Reducing embodied carbon in construction

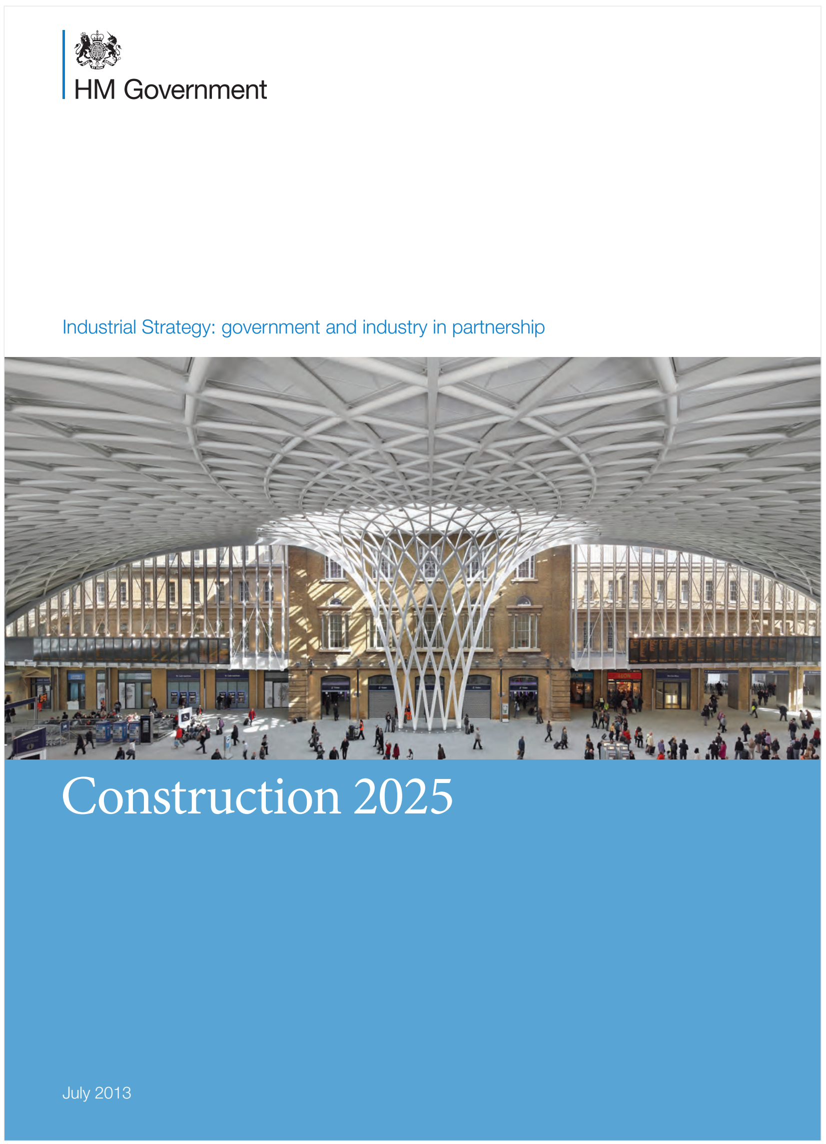
Demonstrating the need for a policy response with the UK Buildings Embodied Carbon Model

Jannik Giesekam

Construction 2025

Government strategy targets 50% reduction in GHG emissions

» Whilst reducing cost and accelerating project delivery




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

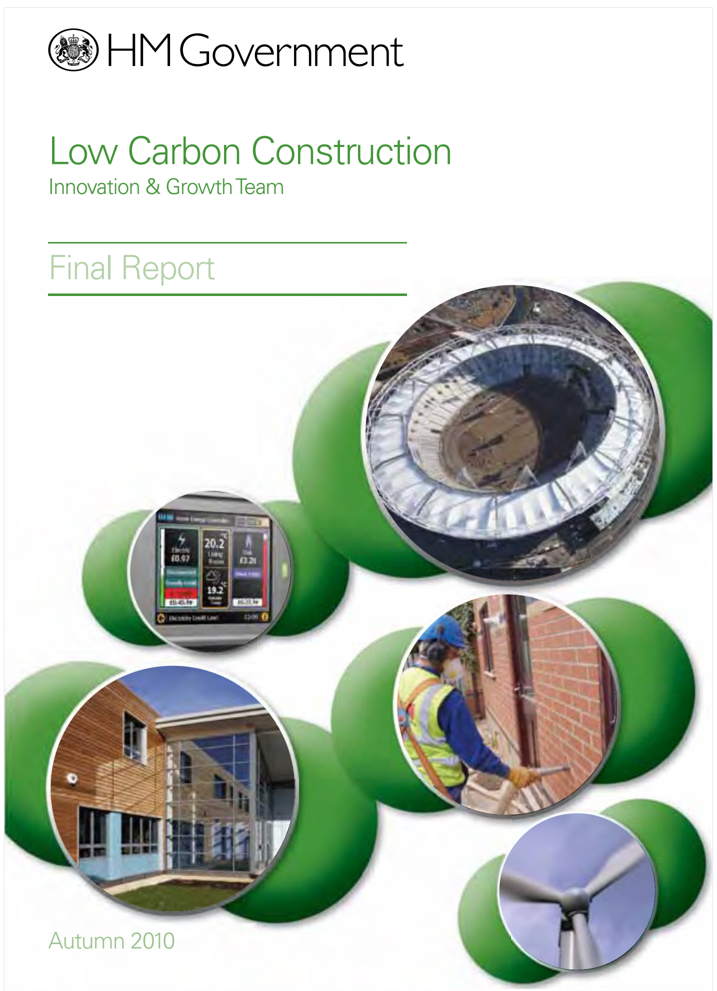
The global construction market is forecast to grow by over 70% by 2025.

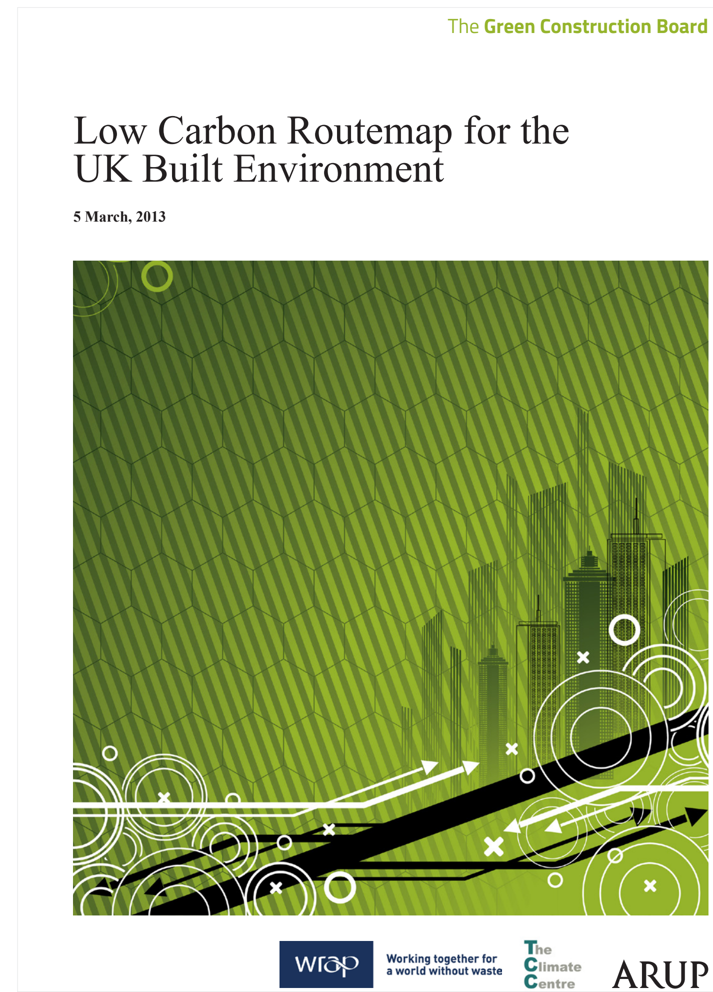
Global Construction 2025; Global Construction Perspectives and Oxford Economics (July 2013)

Low Carbon Construction

Building a plan through successive reports

» Government responded to Innovation and Growth Team recommendations and created Green Construction Board who developed a sector routemap in 2013





Policy response so far

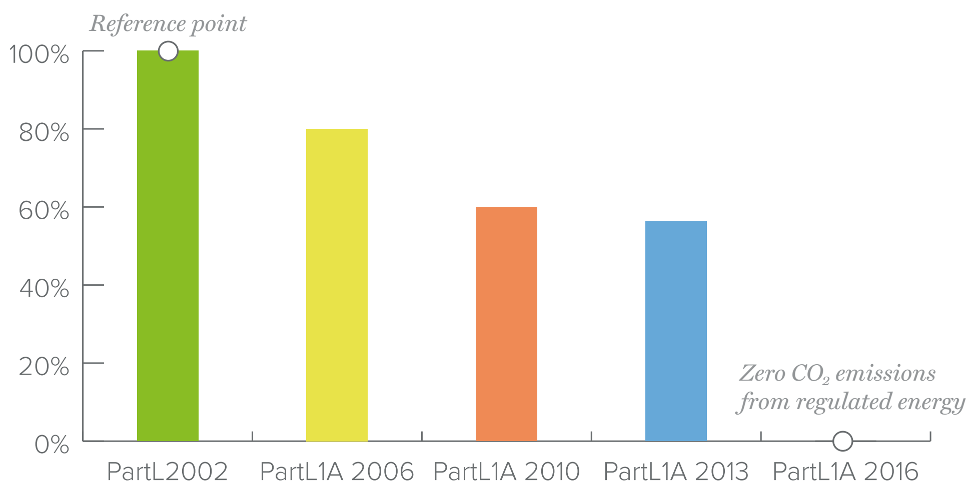
Motivated by EU Energy Performance of Buildings Directive

» Zero Carbon Homes (2016) & Non-domestic buildings (2019)

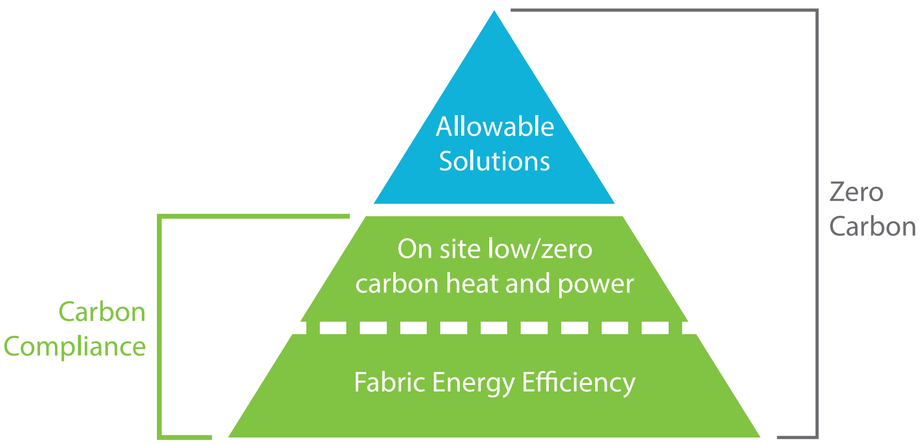
» Changes to Part L of Building Regulations

» Green Deal

PartL1A Improvement over time, aggregated CO_2 emissions reductions



Definition of Zero Carbon



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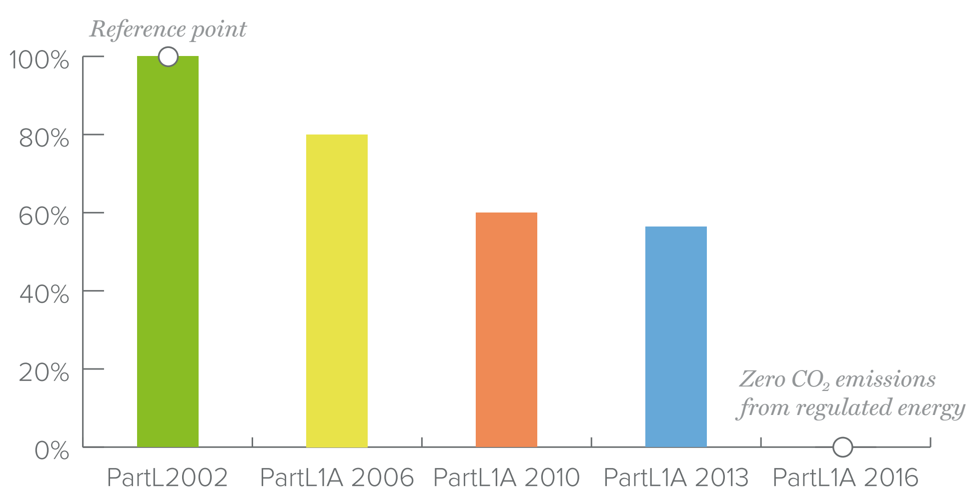

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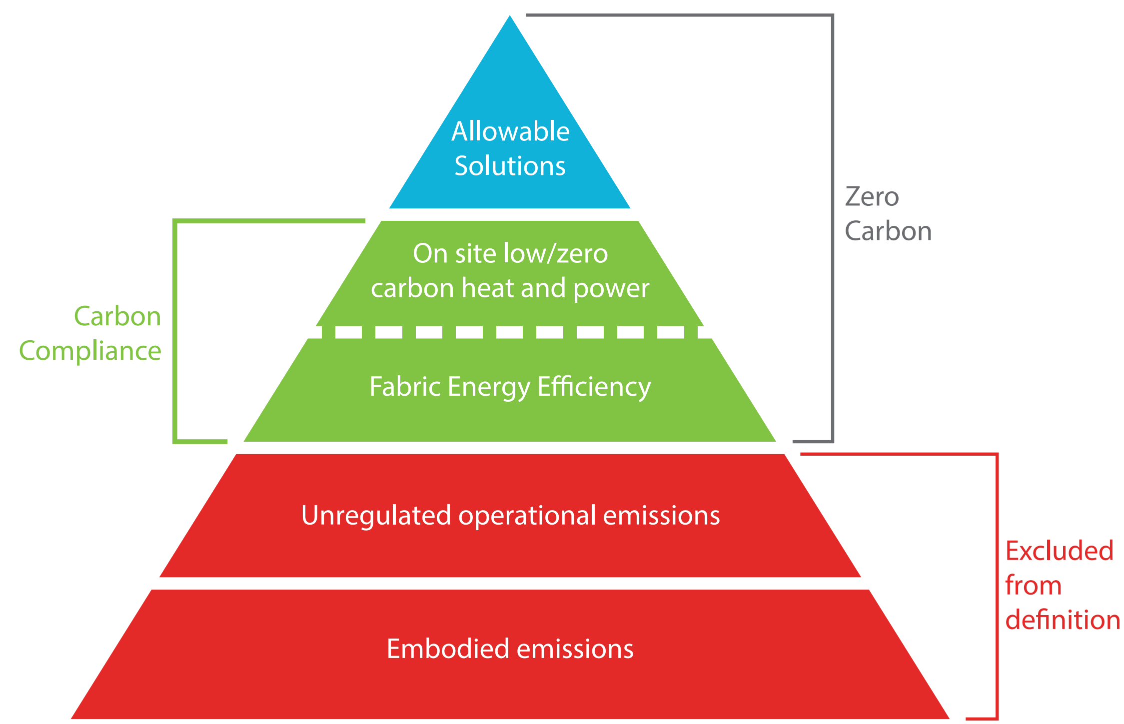
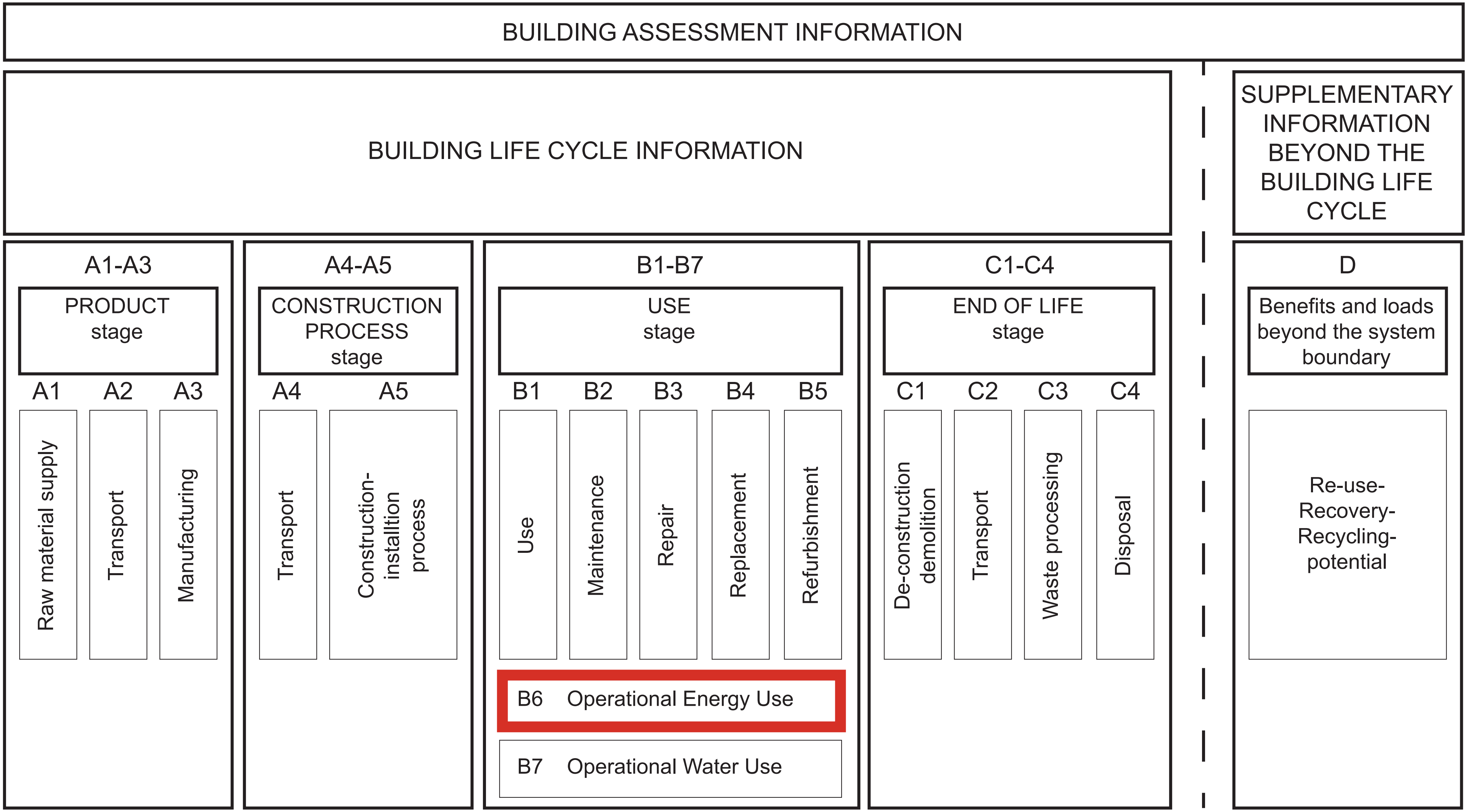


Zero Carbon Hub (2014) Zero Carbon Homes and Nearly Zero Energy Buildings

But...

Policy response only addresses operational energy use



Embodied carbon is significant

Estimated carbon footprint of UK construction supply chain

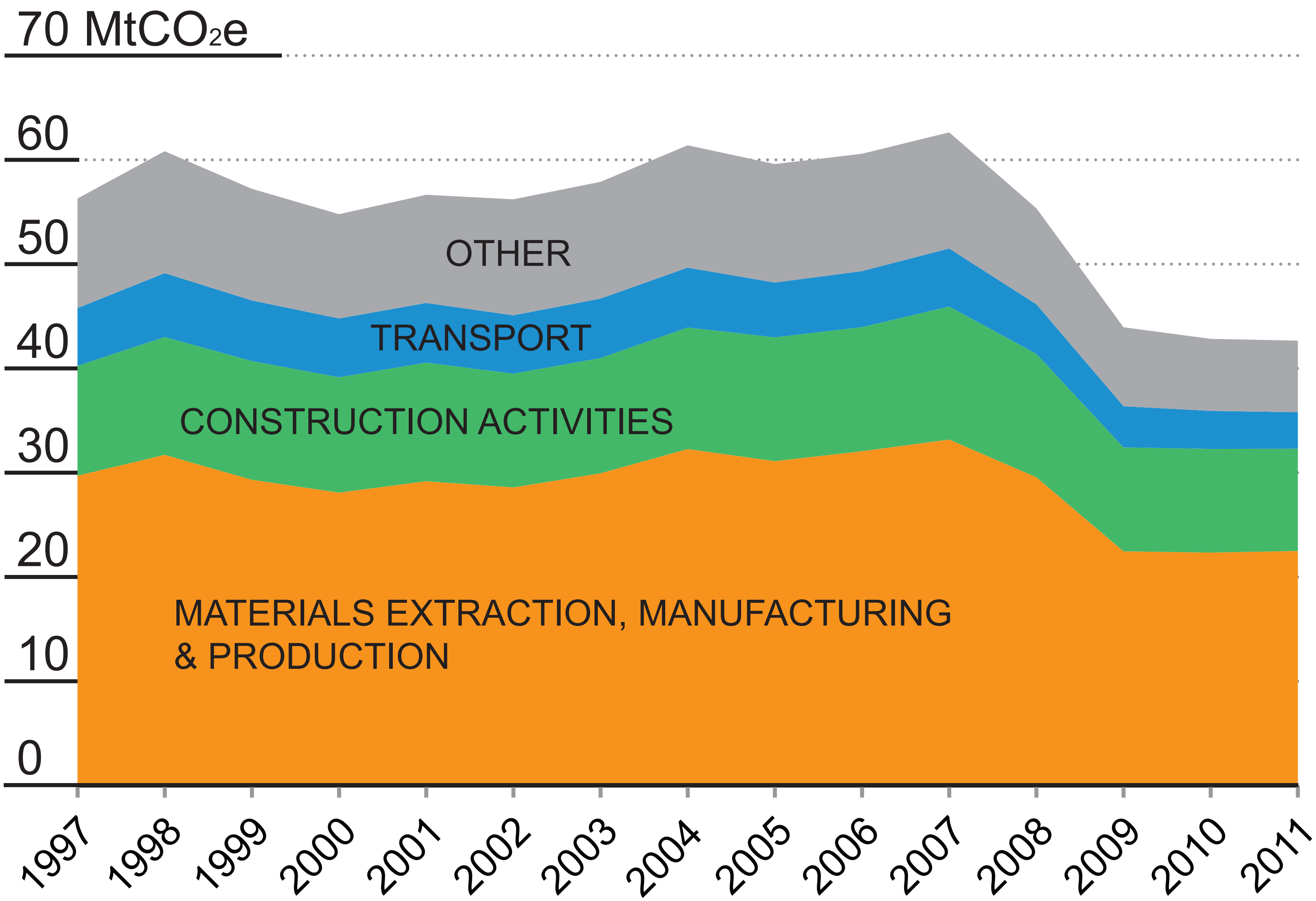
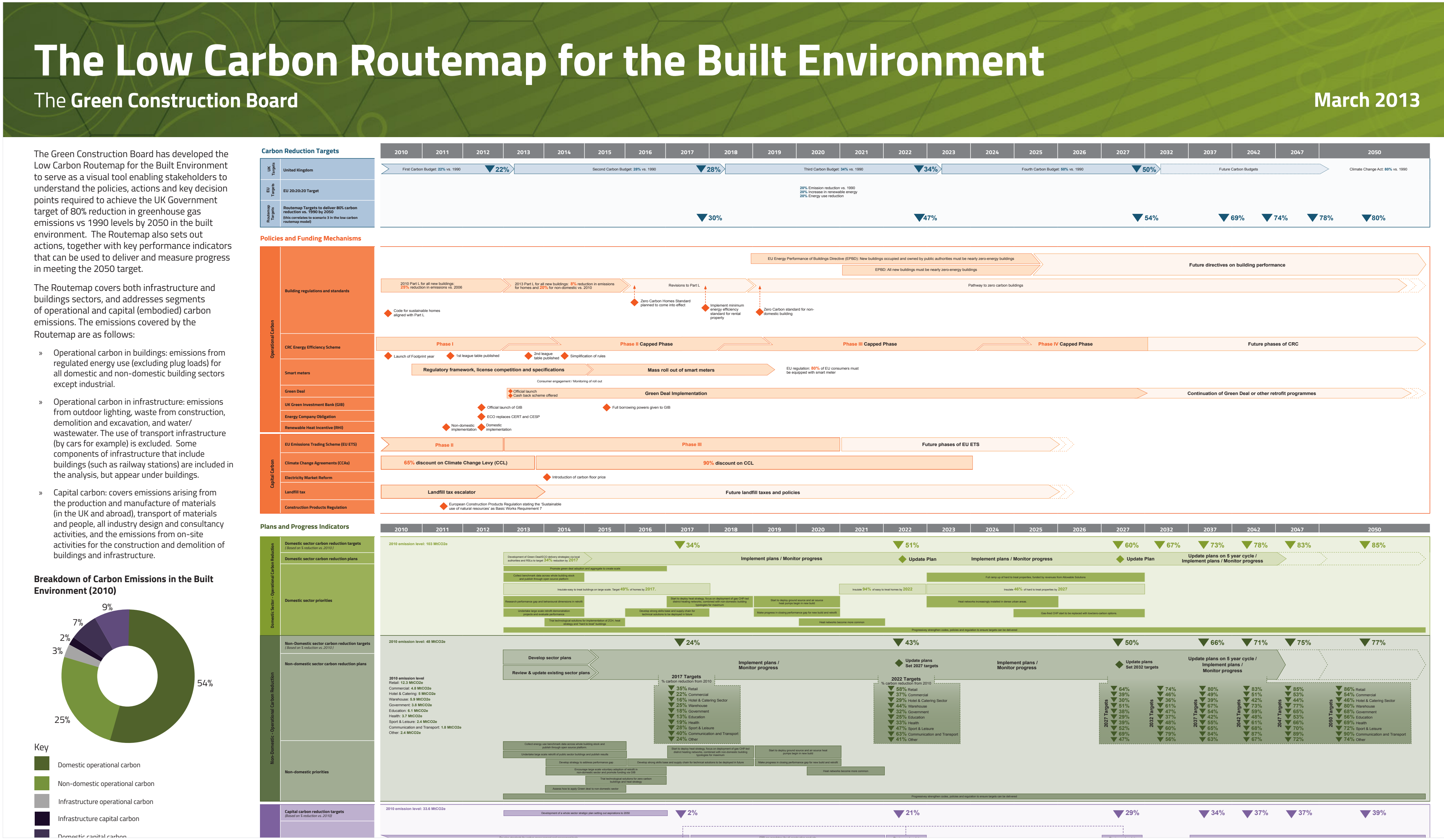


Figure from Giesekam et al. Energy and Buildings 78 pp202-214 (2014)

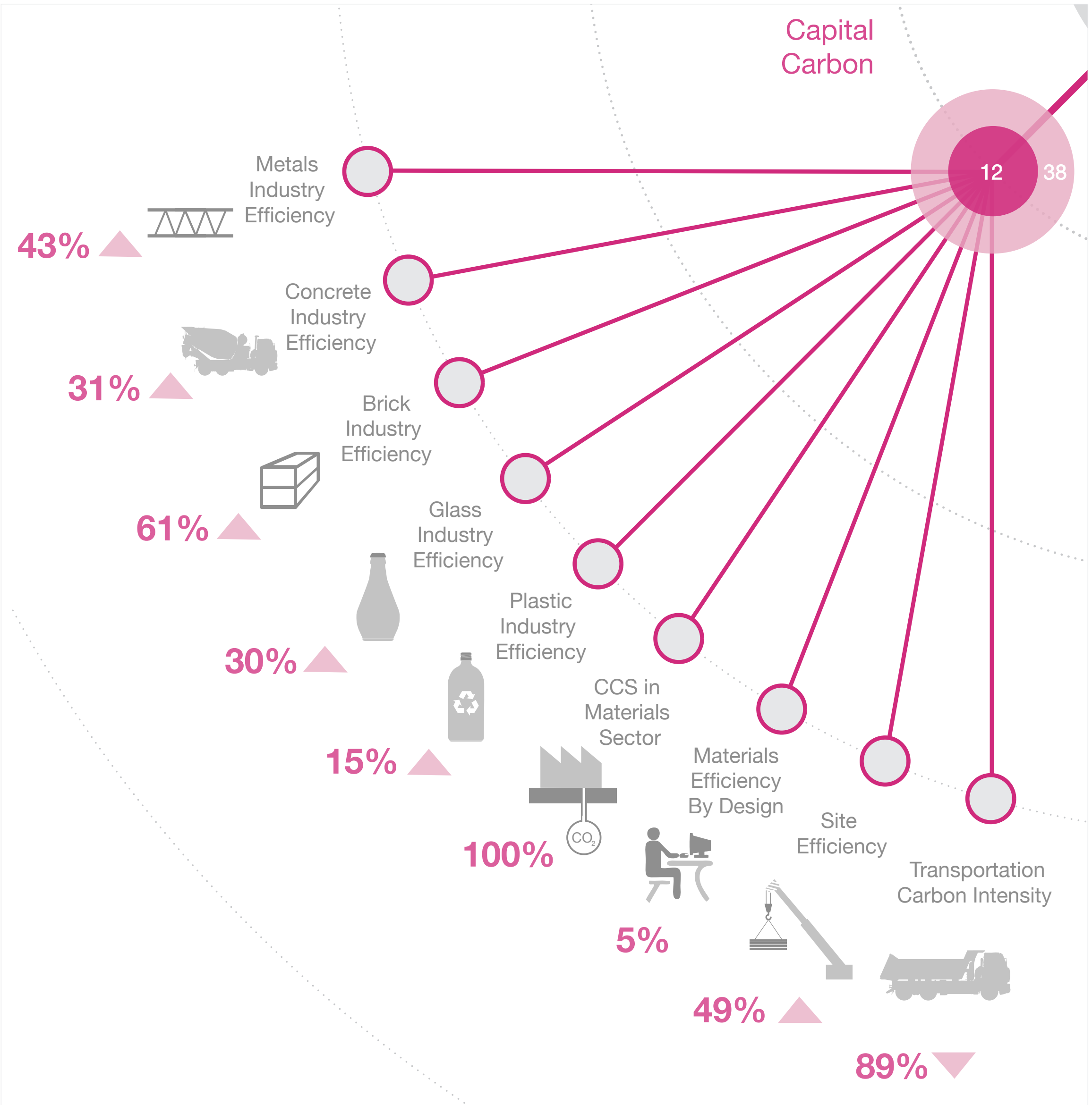
Industry routemap

Requires 39% reduction in embodied carbon by 2050 (from 2010)



Routemap 80% reduction scenario

Sets unrealistic targets for material manufacturers



"My personal view is that the assumptions the model makes are so heroic that I don't believe anyone will believe it will happen in the timeframe."

Paul Morrell - Chief Construction Adviser 2009-2012

Strategies to reduce embodied carbon

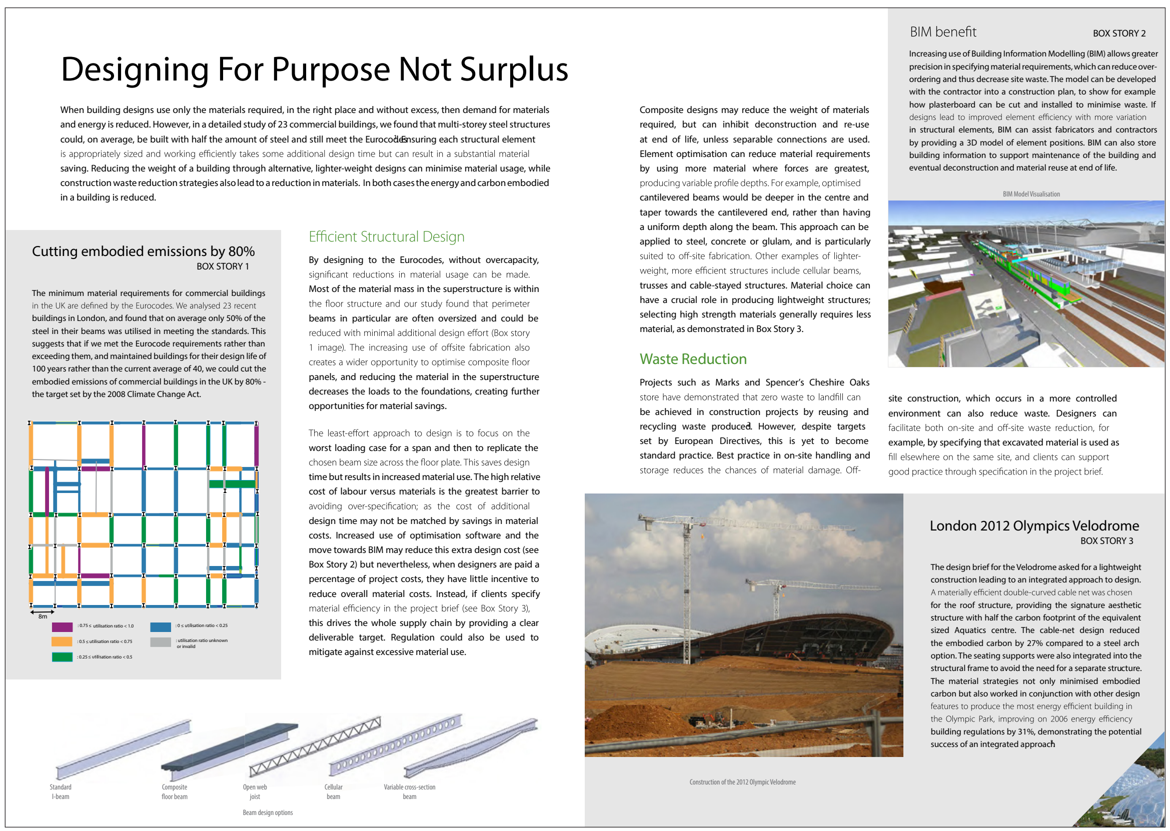
Main strategies

» Designing for purpose not surplus

» Building life extension

» Designing for deconstruction and re-use

» Using alternative materials



Designing For Purpose Not Surplus

When building designs use only the materials required, in the right place and without excess, then demand for materials and energy is reduced. However, in a detailed study of 23 commercial buildings, we found that multi-storey steel structures could, on average, be built with half the amount of steel and still meet the Eurocodes[1]. Ensuring each structural element is appropriately sized and working efficiently takes some additional design time but can result in a substantial material saving. Reducing the weight of a building through alternative, lighter-weight designs can minimise material usage, while construction waste reduction strategies also lead to a reduction in materials. In both cases the energy and carbon embodied in a building is reduced.

Cutting embodied emissions by 80%

BOX STORY 1

The minimum material requirements for commercial buildings in the UK are defined by the Eurocodes. We analysed 23 recent buildings in London, and found that on average only 50% of the steel in their beams was utilised in meeting the standards. This suggests that if we met the Eurocode requirements rather than exceeding them, and maintained buildings for their design life of 100 years rather than the current average of 40, we could cut the embodied emissions of commercial buildings in the UK by 80% - the target set by the 2008 Climate Change Act.

Efficient Structural Design

By designing to the Eurocodes, without overcapacity, significant reductions in material usage can be made. Most of the material mass in the superstructure is within the floor structure and our study found that perimeter beams in particular are often oversized and could be reduced with minimal additional design effort (Box story 1 image). The increasing use of offsite fabrication also creates a wider opportunity to optimise composite floor panels, and reducing the material in the superstructure decreases the loads to the foundations, creating further opportunities for material savings.

The least-effort approach to design is to focus on the worst loading case for a span and then to replicate the chosen beam size across the floor plate. This saves design time but results in increased material use. The high relative cost of labour versus materials is the greatest barrier to avoiding over-specification; as the cost of additional design time may not be matched by savings in material costs. Increased use of optimisation software and the move towards BIM may reduce this extra design cost (see Box Story 2) but nevertheless, when designers are paid a percentage of project costs, they have little incentive to reduce overall material costs. Instead, if clients specify material efficiency in the project brief (see Box Story 3), this drives the whole supply chain by providing a clear deliverable target. Regulation could also be used to mitigate against excessive material use.

Composite designs may reduce the weight of materials required, but can inhibit deconstruction and re-use at end of life, unless separable connections are used. Element optimisation can reduce material requirements by using more material where forces are greatest, producing variable profile depths. For example, optimised cantilevered beams would be deeper in the centre and taper towards the cantilevered end, rather than having a uniform depth along the beam. This approach can be applied to steel, concrete or glulam, and is particularly suited to off-site fabrication. Other examples of lighter-weight, more efficient structures include cellular beams, trusses and cable-stayed structures. Material choice can have a crucial role in producing lightweight structures; selecting high strength materials generally requires less material, as demonstrated in Box Story 3.

Waste Reduction

Projects such as Marks and Spencer's Cheshire Oaks store have demonstrated that zero waste to landfill can be achieved in construction projects by reusing and recycling waste produced[2]. However, despite targets set by European Directives, this is yet to become standard practice. Best practice in on-site handling and storage reduces the chances of material damage. Off-site construction, which occurs in a more controlled environment can also reduce waste. Designers can facilitate both on-site and off-site waste reduction, for example, by specifying that excavated material is used as fill elsewhere on the same site, and clients can support good practice through specification in the project brief.

BIM benefit

BOX STORY 2

Increasing use of Building Information Modelling (BIM) allows greater precision in specifying material requirements, which can reduce over-ordering and thus decrease site waste. The model can be developed with the contractor into a construction plan, to show for example how plasterboard can be cut and installed to minimise waste. If designs lead to improved element efficiency with more variation in structural elements, BIM can assist fabricators and contractors by providing a 3D model of element positions. BIM can also store building information to support maintenance of the building and eventual deconstruction and material reuse at end of life.

BIM Model Visualisation

London 2012 Olympics Velodrome

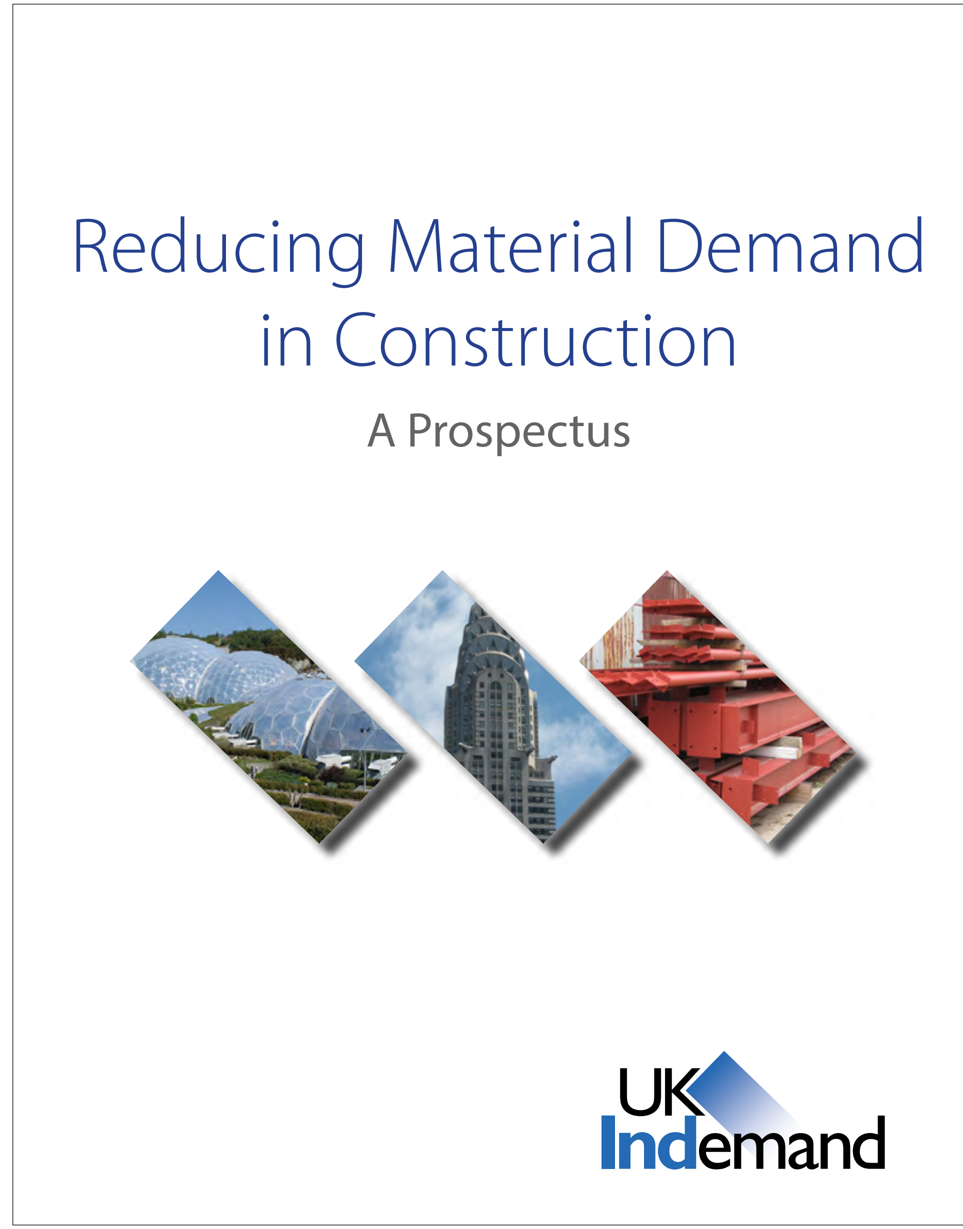
BOX STORY 3

The design brief for the Velodrome asked for a lightweight construction leading to an integrated approach to design. A materially efficient double-curved cable net was chosen for the roof structure, providing the signature aesthetic structure with half the carbon footprint of the equivalent sized Aquatics centre. The cable-net design reduced the embodied carbon by 27% compared to a steel arch option. The seating supports were also integrated into the structural frame to avoid the need for a separate structure. The material strategies not only minimised embodied carbon but also worked in conjunction with other design features to produce the most energy efficient building in the Olympic Park, improving on 2006 energy efficiency building regulations by 31%, demonstrating the potential success of an integrated approach[3]

Construction of the 2012 Olympic Velodrome

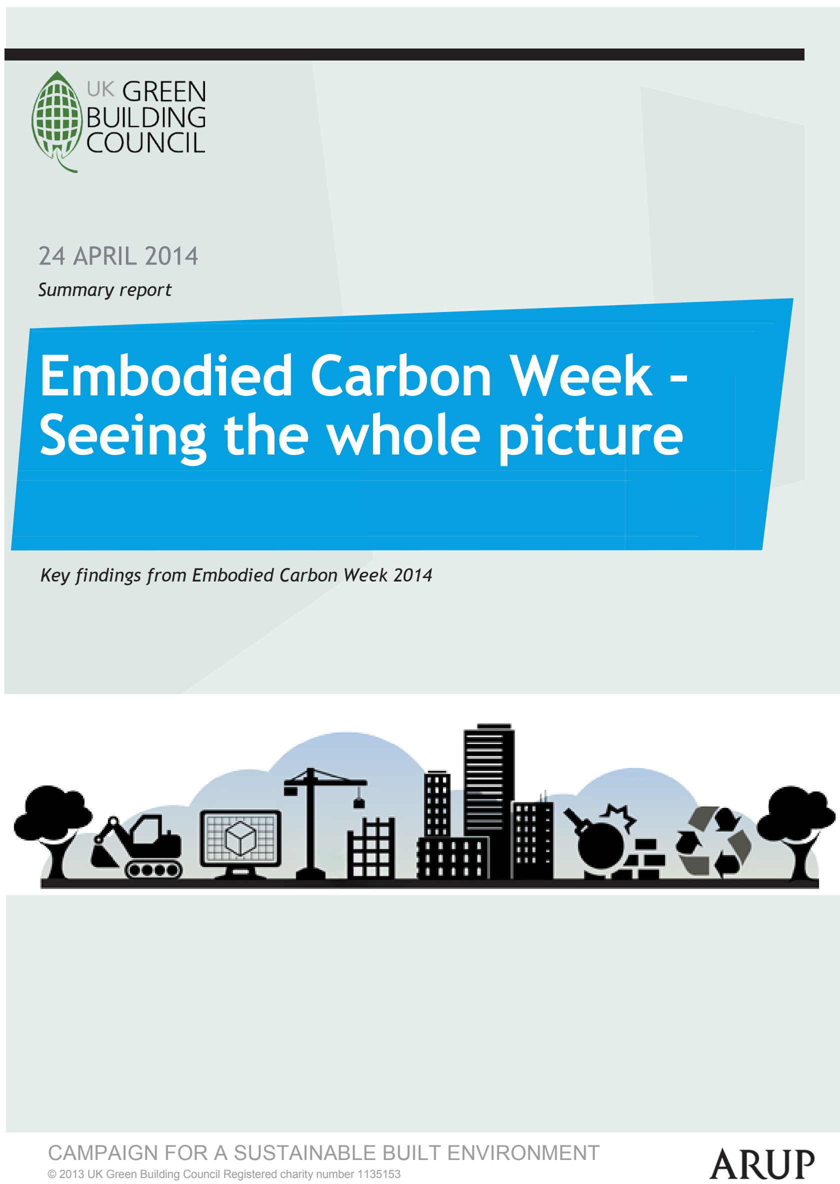
Standard I-beam | Composite floor beam | Open web joist | Cellular beam | Variable cross-section beam

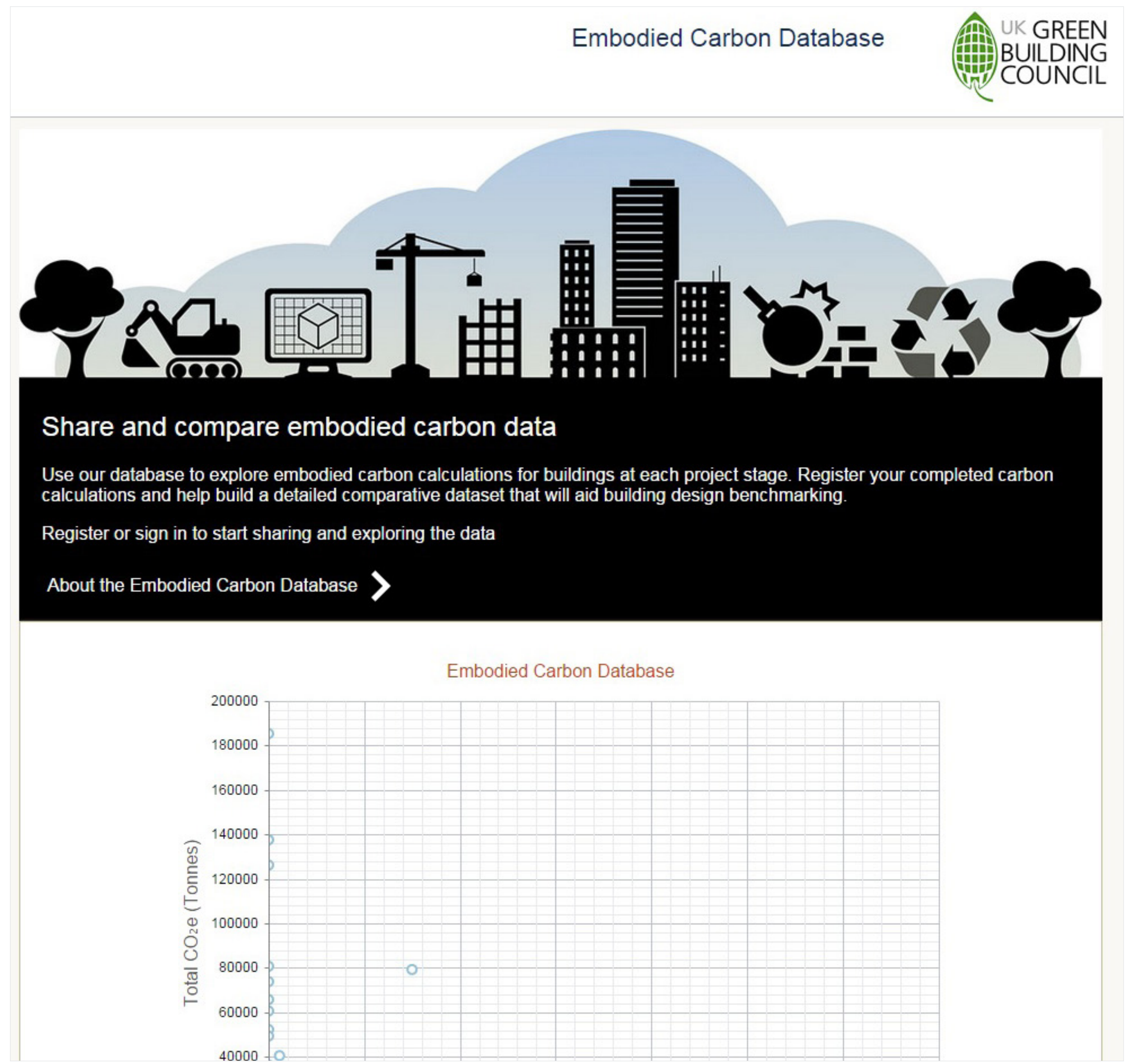
Beam design options



Practitioners are interested

UKGBC Embodied Carbon Week and WRAP database

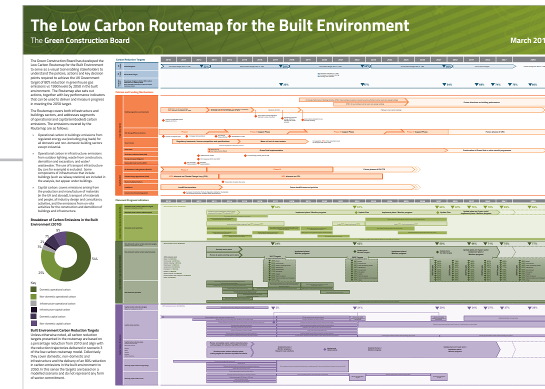




Aligning benchmarks with targets

How can UK targets be translated to project level benchmarks?

UK GHG emissions reduction targets



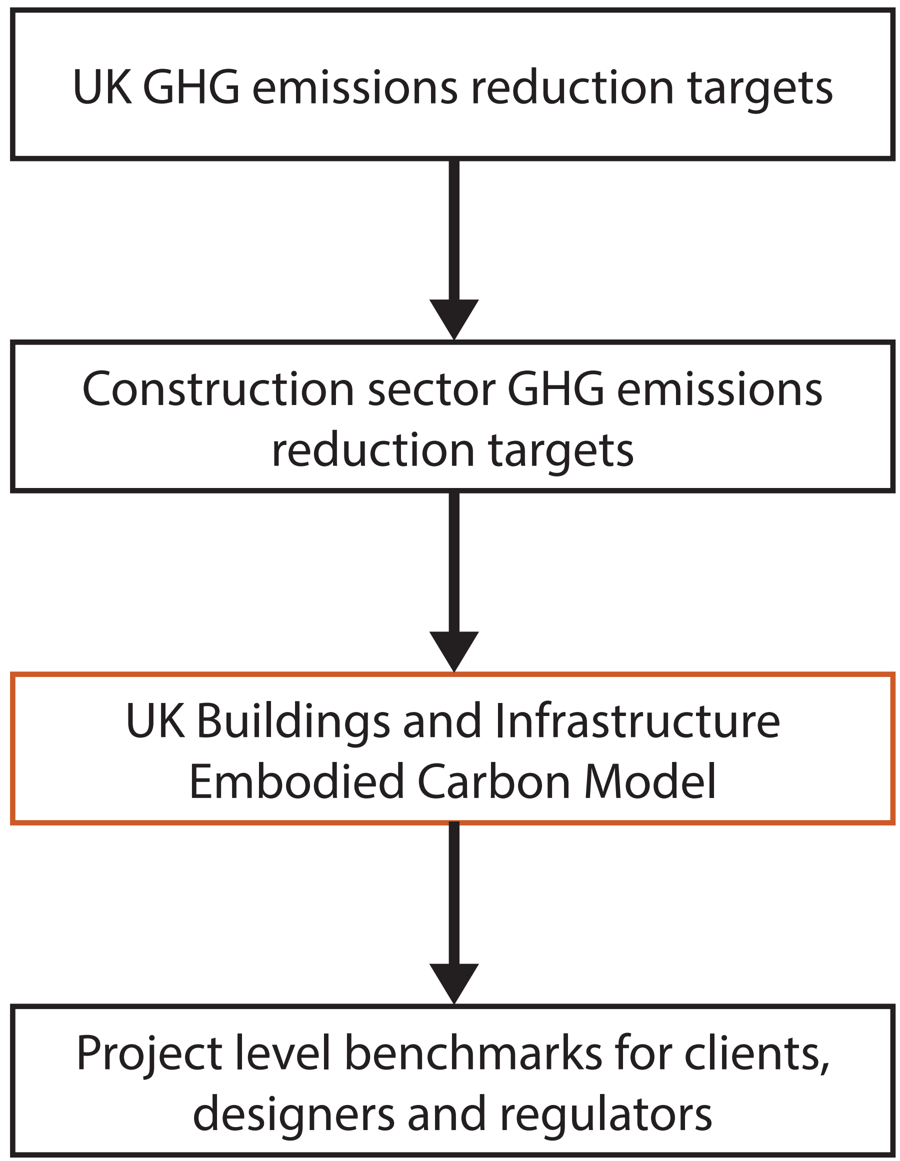
Construction sector GHG emissions reduction targets

?

Project level benchmarks for clients, designers and regulators

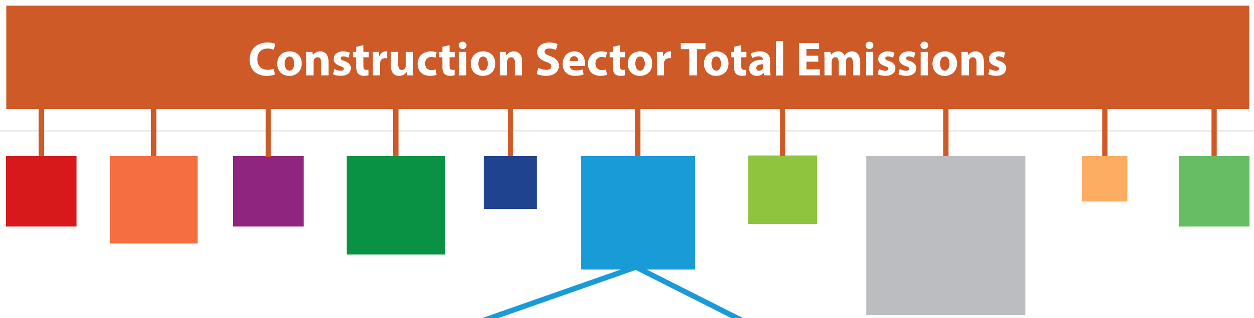
Bridging the gap

A model that integrates top down and bottom up emissions data



UK Buildings Embodied Carbon Model

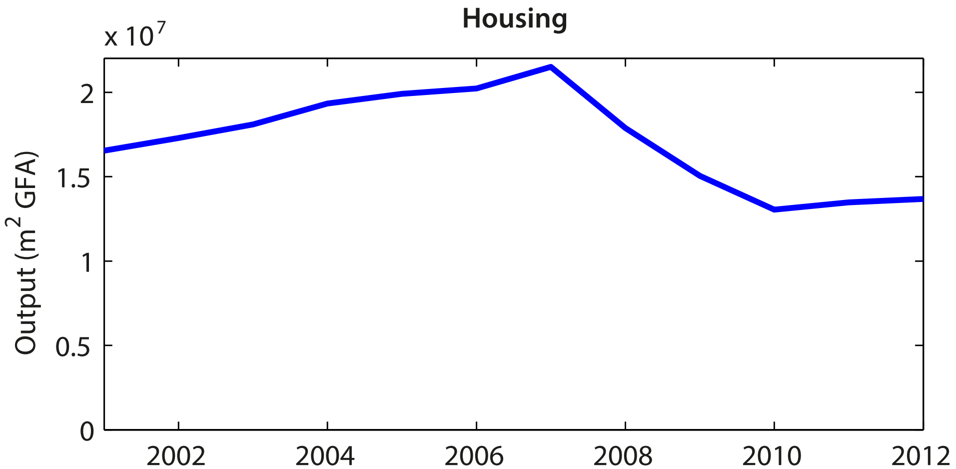
Model structure



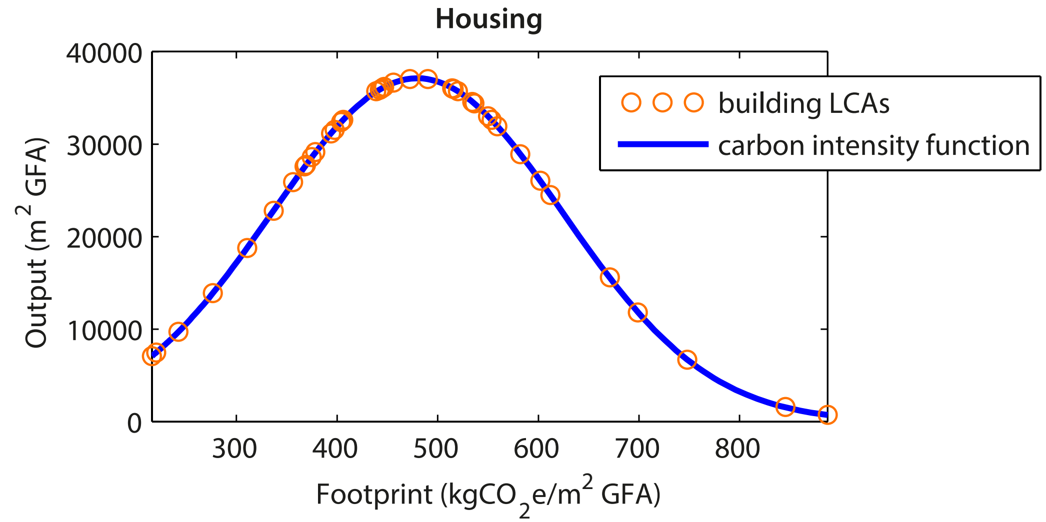
Building classes
Housing, factories, warehouses, education, health, offices, entertainment, retail, infrastructure, miscellaneous

Each building class is represented by

Output profile
Representing area of annual new build floorspace (GFA m²).

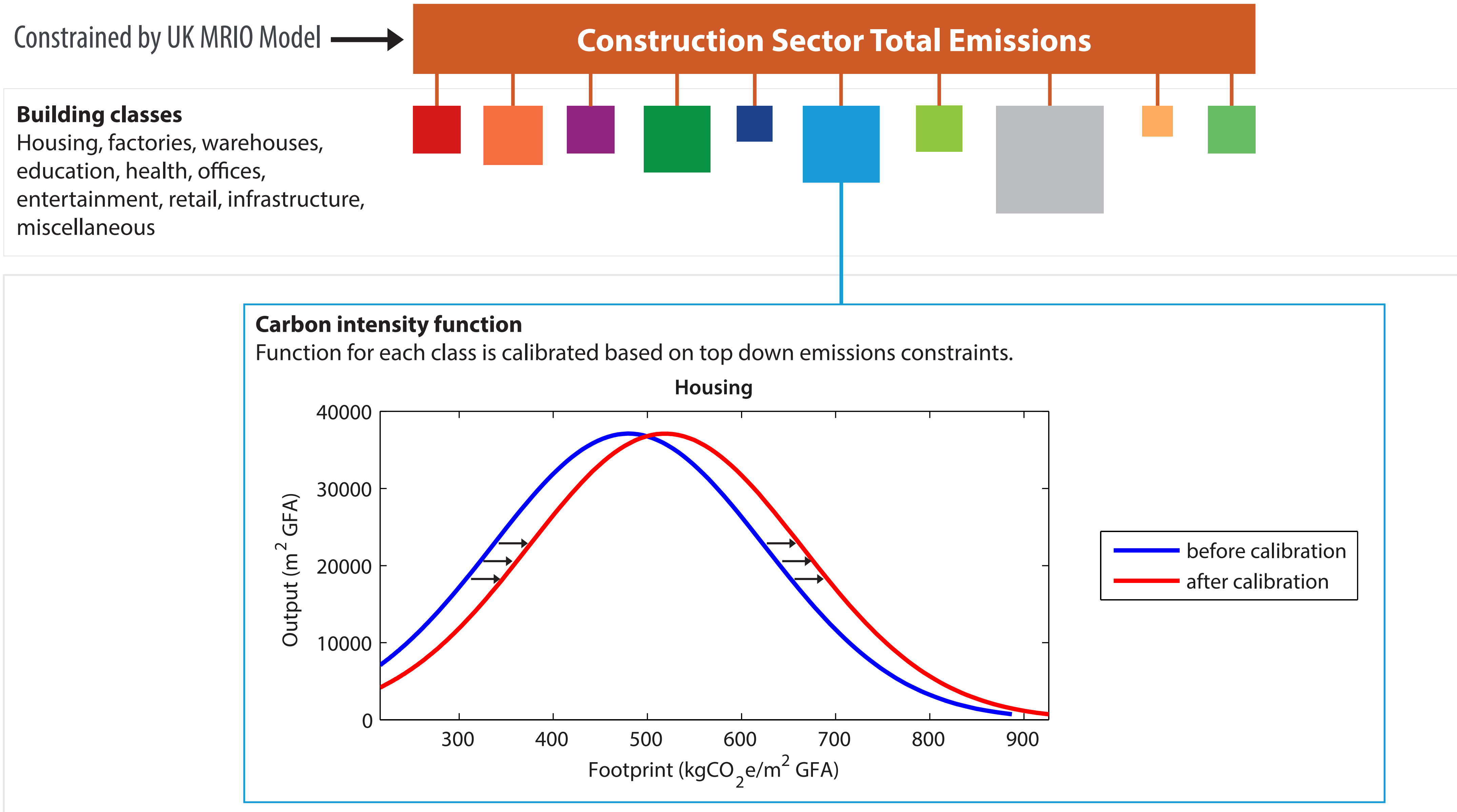


Carbon intensity function
Function representing the range of observed embodied carbon footprints amongst buildings of that class. Based upon collected case studies and entries in WRAP embodied carbon database.



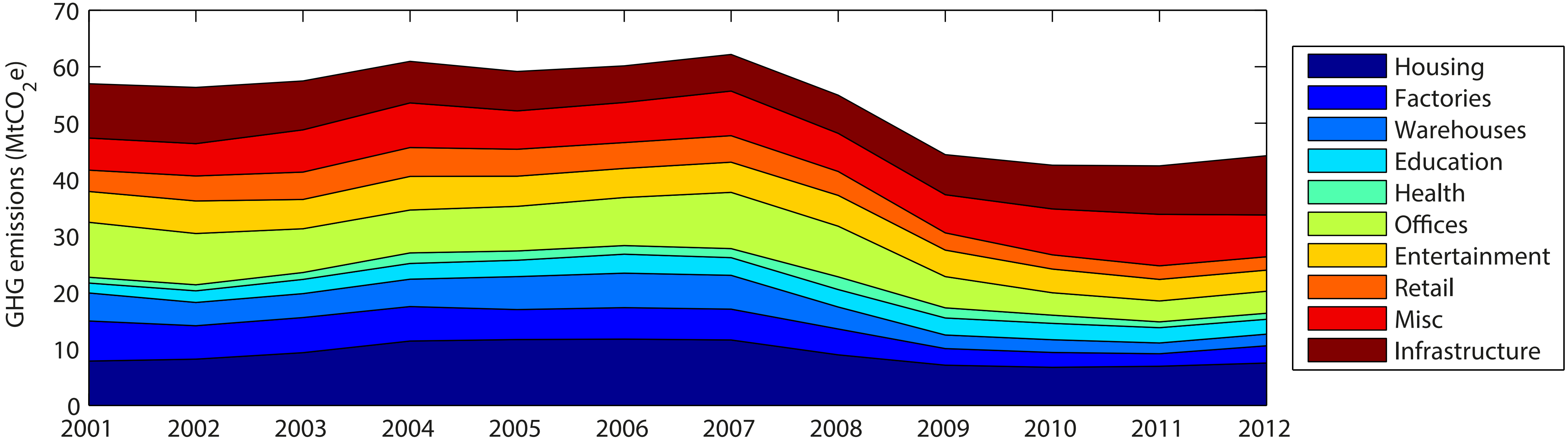
Model calibration

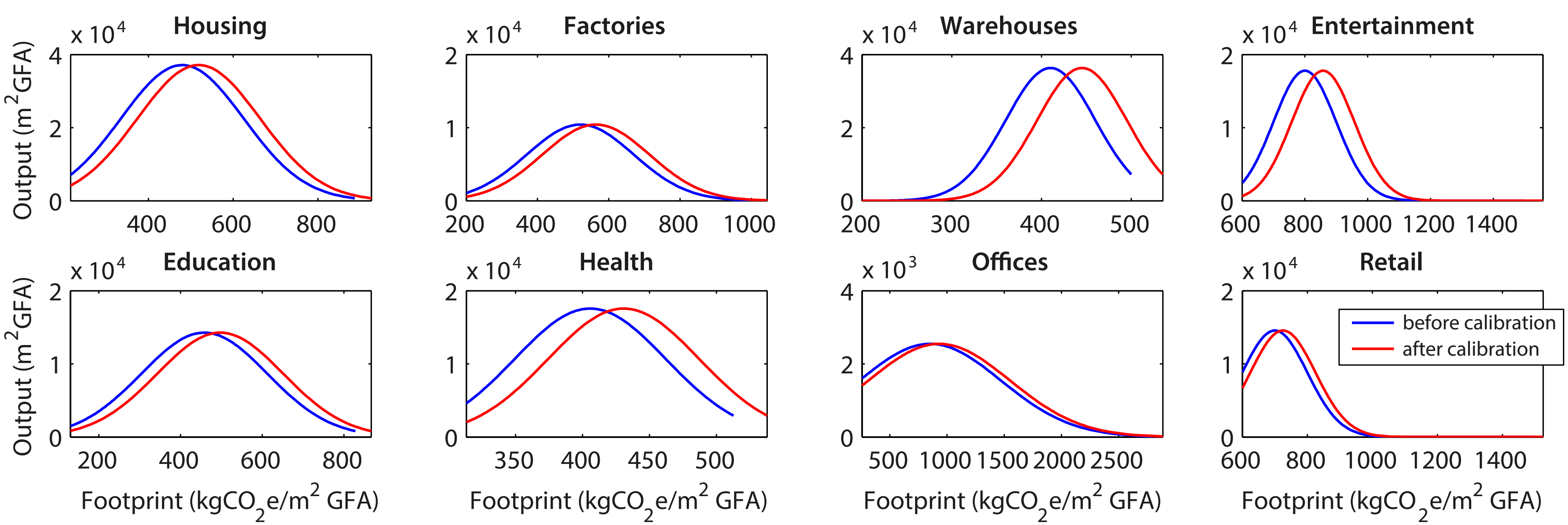
Linking top down and bottom up emissions data



Model calibration

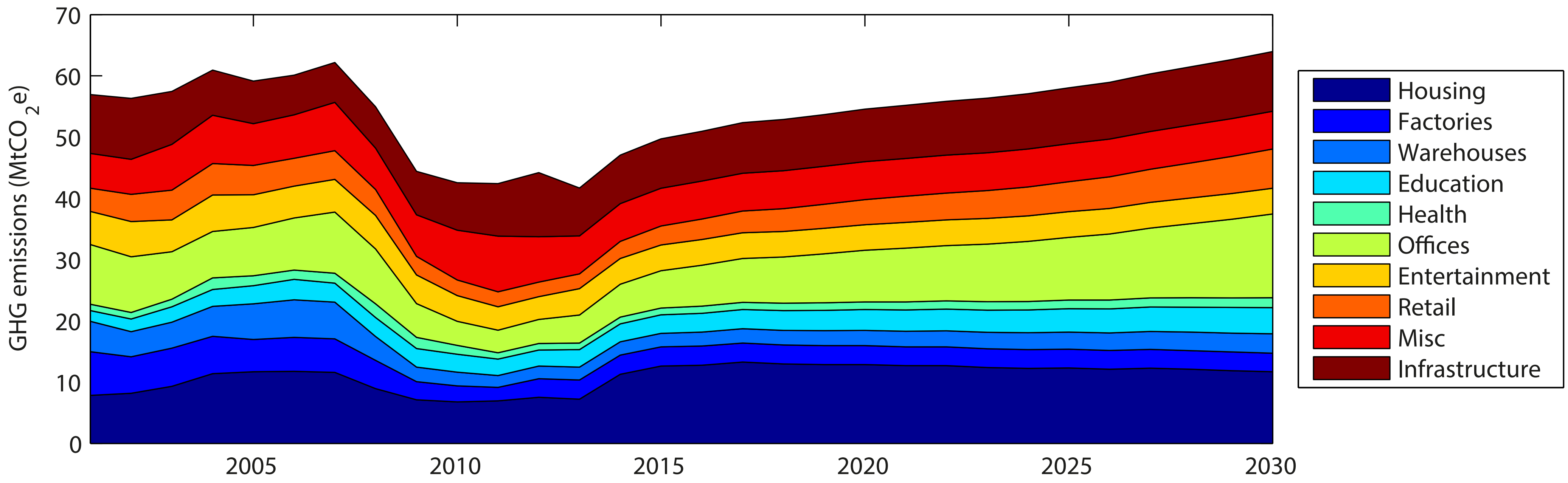
Model has initially been calibrated using data for 2001-2012



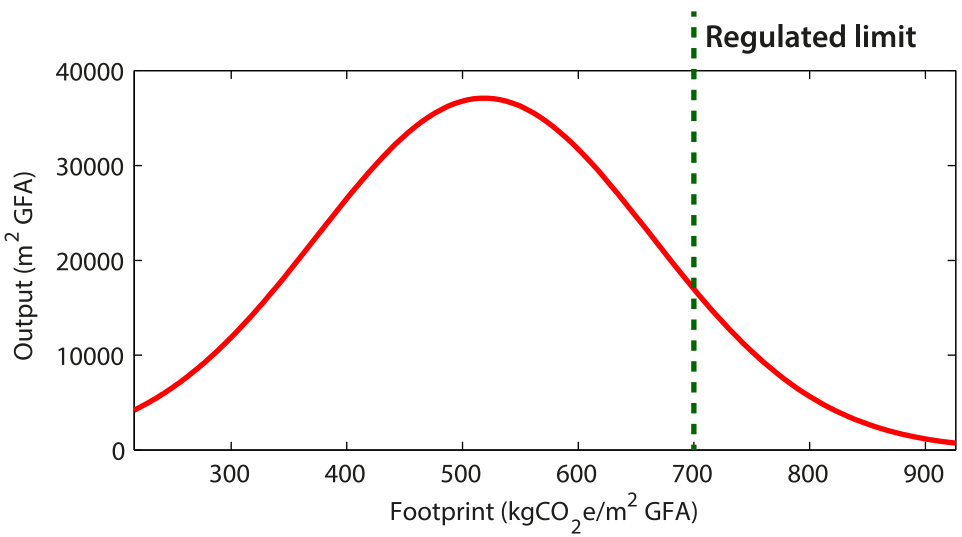


Scenario analysis

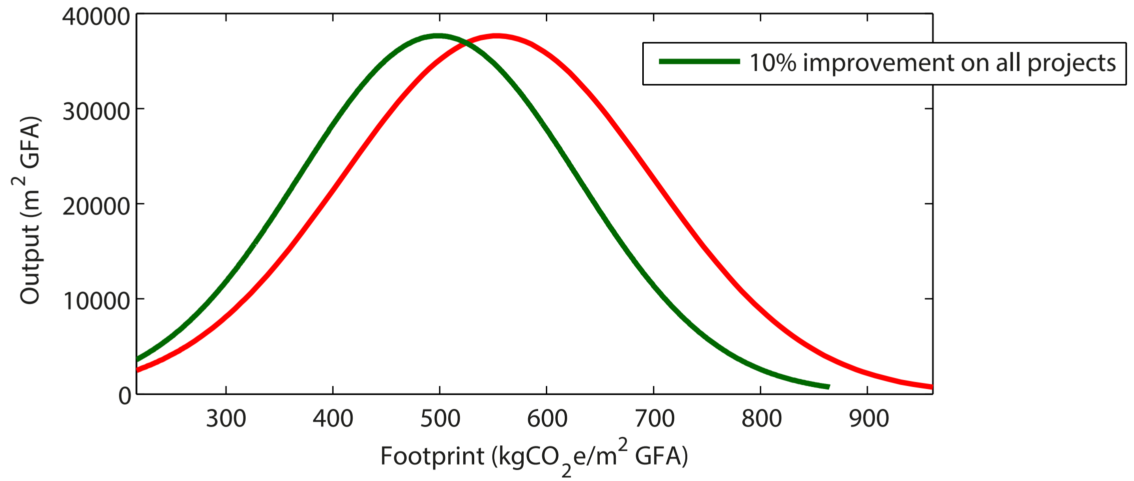
Model can be used to estimate future emissions



Estimate impact of introducing a limit through regulation

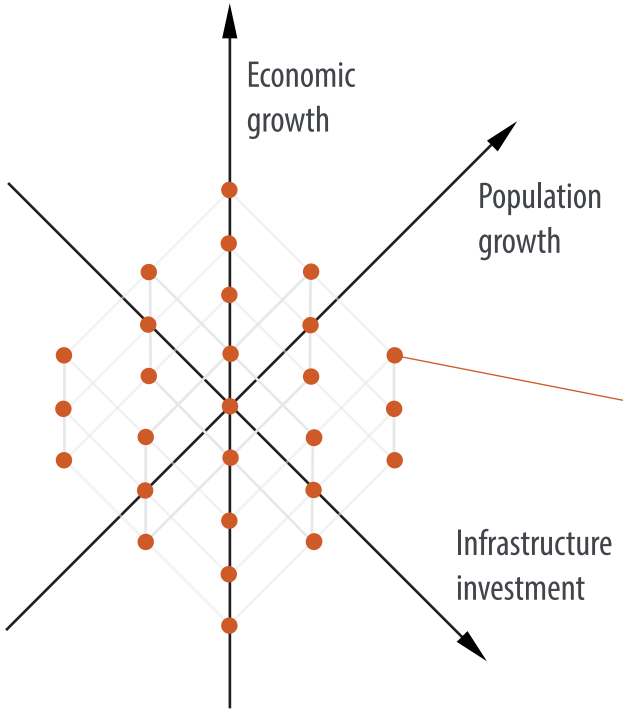


Estimate impact of design improvements



Series of demand projections

27 projections (A-ZZ) for each building class up to 2030



Projection A

» Strong economic growth (1.7-3.1% per annum) throughout the analysis period

» Population growth corresponding to the highest combinatorial variant of the ONS projections

» Growing population and reductions in average household size result in growth in the total number of households corresponding to the upper estimates of DCLG projections

» Housebuilding will increase to meet this demand, in addition to eliminating the existing shortage of homes

» The increase in population is reflected in a corresponding increase in the service industry workforce with requisite increases in office and retail floorspace

» There will be a continued trend to online retail and an expansion of distribution networks, with growth rates in warehouses increasing in line with economic growth

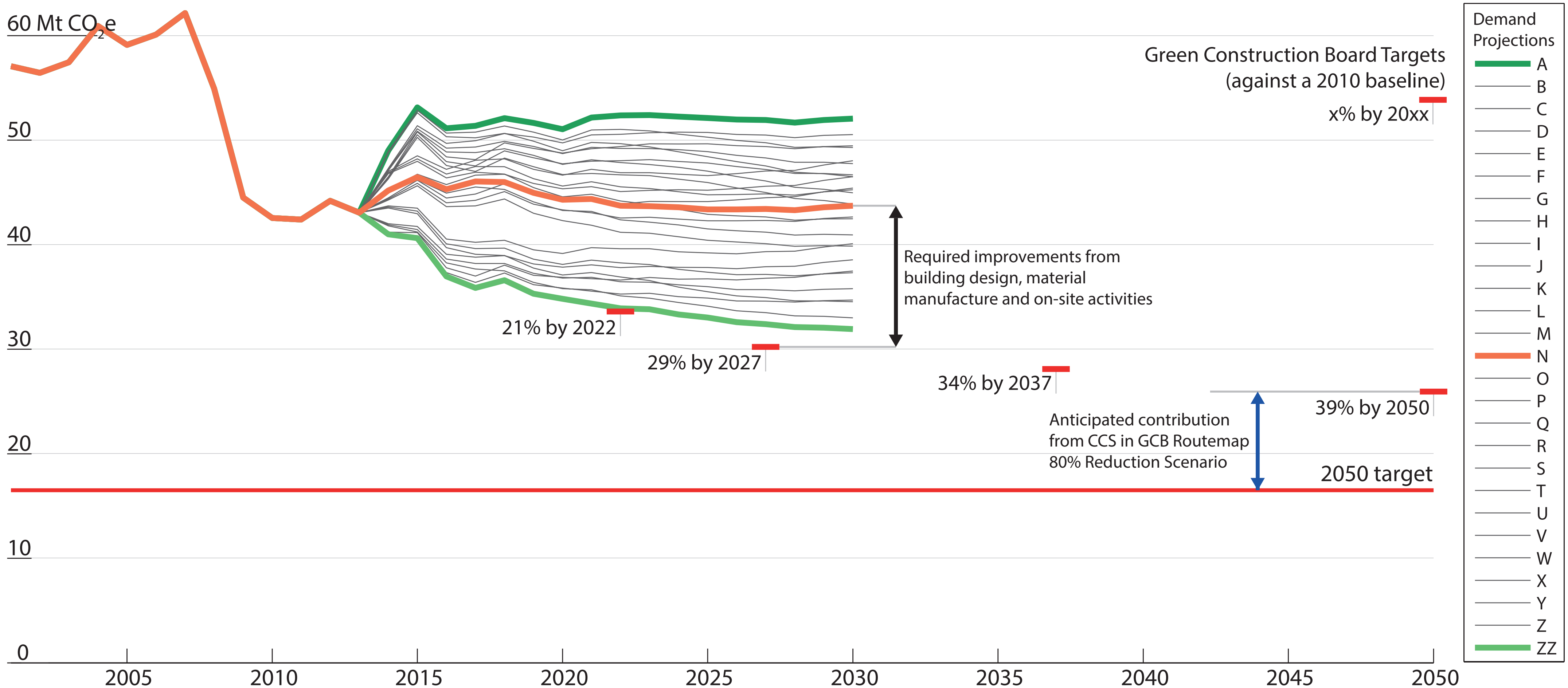
» Increased spending on buildings in health and education, principally to deal with an increasing and ageing population

» Extensive investment in new infrastructure. All projects in the National Infrastructure Pipeline will be completed and investment will be maintained through to 2030

Results

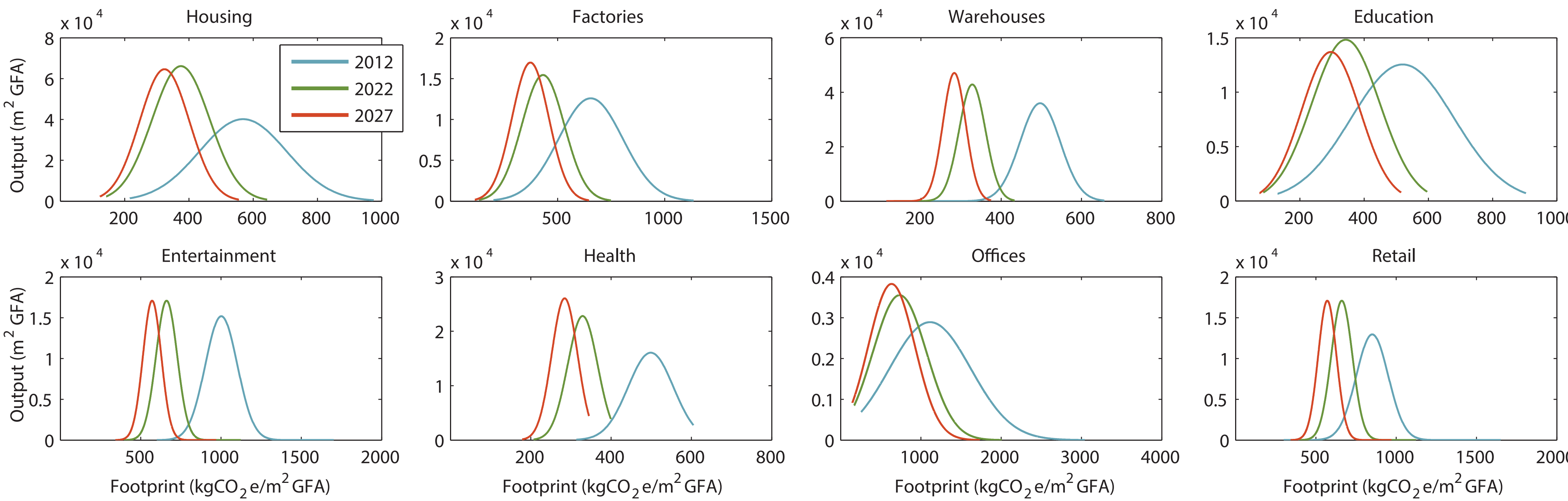
Anticipated embodied emissions of UK construction 2001-2030

» Even with grid decarbonisation included, demand reduction alone will not prove sufficient and significant improvements in design will be required



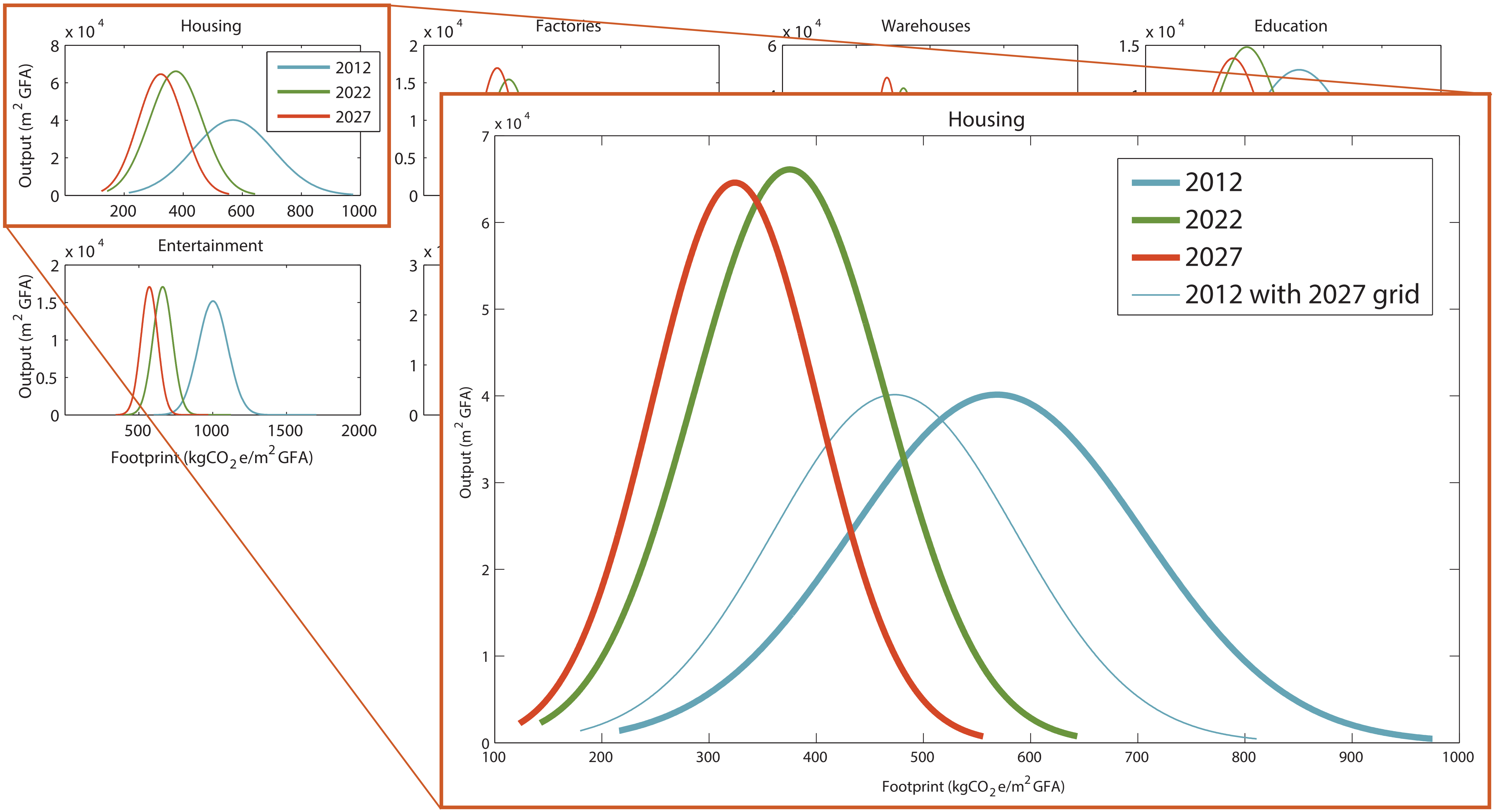
Implications

Meeting the 2027 target requires improvements like these



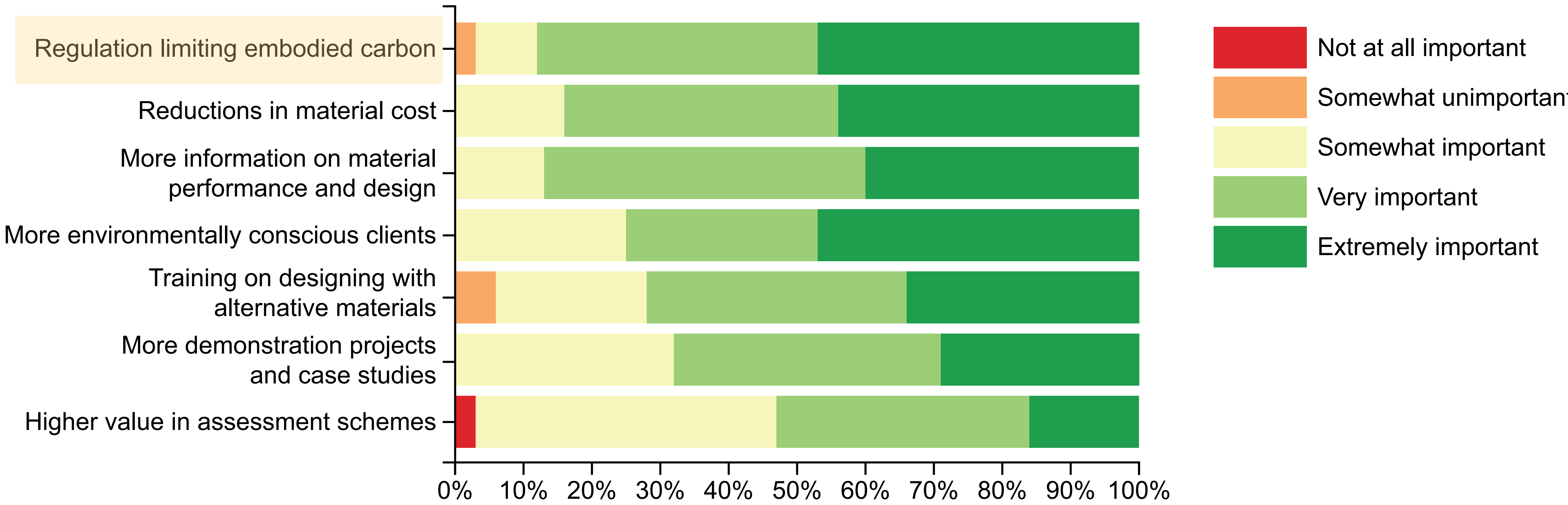
For example

Most housing in 2027 would need to meet current best practice



The need for regulation

Results from industry survey suggest regulation is greatest driver



Responses to survey question #21:
How important do you believe the following developments could be in encouraging greater use of alternative materials and construction products?

Figure from Giesekam et al. 'Construction sector views on low carbon building materials' (under review)

The need for regulation

Industry opinion suggests regulation essential for action

"I think we need to make sure that the regulations make it happen. Without that it'll be left to the moral leaders to continue their work but it won't become an industry."

Chair of Embodied Carbon Task Force

"At the end of the day, the drivers will always be statutory requirements put upon them to do these things, a huge proportion of the marketplace will only respond to that."

Sustainability and LCA Expert – Research technology organisation

Quotes from Giesekam et al. 'Construction sector views on low carbon building materials' (under review)

Precedents for regulation

Both at local and international level

» 6 local authorities (e.g. Brighton & Hove County Council) require embodied carbon estimates

» Requirements for embodied carbon assessment in the Netherlands and Germany (and will shortly be introduced in several other countries)

» Embodied carbon likely to be an indicator in new EU harmonised sustainability assessment framework

» Embodied Carbon Task Force currently lobbying for inclusion of embodied carbon abatement as an Allowable Solution

Recently mentioned in the UKGBC's 10 point plan for buildings in this parliament

9 ANNOUNCE PLANS FOR FUTURE STANDARDS OF NEW HOMES AND NON-DOMESTIC BUILDINGS
The success of the zero carbon policy for homes has demonstrated the effectiveness of providing a long term trajectory for improving standards in new buildings. Government should build on the zero carbon targets, to plan for the inclusion of unregulated and embodied energy in building regulations, and ensure all new buildings help to drive community-scale energy solutions.

Summary

Additional policy addressing embodied carbon is required

» Embodied carbon emissions from construction are substantial and growing

» Current policy excludes embodied emissions

» Policy response is required if emission reduction targets are to be met

» Challenge remains in linking sector targets with project level benchmarks

» The UK Buildings Embodied Carbon Model attempts to bridge this gap by linking the best available top down and bottom up data