Proceedings Paper:

Giesekam, J orcid.org/0000-0003-2915-1323, Densley-Tingley, D and Barrett, J orcid.org/0000-0002-4285-6849 (2016) Building on the Paris Agreement: making the case for embodied carbon intensity targets in construction. In: Jankovic, L, (ed.) Proceedings Of A Conference Held At Birmingham City University. Zero Carbon Buildings Today and in the Future 2016, 08-09 Sep 2016, Birmingham City University, UK. Birmingham City University , pp. 161-169. ISBN 978-1-904839-88-0

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

Jannik Giesekam[1], Danielle Densley-Tingley[2], and John Barrett[1]

[1] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds, UK.

[2] Department of Civil and Structural Engineering, University of Sheffield

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. This paper discusses these concerns and suggests how CITs could in future be determined, implemented and enforced.

INTRODUCTION

The UK's principal construction strategy, Construction 2025, sets a target of halving greenhouse gas (GHG) emissions from the built environment over the coming decade (HM Government, 2013). This is with a view to achieving longer term reductions consistent with the national target of an 80% reduction in GHG emissions by 2050 compared with 1990 levels (Climate Change Act, 2008). The Green Construction Board's Low Carbon Routemap for the Built Environment set out the steps required to achieve this and called for an increased focus upon embodied carbon mitigation (GCB, 2013). A recent update on Routemap progress found a widening gap to sector targets and restated the need to achieve reductions in embodied carbon in addition to operational emissions (Steele et al., 2015). The update recommended the introduction of embodied carbon intensity targets (CITs). CITs challenge design teams to deliver buildings with supply chain carbon emissions below a set level per functional unit and can act as a significant driver of innovation. However, the approach by which CITs should be determined, implemented and enforced remains unclear. This paper addresses a number of outstanding questions on this topic.

The first two sections briefly outline the embodied GHG emissions associated with UK construction activity and current carbon assessment practice. The third section highlights a number of inconsistencies in 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 environment and are comparable in magnitude to annual tailpipe emissions from all cars on UK roads (see Figure 1). Analysis of their distribution reveals that the bulk of emissions are associated with material production and a significant proportion occur overseas (see Figure 2). This restricts the scope of policies addressed at UK and European material producers (such as the EU Emissions Trading Scheme) to achieve substantial emission reductions. With the Government's central estimates suggesting that the UK population will increase by 14 million by 2050 (ONS, 2011), demand for housing and infrastructure is expected to markedly increase. DCLG projects an additional 3.6 million households will require new homes by 2030 (DCLG, 2015); meanwhile the National Infrastructure Delivery Plan 2016-2021 sets out projected infrastructure investments of £483 billion (IPA, 2016b). This increased construction output is likely to incur signficant embodied carbon emissions. Scenario analysis with the UK Buildings and Infrastructure Embodied Carbon model (UK BIEC), developed at the University of Leeds, reveals that anticipated reductions in the carbon intensity of the electricity supply are unlikely to offset the impacts of this increased construction activity (Giesekam et al, In Press) (see Figure 3). Consequently, sizeable reductions in embodied carbon intensity will need to be achieved through design changes across projects of all types if the targets set out in the GCB Routemap are to be achieved whilst meeting anticipated increases in demand. The required reductions in carbon intensity will be even greater if carbon capture and storage technology continues to be uneconomic for material producers.

CURRENT EMBODIED CARBON ASSESSMENT PRACTICE

Embodied carbon assessment has been commonplace in certain sectors of the industry, such as water and sewerage, for some time (Keil et al., 2013). Though, in recent years there has been increasing interest throughout the industry, reflected in a number of well attended cross industry events (UKGBC, 2014; UKGBC, 2015b). This proliferation of embodied carbon assessment has been supported by improved guidance for designers and clients (e.g. RICS, 2012; Clark, 2013; UKGBC, 2015c), and development of resources that facilitate project-level benchmarking (RICS, 2012; WRAP & UKGBC, 2014). The recent launch of PAS 2080: Carbon Management in Infrastructure seeks to instate a common language and carbon management process for the entire infrastructure value chain. A growing number of clients are also targeting carbon reduction in project briefs through CITs. At the time of writing 53 organisations had signed up to the Infrastructure Carbon Review and over 30 companies had introduced commitments relating to embodied carbon assessment or reduction in buildings.

One of the principal objectives of the UK Government Construction Strategy 2016-2020 is to "enable and drive whole-life approaches to cost and carbon reduction" (IPA, 2016a). This includes a specific commitment (Objective 3.6) to "develop data requirements and benchmarks for measurement of whole-life cost and whole-life carbon (embodied and operational)" with a view to ultimately forming "recommendations for a future approach". Though regulators, such as Ofwat, have begun to include reporting requirements on some infrastructure projects, similar requirements have yet to be put in place for buildings. However, precedents have been set elsewhere. For instance, the Netherlands introduced embodied carbon reporting requirements for residential and office developments over 100m^2 in 2013 and LCCAs have been compulsory on publicly funded German buildings since 2008. The European Commission has also proposed including embodied carbon as part of a suite of common indicators for assessing the environmental performance of buildings (EC, 2014).

Assessment of embodied carbon can be conducted at different stages of the project development. Best practice is to track embodied carbon throughout the project from an initial design phase estimate through procurement and construction to a final assessment upon project completion. For a practical example of this see the publicly available embodied carbon tracking report from British Land's 5 Broadgate development (Arup, 2014). Whilst this represents best practice, in most cases where embodied carbon is fully assessed by the UK industry it tends to be only after the building has been constructed (Moncaster & Symons, 2013). Despite the introduction of BS EN 15978 in 2011, approaches to assessment are still far from standardised with many practitioners using different system boundaries, assumed life times and so on (Gavotsis & Moncaster, 2015). Consequently the bulk of current research on embodied carbon focusses on standardising assessment procedures or developing integrated tools to support real time assessment. Though some of this research has called for additional drivers, such as regulation (Gavotsis & Moncaster, 2015; Giesekam et al., 2016), little work has been done to develop robust policy proposals (Battle, 2014), or understand how CITs should best be determined, implemented and enforced.

CURRENT DETERMINATION AND USE OF CARBON INTENSITY TARGETS

Though the use of CITs so far has been sporadic, examples have demonstrated that CITs can be an effective driver of innovation. For instance, the introduction of CITs in Anglian Water has motivated major changes in established design and construction practice and the use of alternative materials. CITs supported the achievement of a 54% reduction in embodied carbon by 2014 against the company's 2010 baseline (Anglian Water, 2015). Comparable reductions have been achieved on some building projects, such as the University of East Anglia Enterprise Centre (Pearson, 2015). On this project the client set the design team a whole life carbon target of 500 $kgCO_2/m^2$ emitted over the anticipated 100-year life of the building. This motivated radical changes in design, including extensive use of bio-based materials (>70%), and resulted in an achieved footprint of 440 $kgCO_2/m^2$ – around a quarter of the typical footprint of an equivalent university building. The Infrastructure Carbon Review has strongly advocated that this innovation, reduced material and energy use also yields cost savings (HM Treasury, 2013). Setting assessment or reduction targets can also encourage good on site practice and skills development amongst contractors (Davies et al., 2014). Therefore, at a project level, there are clear benefits associated with the introduction of CITs.

The current process of determining boundaries and values for building CITs varies widely between clients and projects. Some CITs apply only to embodied carbon, others target whole life carbon. The specific target boundaries also vary, with some CITs encompassing all embodied emissions, others only targetting key materials or 'carbon hot-spots'. For example, the British Land 2014 sustainability brief required that embodied carbon in "concrete, steel, rebar, aluminium and glass" be reduced by 10% compared to the concept design (British Land, 2014). In comparison Marks and Spencer target the "carbon hotspots in walls, ceilings and floors" (Marks and Spencer, 2014). Whereas the Crown Estate adopt a simple headline project target in $kgCO_2/m^2/yr$ (The Crown Estate, 2013). Where headline targets such as this are adopted the baseline can also be determined in different ways. Some baselines are determined against an initial project design. Others are against a notional reference building. Some are compared with past projects the client has been involved in. Others are determined from comparison with similar buildings or benchmark data from the WRAP database and similar sources (RICS, 2012; WRAP & UKGBC, 2014). The desired reduction against this baseline is also often determined in an arbitrary manner. Commonly a simple percentage reduction is set based on the client's intuition or past experience. In some cases a specific round value is selected. In other cases, highly specific targets have been instated through a desire to offset operational emissions. For instance, on the Westgate Oxford development a CIT for embodied emissions reduction against the RIBA Stage C design was set equal to the anticipated regulated operational carbon over the building life.

Should these differences be considered as welcome variety or as frustrating inconsistencies? It can reasonably be argued that for different project types with different distributions of carbon, adopting different functional units and assessment boundaries makes sense. However, this can increase complexity for project participants and reduce the comparability of results between projects. Even ignoring these concerns, the typical relative comparison between one building design and another allows for benchmarking but does not indicate if the design's emissions are consistent with sectoral or national mitigation targets. Furthermore, whilst an individual client or design team is principally concerned with determining an appropriate CIT for their current project, firms, educators and product developers must prepare for the implications of deep long-term reductions. This may require significant changes in design and construction practice and the workforce must be skilled accordingly. This requires an appreciation of how targets may change over time and the concomitant changes in materials and design practices.

This discussion highlights a number of problems. Firstly, how should the approach to setting CITs be standardised (if at all)? Secondly, how can target setters ensure consistency with sectoral or national targets? Thirdly, how should these targets be adjusted over time in response to changes in international ambition or developments in other sectors of the economy? The following section addresses these questions in turn.

FUTURE DETERMINATION OF CITS

Standardising the approach

An ongoing Innovate UK funded project 'Implementing Whole Life Carbon In Buildings' seeks to address a number of outstanding issues in the standardisation of embodied carbon assessment. However, in the case of CITs, the priority must be standardising project practices not assessment boundaries and methodologies. On different projects, particular building elements may contribute more or less to the project total, requiring a more or less detailed assessment. Accordingly, clients must set CIT boundaries that encompass the principal sources of carbon whilst avoiding excessive assessment time and thus expense. For instance the Embodied Carbon Task Force propose a common set of boundaries that encompass product and construction stage emissions for substructure and superstructure (Battle, 2014). Irrespective of boundary differences, there are potential benefits to adopting a more standardised approach to establishing, introducing and reporting against project CITs. This could be done by adopting a common set of project embodied carbon checkpoints, such as those suggested by the GLA (2013) and Doran (2014). An example set is presented in Figure 4 against the 2013 RIBA Plan of Work. Under such an approach an initial project CIT would be introduced at RIBA Stage 1. The early introduction of a target will influence the initial concept design and ensure low carbon solutions are embedded early in the project. This high level target could subsequently be translated into a carbon plan (analogous to a cost plan) that breaks down the carbon budget by building elements. Subsequent steps would ensure routine reporting against the target throughout the project.

Ensuring consistency with sectoral and national targets

With targets currently set largely on an ad hoc basis by a selection of clients relative only to a baseline design or a comparable building, there is no means to ensure consistency with sector or national mitigation targets. Firstly, the sample of assessments is too small to reasonably assess the status quo across the sector. Secondly, the intermediate link between project level assessments and aggregate sector emissions is not yet in place. The form of such a link has been proposed with the UK BIEC model (Giesekam et al., In Press), but the available data remains insufficiently granular to return detailed project targets. Even once such targets are computed, the best means of communicating these to the industry has yet to be determined.

One potential form would be the preparation of a series of common documents, or an online resource, that compiled headline targets, example carbon plans and benchmark data for a set of standard building typologies. This resource would be updated periodically and adminstered by a respected industry body, such as the RICS. This would provide clients with an advised target, consistent with national targets, which they could choose to use or exceed. Establishing such a common, central resource would allow clients to set appropriate targets without particular expertise in this area, enabling a swifter propagation of best practice.

Developing a ratchet mechanism

If such a resource was established, periodic updates could incorporate the impacts of progressive grid decarbonisation, additional building assessment data, and adjustments to sector targets based on national mitigation progress. The introduction of future Carbon Budgets and any changes in national targets motivated by the Paris Agreement ratchet mechanism could be translated into new project targets using the intermediate model.

In addition to significantly reducing current emissions, the construction industry must also be prepared to deliver a large volume of carbon sinks in order to meet the Paris Agreement goal of achieving "a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (United Nations, 2015). The market for sinks is potentially lucrative given the anticipated growth in the price of carbon. In the UK these sinks will likely take the form of increased forestry, and the resultant wood could in part be used for construction. The emergence of other bio-based building materials, such as hemp-lime and modular straw bale, into mainstream construction may also contribute to achieving the long-term net zero goal (MacDougall, 2008). This should be supported by further development of products incorporating UK resources such as: CLT from domestic wood species (Crawford et al., 2015), brettstapel (Smith, 2013) and novel biocomposites (NetComposites Ltd, 2014). The potential is sizeable, with one report estimating that net carbon sequestration of up to 22 $MtCO_2e$ could be achieved by 2050 through policies promoting wood products alone (Sadler & Robson, 2013).

DRIVERS FOR IMPLEMENTATION OF CITS

In addition to addressing concerns with current practice, the research community must consider the drivers needed to replicate best practice across the industry. This will require proposals for long-term policy and market drivers that ensure widespread implementation and enforcement of CITs. Let us consider the critical characteristics of such drivers.

Client led drivers

Clients must be seen to value this issue if CITs are to be introduced and enforced. Clients can demonstrate leadership by providing a strong inventive for other members of the supply chain. For example, the scoring of tenders based upon sustainability credentials provides a competitive advantage for designers and contractors that can deliver embodied carbon assessment and mitigation. The introduction of shared targets and rewards in contract documents also motivates the requisite collaboration and exchange of ideas across the supply chain. Motivated members of the client team must also work internally to ensure organisational buy in. This is critical to ensure CITs exist beyond the project brief and are reported against throughout the project.

However, clients cannot be expected to seek out and develop expertise in this area in the absence of strong financial or regulatory drivers. Progressive clients need additional support from the research community and proactive recommendations from designers and contractors. Industry institutions must also provide a better platform for clients to share experiences and standardise approaches. The development of a centralised information source – containing guidance, benchmark data and suggested targets (as proposed in the previous section) – could also support engagement from smaller clients with less organisational capacity.

Were such a central resource to be introduced, complementary drivers may also be required to encourage clients to specify CITs beyond the recommended levels. Potential incentives could be perceived reputational benefits and positive marketing opportunities, through facilitating claims such as completing a '2050-ready' building. Alternately, competition could be encouraged between firms through a public league table of carbon commitments. In the longer term, measures such as extending listed company emissions reporting to include principal sources of Scope 3 emissions, could provide a strong financial driver. Voluntary initiatives that promote early action also offer clients the opportunity to be ahead of the curve with regards to any future regulation.

Regulation

In a recent industry survey respondents highlighted that regulation is potentially the greatest driver of embodied carbon reduction (Giesekam et al., 2016). However, if regulations promoting embodied carbon measurement or reduction are to emerge a number of issues must first be resolved. These principally concern ownership, advocacy, narrative development, and evidence gathering.

Ownership and advocacy

No Government department has sole ownership of this issue. Whilst DECC notionally formulates plans for climate mitigation, BIS are tasked with determining industrial strategy. Policies affecting new build are principally set by DCLG and local authorities. Meanwhile numerous other departments, such as the Department for Transport and DEFRA, determine the overall demand for new buildings and infrastructure through their investment decisions. In addition to the present lack of cross-departmental strategy and collaboration, even within departments it is difficult to identify individuals whose remit could sensibly include embodied carbon. Consequently, for advocates within the industry lobbying for action it is difficult to distinguish appropriate points of influence. Embodied carbon has yet to garner serious consideration within mainstream policy circles and, in many ways, remains an issue without a home.

Similarly, within the industry there are few suitable organisations who can take effective ownership of this issue. Many of the actions advocates propose to drive forward this agenda, such as establishing and maintaining a common UK LCI and EPD database, require investment and long term commitments to maintenance from an impartial and respected source. This source must be willing to demonstrate leadership and be seen to represent firms spanning the full supply chain. Recent movements from professional institutions such as the RICS, and membership organisations such as the UKGBC, have been positive but there remain few commercial advantages to demonstrating leadership on this issue at the present time. If progress is to be made, it will require not just leadership from a handful of high profile firms but sustained support and coordination from a cross industry group. One potential solution could be the establishment of a formal body, such as a UKGBC Task Group. In the meantime, it remains difficult for the current assortment of small and isolated advocates to develop the requisite social and political capital.

Narrative development

It is essential for advocates to consider the narrative and framing of potential policy options. In the absence of a broader strategic narrative for climate change in the UK, it is impossible to appeal to the benefits of action addressing embodied carbon purely in terms of climate mitigation (Bushell et al., 2015). In order to secure engagement from a multitude of actors across the complex industry supply chain, it may be necessary to simultaneously appeal to numerous co-benefits or to a broader narrative of improved competitiveness. Whilst the most prominent narrative to date *'reducing carbon reduces cost'* has inspired some action; the majority of embodied carbon assessment has been undertaken by a small number of exemplar firms: 'the usual suspects' (UKGBC, 2015a p. 12). Many within the industry remain sceptical that the demonstrated cost and carbon savings on these projects can be replicated at scale outwith this group of innovative firms. To overcome this, it is imperative that advocates develop more effective means of ennumerating and expressing the other co-benefits associated with the more sustainable use of building materials. The current political narrative of deregulation to "keep Britain building" (Osborne, 2015) is also a substantial hurdle.

If the strategic political narrative does change, it is imperative that an evidence base is already in place that can support appeals to the new narrative. Effectively capitalising on changes in narrative requires a prolonged accrual of evidence, rather than a frenetic response to opportunities presented by consultations and the like. This requires a structured process of data collection and input from a multitude of stakeholders.

Evidence gathering

Despite growing industry interest and expertise, the evidence base that could inform policy making remains limited. The aggregate number of assessments to date remains insufficient to form detailed benchmarks, and there is no central depository for information on costs incurred. Consequently, there is insufficient evidence to undertake the sort of economic analysis required under a typical policy impact assessment. Encouraging sufficient assessments to form a robust evidence base may require additional stimuli. However, additional stimuli are unlikely to be introduced without a robust evidence base. Overcoming this catch 22, in an environment where funding for exemplar projects is limited, will likely require leadership from industry institutions alongside support from the research community. This will require extensive collaboration and a willingness to share data and experiences.

In the long term, a multi-level response will likely be required, with local authorities and a small cohort of firms initially demonstrating best practice, introducing progressively more stringent requirements, assembling an evidence base for policy makers, and disseminating their experiences to the mainstream industry. Only once respected advocates are identified, a robust evidence base is in place, and an appropriate narrative determined, is national regulation likely to proceed.

OTHER CHALLENGES

In addition to addressing the outlined concerns, the research community must:

- Articulate a vision for the construction industry in a net zero emissions future.
- Develop alternative low carbon building materials and design approaches, particularly for high-rise structures, which currently have a very limited range of viable materials.
- Improve the understanding of current barriers to uptake of alternative and re-used materials
- Develop a range of policy options for addressing whole life carbon emissions

CONCLUSIONS

Substantial reductions in embodied carbon will be required to meet sectoral and national climate mitigation goals. These reductions must be motivated by the introduction of project CITs. Examples to date show CITs can encourage innovation; however, a number of issues must be addressed if CITs are to achieve widespread adoption consistent with targeted emission reductions. Approaches to target setting and reporting should be further standardised, steps must be taken to link sector and project level targets, and additional drivers for embodied carbon reduction must be introduced. This paper has offered initial insights on these topics, proposed some potential solutions and highlighted a number of areas requiring further research.

ACKNOWLEDGEMENTS

The contribution of the first and third authors forms part of the research of the CIEMAP centre, funded by the RCUK Energy Programme (EP/K011774/1).

REFERENCES

Anglian Water (2015). Greenhouse Gas Emissions Annual Report 2015. Available from: http://www.anglianwater.co.uk/_assets/media/ghg_emissions_report_2015_H_res.pdf

Arup (2014). 5 Broadgate Embodied Carbon Tracking Report. Available from: http://www.britishland.com/~/media/Files/B/British-Land/downloads/2014/BL Arup 5 Broadgate Embodied Carbon Report 2014.pdf

Battle, G. (2014). Embodied Carbon Industry Task Force Recommendations. Proposals for Standardised Measurement Method and Recommendations for Zero Carbon Building Regulations and Allowable Solutions.

British Land (2014). Supporting Communities and Enhancing Environments: Sustainability Brief for Developments. Available from: http://www.britishland.com/~/media/Files/B/British-Land/downloads/investor-downloads/bl-sustainability-brief-2014.pdf

Bushell, S., Colley, T. and Workman, M. (2015). A unified narrative for climate change. Nature Climate Change. 5(11), 971–973

Clark, D. (2013). What Colour Is Your Building? RIBA Publishing. ISBN 9781859464472

Climate Change Act 2008 (2008) Elizabeth II. Her Majesty's Stationery Office, London, UK

Crawford, D., Hairstans, R., Smith, S. and Papastravou, P. (2015). Viability of cross-laminated timber from UK resources. Proceedings of the ICE - Construction Materials. 168(CM3), 110–120.

Davies, P.J., Emmitt, S. and Firth, S.K. (2014). Challenges for capturing and assessing initial embodied energy: a contractor's perspective. Construction Management and Economics. 32(3), 290–308.

DCLG (2015). Household projections, United Kingdom, 1961-2037. Available from: https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections

DECC (2014). Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. Electricity emissions factors to 2100. Available from: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Doran, D. (2014). Linking construction embodied carbon assessment to the UK carbon budget – from the top-down. Report to the BRE Trust.

EC (European Commission) (2014). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions on Resource Efficiency Opportunities in the Building Sector. Available from: http://ec.europa.eu/environment/eussd/pdf/SustainableBuildingsCommunication.pdf

Gavotsis, E. and Moncaster, A. (2015). Improved Embodied Energy and Carbon Accounting: Recommendations for Industry and Policy. Athens Journal of Technology & Engineering 2(1), 9-23.

Green Construction Board (2013). Low Carbon Routemap for the UK Built Environment. Available from: http://www.greenconstructionboard.org/otherdocs/Routemap final report 05032013.pdf

Giesekam J, Barrett J, Taylor P, and Owen A (2014) The greenhouse gas emissions and mitigation options for materials used in UK construction, Energy and Buildings. 78, 202-214

Giesekam, J., Barrett J. and Taylor, P. (2016). Construction sector views on low carbon building materials. Building Research and Information. 44(4), 423-444

Giesekam J, Barrett J, and Taylor P. (In Press) Scenario analysis of embodied carbon in UK construction. Proceedings of the ICE - Engineering Sustainability

GLA (Greater London Authority) (2013) Construction Scope 3 (Embodied) Greenhouse Gas Accounting and Reporting Guidance

HM Government (2013). Construction 2025. URN BIS/13/955

HM Treasury (2013). Infrastructure Carbon Review. ISBN 978-1-909790-44-5

IPA (Infrastructure and Projects Authority) (2016a). Government Construction Strategy 2016-20.

IPA (2016b). National Infrastructure Delivery Plan 2016-2021.

Keil, M., Perry, H., Humphrey, J. and Holdway, R. (2013). Understanding embodied greenhouse gas emissions in the water and sewerage sectors. Water and Environment Journal. 27(2), 253–260.

Marks and Spencer (2014). Plan A Report 2014. Availablefrom:http://planareport.marksandspencer.com/downloads/M&S-PlanA-2014.pdf

MacDougall, C. (2008) Natural Building Materials in Mainstream Construction: Lessons from the UK. Journal of Green Building, 3(3), 3–14

Moncaster, A. and Symons, K.E. (2013). A method and tool for 'cradle to grave' embodied carbon and energy impacts of UK buildings in compliance with the new TC350 standards. Energy and Buildings. 66, 514–523.

NetComposites Ltd (2014). "BioBuild". Available from: http://biobuildproject.eu/ [Accessed 26/11/15].

ONS (2011). 2010-Based National Population Projections. Available from: http://www.ons.gov.uk/ons/rel/npp/national-population-projections/2010-based-projections/rep-2010-based-npp-results-summary.html#tab-Results [Accessed 30/03/15].

Osborne, G. (2015). Chancellor George Osborne's Budget 2015 speech. Available from: https://www.gov.uk/government/speeches/chancellor-george-osbornes-budget-2015-speech [Accessed 08/10/15].

Pearson, A. (2015). No compromise – Passivhaus Enterprise Centre in Norwich. CIBSE Journal. Available from: http://www.cibsejournal.com/case-studies/no-compromise/

RICS (2012). Methodology to calculate embodied carbon of materials IP 32/2012.

Sadler, P. and Robson, D. (2013). Carbon Sequestration By Buildings. Available from: http://www.asbp.org.uk/uploads/documents/resources/ASBP_Carbon sequestration by buildings.pdf

Smith, S. (2013). Grown in Britain - a review of the use of timber in UK construction. The Structural Engineer. 31, 54–56.

Steele, K., Hurst, T. and Giesekam, J. (2015). Green Construction Board Low Carbon Routemap for the Built Environment 2015 Routemap Progress Technical Report. Available from: http://www.greenconstructionboard.org/otherdocs/2015 Built environment low carbon routemap progress report 2015-12-15.pdf

The Crown Estate (2013). Development Sustainability Principles. Available from: http://www.thecrownestate.co.uk/media/5214/urb-development-sustainability-principles.pdf

UKGBC (2014). Embodied Carbon Week – Seeing the whole picture. Available from: http://www.ukgbc.org/resources/publication/embodied-carbon-week-2014-report

UKGBC (2015a). COP21 Special The Knowledge(3)

UKGBC (2015b). Embodied Carbon Conference: Review. Available from: http://www.ukgbc.org/sites/default/files/Embodied Carbon Conference review.pdf

UKGBC (2015c). Tackling embodied carbon in buildings. Available from: http://www.ukgbc.org/resources/publication/tackling-embodied-carbon-buildings

United Nations (2015). Adoption of the Paris Agreement. Available from: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

WRAP and UKGBC (2014). WRAP Embodied Carbon Database. Available from: http://ecdb.wrap.org.uk/Default.aspx [Accessed 12/10/14]

FIGURES

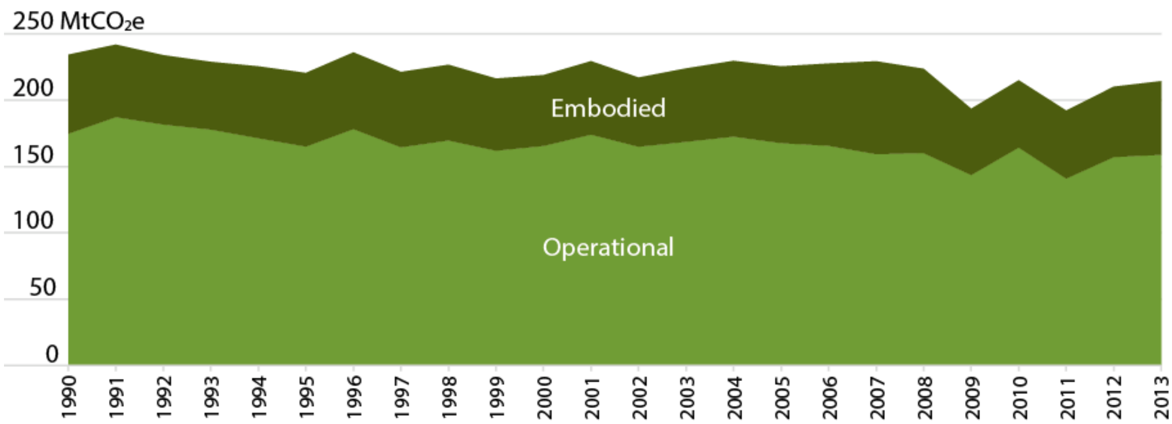

Figure 1 – Carbon emissions attributable to the UK built environment 1990-2013

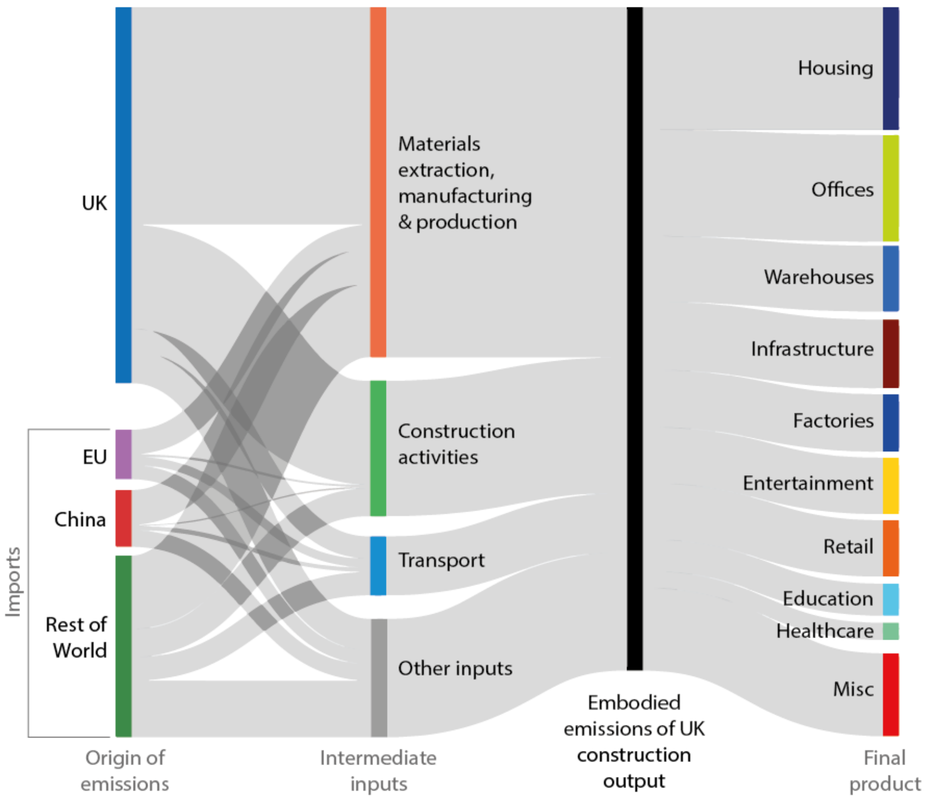

Figure 2 –Distribution of UK built environment supply chain GHG emissions in 2007 (based upon data from Giesekam et al., 2014 and Giesekam et al., In Press)

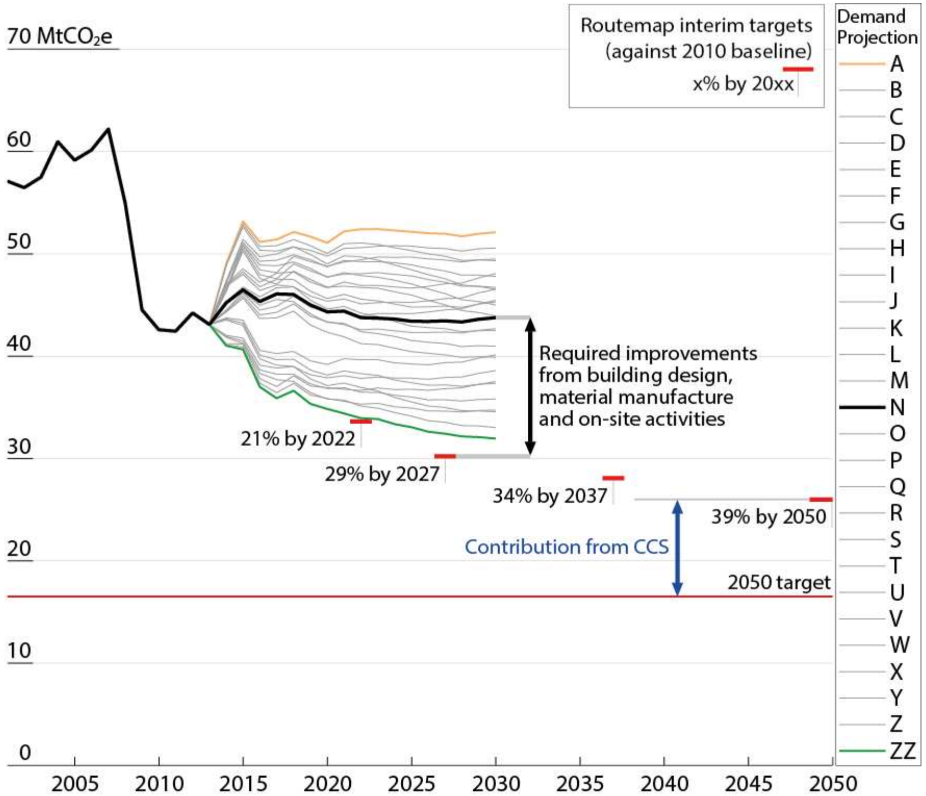

Figure 3 – Projections of future embodied GHG emissions from UK construction. All demand projections taken from scenario analysis with UK BIEC model (Giesekam et al, In Press) including decarbonisation of the electricity supply at the rate projected by DECC (2014).

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

Figure 4 – Suggested project embodied carbon checkpoints, adapted from GLA (2013) and Doran (2014).