FEBRUARY 2015

Tackling embodied carbon in buildings

CAMPAIGN FOR A SUSTAINABLE BUILT ENVIRONMENT

CONTENTS

INTRODUCTION

UK-GBC sees embodied carbon as an increasingly important area for all sectors of the built environment to actively address and is working with members to assist them in the process of making buildings more resource efficient.

A number of UK-GBC activities have been undertaken to address this topic including:

- *establishing a public database* with WRAP
- *Masterclasses* & *London 2012 Lessons learned series*
- *how to guides*
- Webinars on the *Dutch* and *German* national embodied carbon databases
- *Embodied Carbon Week*.

Reducing embodied carbon is important for many reasons; not only for reducing resources and associated costs but also alleviating longer term risks around resource availability. This guide has been developed with input from industry to help the client sector understand their role in reducing embodied carbon within the built environment.

Background to UK-GBC's work on embodied carbon

In March 2014 the UK-GBC coordinated Embodied Carbon Week, during which 22 events were attended by 300 organisations. A summary document of Embodied Carbon week set out the key themes and areas for further work.

The key themes that emerged from the week were:

- The need for new drivers for action on embodied carbon from within the industry itself, specifically a clear explanation of the business case for reducing embodied carbon.
- The challenges of changing industry's attitudes and practices, and overcoming the perception that considering embodied carbon adds cost and complexity to the project.
- The engagement of clients as priority stakeholders was identified as an important starting point.
- The need to improve consistency of measurement of embodied carbon:
  - A lack of industry-wide education and knowledge sharing in this area
  - A lack of openly available and transparent data
  - A need for better benchmarking and data services.

Who this guide is for

This guide is intended to address the first of the issues above, and is designed for clients and developers who want to begin to consider and to reduce the embodied carbon impacts of their developments.

A key requirement of UK-GBC's new Member Commitment is for member organisations to actively adopt leading sustainability practice and continually work towards creating a more sustainable built environment. Embodied carbon reduction is swiftly emerging as an important area for consideration and therefore UK-GBC expects our Members to begin managing embodied carbon as part of their commitment. This resource has been developed as a starting point guide and provides some useful further resources. The aim is to equip clients with the information they require to be able to discuss embodied carbon with design teams and, importantly, begin to measure and reduce it in their buildings.

Another aspect heavily discussed during Embodied Carbon Week was the current issues around measurement of embodied carbon and availability of data, this is discussed in the second part of this document. The aim of this section is to navigate some of the issues and provide signposts to further information.

WHAT IS EMBODIED CARBON

In the building life cycle embodied carbon is the carbon dioxide equivalent (CO_{2e}) or greenhouse gas (GHG) emissions associated with the non-operational phase of the project. This includes emissions cause by extraction, manufacture, transportation, assembly, maintenance, replacement, deconstruction, disposal and end of life aspects of the materials and systems that make up a building.

The whole life carbon of the building is both the embodied carbon and the carbon associated with operation (heating, cooling, powering, providing water etc). Understanding the relationships between 'embodied' carbon and 'operational' carbon can assist in determining the overall optimum carbon reductions.

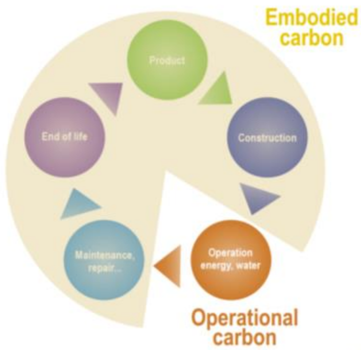


Figure 1: From 'A methodology for measuring embodied carbon', Sean Lockie, Faithful + Gould

As we build increasingly energy efficient buildings that use less and less energy to run and rely increasingly on locally-generated low or zero carbon heat and power sources, the proportion of the building's lifecycle carbon that comes from the embodied carbon becomes more significant.

In contrast to operational carbon emissions for new buildings, which are regulated through Building Regulations, embodied carbon is currently not regulated. However, embodied carbon is receiving increased attention at the European level, with embodied energy defined as one of the proposed core indicators in the EU Framework for Building Assessment, which is currently the subject of a consultation.[1]

There remains a significant, and still largely untapped, opportunity to address the embodied carbon of a building or project, alongside its operational efficiency, of a building. The greatest opportunity for impact on embodied carbon comes at the design

[1] http://ec.europa.eu/environment/eussd/pdf/SustainableBuildingsCommunication.pdf

stage, in particular in the building structure. If opportunities are not taken at this early stage, the embodied carbon savings are lost for the entire lifetime of the building.

The below (purely for illustration) provides an idea of the potential breakdown of carbon impacts at each stage of a building's lifetime, for different building types.

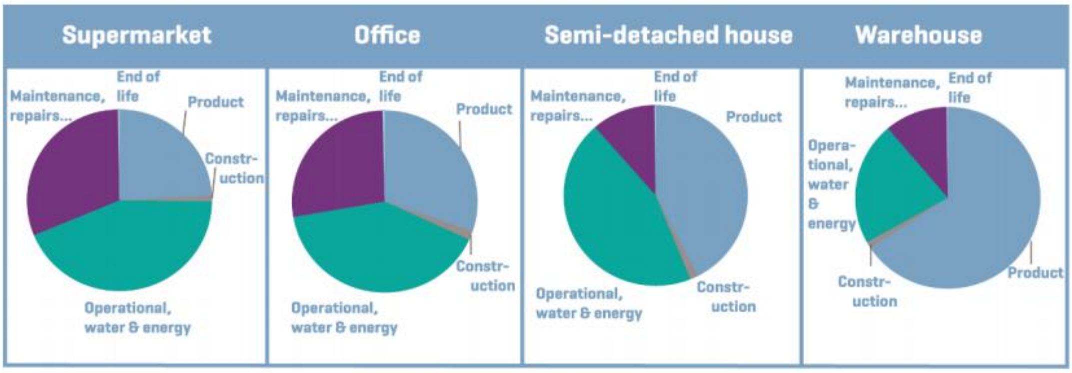


Figure 2: Impact of the consequent life cycle stages on the overall carbon footprint for different types of buildings, calculated over 30 years (RICS Professional Guidance, Methodology to calculate the embodied carbon of materials, 1st Edition) or similar from Embodied Carbon: Embodied Carbon -Relevance, Guidance and Methodology, Sean Lockie, Faithful +Gould

Depending on building type, by the time a building is occupied somewhere between 30% and 70% of its lifetime carbon may already have been accounted for (the higher end of this range is most likely in buildings such as warehouses and distribution centres or those built to Passivhaus standards, which have low operational carbon requirements).

Recognising this opportunity for carbon savings that is being missed, progressive clients, developers and contractors are increasingly measuring, managing and reducing the embodied carbon in building projects.

THE BUSINESS CASE

Cost reduction

One of the main sources of embodied carbon reductions in a building design is from the identification of efficiency gains, and thereby cost savings, through:

- the identification of designs that optimise building use
- the more efficient use of resources and materials
- the use of more resilient materials or ones that are more appropriate for the expected lifetime of the building/element
- and more efficient transportation and construction processes can all produce reductions in not only embodied carbon but also in cost

In this way embodied carbon management may be seen as a proxy for cost management, providing an additional means of value engineering at early design stages.

Capital investment can be reduced as can maintenance, repair and replacement costs.

In the infrastructure sector, Anglian Water has demonstrated between 30%-50% capital cost savings by tracking embodied carbon.[2]

At the new WWF Living Planet Centre in Woking a 'whole life' carbon assessment showed that, for this building, double glazing was more carbon efficient than triple. This was because the lifetime capital carbon costs outweighed the operational carbon savings over the anticipated life. This choice also significantly reduced initial capital expenditure, with only a small operational increase.

Embodied carbon assessments can also contribute to and encourage positive benefits of long term thinking by design teams in which the whole lifetime, and therefore the longevity and future uses of an asset, are taken into consideration.

Carbon and sustainability

A significant proportion of a building's lifetime carbon is locked into the fabric and systems. Addressing the embodied carbon can provide cost-effective potential for carbon savings and cost savings over and above those traditionally targeted through operational savings. Much of the low-hanging fruit of embodied carbon abatement is yet to be taken advantage of. It therefore provides a significant opportunity to reduce the carbon impact of the business and increase organisational carbon savings.

Reduction in embodied carbon is not subject to ongoing building user behaviour in the way that operational carbon savings are. As a result, embodied carbon benefits can be more accurate and identifiable than predicted operational carbon reductions, particularly the final occupant of the building is not known at the time.

Embodied carbon savings made during the design and construction stage are also delivered today. This contrasts with operational emissions savings which are delivered over time in the future. Defra data shows that a Kg of CO_2 saved over the next 5 years has a greater environmental value than a kg saved in say 10 or more years' time.

Embodied carbon assessment can also contribute to other sustainability targets and priorities beside carbon. For example, use of recycled content, recyclability of building materials, and reduced waste materials to landfill can all result from a focus on embodied carbon and also contribute to waste targets. Similarly, benefits to the local community can accrue from reduced on-site energy generation and cleaner fabrication processes which mitigate the impact of the development site on the local area; the use of more local sourcing and local supply chains can also support jobs and the economy in the locale (or if not local, at regional or national level).

Resilience

Rising or volatile energy and materials costs are a significant threat to the profitability and viability of the sector. Managing the embodied carbon of projects mitigates this risk by ensuring that building materials are used efficiently throughout the building life and that the manufacturing, transportation and construction processes are energy efficient and clean.

---

[2] Embodied Carbon Task Force, Guy Battle (Chair), 2014 *Embodied carbon industry task group recommendations: Proposals for Standardised Measurement Method and Recommendations for Zero Carbon Building Regulations and Allowable Solutions*

Therefore low embodied carbon building designs can make projects more resilient to future resource and materials scarcity, price rises and uncertainty, as well as rising energy prices.

Creating opportunities

A number of local authorities (eg Westminster City Council, Brighton, Oxford, Hammersmith and Fulham, Camden, City of London[3]) have begun enquiring as to the embodied carbon footprints of developments. Therefore, embodied carbon evaluation may increasingly be a differentiator in the planning process.

Building rating systems such as BREEAM, LEED and Green Star all recognise embodied carbon measurement and mitigation as part of minimising building life cycle impacts.

As the industry increasingly seeks to manage embodied carbon, more opportunities for innovation and collaboration in new processes and products emerge. This collaboration and innovation produces business opportunities to further reduce impact and cost, and create business differentiation.

Reputation

Measurement, management and reduction of embodied carbon is swiftly becoming best practice.

For more on the business case for reducing embodied carbon see:

- WRAP *The business case for managing and reducing embodied carbon in building projects* and the sister resource for *infrastructure projects*
- WRAP *Business case for resource efficiency in construction* resource

ASSESSING AND REDUCING EMBODIED CARBON

Getting started

In order to lock embodied carbon reductions in to a building, consideration of embodied carbon needs to start as early as possible in the planning and design phases.

As a client, triggering the process of identifying and benefiting from embodied carbon savings can be as simple as including a requirement in procurement documents or in the project specification.

WRAP[4] proposes the following inclusion to begin a simple opportunity identification:

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

[3] Embodied Carbon Task Force, Guy Battle (Chair) 2014 *Embodied carbon industry task group recommendations: Proposals for Standardised Measurement Method and Recommendations for Zero Carbon Building Regulations and Allowable Solutions*
[4] WRAP, *Cutting carbon in construction projects*

This requirement would encourage the design team to produce “with/without” calculations for these elements. This approach to embodied carbon reduction can be taken without the need to perform a full embodied carbon calculation for every element of the building.

For a more comprehensive understanding of the embodied carbon impacts of design decisions over the lifetime of the building, a full embodied carbon study can be commissioned or BIM (Building Information Modelling) can be used to enable iterative analysis through the process of design and maintenance. For more information on the issues to consider when commissioning an in-depth assessment, and the methodological approach to performing a whole life embodied carbon assessment, see the section on *Embodied carbon assessment and data*.

Who should be involved?

Architects, structural engineers and quantity surveyors all need to be involved in initial discussions about embodied carbon. As with other value-based decisions, the ultimate decision to choose one design or product over the other usually rests with the client.

Specify someone as responsible for embodied carbon throughout the life cycle eg:

- the cost consultant, or specialist carbon consultant to project completion
- the facilities manager for building in operation
- the project manager of building in periodical refurbishment

Embed the responsibilities associated with the assessment throughout the supply chain:

- specify measurement, recording and reporting of embodied carbon – on steel and concrete to start with – and get it passed down the supply chain to subcontractors.
- consider embodied carbon measurement in procurement and sourcing – look at the recycled content of products, recyclable materials, leasing products during the construction period etc.
- ask the cost/carbon consultant to engage the supply chain
- consider the likely leasing structure of the building – in particular how the length of lease(s) coincides with lifespan of particular building elements. Is there a need to design for the deconstruction of those elements that have a shorter life span to coincide with likely refurbishment cycle(s)?

Practical guidance

The below provides a simple hierarchy of questions illustrating the key questions that can affect the amount of embodied carbon locked into a design.

- “Do I need it at all?”
- “What is it made of?”
- “How is it made?”
- “Where does it come from, and to?”

Courtesy of Philippa Gill, Tishman Speyer[5]

A good summary of some practical ways the client and the project team can reduce the embodied carbon impacts at each of 4 stages of the building life cycle – product, construction, in-use and end of life – is contained in the UK-GBC and BRE *How to Guide: measuring embodied carbon on a project*

[5] Referenced in UK-GBC and BRE, 2014, *‘How to Guide’ – Measuring embodied carbon on a project*

The WRAP Information sheet: *Cutting embodied carbon in construction projects* also provides some useful suggestions on identifying basic cost effective actions across the building's design and construction. These include more efficient building design (eg more compact form), changing the specification for building elements (eg lower weight roof), designing for less on-site waste, considering materials and designing for reuse and deconstruction.

Embodied carbon hotspots

Identifying which elements of the building hold the most significant proportion of the overall embodied carbon - the 'hotspots' - can provide 'shortcuts' to significant reductions.

The illustration below, based on British Land's Leadenhall Building, shows that, as might be expected, the **structure** holds the key to a large proportion of the embodied carbon.

The 2014 RICS Guidance Note *Methodology to calculate embodied carbon, 1st edition* also offers an assessment of the carbon critical building elements that RICS recommends quantity surveyors include in their embodied carbon calculations. It identifies the substructure, superstructure, internal finishes (wall, floor ceiling) and external works (roads, paths paving and external drainage and services) as hotspots that should be included as a minimum.

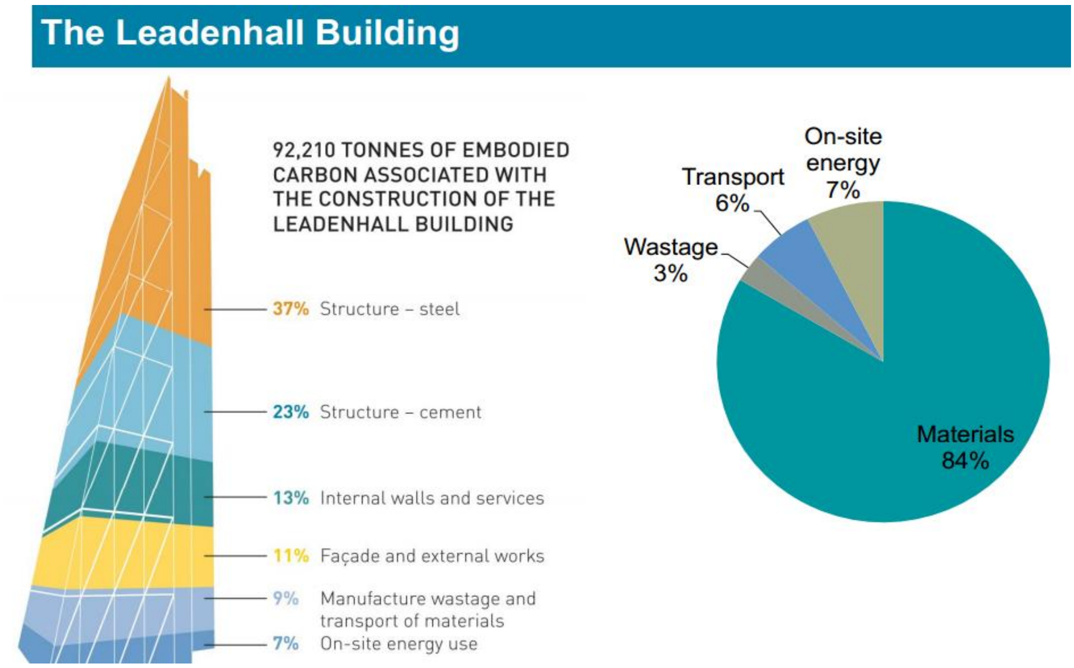


Figure 3: Proportions of embodied carbon in the different elements of the Leadenhall Building (courtesy of British Land)

For homes, in both timber frame and masonry home construction types, the impact of the foundations and ground floor dominates the embodied carbon impact as shown in a study from the NHBC Foundation.[6] In masonry construction, unsurprisingly, the external walls also have a major impact. These elements are expected to last the lifetime of the

[6] NHBC Foundation, 2011, *Operational and embodied carbon in new build housing: a reappraisal*.

home. Due to their shorter lifetime and more frequent replacement cycle windows, doors, and floor finishes were also found to have a relatively large impact.

This hotspot identification further illustrates the need to include an embodied carbon assessment as early as possible in the concept design stage since structural hotspots can usually not be modified at later stages in the design process.

As the graph below illustrates, although a large part of the building's lifetime carbon is locked in to its construction phase, significant opportunities occur at major refurbishment or replacement cycles which are typically every 7-15 years. Beyond these major cycles, smaller remodelling, fit-out and shop-fit events, typically on shorter cycles, provide further opportunities.

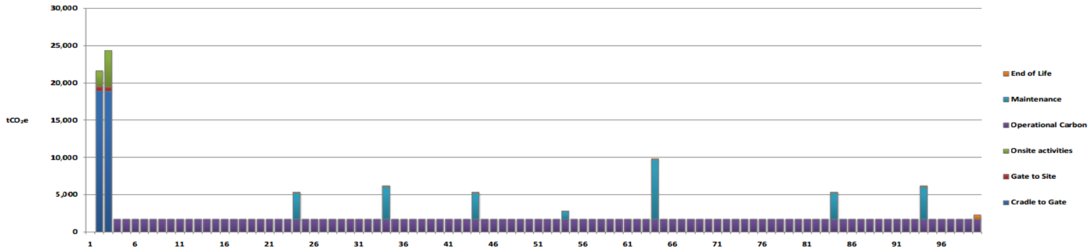


Figure 3 Building Lifetime Emissions (100 years)[x]

Figure 4: Analysis by Deloitte based for an office building over 100 year lifetime[7]

CASE STUDIES

For a bit of inspiration and illustration of this becoming best practice:

- LOCOG (London 2012): *Reducing embodied carbon through efficient design* and *The procurement and use of sustainable concrete on the Olympic Park*
- Olympic Delivery Authority: *Reducing embodied carbon through efficient design*
- British Land, *Ropemaker Place Life cycle carbon assessment* and *5 Broadgate*
- Building Magazine, 'Whole life' series contains studies on:
    - *schools*
    - *offices*
    - *shopping centres*
    - *new and refrofitted homes*
    - *hotels*
    - *airports*
- WWF *Living Planet Centre*
- AIMC4 – *Will fabric first solutions (for house building) increase embodied carbon?*

[7] Embodied Carbon Task Force, Guy Battle (Chair) 2014 *Embodied carbon industry task group recommendations: Proposals for Standardised Measurement Method and Recommendations for Zero Carbon Building Regulations and Allowable Solutions*

EMBODIED CARBON ASSESSMENT AND DATA

There is a considerable amount of work that has recently and continues to be undertaken to develop standardised methodologies for assessing and measuring embodied carbon. This section presents some of the standards, assessment methodologies and sources of data available.

The key issues to consider are:

- defining the life cycle boundary for the assessment
- sourcing robust data for the defined lifecycle
- ensuring the data used to assess the different options is consistent
- sharing your data to improve the size and robustness of the industry dataset

Embodied carbon assessment continues to evolve and improve its accuracy and there is important work on methodologies currently underway in the UK and across Europe.

Life time embodied carbon calculation

In the most simple terms, embodied carbon is calculated by finding the quantity of all materials needed for the building's lifetime and multiplying this by the carbon factor (expressed in kg CO_2e per kg of material/product) for each material to produce the embodied carbon figure.

The complexity arises from the fact that there is no one single source of accurate and exhaustive data, based on the same parameters of assessment. Not all carbon factors for materials/products consider the carbon associated with the same boundaries of life cycle. Some carbon factor calculations consider the carbon from "cradle to gate", others from "cradle to completed construction" and others consider the carbon from "cradle to end of life and recycling/reuse".

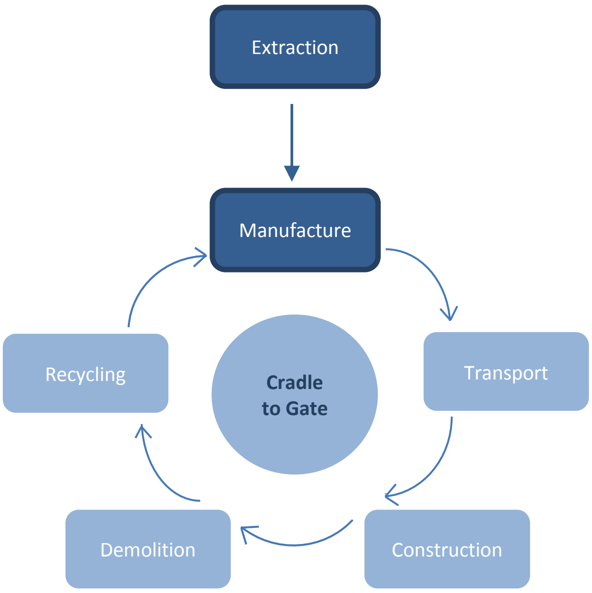
Boundaries of Life Cycle Assessment

An important distinction to be made when analysing the data on impacts of a construction product, or an entire building, is the boundaries of the life cycle assessment used to produce the data.

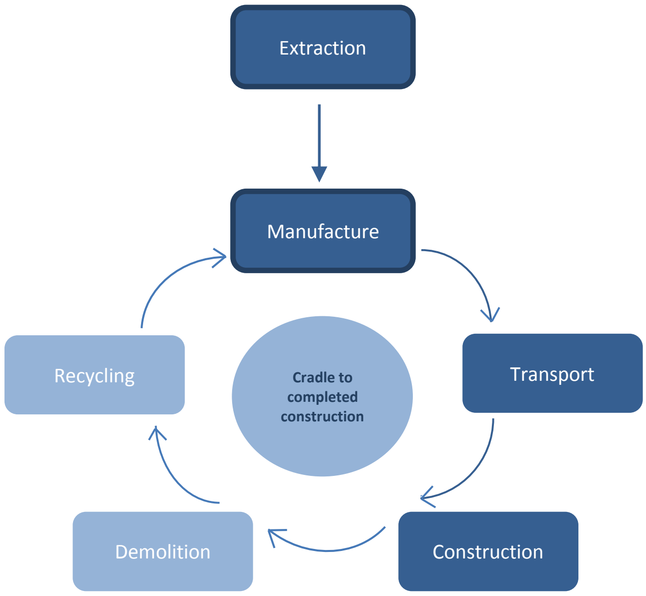
In simple terms, the more stages of the lifecycle that are included in the life cycle assessment, the more of the carbon emissions associated with the product or building that are brought into the analysis.

An illustration of some of the common boundaries of assessment are outlined below.

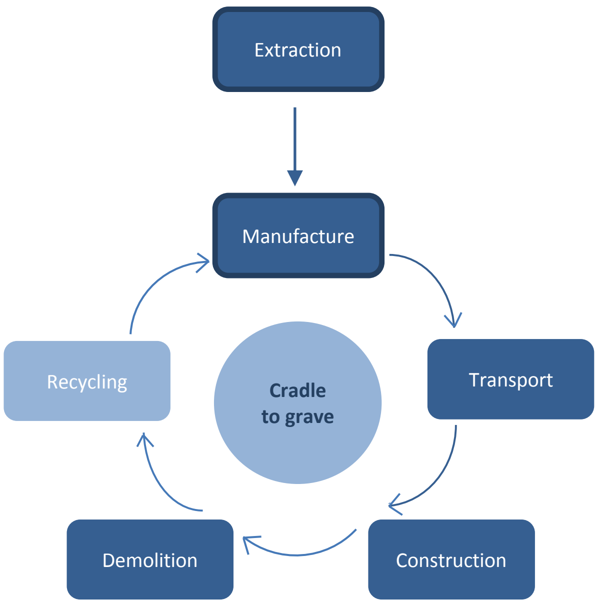
Cradle-to-gate – the carbon emitted to bring from material or product from the cradle (earth) to the point it leaves factory gate after processing and manufacturing (not including the transportation to the site)



Cradle-to-completed construction - cradle to gate plus delivery to the site construction and assembly on-site



Cradle-to-grave - cradle to completed construction plus maintenance, refurbishments, demolition, waste treatment and disposals (grave)



Cradle-to-cradle - The process of making a component or product and then, at the end of its life, converting it into a new component of a) the same quality or b) a lesser quality

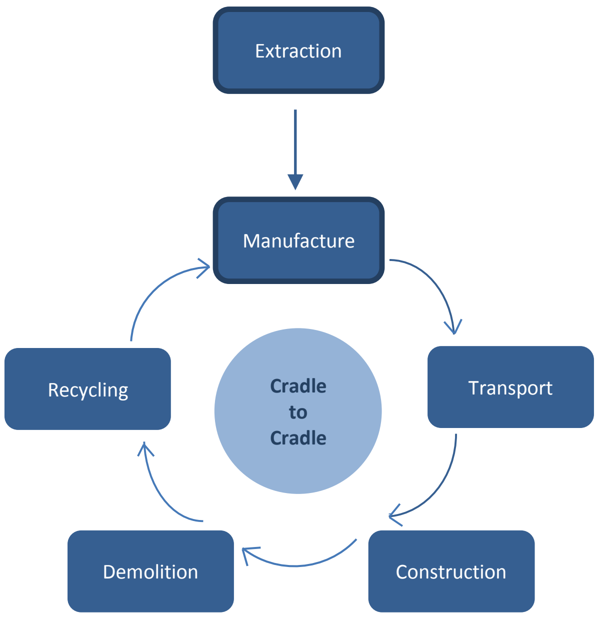


Figure 5: Boundaries of life cycle assessment. Image adapted from Tata Steel and BCSA, [Steel construction: embodied carbon]()

It should be noted that the boundaries of life cycle definition 'advantage' or 'disadvantage' different products and materials when the data is used to make design and substitution decisions. For example, highly recycled materials such as metals (like steel) can be disadvantaged by limiting the assessment to cradle to gate, whereas materials that are more likely to be downcycled (concrete) or disposed of as waste (timber) might be advantaged.

In 2014 a Task Force of practitioners, academics and developers came together to build consensus on how embodied carbon should be measured and reported. This group agreed that all practitioners within the group would follow and report upon the minimum requirements for boundaries to cover at least product stage and construction stage, and assessments to include at a minimum the substructure and superstructure of buildings.[8]

Methodology

A recent and authoritative contribution to the debate on the methodology for calculating embodied carbon was published in 2014 in the form of the RICS Guidance Note: *Methodology to calculate embodied carbon, 1st edition*.[9] This Guidance draws heavily on the British Standard that sets out the methodology for Life Cycle Assessment in relation to buildings (BS EN 15978 *The sustainability of construction works - assessment of environmental performance of buildings - calculation method)*.

In this Guidance, RICS recommends that its Quantity Surveyor members start their assessments on the product stage (cradle to gate). This recommendation is due to '*calculation complexity and limited potential to influence embodied carbon associated with other life cycle stages. Additionally, early in the design process, quantity surveyors are unlikely to have access to the detailed information required to calculate emissions from other stages, causing very high levels of uncertainty and inaccuracy*'.

Though written for Quantity Surveyors, the Guidance is very useful to the whole project team in that, in addition to a thorough description of product stage embodied carbon assessment methodology, it also provides guidance on producing an assessment for further life cycle stages. It identifies the main sources of embodied carbon at:

- construction stage (eg transport of product to site, storage of products, wastage, waste processing of packaging and product waste, installation of product into the building including ancillary materials and water and energy required)
- use stage (through the maintenance, repair, replacement and refurbishment phases)
- end of life stage (de-construction or demolition, transport, waste processing, disposal of waste).

The Guidance also provides some strategies to reduce embodied carbon at each of the above lifecycle stages.

The RICS Guidance does not however cover the final recycling or reuse impacts, which would need to be included in a cradle to cradle assessment.

[8] Embodied Carbon Task Force, Guy Battle (Chair) 2014 *Embodied carbon industry task group recommendations: Proposals for Standardised Measurement Method and Recommendations for Zero Carbon Building Regulations and Allowable Solutions*
[9] This builds on the 2012 Guidance Note *Methodology to calculate the embodied carbon of materials*, 1st edition which focussed on the cradle to gate emissions of materials.

This presentation from Sean Lockie of Faithful and Gould provides a walk-through of the RICS methodology.

Embodied carbon data

In order for data on the embodied carbon of a building material or product to be robust and reliable, it is important that it is gathered using a recognised and verifiable methodology.

As clients, developers, and contractors increasingly perform embodied carbon assessments on their buildings, the industry is responding by creating and providing more data.

At present, not all construction product data is collected using consistent boundaries of assessment, and product specific data emerging from manufacturers is not always comparable with the more generic product data. Much of the data on construction products available covers only cradle to gate stages and data on the impacts covering more life cycle stages is still developing.

One of the main sources of product data is an Environmental Product Declaration (EPD). Importantly, the rules that guide how a product's environmental impacts are assessed and communicated through the EPD allow for the definition of different boundaries. In addition, although there is one international standard (ISO 14025) that sets out the standards any EPD should meet, it allows for different sets of Product Category Rules to be defined by different countries and programmes. Therefore EPD for a construction product that is developed under different Product Category Rules are not comparable.

In an effort to standardise EPD across the European Union, the a European Standards Technical Committee (CEN TC 350) has developed a suite of standards, which includes the BS EN 15804 which provides the core rules for the creation of EPD for the Product Category 'construction products'. However as yet there is no compulsory harmonised European standard on EPD preparation. In the UK the national scheme was developed by BRE called the 15804 EPD scheme.

For more information:

For a simple guide to life cycle assessment of products and the presentation of data through EPD see the Construction Product Associations' *Guide to understanding the environmental impacts of construction products.*

RICS' *Methodology to calculate the embodied carbon of materials* (2012) (available to RICS members only) provides practical guidance designed for quantity surveyors on how to calculate **Cradle to Gate** embodied carbon emissions.

Share your data

All calculations of embodied carbon rely on data, largely from external sources, whether this be carbon factor data for a building product/material, data on post product stage lifecycle impacts to use in calculations, or a benchmark for a building type or building element to use for comparison.

The continued improvement in the accuracy of calculations and benchmarks relies on larger and more robust data sets.

It is therefore critical that the industry share its embodied carbon calculations.

WRAP and the UK-GBC have recently launched an open access database that captures and shares embodied carbon data for building projects. The database allows the input of project data at different lifecycle stages and it indicates which lifecycle stages have been considered for each project in the database. The database can accommodate data on new build projects as well as refurbishments and demolition. The aim of this database is to build a detailed comparative dataset to enable benchmarking of designs. Clearly the more data in this database the better the benchmarks for the whole industry to use.

We strongly encourage clients to include the addition of project data into the WRAP database as part of their contract requirements with the project team. In this way, the database will quickly provide detailed benchmarking information for comparisons and projections alike.

This presentation from Andrea Charlson of ARUP provides an introduction and guide to using the *database*.

Sources of embodied carbon data

The majority of data sources provide generic building product/material information. This information can enable the identification of hotspots of embodied carbon and the potential for product substitution to reduce embodied impacts. Manufacturer specific data is beginning to be generated which will allow a further level of product differentiation.

Data on products, materials and building elements can be found:

- *Inventory of Energy and Carbon (ICE) database* (building materials database developed at the University of Bath presenting average values developed through a review of range of studies, available to download in excel or published in hard copy by BSRIA)
- *BRE Global Green guide to specification* (database of generic environmental impact data on building materials, components and elements[10])
- BRE Global *Green Book live* (database of manufacturer specific data on products and services)
- *European Reference Lifecycle database* (life cycle inventory data collected from EU associations and other sources for materials, energy carriers, transport and waste management)
- *SteelConstruction.Info* holds generic figures for brick, concrete and steel
- *Wood for Good Lifecycle Database* holds generic information for timber, timber products and panels.

Data on buildings and building elements can be found:

- *WRAP database* - data and benchmarks covering all life cycle stages
- Product Stage benchmarks are published in the RICS 2014 *Methodology to calculate embodied carbon, 1st edition*

See also *Embodied carbon - Come share with me: Where is all the data and how can I get to it?,* a presentation from Philippa Gill of Tishman Speyer, for a comprehensive outline of data sources and tools/projects.

[10] The data in the Green Guide is prepared using the BRE Environmental Profiles Methodology. This is a different methodology to the BRE 15804 EPD methodology so the data cannot be directly compared. Data from both sources can however both be used to qualify for BREEAM credits.

ABOUT THIS REPORT

This report was produced with the support of:

THE CROWN ESTATE

UK-GBC would particularly like to thank Jane Baptist for her input.

UK Green Building Council
The Building Centre
26 Store Street
London WC1E 7BT

T: +44 (0)20 7580 0623
E: *info@ukgbc.org*
W: www.ukgbc.org