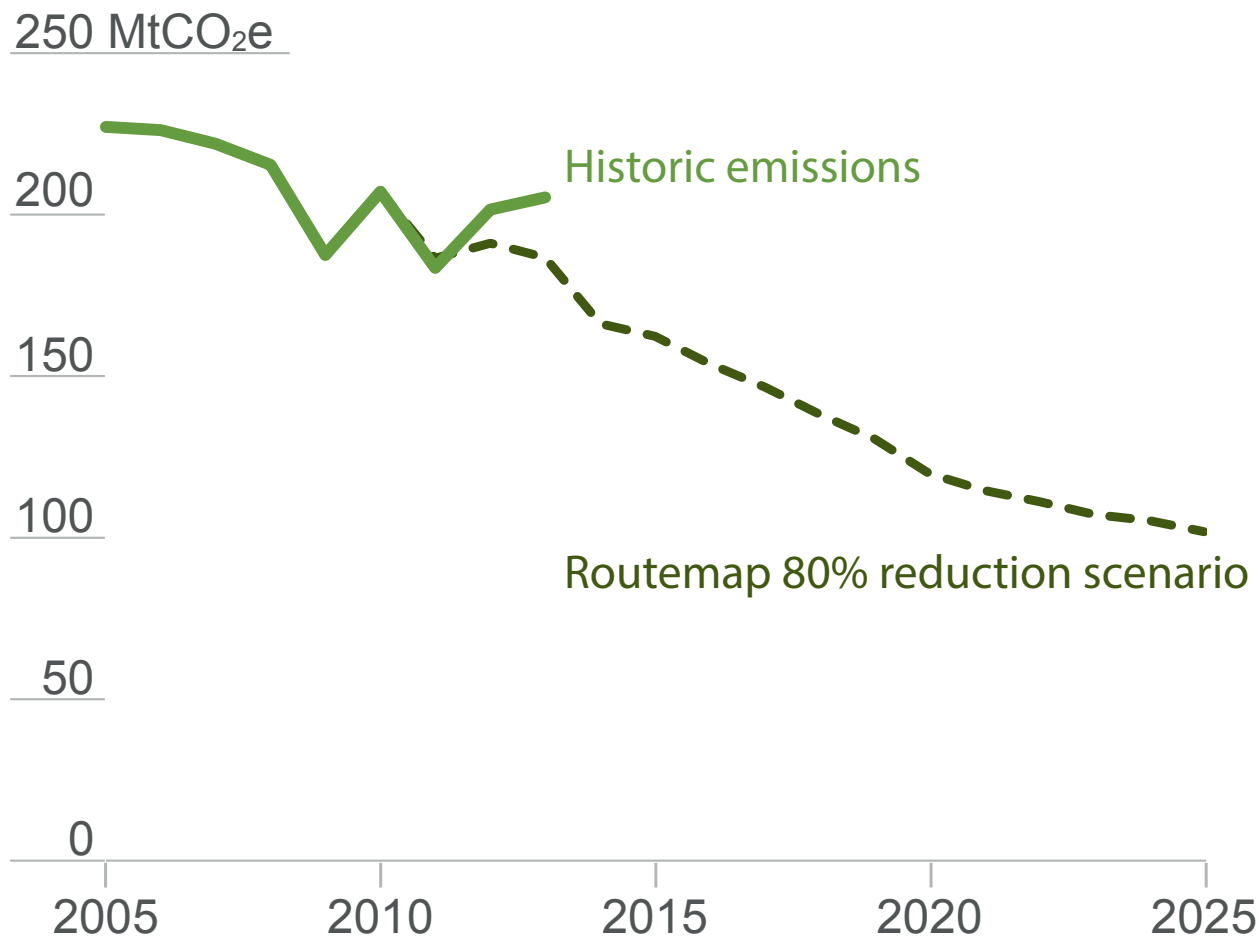
Common definition



Low Carbon Routemap

Progress report produced in December 2015

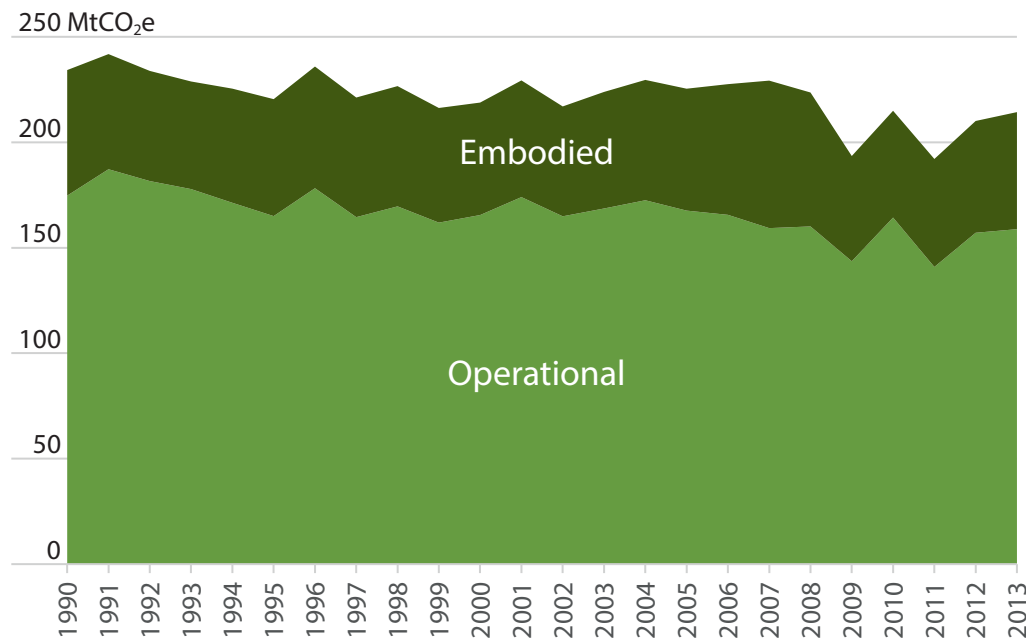
- » Progress to 2013 suggests we are not on trend to meet 2025 ambitions
- » Capital carbon emissions have increased since original report



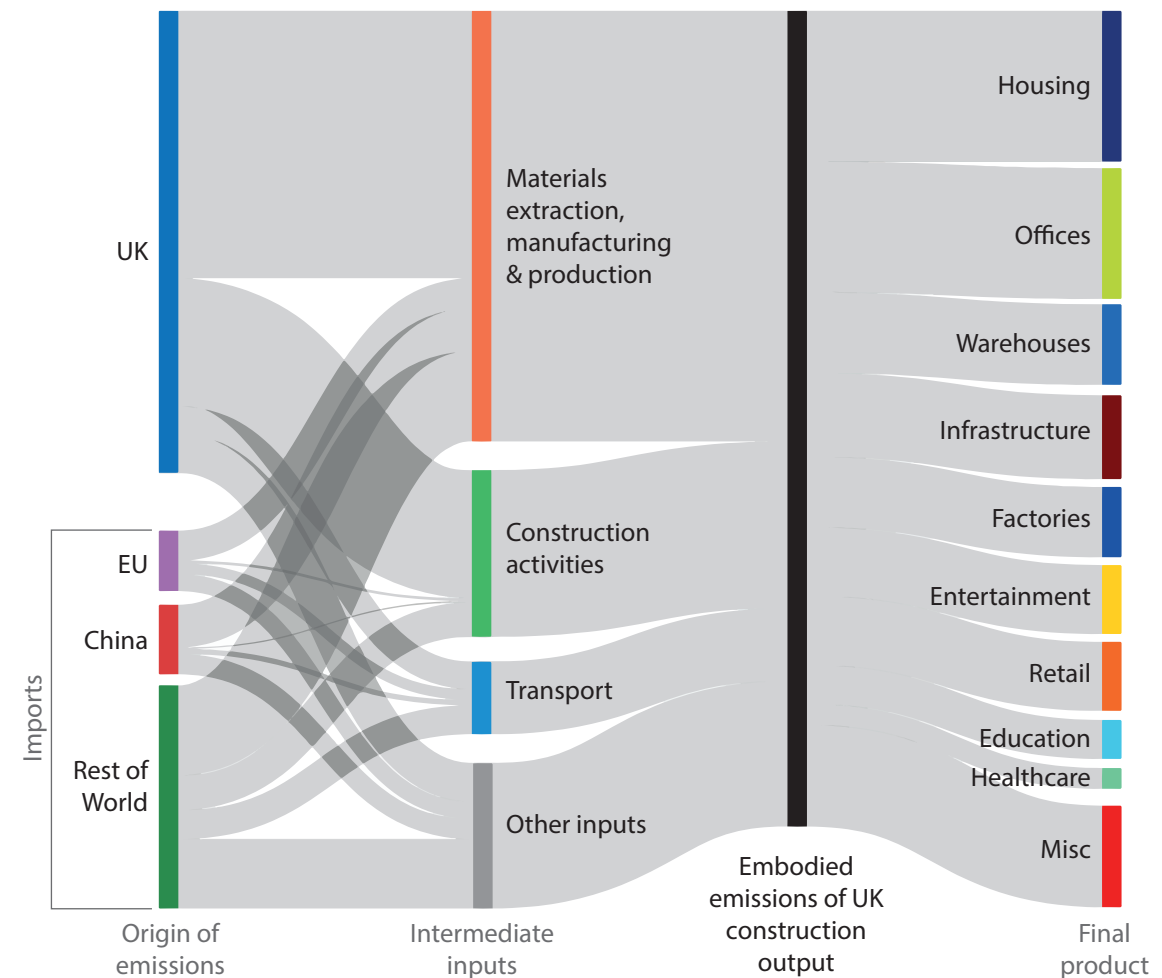
Embodied carbon in construction

Estimated carbon footprint of UK construction supply chain

» Built environment emissions 1990-2013



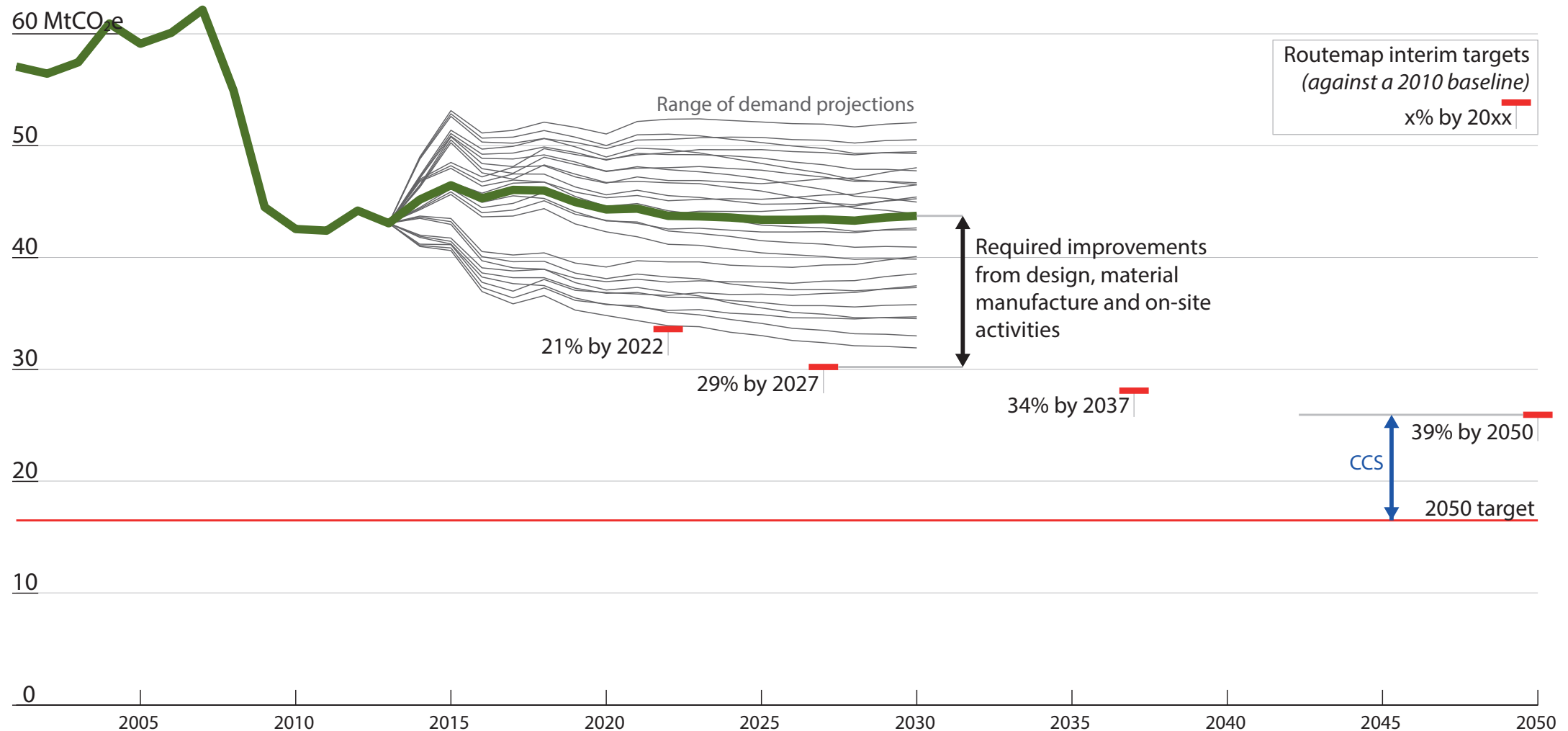
» Embodied emissions in 2007



Required reductions

Anticipated embodied emissions of UK construction 2001-2030

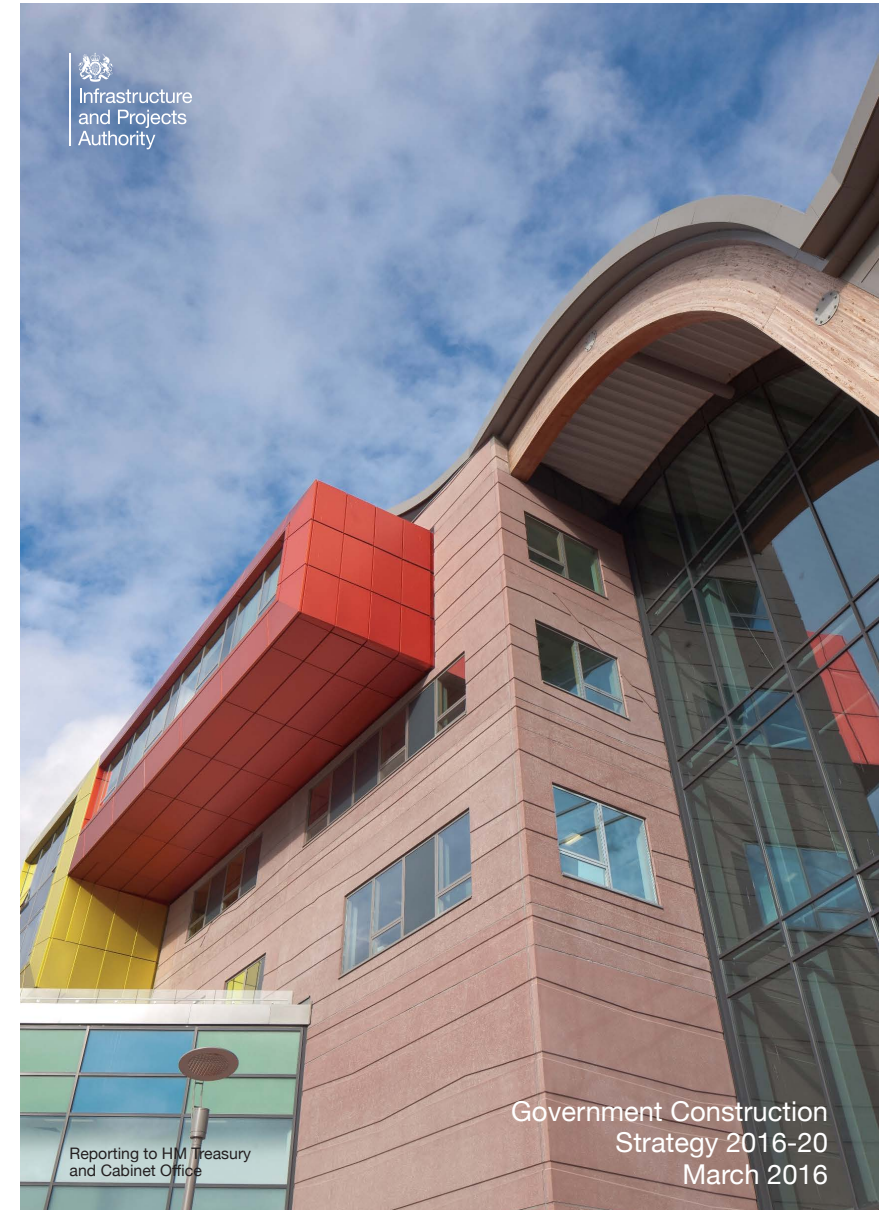
- » 27 scenarios using UK Buildings and Infrastructure Embodied Carbon model
- » **Including** improvements in grid intensity from DECC



Government Construction Strategy

For the current parliament

- » One of the principal objectives is to *“enable and drive whole-life approaches to cost and carbon reduction”*
- » Objective 3.6 is to *“Develop data requirements and benchmarks for measurement of whole-life cost and whole-life carbon (embodied and operational)”*
- » *“Government contracts will encourage innovative sustainability solutions on carbon reduction where value can be demonstrated”*
- » Ultimately forming *“recommendations for a future approach”*



Drivers of low carbon construction

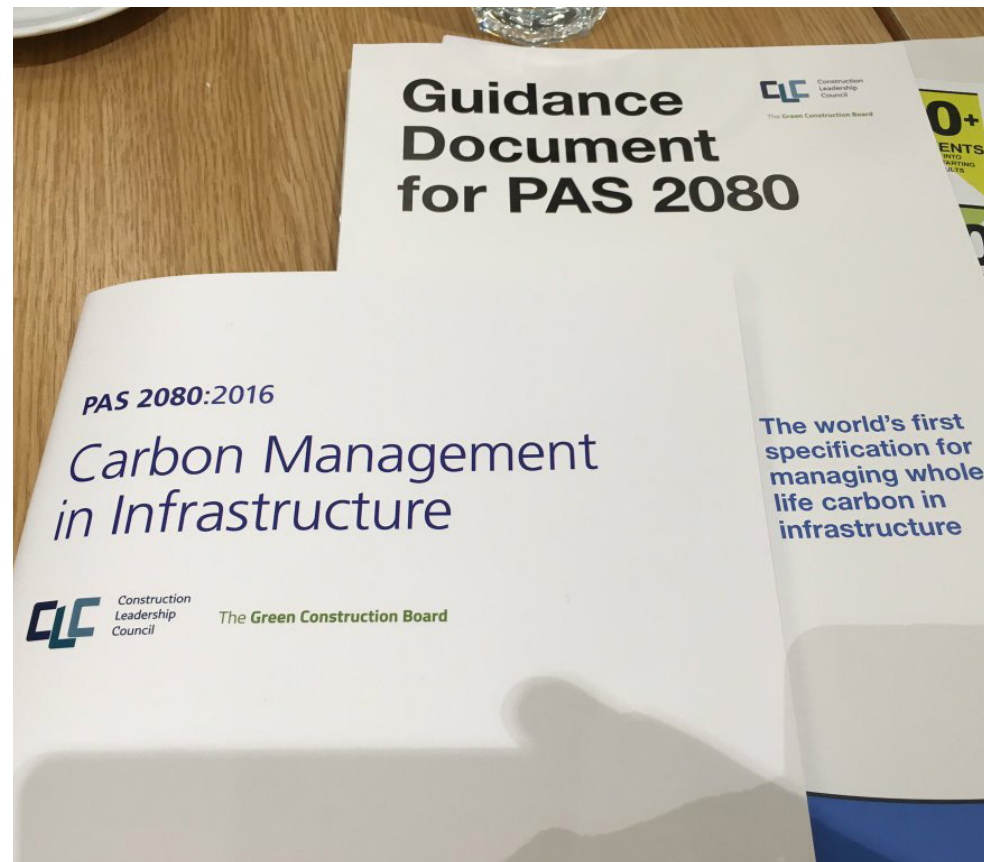
Client demands

- » 50+ organisations signed up to Infrastructure Carbon Review
- » 30+ organisations with commitments to measure or reduce embodied carbon in buildings
- » 10+ Local Authorities interested



HM Treasury

Infrastructure Carbon Review



Guidance on embodied carbon

Array of recent publications

WRAP Working together for a world without waste

The Business Case for Managing and Reducing Embodied Carbon in Building Projects

Making zero carbon buildings a reality

Managing and reducing the embodied carbon impact of a project can be achieved by building less, building clever and building efficiently. Effective leadership, innovation and procurement is essential to enable the management and reduction of embodied carbon.

Why take action

Embodied carbon is the emissions (CO₂e) created from all the activities of the creation and demolition of a building. It is the total life cycle carbon less the operational carbon impact. It covers the emissions that arise from the energy and industrial processes used in the processing, manufacture and transportation of the materials, products and components required to construct, maintain and refurbish a building.

■ It is becoming widely recognised that the balance between **operational and embodied carbon emissions** needs to be considered to understand the true carbon impact of new and refurbished buildings.

■ Embodied carbon impacts are **becoming increasingly significant**, as operational emissions fall in response to building regulations and more efficient operational processes and technologies, see Figure 1.

■ Studies suggest embodied carbon in domestic buildings may be equivalent to **10 times annual operational energy use**; and for complex commercial buildings, the ratio can be as high as 30:1³.

■ Industry stakeholders generally agree there is a high chance that the measurement, management and reduction of embodied carbon in construction projects **could soon become a mandatory requirement**.

■ Rising energy and material costs are the **third most significant threat** to growth identified by CEOs in the engineering and construction sector⁴.

■ Buildings with **low embodied carbon** credentials can be **more desirable** to blue chip clients and tenants alike.

Figure 1: Changing significance of embodied carbon: 2010 and 2050³

Modelling by the Green Construction Board (GCB) predicts that in 2050 embodied carbon will represent around 32% of the built environment's emissions versus 18% in 2010³.

Benefits of taking action

Reducing the embodied carbon impact of a building can realise a number of benefits:

- cost savings associated with a reduction in material use, increased use of secondary and recycled materials, and lower wastage rates;
- a reputation for good environmental management;
- being 'ahead of the curve' with regards to future legislation;
- being resilient to resource price rises and resource scarcity risks; and
- being less reliant on energy-intensive manufacturing routes.

Embodied Carbon

Industry Task Force Recommendations

Proposals for Standardised Measurement Method and

Recommendations for Zero Carbon Building Regulations and Allowable Solutions

June 2014

Supported by

ARUP | ATKINS | AECOM | circular ecology

Sustainable Business Partnership

SKANSKA

sturgis | carbon profiling | Turley | TISHMAN SPEYER

WRAP Material change for a better environment

Cutting embodied carbon in construction projects

This guidance will help you identify basic cost-effective actions to reduce the carbon impact of the materials used in your construction projects.

What is good practice?

As Building Regulations reduce operational emissions towards zero, the "embodied" CO₂ emissions associated with supplying materials can be as much as 50% of total emissions over a building's lifetime.

If you reduce embodied carbon, you can benefit financially from:

- reductions in materials use and waste;
- less reliance on energy-intensive manufacturing routes; and
- a reputation for good environmental management.

From the client's perspective, a simple approach to cutting embodied carbon is to set the following requirement in the project specification and design team appointment:

"Identify the [5-10] most significant cost-effective opportunities to reduce the embodied carbon emissions associated with the project (e.g. through leaner design, designing out waste, reusing materials, and selecting materials with lower embodied carbon over the project life-cycle), quantify the savings made through individual design changes, and report actions and outcomes as part of a Carbon Efficiency Plan"

In response, the design team would focus on quantifying the savings associated with just a few changes for specific project elements/components. They can use existing assessment methods (and, in the future, methods compliant with the emerging European standard EN 15978). They do not need to calculate a carbon footprint for the whole project – they would simply estimate with/without differences.

The following Table lists the types of action a design team should consider and the scale of savings achievable (which will vary from project to project). The examples mainly refer to buildings, although the principles apply to infrastructure projects as well.

Carbon saving action	Range of carbon savings
Using lean materials	
1. More efficient building design (e.g. compact building form)	Varies by building type – typically, up to 10% of a building's total embodied carbon
2. Change the specification for building elements (e.g. lower-weight roof design)	Varies by element type and specification – typically, up to 10% for major structure and cladding elements by activation – see also 6 below
3. Design for lean waste on site (e.g. 20% waste reduction on the top 20 materials from baseline to good practice)	Varies depending on materials specified and extent of off-site construction – typically up to 10% in activation
4. Design for off-site construction (e.g. to benefit from lower embodied carbon in off-site construction – up to 10% in activation)	Varies depending on the extent of off-site construction – typically up to 10% in activation
5. Design for reuse and deconstruction (e.g. increase reuse of materials from demolition and earthworks on the current site design a building for the design a building for easy deconstruction during its life)	Significant savings on whole-life basis. Little impact on embodied carbon savings on 'cradle to gate' basis (see footnote 2)
Using alternative materials	
6. Select materials with lower carbon intensity (e.g. cement substitutes such as PFA or sustainably-sourced timber)	Varies by building type and specification – typically, up to 10% in activation
7. Select reused or higher recycled content products and materials (e.g. reclaimed bricks, higher recycled content blocks, locally sourced materials)	Varies by extent of reusable materials available – typically up to 10% in activation, and more in infrastructure
8. Select materials with lower transport-related carbon emissions (e.g. locally-sourced aggregates)	Varies by transport volumes and modes – typically up to 10% in activation, and more in infrastructure
9. Select materials with high levels of durability and low through-life maintenance (e.g. facades and cladding materials which last as long as the building frame)	Significant savings on whole-life basis. Little impact on embodied carbon savings on 'cradle to gate' basis (see footnote 2)

ice Institution of Civil Engineers

Energy Briefing Sheet: Embodied Energy and Carbon

ICE's Energy Expert Panel has published a series of status reports concerned with various forms of energy such as wind, hydro, nuclear and energy from waste. Designed to be both informative and contemporary, the reports are updated regularly to provide accurate information to a varied audience. The present report focuses on embodied energy and carbon in construction.

Definition

The dictionary of energy defines embodied energy as "the sum of the energy requirements associated, directly or indirectly, with the delivery of a good or service" (Cleveland & Morris, 2000). In practice however there are different ways of defining embodied energy depending on the chosen boundaries of the study. The three most common options are: cradle-to-gate, cradle-to-site, and cradle-to-grave (Cansler, Tinsley & Davidson, 2011). The two following definitions illustrate this more clearly:

Cradle-to-Site

A cradle-to-site study favours defining the embodied energy of individual building components as the energy required to extract the raw materials, process them, assemble them into usable products and transport them to site. This definition is useful when looking at the comparative scale of building components and relates more to the "good" in Cleveland & Morris's definition as it neglects any maintenance or end of life costs. A cradle-to-gate model simply describes the energy required to produce the finished product without any further considerations.

Cradle-to-Grave

A cradle-to-grave approach defines embodied energy as that "consumed" by a building throughout its life. This definition is a far more useful one when looking at a building or project holistically, though admittedly much more complex to estimate. The energy consumption can be broken down further (Yohanes & Norton, 2002) into:

Initial embodied energy is the energy required to initially produce the building. It includes the energy used for the abstraction, often referred to as primary energy, the processing and manufacture of the materials of the building as well as their transportation and assembly on site.

Recurring embodied energy is the energy needed to refurbish and maintain the building over its lifetime.

Demolition energy is the energy necessary to demolish and dispose of the building at the end of its life.

1 Energy Briefing Sheet: Embodied Energy and Carbon Institution of Civil Engineers ice

UK GREEN BUILDING COUNCIL

FEBRUARY 2015

Tackling embodied carbon in buildings

CAMPAIN FOR A SUSTAINABLE BUILT ENVIRONMENT

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THE CROWN ESTATE

RICS GB & Construction Standards IP 10/2012

Methodology to calculate embodied carbon of materials

1st edition, information paper

RICS | the mark of property professionalism

rics.org/standards

UK GREEN BUILDING COUNCIL

bre

Practical how-to guide: Measuring Embodied Carbon on a Project

For this 'How To' Masterclass, the UK Green Building Council has partnered with BRE to provide you with a short guidance note on how to get started measuring embodied carbon on a project. Please note, this guide may be updated at the end of Embodied Carbon Week.

Background to BRE & UK Green Building Council

The UK Green Building Council requires its members to continually improve performance around sustainability. Resource efficiency and reducing embodied carbon is rapidly becoming a key area of focus for industry. For many the topic is complex, difficult to navigate and unclear in terms of where to start with measurement and reporting.

For almost 20 years the Green Guide to Specification has provided a means for designers to compare the embodied environmental impacts, including carbon, of building elements (e.g. floors, roofs, walls). The Green Guide is also how embodied impacts are assessed in BRE's schemes. In addition, BRE carries out EPD (environmental product declarations) and responsible sourcing certification for construction products. Recently BRE, along with three other partners, launched BIPAC – whole building life cycle assessment for B10.

Useful links and resources on embodied carbon measurement for a project

The information on the following pages has been prepared to provide you with a simple 'quick start' guide; setting out the fundamental steps involved in measuring and reducing embodied carbon on a project. By following these simple steps, you will have a good foundation-level understanding of how to measure embodied carbon on a project.

Top tips before you get started:

- ✓ Start early in the design process
- ✓ Familiarise yourself with basics of life cycle assessment
- ✓ Establish the commissioning client's requirements and develop a goal and scope (e.g. carbon only or with other indicators, cradle to gate or grave, compliance with standards e.g. EN 15978, options to appraise, target setting, BRE's LCA, LED etc. credits)
- ✓ Decide if you have the required skill to undertake the assessment, or if you need a specialist consultant
- ✓ Identify a tool that will improve the accuracy and efficiency of the assessment
- ✓ Engage all of the design team members into the process

1

WHAT COLOUR is YOUR BUILDING?

David H. Clark

OPERATING TRANSPORT

GREATER LONDON AUTHORITY

LONDON SUSTAINABLE DEVELOPMENT COMMISSION

Construction Scope 3 (Embodied)

Greenhouse Gas Accounting and Reporting Guidance

March 2013

Current assessment practice

Numerous concerns

- » Assessments often retrospective and fail to inform product selection
- » Different system boundaries (cradle-to-gate, cradle-to-site, cradle-to-practical completion, cradle-to-cradle etc.)
- » Limited availability of product LCI data
- » Little evidence to support assumed building life times
- » Challenges capturing data on site
- » Knowledge of embodied carbon varies widely across industry

Recent signs of progress

- » Some areas of industry (e.g. water & sewerage) now making routine detailed assessments using component level databases
- » Increase in EPD production
- » Numerous ongoing projects to further standardise assessments e.g. Innovate UK 'Implementing Whole Life Carbon in Buildings'

Example commitments

To reduce embodied carbon in construction

» British Land target relative to concept design

>£50m: Achieve 15% reduction in embodied carbon in concrete, steel, rebar, aluminium and glass in construction, compared to the concept design

» Land Securities target

Carry out embodied carbon analysis to inform the selection and procurement of building materials to reduce environmental impacts and achieve at least a 15% reduction in embodied carbon

» M&S Plan A commitment

EMBODIED CARBON IN BUILDINGS

ON PLAN

AIM By 2020, we will reduce the embodied carbon in UK and ROI new store builds by addressing the carbon hotspots of walls, ceilings and floors where possible.

» Prologis UK have had requirements to minimise and offset remaining embodied carbon since 2009

» Anglian Water have already achieved substantial reductions since 2010

Capital (embodied) carbon emissions have reduced by 54% against our 2010 baseline. This

Medium-term target

Reduce capital carbon emissions by 60% by 2020 from a 2010 baseline.

Setting Carbon Intensity Targets (CITs)

Examples of different approaches

- » Assess embodied carbon of concept design and then set **target for embodied carbon at practical completion** to be $x\%$ lower
- » Set a **whole life carbon target** of $x\text{kgCO}_2\text{e/m}^2\text{/year}$ for an assumed design life based on comparison with **benchmark data**
- » Aim for an $x\%$ reduction in embodied carbon against the total for a **notional reference building** deemed to be typical of that building class
- » Assess the operational emissions at concept design stage then aim for equivalent reductions in embodied emissions to **'offset' anticipated life time operational emissions**
- » Aim for an $x\%$ reduction in embodied carbon (in $\text{kgCO}_2\text{e/m}^2$) **against a previous project** the client has completed
- » Assess the **10 largest contributing elements** to the embodied carbon total and then achieve an $x\%$ reduction in those elements
- » and so on...

Shortcomings of current CITs

Include

- » Different system boundaries preclude fair comparison between projects
- » Selection of CIT value often arbitrary
- » Relative comparisons with other buildings do not ensure consistency with sector or national carbon reduction targets
- » Little understanding of how these targets may change over time and the concomitant changes in materials and design
- » Targets often poorly communicated and rarely compiled

Implementing CITs

Example check points



RIBA
Plan of
Work
2013

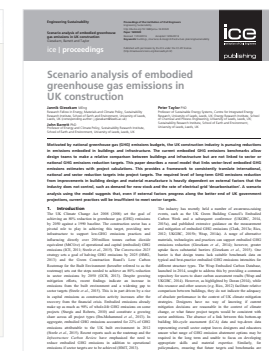
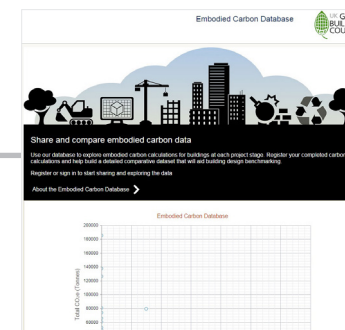
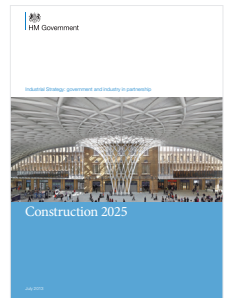
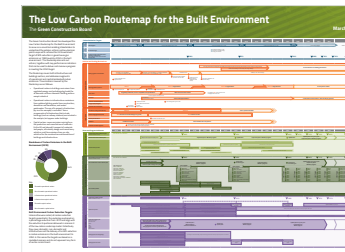
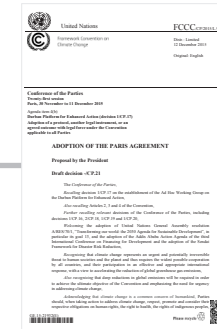
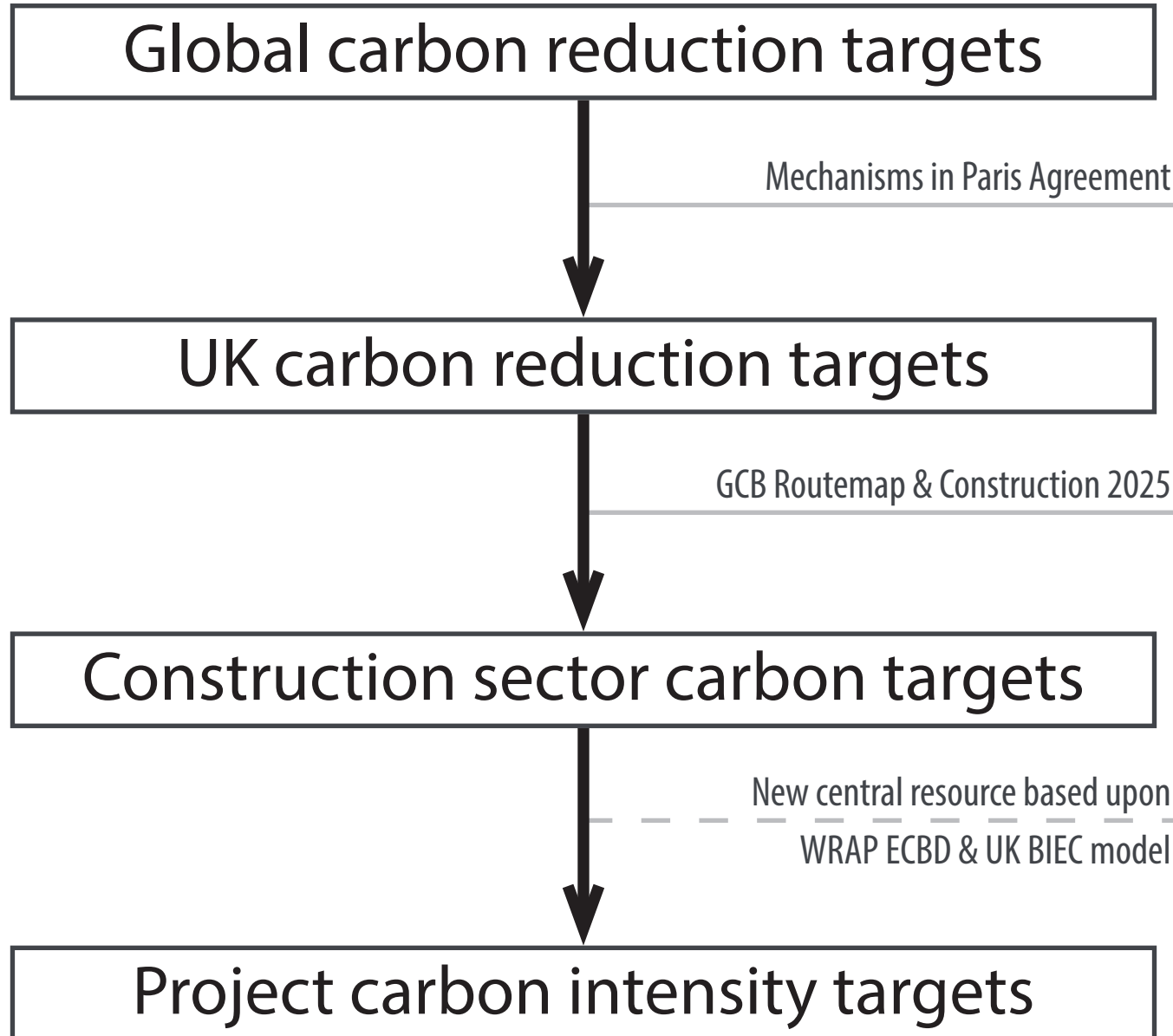
Tasks ▼

Embodied Carbon Checkpoints

Stages	0	1	2	3	4	5	6	7
	Strategic Definition	Preparation and Brief	Concept Design	Developed Design	Technical Design	Construction	Handover and Close Out	In Use
S	<p>Identify opportunities for re-use of serviceable elements (typically substructure, frame, façade) or on-site recycling of materials from existing buildings/brown field sites.</p> <p>Assess potential to deliver objectives using temporary re-usable structures.</p> <p>Consider potential emissions impact of site choices.</p>	<p>Determine project embodied carbon target (e.g. based on building type and GIA, client ambition and available benchmark data).</p> <p>Review building embodied carbon footprint design tools, methods and data sources and compliance with relevant standards.</p> <p>Identify building embodied carbon footprint certification body and discuss selection of tool, method and initial data sources.</p>	<p>Allocate responsibility for carbon management within project team (e.g. designate roles as per PAS 2080).</p> <p>Determine embodied carbon target/allocation % for each building element.</p> <p>Complete initial building assessment model using element-level specifications.</p> <p>Review initial concept design embodied carbon footprint against project target.</p> <p>Identify elements with high impact rate and/or high quantity in building, review alternative solutions and revise design. Work iteratively; refer to building total regularly. Also consider impact of decisions on design life and maintenance cycles.</p> <p>Revise building embodied carbon target (if necessary).</p> <p>Produce 'Concept stage' embodied carbon report.</p>	<p>As technical/detailed design information is produced, replace element-level specifications with product-level specifications.</p> <p>Identify 'significant' products/materials that are high impact and/or high quantity.</p> <p>For 'significant' products/materials investigate alternatives (of a different product type).</p> <p>Identify overdesign; reduce product/material quantities where possible.</p> <p>Identify on-site waste reduction opportunities.</p> <p>Identify products with Environmental Product Declarations and, where better than generic products, consider proprietary specification.</p> <p>Work iteratively; refer to building total regularly.</p> <p>Produce 'Design stage' embodied carbon report and footprint.</p> <p>Submit 'Design stage' embodied carbon footprint for certification.</p> <p>Submit 'Design stage' embodied carbon footprint to relevant data gathering organisations.</p>	<p>Ensure embodied carbon targets, reporting requirements and any stipulations on material specification and sourcing are clearly included in tender.</p> <p>Contractor credentials should be assessed against these requirements.</p> <p>Review effect of any product/material substitution requests from contactor.</p> <p>Work with contractor to further reduce overdesign and on-site waste.</p>	<p>Produce 'As constructed' embodied carbon report and final embodied carbon footprint based on 'actual' quantities.</p> <p>Submit 'As constructed' embodied carbon footprint for certification.</p> <p>Submit 'As constructed' embodied carbon footprint to relevant data gathering organisations.</p> <p>Ensure lessons learned are documented and communicated.</p> <p>Ensure handover information includes embodied carbon report, including estimated service lives.</p>	<p>Periodically, ask building owner for update on actual repair and maintenance activities and submit to relevant data gathering organisations.</p>	

Future determination of CITs

Ensuring consistency with sector & national targets



Proposed central resource

Would include

- » Benchmark data from revived WRAP Embodied Carbon Buildings Database
- » Suggested CITs based upon UK BIEC model outputs
- » Example carbon plans for a range of standard building typologies
- » Procurement guide featuring example wording for brief and contracts

Would help

- » Inexperienced clients to easily specify for low embodied carbon
- » Experienced clients to aim for more ambitious targets e.g. '2050 ready' building
- » All clients to have a common information source and reporting platform

Securing additional drivers of CITs

Client led drivers

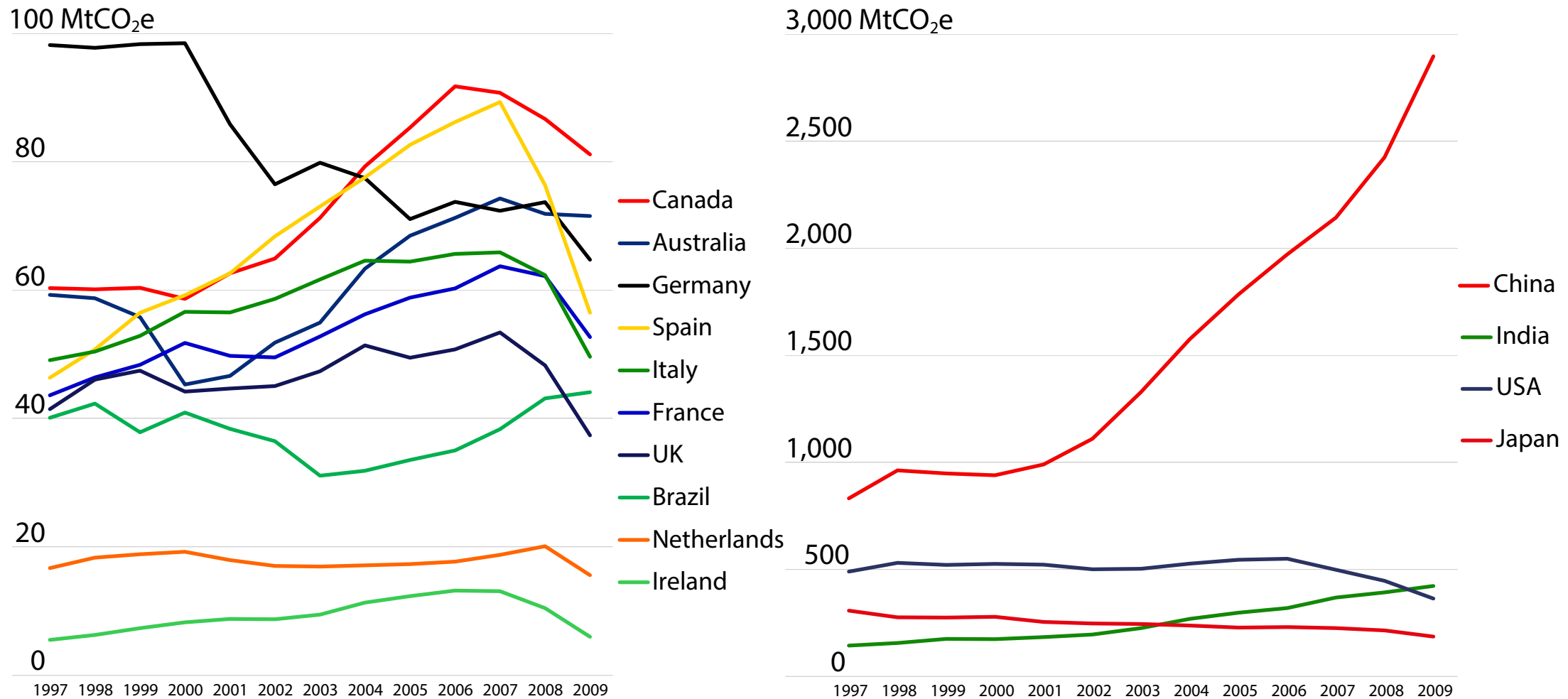
- » Requires further information on value of CITs
- » Requires stronger evidence on link between cost and carbon
- » Changes in culture required to ensure implementation
- » Voluntary initiatives a good starting point

Regulation

- » Must address ownership of issue within industry and government
- » Needs collective action from broader range of advocates across value chain
- » Narrative development is critical
- » Further evidence gathering required

International scope

GHG emissions of construction sector supply chain by country



» Construction firms in these 14 countries alone influence 4.4 GtCO₂e of supply chain emissions

Summary

The case for CITs in construction

- » The UK construction industry must address embodied carbon if sector carbon reduction targets are to be met
- » Introduction of CITs is the best approach to motivate requisite changes in design, product selection and construction practices
- » Challenges to be overcome include: standardising the approach to CITs; ensuring consistency with national and sector targets; and developing an appropriate central resource for clients and practitioners
- » Additional drivers for CITs are also required
- » Sizeable mitigation potential if CITs are widely adopted
- » Read the conference paper for further discussion