CIE-MAP

Centre for Industrial Energy, Materials and Products

Research Councils UK Energy For a Low Carbon Future

Embodied carbon & strategies for reduction

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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

CIE-MAP

Centre for Industrial Energy, Materials and Products

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@CIEMAP

NOTTINGHAM TRENT UNIVERSITY

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

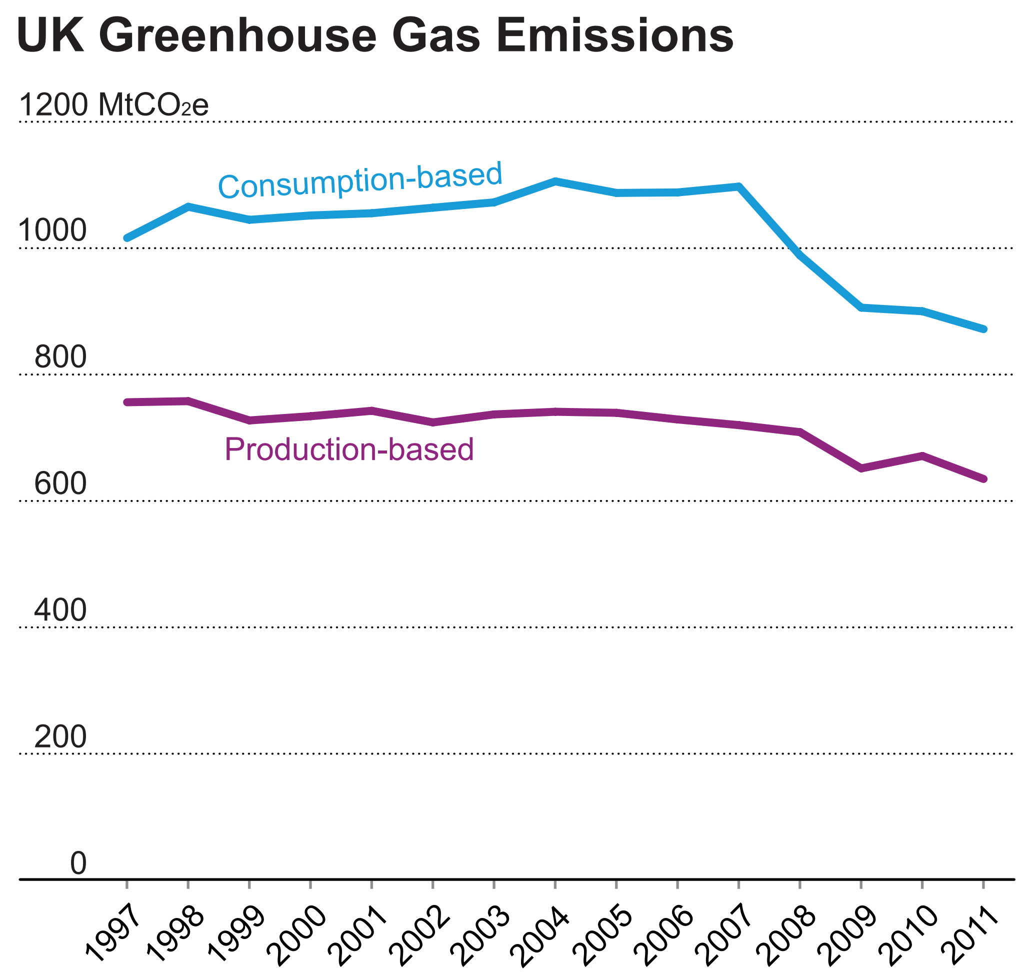
UNIVERSITY OF LEEDS

UNIVERSITY OF BATH

CIEMAP

Our work

- Policy relevant research to understand the relationship between environmental pressures, the economy and society
- Develop quantitative approaches to understand how energy and emissions interact with production and consumption systems
- Develop scenarios to understand underlying drivers and policy responses to minimise environmental pressures

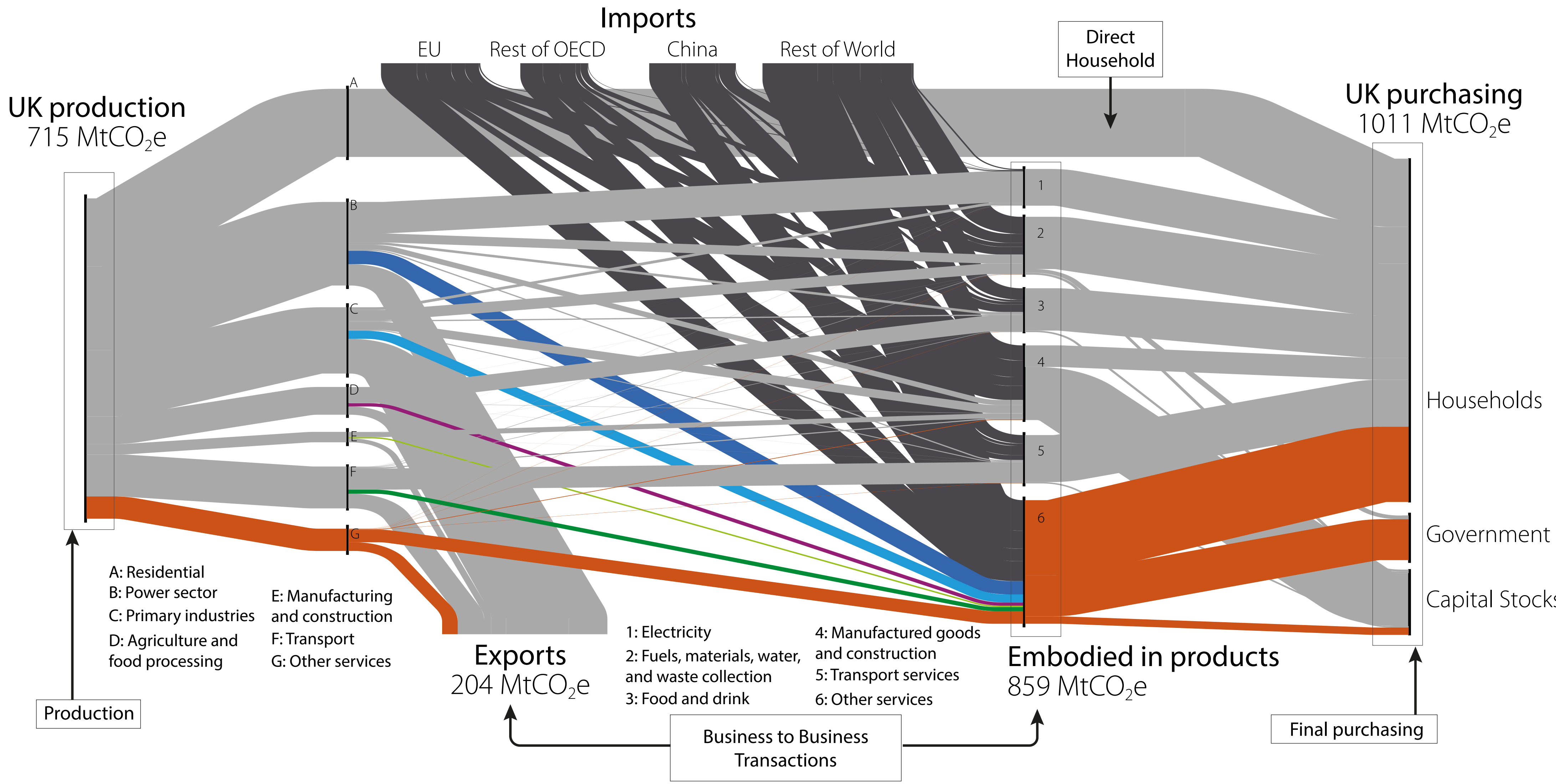


CIEMAP (2012) The UK's Carbon Footprint produced under contract for DEFRA

CIEMAP

Our approach

» Combining economy wide and sector specific analyses along supply chains



CIEMAP

Our methods

» Mix of techniques required to analyse complex systems

Quantitative

» Multi Region Input Output (MRIO)

» Life Cycle Assessment (LCA):
process based, IO and hybrids

» Material Flow Accounting (MFA)

» Exergy analysis

Qualitative

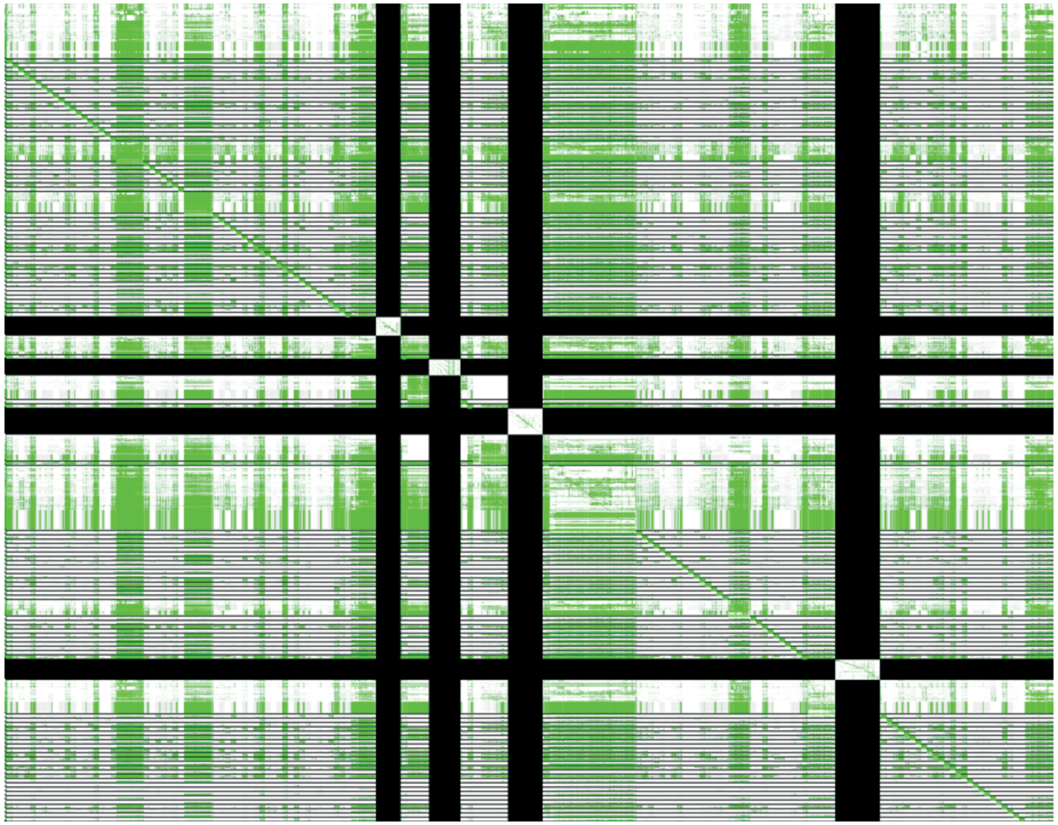
» Surveys

» Interviews

» Workshops

» Other participatory approaches

Global IO matrix (with ~112 billion entries)



CIEMAP work in construction

Two key areas

» Assessing current and future material use and embodied carbon emissions

» Understanding the barriers to greater material efficiency and the use of low carbon materials


Energy and Buildings 78 (2014) 202–214

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The greenhouse gas emissions and mitigation options for materials used in UK construction

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ABSTRACT

The UK construction industry faces the daunting task of replacing and extending a significant p
tion of UK infrastructure, meeting a growing housing shortage and retrofitting millions of homes
achieving greenhouse gas (GHG) emission reductions compatible with the UK's legally binding ta
an 80% reduction by 2050. This paper presents a detailed time series of embodied GHG emissio
the construction sector for 1997–2011. This data is used to demonstrate that strategies which focu
on improving operational performance of buildings and the production efficiencies of domestic m
producers will be insufficient to meet sector emission reduction targets. Reductions in the order


BRI Building Research & Information 2015
http://dx.doi.org/10.1080/09613218.2016.1086872

Routledge

RESEARCH PAPER

Construction sector views on low carbon building materials

Jannik Giesekam[1], John R. Barrett[2] and Peter Taylor[3]

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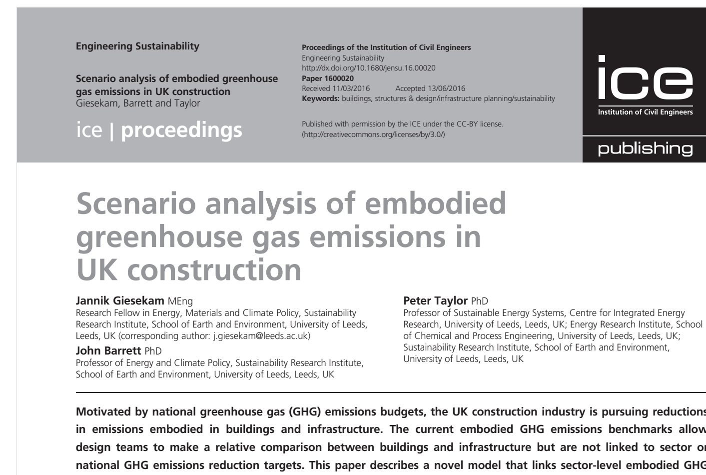
As is the case in a number of countries, the UK construction industry faces the challenge of expanding production whilst making ambitious greenhouse gas emission reductions. Embodied carbon constitutes a growing proportion of whole-life carbon emissions and accounts for a significant share of total UK emissions. A key mitigation strategy is increasing the


Engineering Sustainability

Scenario analysis of embodied greenhouse gas emissions in UK construction
Giesekam, Barrett and Taylor

ice | proceedings

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Paper 1600020
Received 11/03/2016 Accepted 13/06/2016
Keywords: buildings, structures & design/infrastructure planning/sustainability

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ice
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Scenario analysis of embodied greenhouse gas emissions in UK construction

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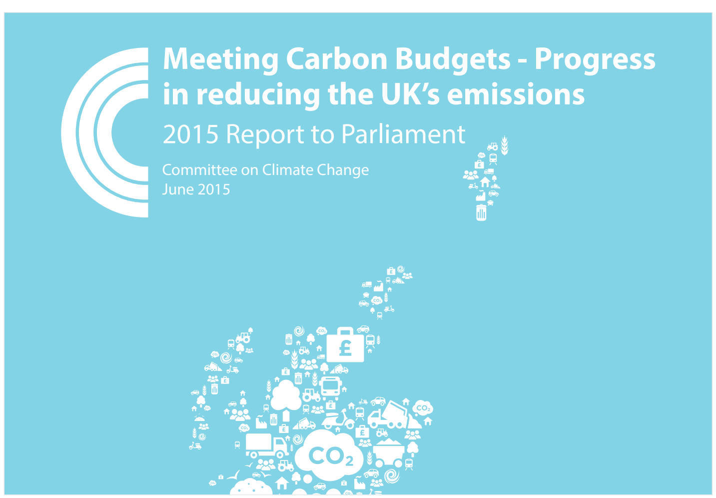
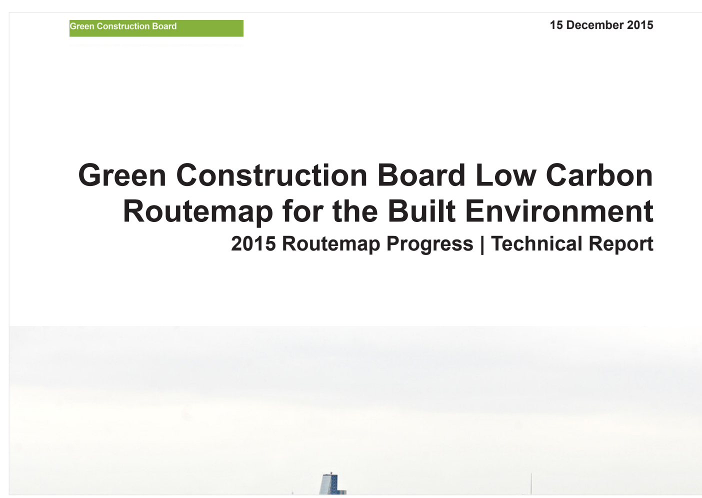
Motivated by national greenhouse gas (GHG) emissions budgets, the UK construction industry is pursuing reductions in emissions embodied in buildings and infrastructure. The current embodied GHG emissions benchmarks allow design teams to make a relative comparison between buildings and infrastructure but are not linked to sector or national GHG emissions reduction targets. This paper describes a novel model that links sector-level embodied GHG




Green Construction Board

15 December 2015

Green Construction Board Low Carbon Routemap for the Built Environment
2015 Routemap Progress | Technical Report


BUILDING ON THE PARIS AGREEMENT: MAKING THE CASE FOR EMBODIED CARBON INTENSITY TARGETS IN CONSTRUCTION

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ABSTRACT

Progressive clients are targeting embodied carbon reduction through the introduction of carbon intensity targets (CITs). CITs challenge design teams to deliver buildings with supply chain carbon emissions below a set level per functional unit. Despite CITs acting as catalysts for innovation, there are few drivers for their use and substantial variations in their implementation. There is also no means for ensuring consistency between project CITs and national mitigation targets, nor a mechanism for ratcheting up ambitions as anticipated by the Paris Agreement on climate change. the current determination of CITs. The fourth section proposes measures to improve the future determination of CITs, and the fifth section considers the corresponding drivers for their use. The final section draws together some outstanding questions that should be the subject of future research.

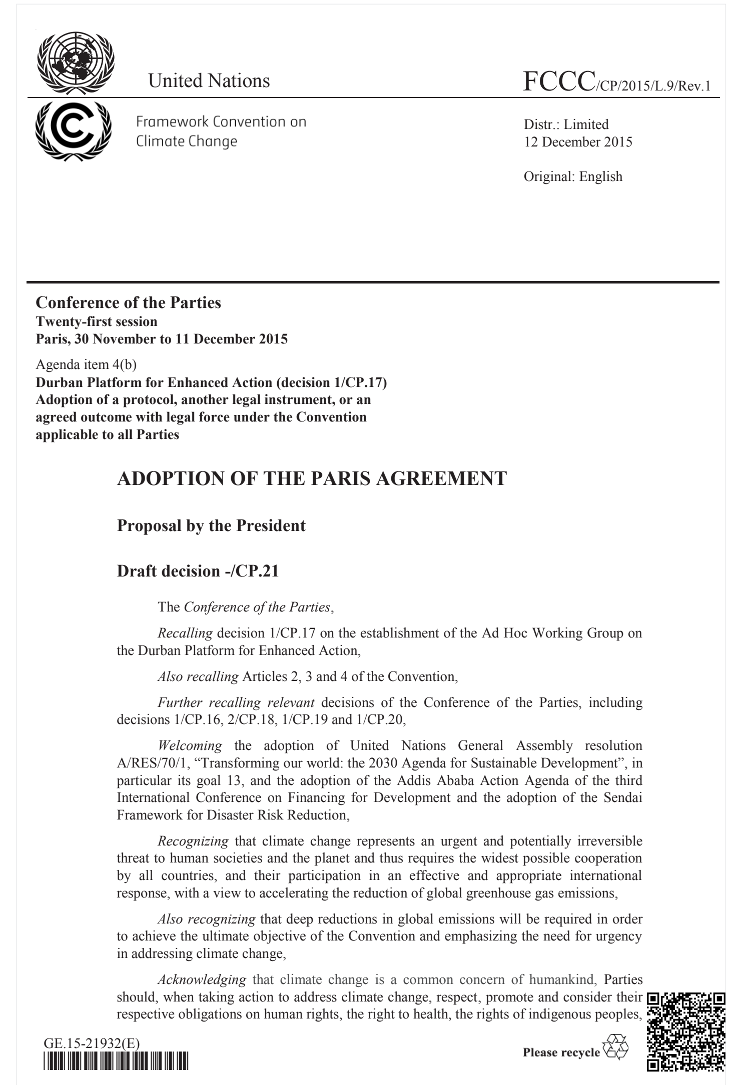
EMBODIED CARBON IN THE UK CONSTRUCTION INDUSTRY

Over recent years, embodied carbon emissions in the construction supply chain have typically accounted for a quarter of total GHG emissions from the built

Paris Agreement on climate change

Global agreement in December 2015

- Signed by 180 parties, ratified by 27 so far (representing 39% of global emissions)
- 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
- IPCC to produce 2018 report on pathways to 1.5°C



United Nations FCCC/CP/2015/L.9/Rev.1

Framework Convention on Climate Change

Distr.: Limited
12 December 2015

Original: English

Conference of the Parties
Twenty-first session
Paris, 30 November to 11 December 2015

Agenda item 4(b)
Durban Platform for Enhanced Action (decision 1/CP.17)
Adoption of a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all Parties

ADOPTION OF THE PARIS AGREEMENT

Proposal by the President

Draft decision -/CP.21

The *Conference of the Parties*,

Recalling decision 1/CP.17 on the establishment of the Ad Hoc Working Group on the Durban Platform for Enhanced Action,

Also recalling Articles 2, 3 and 4 of the Convention,

Further recalling relevant decisions of the Conference of the Parties, including decisions 1/CP.16, 2/CP.18, 1/CP.19 and 1/CP.20,

Welcoming the adoption of United Nations General Assembly resolution A/RES/70/1, "Transforming our world: the 2030 Agenda for Sustainable Development", in particular its goal 13, and the adoption of the Addis Ababa Action Agenda of the third International Conference on Financing for Development and the adoption of the Sendai Framework for Disaster Risk Reduction,

Recognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions,

Also recognizing that deep reductions in global emissions will be required in order to achieve the ultimate objective of the Convention and emphasizing the need for urgency in addressing climate change,

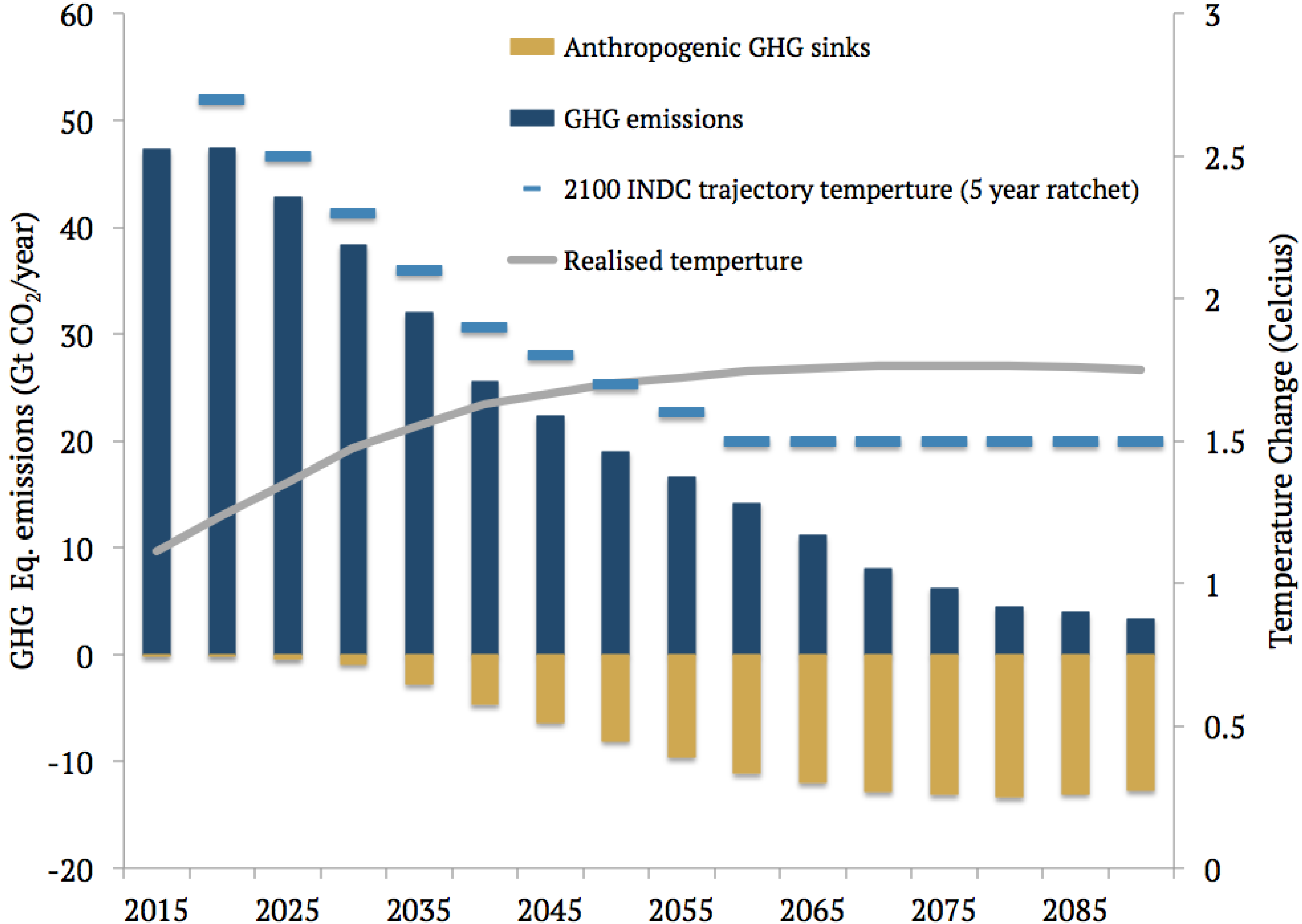
Acknowledging that climate change is a common concern of humankind, Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples,

GE.15-21932(E)

Please recycle

What might this look like?

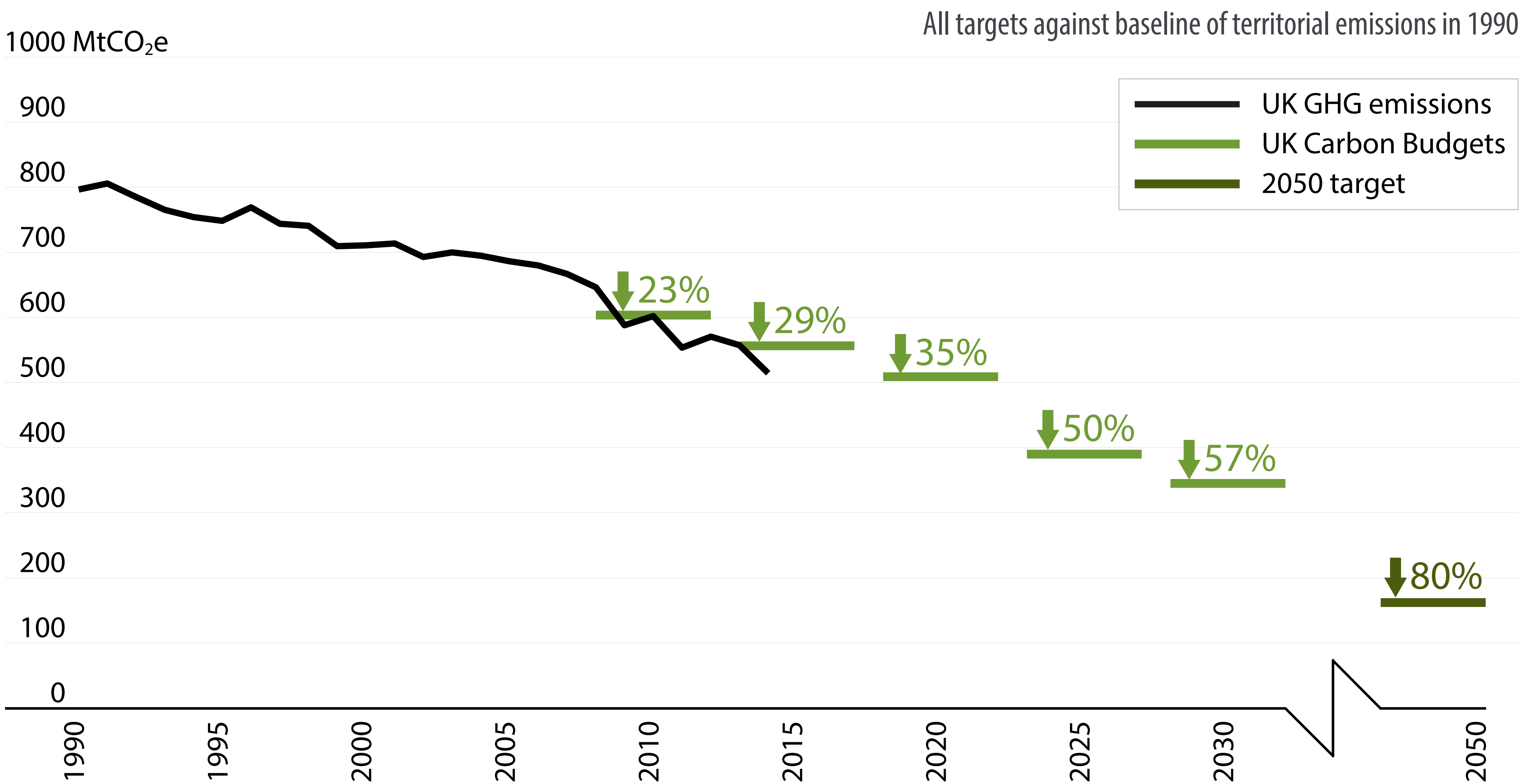
One potential pathway



Forster (2015) - more info at www.carbonbrief.org/piers-forster-1-5c-is-a-brave-new-world

Interim targets for the UK

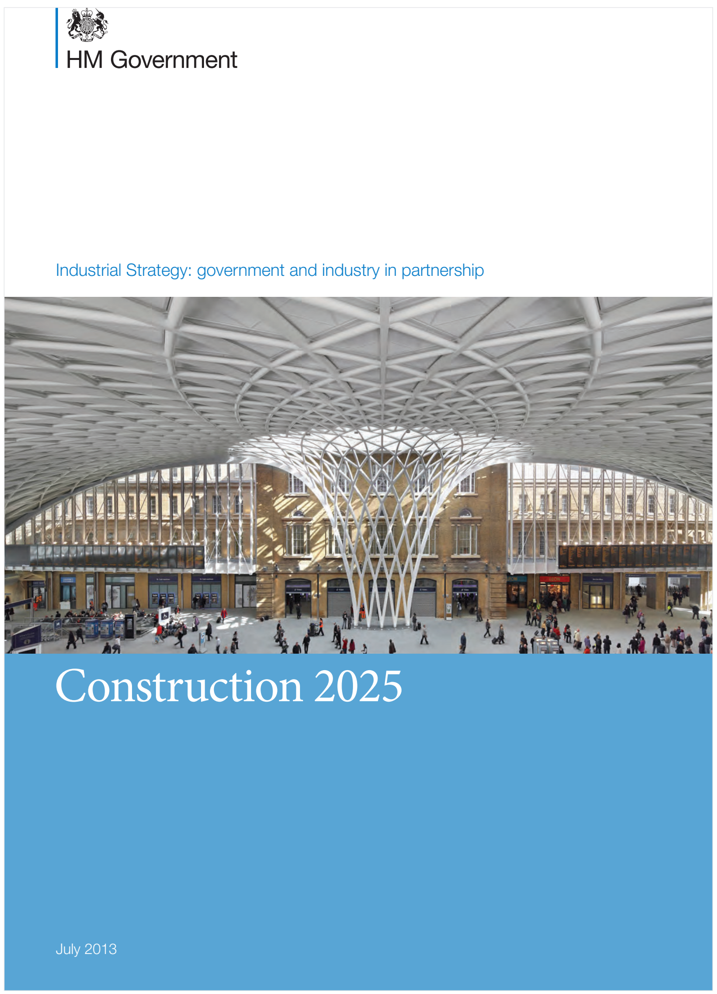
Based on series of legally binding 5 year budgets

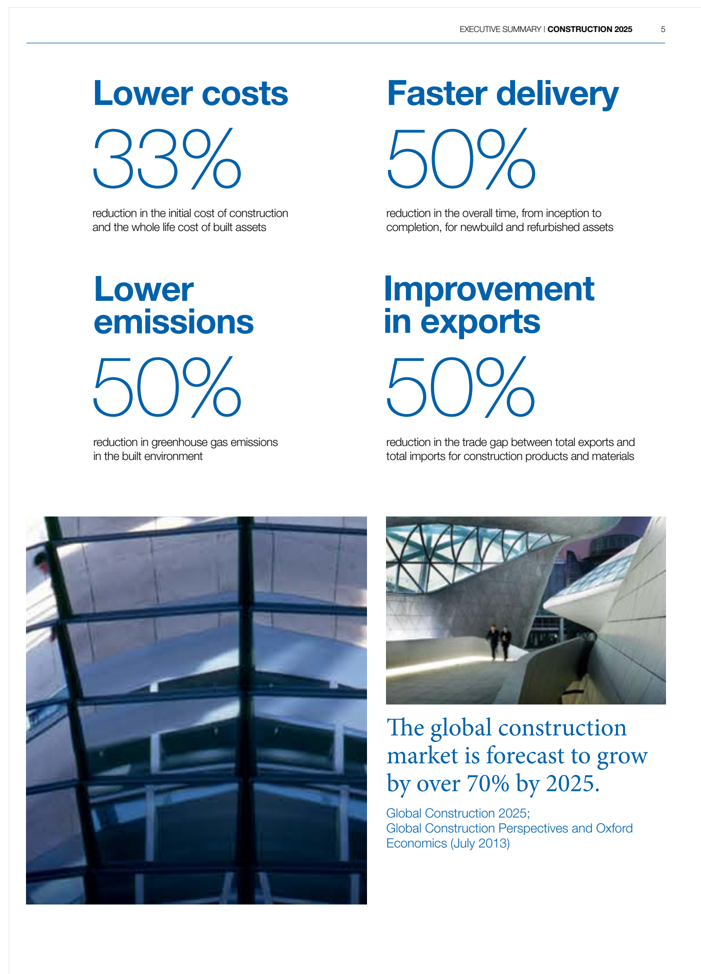


Construction 2025

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”*




EXECUTIVE SUMMARY | CONSTRUCTION 2025 5

Lower costs
33%
reduction in the initial cost of construction and the whole life cost of built assets

Faster delivery
50%
reduction in the overall time, from inception to completion, for newbuild and refurbished assets

Lower emissions
50%
reduction in greenhouse gas emissions in the built environment

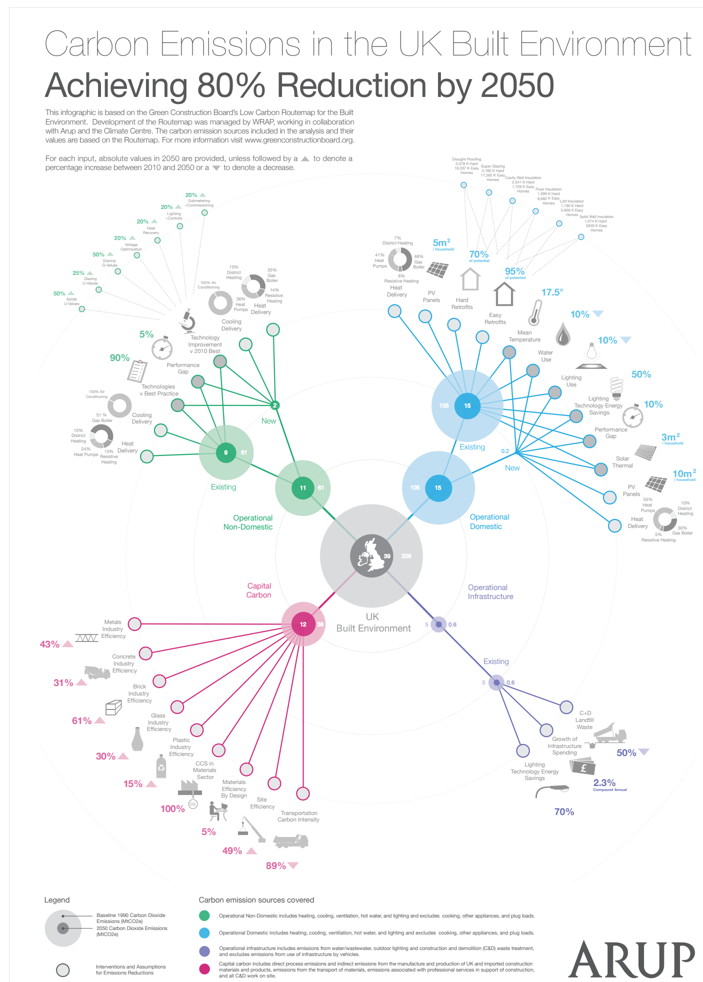
Improvement in exports
50%
reduction in the trade gap between total exports and total imports for construction products and materials

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

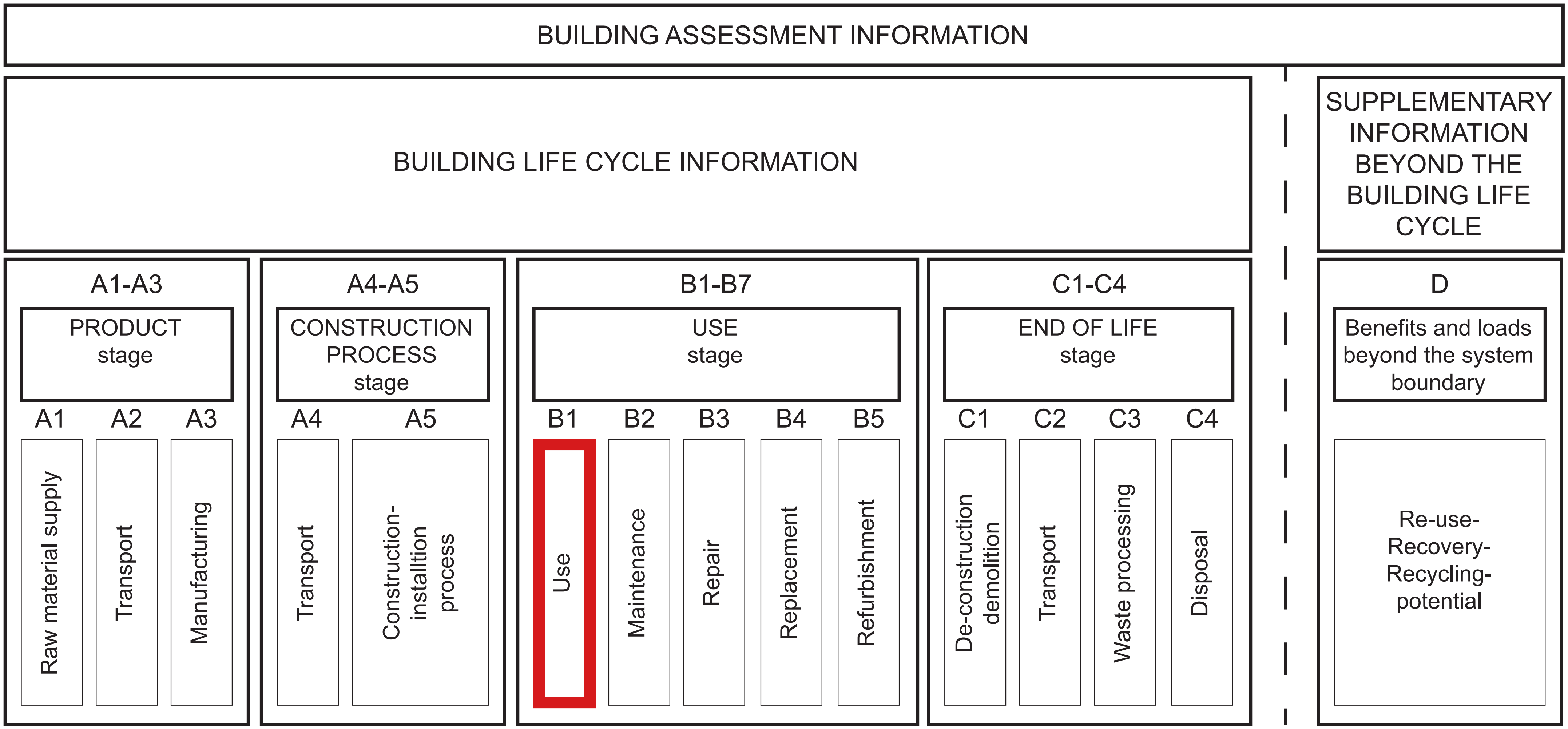
Initial report set out target trajectory to 2050

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



Life cycle emissions

Common definition



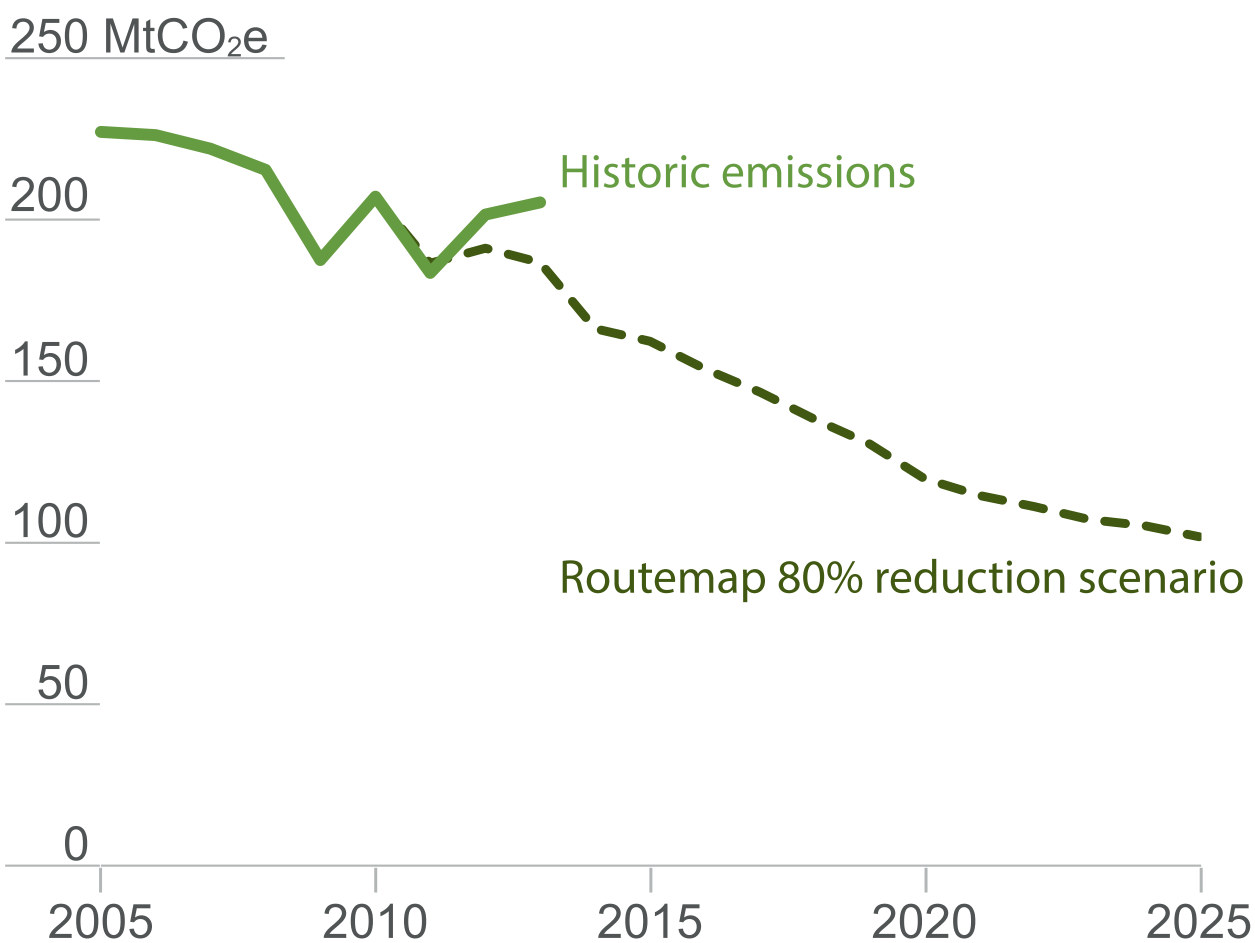
Stages from BS EN 15978:2011

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

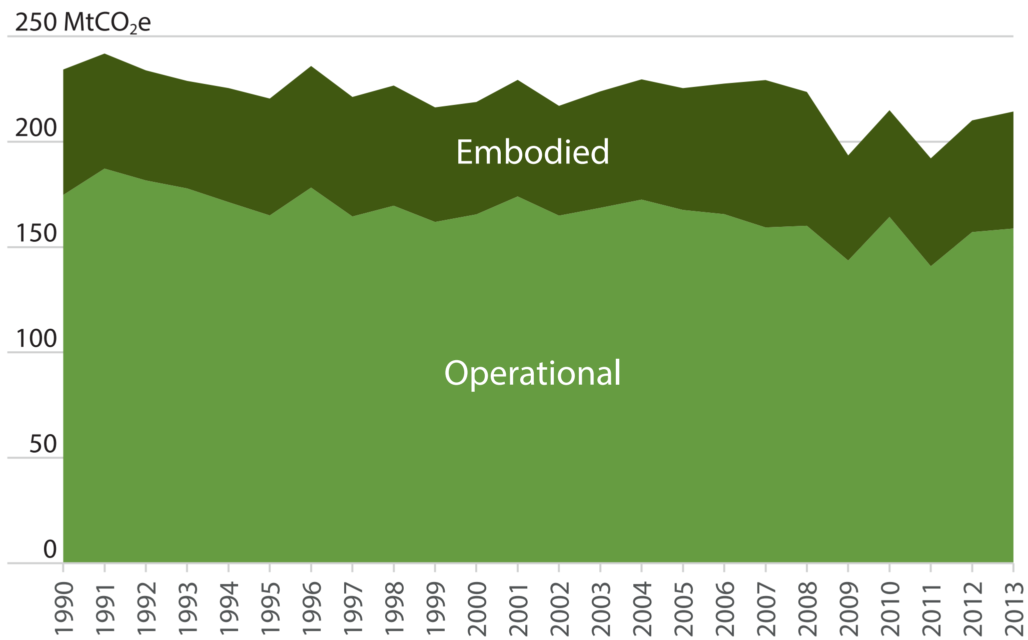


Green Construction Board (2015) Low Carbon Routemap for the UK Built Environment. Routemap Progress Technical Report

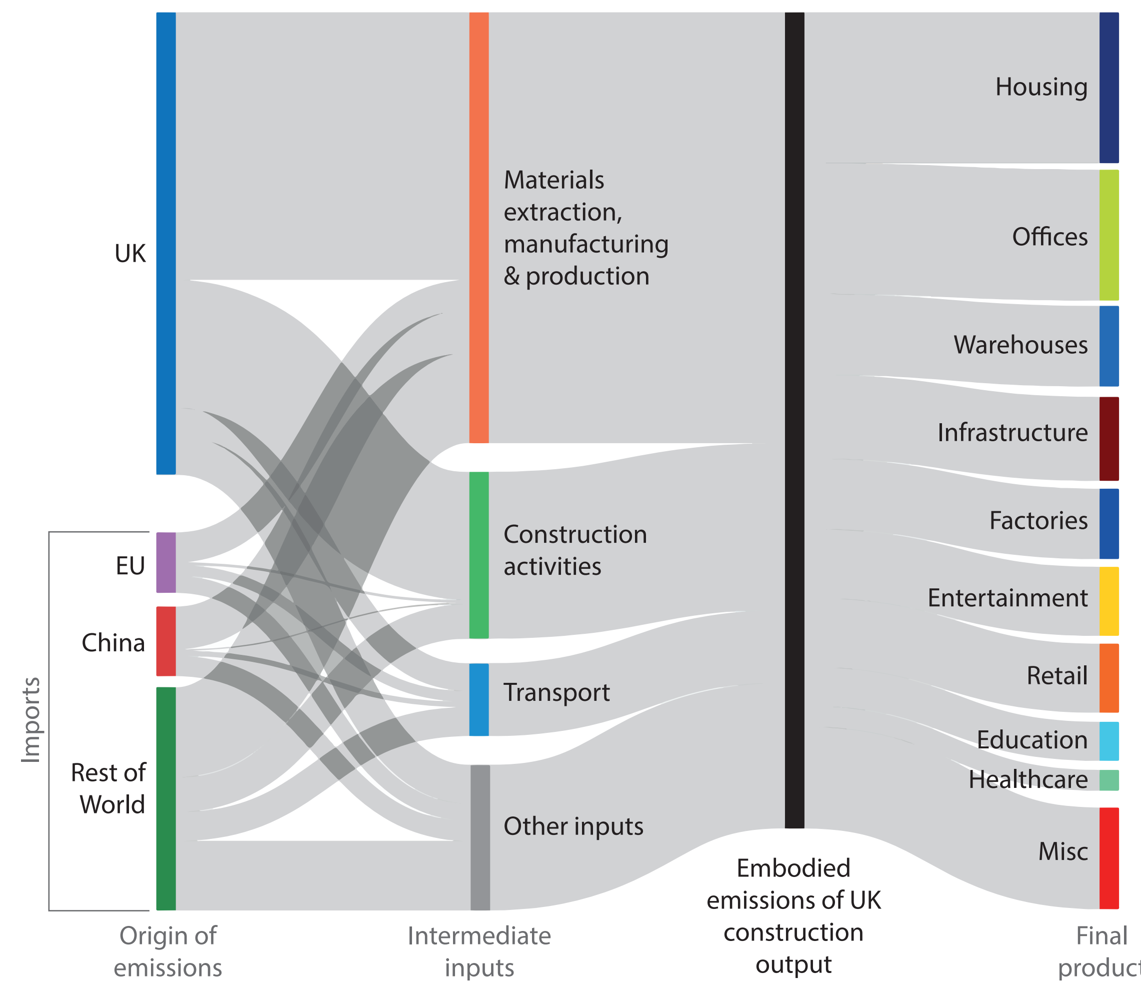
Carbon in UK construction

Estimated carbon footprint of UK construction supply chain

» Built environment emissions 1990-2013



» Embodied emissions in 2007

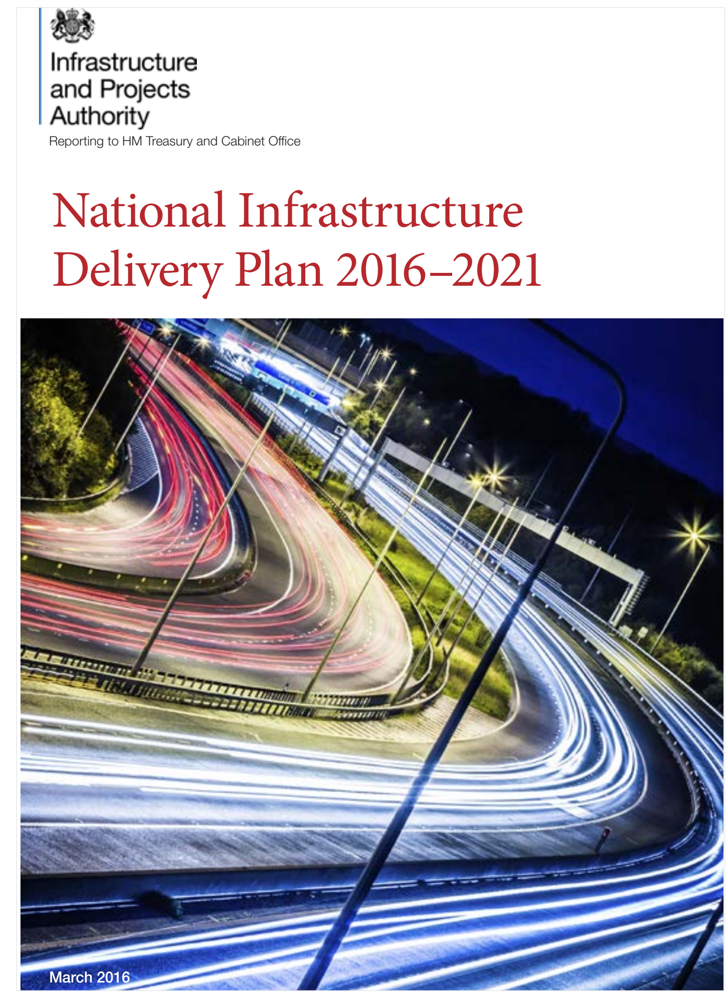


Scope for mitigation in infrastructure

Assessment of embodied carbon in NIP for CCC

» High level assessment projected ~244 $MtCO_2e$ associated with 2014 NIP

» Next step is to integrate embodied carbon into asset level demand projections



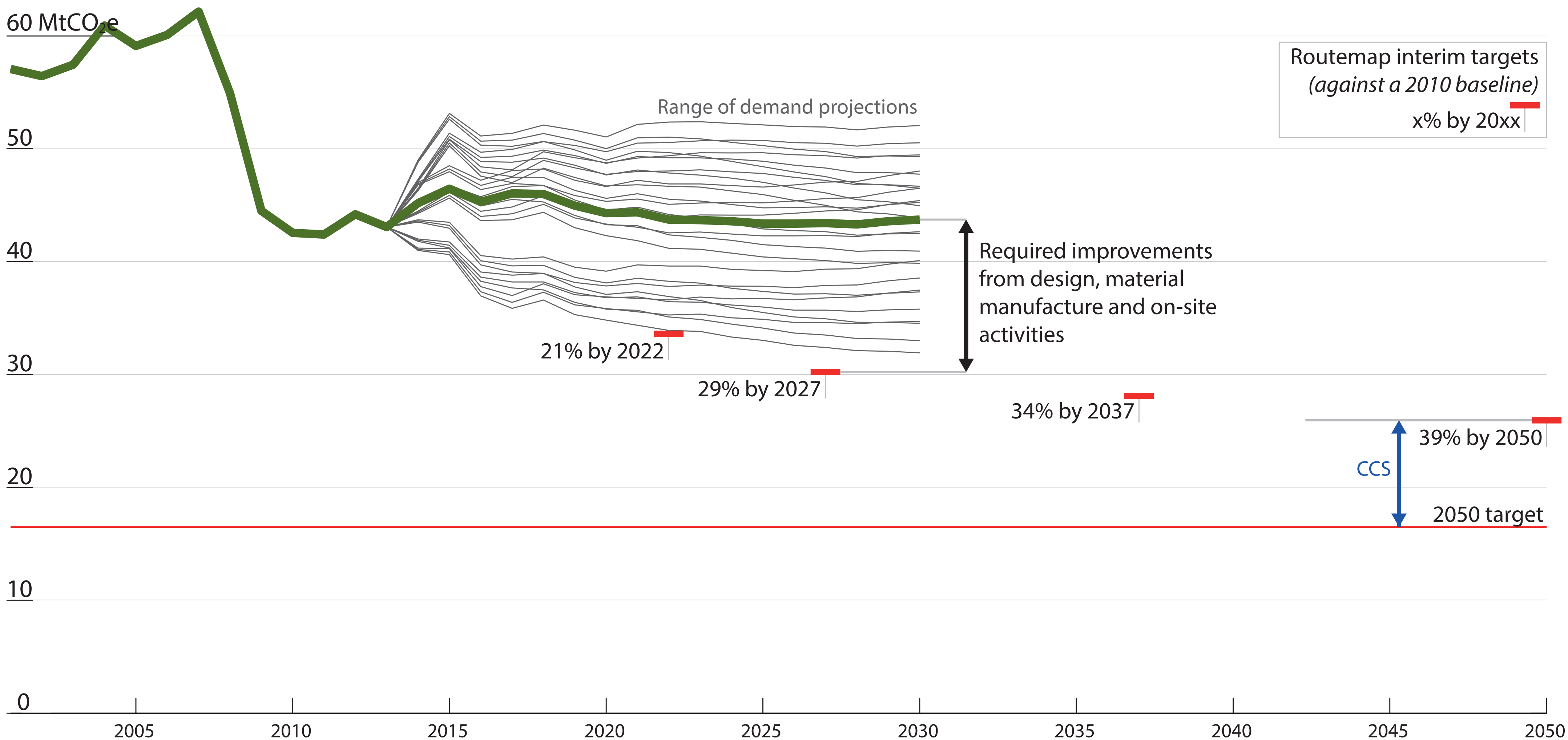
Assessment reported in CCC (2015) Meeting Carbon Budgets *Report to Parliament*

Required reductions

Anticipated embodied emissions of UK construction 2001-2030

» 27 scenarios using UK Buildings and Infrastructure Embodied Carbon model

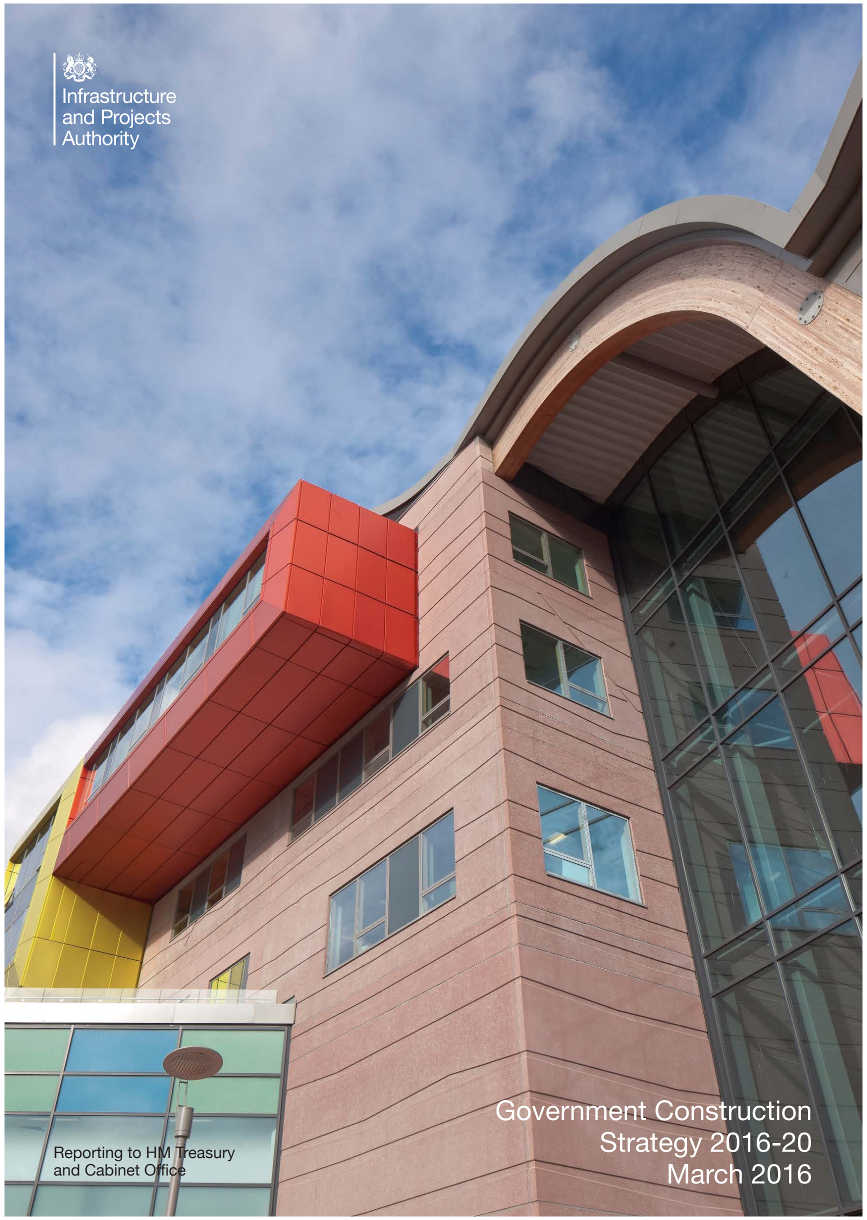
» **Including** improvements in grid intensity from DECC



Government Construction Strategy

For the current parliament

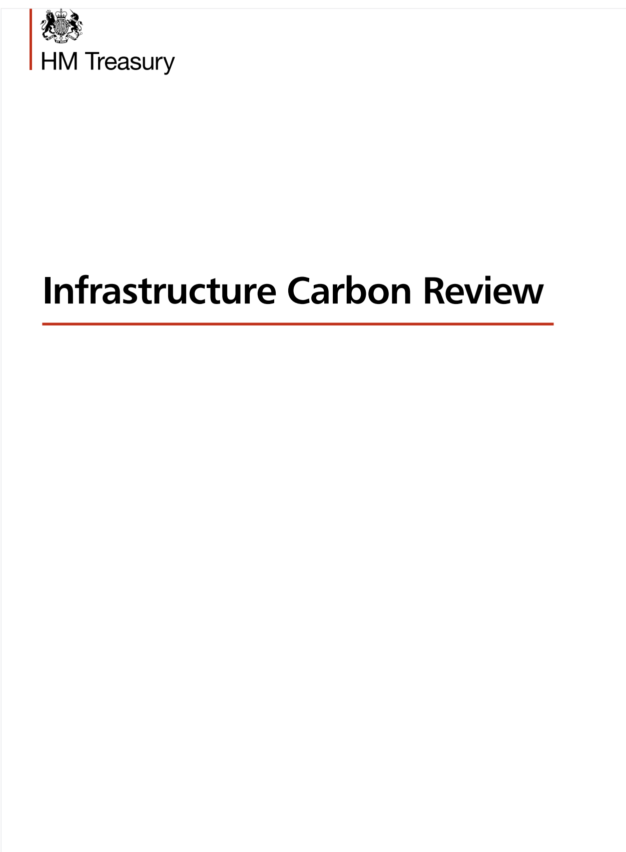
- One of the principal objectives is to *"enable and drive whole-life approaches to cost and carbon reduction"*
- Objective 3.6 is to *"Develop data requirements and benchmarks for measurement of whole-life cost and whole-life carbon (embodied and operational)"*
- *"Government contracts will encourage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

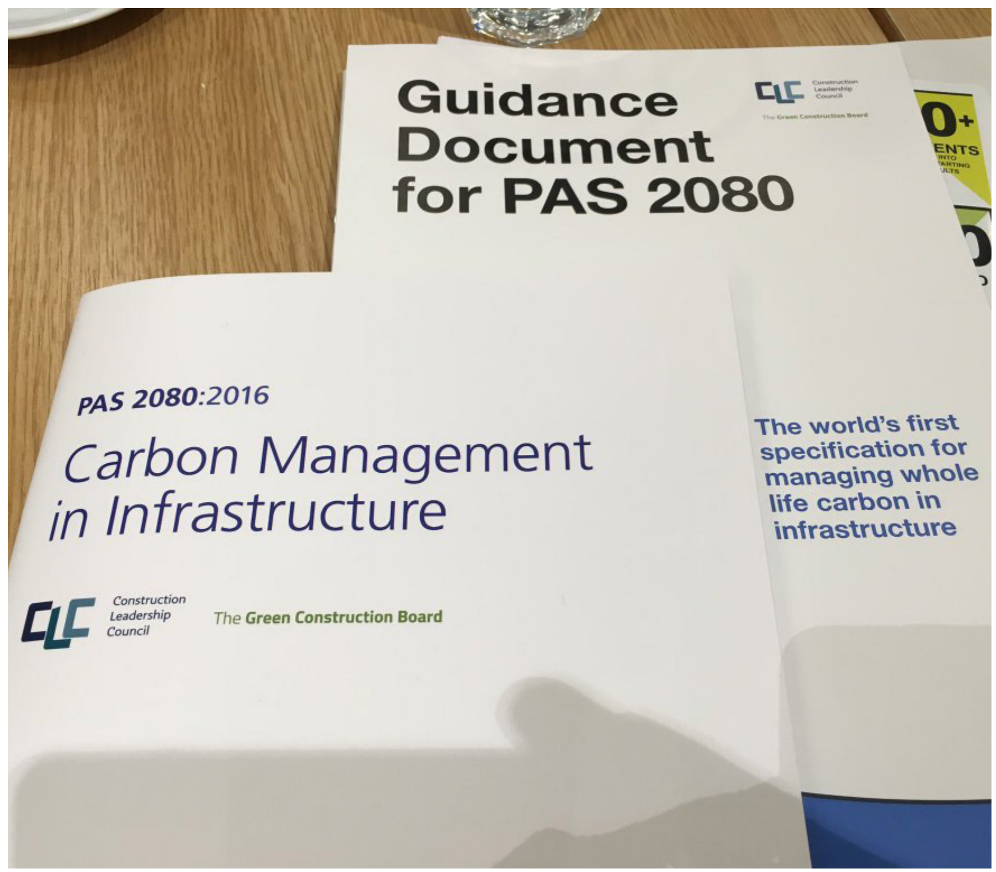


Drivers of low carbon construction

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

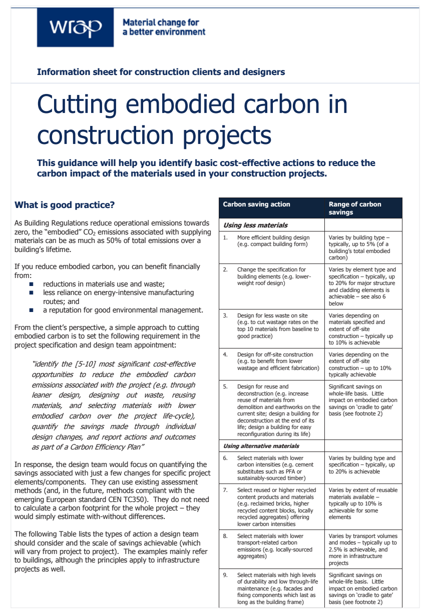


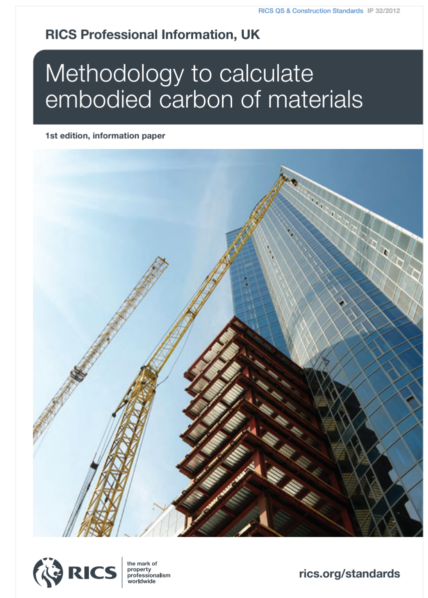


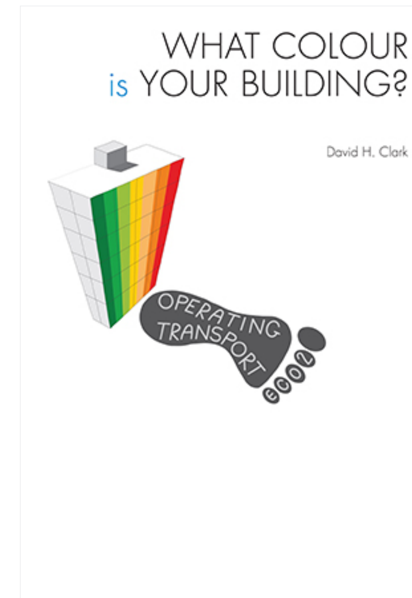
HM Treasury (2013) Infrastructure Carbon Review
BSI (2016) PAS 2080: Carbon Management in Infrastructure

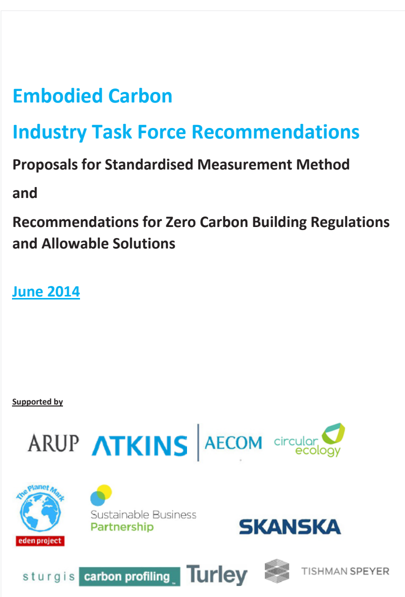
Guidance on embodied carbon

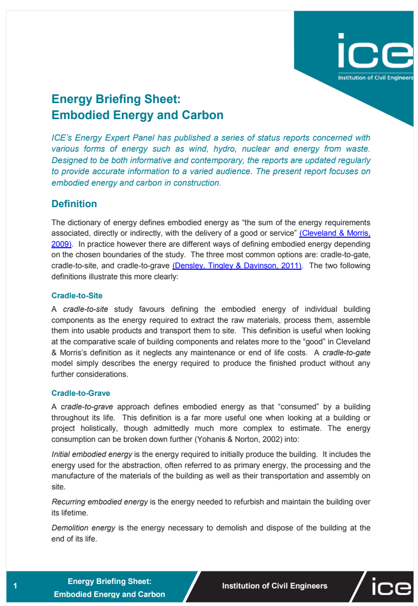
Array of recent industry publications

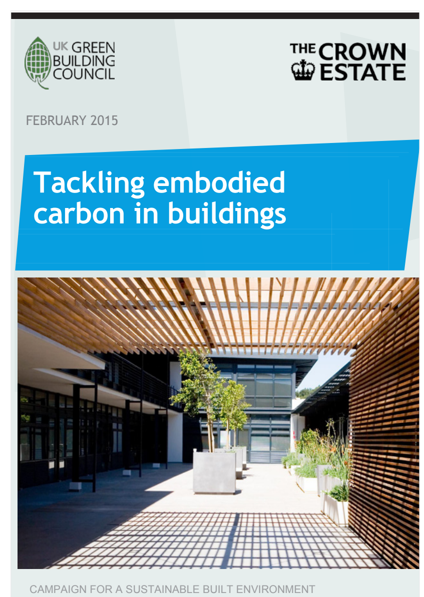


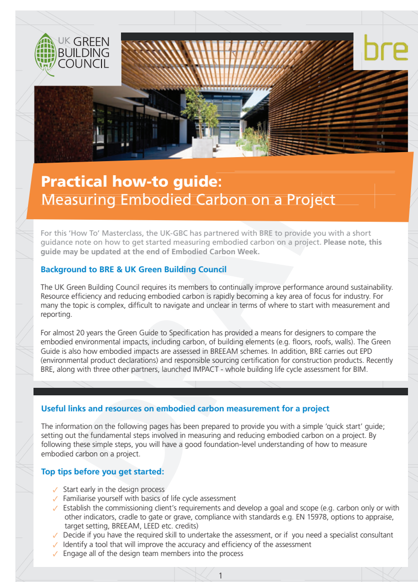


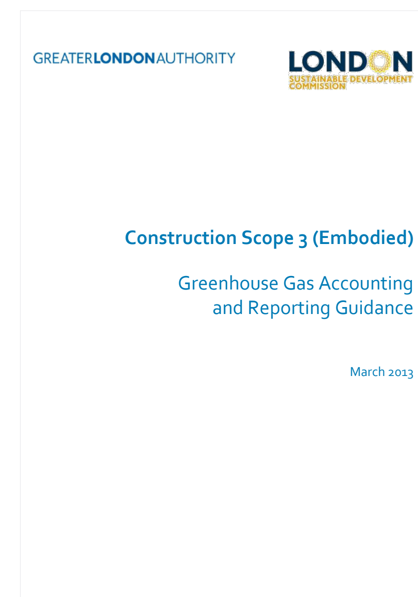












WRAP (2011, 2014); RICS (2012); Clark (2013); Battle (2014); ICE (2011); UKGBC (2015); GLA(2013)

Academic research

Rapidly expanding area of study

- » Pomponi & Moncaster provide recent overview of academic literature
- » Upcoming 2017 Springer book ‘Embodied Carbon in Buildings: Measurement, Management, and Mitigation’ will cover state-of-the-art

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ELSEVIER

Review

Embodied carbon mitigation and reduction in the built environment – What does the evidence say?

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A R T I C L E I N F O

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Low carbon built environment
LCA buildings

A B S T R A C T

Of all industrial sectors, the built environment puts the most pressure on the natural environment, and in spite of significant efforts the International Energy Agency suggests that buildings-related emissions are on track to double by 2050. Whilst operational energy efficiency continues to receive significant attention by researchers, a less well-researched area is the assessment of embodied carbon in the built environment in order to understand where the greatest opportunities for its mitigation and reduction lie. This article approaches the body of academic knowledge on strategies to tackle embodied carbon (EC) and uses a systematic review of the available evidence to answer the following research question: how should we mitigate and reduce EC in the built environment? 102 journal articles have been reviewed systematically in the fields of embodied carbon mitigation and reduction, and life cycle assessment. In total, 17 mitigation strategies have been identified from within the existing literature which have been discussed through a meta-analysis on available data. Results reveal that no single mitigation strategy alone seems able to tackle the problem; rather, a pluralistic approach is necessary. The use of materials with lower EC, better design, an increased reuse of EC-intensive materials, and stronger policy drivers all emerged as key elements for a quicker transition to a low carbon built environment. The meta-analysis on 77 LCAs also shows an extremely incomplete and short-sighted approach to life cycle studies. Most studies only assess the manufacturing stages, often completely overlooking impacts occurring during the occupancy stage and at the end of life of the building. The LCA research community have the responsibility to address such shortcomings and work towards more complete and meaningful assessments.

Table 1
Details of the mitigation strategies (MSs) identified in the literature.

MS	Description
1	Practical guidelines for a wider use of low-EC materials
2	Better design
3	Reduction, re-use and recovery of EE/EC intensive construction materials
4	Tools, methods, and methodologies
5	Policy and regulations (Governments)
6	Refurbishment of existing buildings instead of new built
7	Decarbonisation of energy supply/grid
8	Inclusion of waste, by-product, used materials into building materials
9	Increased use of local materials
10	Policy and regulations (Construction sector)
11	People-driven change (key role of all BE stakeholders)
12	More efficient construction processes/techniques
13	Carbon mitigation offsets, emissions trading, and carbon tax
14	Carbon sequestration
15	Extending the building's life
16	Increased use of prefabricated elements/off-site manufacturing
17	Demolition and rebuild

Pomponi & Moncaster (2016) *Journal of Environmental Management* 181 pp 687-700 doi: 10.1016/j.jenvman.2016.08.036

Current carbon 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 life cycle inventory 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 segments of industry (e.g. water & sewerage) now making routine detailed assessments using component level databases
- Increase in EPD production (3000+)
- Numerous ongoing projects to further standardise assessment practice 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.

British Land (2015); Land Securities (2016); M&S (2016); Anglian Water (2015)

Implementing EC assessment

Example checkpoints

RIBA Plan of Work 2013

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

Adapted from GLA (2013) and Doran (2014)

Setting carbon intensity targets

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*kgCO_2e/m^2/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 kgCO_2e/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 project targets

Currently include

- Different system boundaries preclude fair comparison between projects
- Selection of target 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
- **New paper addresses these issues, proposes means of linking project with sector targets and a new central information resource**

BUILDING ON THE PARIS AGREEMENT: MAKING THE CASE FOR EMBODIED CARBON INTENSITY TARGETS IN CONSTRUCTION

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ABSTRACT

Progressive clients are targeting embodied carbon reduction through the introduction of carbon intensity targets (CITs). CITs challenge design teams to deliver buildings with supply chain carbon emissions below a set level per functional unit. Despite CITs acting as

the current determination of CITs. The fourth section proposes measures to improve the future determination of CITs, and the fifth section considers the corresponding drivers for their use. The final section draws together some outstanding questions that should be the subject of future research.

Giesekam et al. (2016) Building on the Paris Agreement: making the case for embodied carbon intensity targets in construction

CIEMAP work in construction

Two key areas

» Assessing current and future material use and embodied carbon emissions

» **Understanding the barriers to greater material efficiency and the use of low carbon materials**

Within the industry

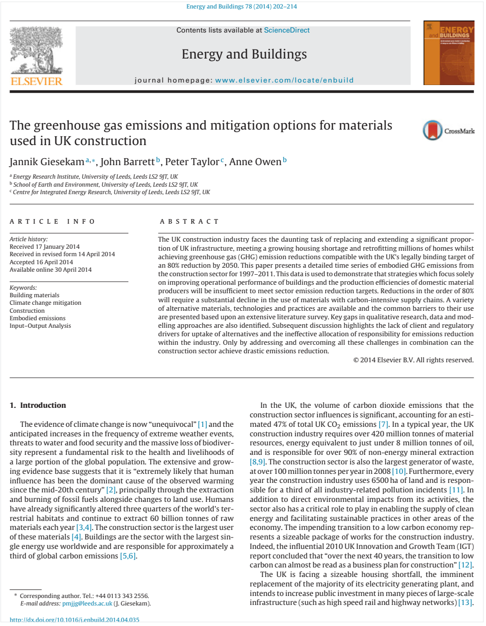
» Conducted surveys and interviews and undertaking an ongoing programme of stakeholder engagement

And amongst end users

» Current collaboration between universities of York, Sheffield and Leeds assessing 'public perceptions and experiences of low carbon building materials'

» **Online survey currently open**

» Workshops scheduled for 2017


Energy and Buildings 78 (2014) 202–214
Contents lists available at ScienceDirect
Energy and Buildings
journal homepage: www.elsevier.com/locate/enbuild
The greenhouse gas emissions and mitigation options for materials used in UK construction
Jannik Giesekam, John Barrett, Peter Taylor, Anne Owen


RESEARCH PAPER
Construction sector views on low carbon building materials
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White Rose university consortium

Giesekam et al. (2014) The GHG emissions and mitigation options for materials used in UK construction *Energy and Buildings*
Giesekam et al. (2016) Construction sector views on low carbon building materials *Building Research & Information*

Why use low carbon materials?

Potential benefits

» Embodied/capital carbon reduction

» Improved resource efficiency

» Improved air quality and occupant health

» Better resource security

» Greater energy efficiency

» Improved social sustainability (e.g. local employment) etc.

Drivers and incentives

» Cost savings

» Client demands

» Credits in environmental assessment schemes (BREEAM, LEED etc.)

» Green reputation

» Moral convictions

Giesekam et al. (2016) Construction sector views on low carbon building materials *Building Research & Information*

Securing additional drivers

Client led drivers

» Requires stronger evidence on link between cost and carbon

» Changes in culture required to ensure implementation

» Voluntary initiatives a good starting point

» Leadership is required in absence of clear business case

Regulation

» Must address ownership of issue within industry and government

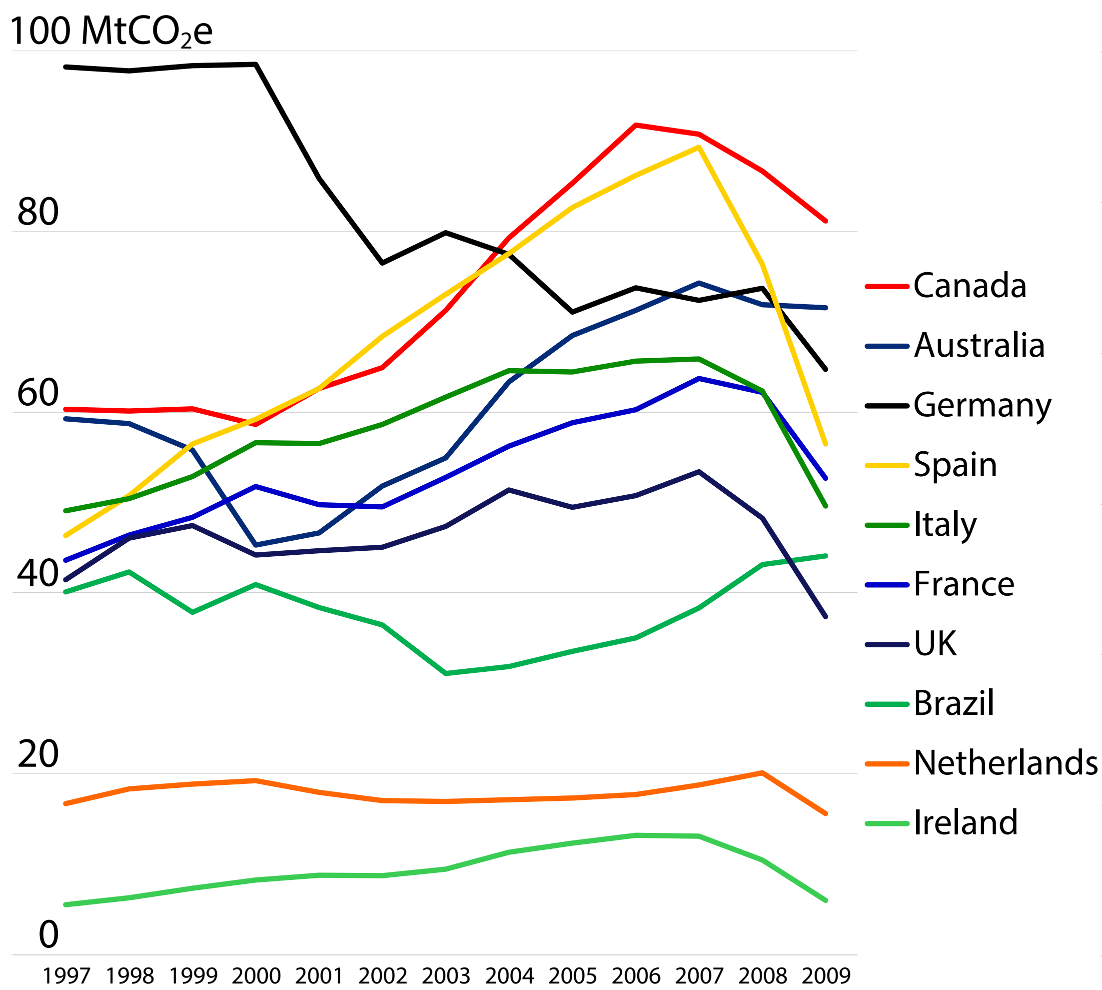
» Needs collective action from broader range of advocates across value chain

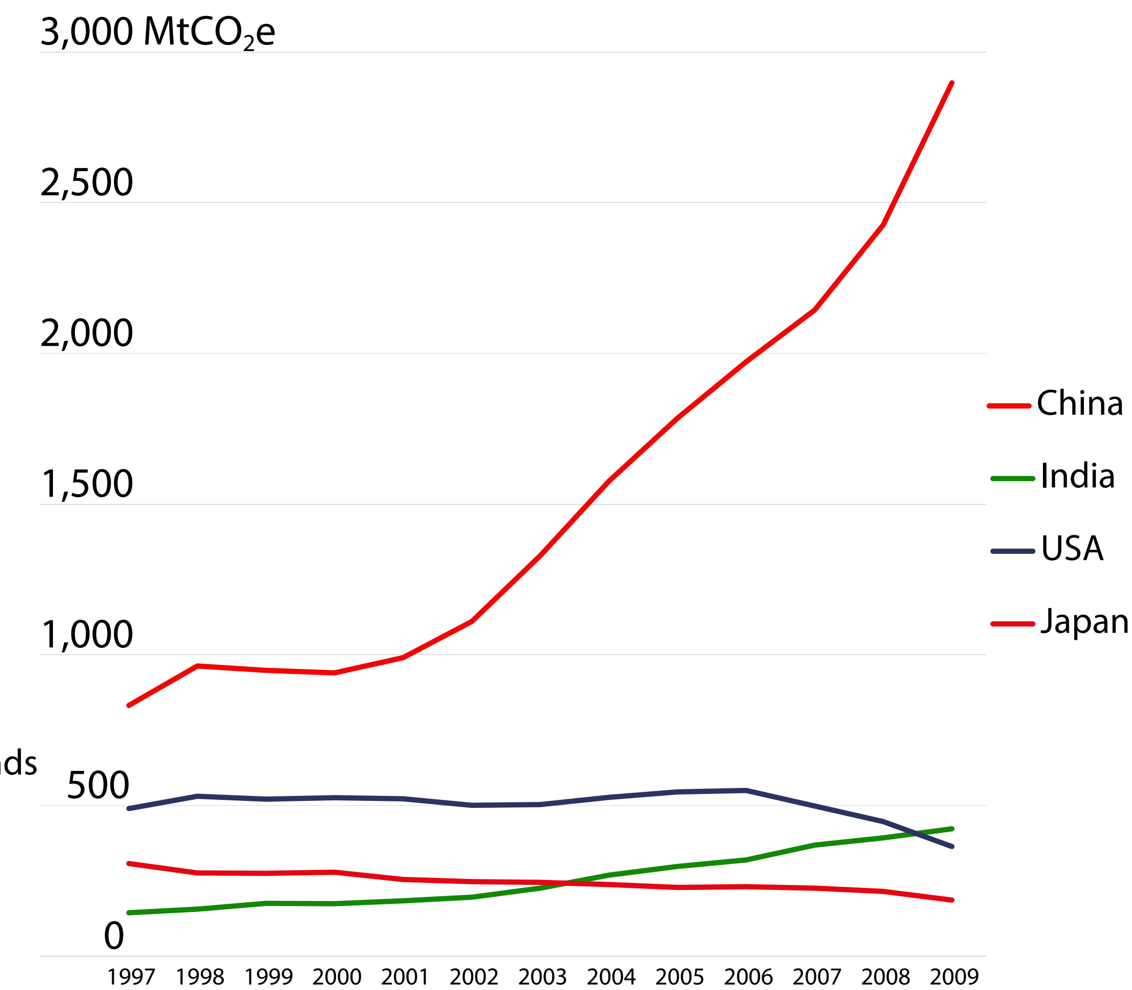
» Narrative development is critical

» Further evidence gathering required

Vast international scope

GHG emissions of construction sector supply chain by country





» Construction firms in these 14 countries alone influence 4.4 $GtCO_2e$ of supply chain emissions

Based upon MRIO analysis using WIOD data for 40 countries plus 'rest of world'

Summary

Embodied carbon status quo

» The UK construction industry must address embodied carbon if sector carbon reduction targets are to be met

» Sizeable mitigation potential if range of known measures are adopted

» Still wide variations in embodied carbon assessment practices but more guidance and product data available

» Introduction of embodied carbon targets is the best approach to motivate requisite changes in design, product selection and construction practices

» Project targets not yet consistent with national and sector targets

» Many potential benefits but few strong drivers for sustainable material use

» Industry, academia and government must work together to translate ambitious carbon targets into robust drivers