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Scottish Futures Trust: Measuring and Target Setting on the Embodied Carbon of New Buildings

Authors: Dr Craig Jones and Dr Matthew Fishwick

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Introduction

In 2016 the Scottish Futures Trust (SFT) launched its Whole Life Appraisal tool, which includes a database on embodied carbon emissions and associated calculator tool for embodied and operational carbon. Both the embodied carbon benchmarks and Excel tool have been further developed as a part of this current (2019) project.

This short guidance note summarises good practice approaches to measuring and reporting embodied carbon in new buildings. It will assist public bodies to articulate targets for embodied carbon in their briefs for newbuild projects and for checking such targets are met at key stages through the projects.

In order to achieve the goal and scope of study, there are various project outputs:

- This report summarising good practice approaches to embodied carbon measurement and target setting;
- A report summarising the embodied carbon benchmarks and Excel tool;
- An accompanying Excel file with the embodied carbon benchmarks; and
- The embodied carbon tool, in Excel format.

For an introduction to the benchmarks and tool, see the above documents.

Summary of good practice approaches to measuring and reporting embodied carbon

Embodied carbon is the sum of greenhouse gas (GHG emissions) associated with the manufacture, transportation and construction of materials and products. The cradle-to-construction embodied carbon is typically the largest single release of embodied carbon emissions. However, material replacement and refurbishment can also have a notable embodied carbon contribution, but this is beyond the scope of this briefing note.

The embodied carbon of new buildings is often overshadowed by operational carbon emissions. However, embodied carbon is a large single release of GHG emissions, which will become more and more important as we move towards zero carbon in operation[1]. Whilst operational carbon is emitted up over a long period of time, embodied carbon is different, in that it is released largely upfront. For this reason, it is sometimes called capital carbon, particularly for infrastructure projects.

In regards to reducing embodied carbon emissions, the potential for improvement is greatest at the start of a project. What's more, once the building is constructed the opportunity to improve the embodied carbon has disappeared altogether – it is too late, the materials have been produced, the transport has occurred and the opportunity to reduce the embodied carbon for this building has

[1] Note that the UK Green Building council are currently developing a definition for zero carbon building in the UK (due to be complete at the end of April 2019). https://www.ukgbc.org/wp-content/uploads/2019/02/NZCB-Consultation-Paper.pdf

passed. Figure 1 provides an illustration of the greater opportunity to reduce embodied carbon at the start of a building project.

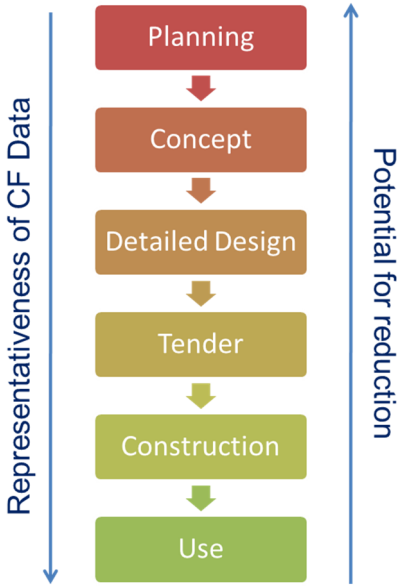

Figure 1 - Opportunity to reduce embodied carbon emissions

This means to achieve the most effective and efficient embodied carbon reductions, it is best to consider embodied carbon into a project early into the brief and design. In order to effectively measure and report embodied carbon of a new building, organisations will need to consider many things, including, for example:

- When to set a target;
- Accuracy of embodied carbon measurement;
- Realistic reduction potential;
- Measurement approach; and
- Reporting.

In order to assist with this, there are many wider guidance documents, tools and data resources. A summary of which is provided in this brief.

A summary of good practice approaches to measuring and reporting embodied carbon of new buildings is shown in Figure 2.

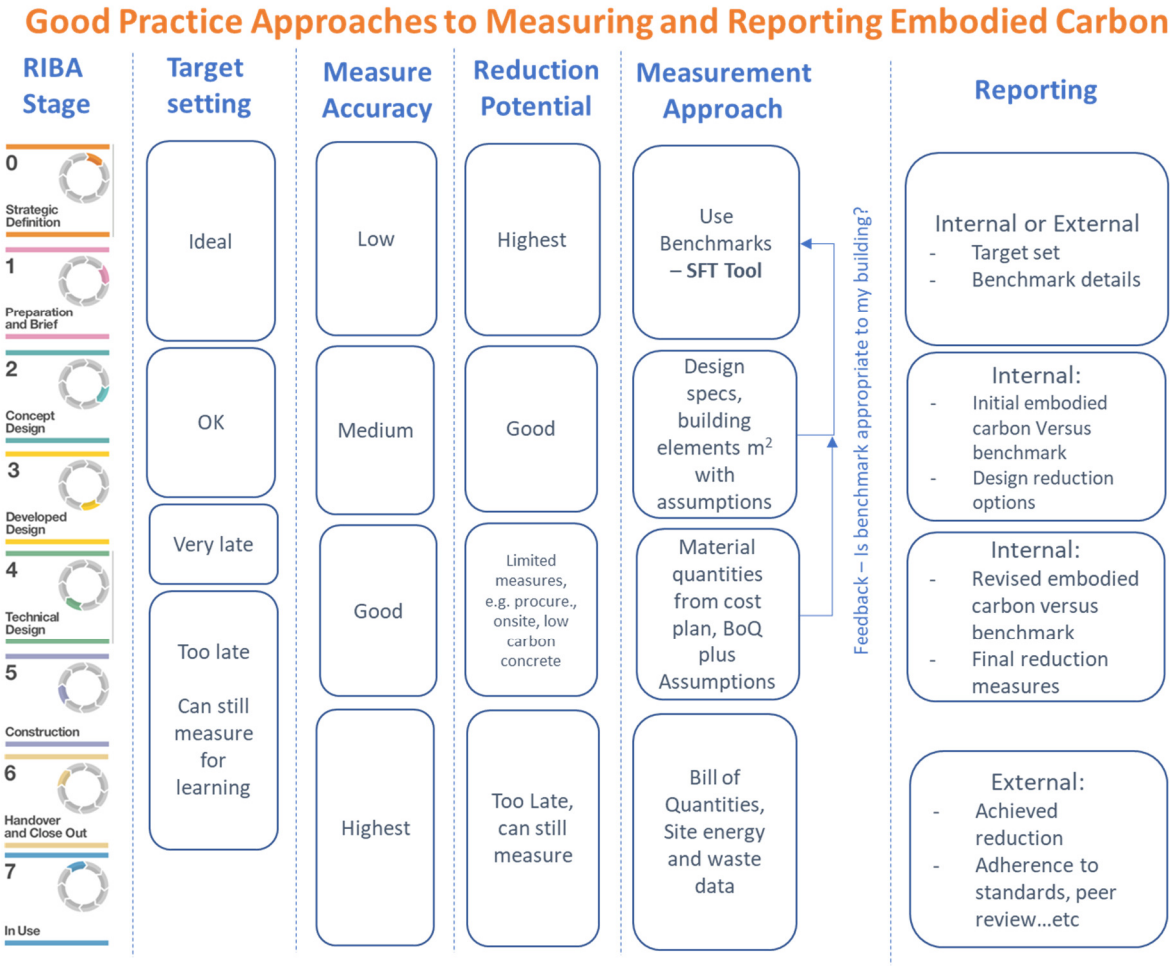

Figure 2- Good practice approaches to measuring and reporting embodied carbon. (Source of RIBA stage diagram: RIBA)

Breaking down and summarising Figure 2:

Target setting:

- Ideally set a target early into the project;
- Last minute targets can be set up until the technical design stage; and
- Beyond this, when it's too late to set a target, move on to measurement as a learning exercise for the next project.

Measurement accuracy and reduction potential:

- The earlier in the project the lower the accuracy of embodied carbon estimates, however, the greater the opportunity to reduce; and
- Therefore, don't focus too much on uncertainty of calculation at this stage, focus on reduction.
    - Doing something is better than doing nothing.

Measurement approach:

- The SFT tool will be useful to set a target, and also to compare baseline buildings; and
- When it comes to measuring embodied carbon, approaches include:
    - Using design specs – this is an elemental approach, requiring data on area of external walls, roof, floor…etc. combined with their design spec, to estimate material composition.
    - Using a cost plan – this is the more detailed approach. A bill of quantities (BoQ) can be converted to embodied carbon, using embodied carbon factors following unit conversions. A cost plan won't always be available in earlier design stages

Readers are directed to the guidance note, RICS (2018), as a good general document for embodied carbon measurement approach.

Reporting:

When reporting on embodied carbon targets setting, measurement and reduction, it is generally recommended for those new to embodied carbon to mainly keep communication internal to the project until the building is constructed. This is because embodied carbon is best seen as an iterative field. There is a learning process to go through and lessons should be used to feed into the next project. The exception is for very long timeline projects, which are likely to be the largest construction projects around.

Once an organisation is more familiar with embodied carbon assessment, it is then recommended to communicate externally at the start of a project, if desirable, as well as external communication at the end of the project. This could be that "our project has an embodied carbon reduction target of X%".

Summary

In order to assist with embodied carbon target setting, measurement and reduction, there are many standards and guidance documents, data resources and tools. Some of the main resources are summarised in the following sections.

Overview of key standards and guidance

There are many standards and guidance documents on embodied carbon for construction. To assist with cutting through the landscape, an overview of standards and guidance on the measurement and reporting of embodied carbon of new buildings is presented in Figure 3. The authors have presented some of the main ones, at the point of publication. The standards and guidance are categorised as either having product focus or a building focus.

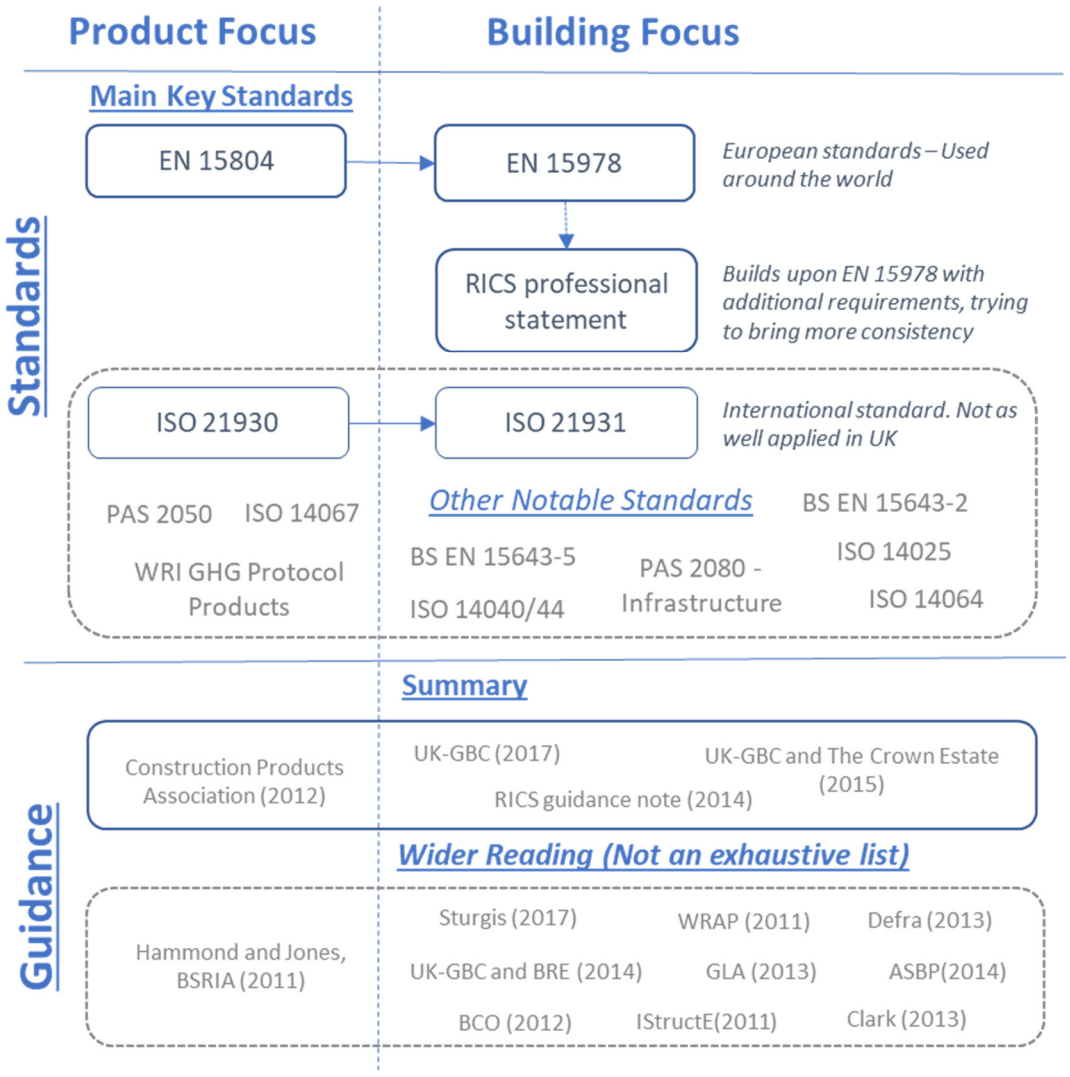

Figure 3 – Summary of standards and guidance available relating to the measurement of embodied carbon of buildings.

The standards and presented in terms of being key or supplementary. This does not mean that the supplementary standards are not important. In the authors experience, they are standards that are nice to know about and active organisations are likely to come across at some point. However, the key standards cover the main considerations for most people.

There are a large number of guidance documents. Those that were considered good summaries of the subject are identified in Figure 3. They will give a good introduction to key concepts on embodied carbon assessment. Examples of other guidance documents are presented, which is not an exhaustive list, but those literature will also be of use, to those that have the time.

All standards and guidance documents are fully referenced in the references section.

Framing all of these standards documents, there are the standards for life cycle assessment (ISO 14040/44), the standard for environmental product declarations (ISO 14025), product carbon footprint standards and specifications (ISO 14067, PAS 2050 and the Greenhouse Gas Protocol for product), the project carbon footprint standard (ISO 14064-2) and infrastructure specific standards (BS EN 15643-5 and PAS 2080).

To gain an efficient but effective overview of standards:

- **BS EN 15804** *(Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products)*: this standard provides core rules for environmental product declarations (EPD) for construction products, which need to be followed in order to publish an EPD. The standard covers a ranges of impact categories including ozone depletion, eutrophication, resource use, in addition to carbon footprint. Further product category rules (PCR) with more specific requirements are provided by EPD programme operators, which in some cases are sub-divided into sub-PCRs. For example, The International EPD System has PCR 2012:01 for construction products and sub-PCRs for mortars, concrete, cement etc.
- **BS EN 15978** *(Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method)*: this standard provides a calculation method to assess the environmental impacts associated with the whole life of building (both new and existing). The standard covers a range of impact categories including ozone depletion, eutrophication, resource use, in addition to carbon footprint. It also provides guidance on the reporting and communication of results. This standard is not prescriptive enough to allow for consistent assessment between practitioners and therefore further guidance documents have been released to address this (e.g. RICS, 2017).
- **RICS professional statement (2017)** *(Whole life carbon assessment for the built environment)*: specific guidance and requirements (for RICS members) on the calculation of whole life carbon of buildings and infrastructure to address the inconsistent application of BS EN 15978 by practitioners. Provides useful guidance on many aspects of assessment.

Other key standards:

- **ISO 14040/44** *(Environmental management -- Life cycle assessment)*: these two standards provide the life cycle assessment (LCA) principles and framework. They underpin all other standards on embodied carbon, carbon footprinting and the measurement of wider environmental impacts. In most embodied carbon standards, they are referred to as normative standards. As a result of this, adherence to the main embodied impacts standard normally gives good adherence to these LCA standards.
- **ISO 21930** *(Sustainability in building construction. Environmental declaration of building products)*: this standard provides principles and requirements for EPDs for construction products, which need to be followed in order to publish an EPD. The standard covers a ranges of impact categories

including ozone depletion, eutrophication, resource use, in addition to carbon footprint. It can be seen as the international equivalent of BS EN 15804, however, it is not very widely used in the UK.

- **ISO 21931** *(Sustainability in building construction – Framework for methods of assessment of the environmental performance of construction works – Part 1: Buildings)*: this standard provides a framework for improving both the quality and comparability of method for assessing the environmental impacts associated with the whole life of building. It can be seen as the international equivalent of BS EN 15978, however, it is not very widely used in the UK.
- **BS EN 15643-2** *(Sustainability of construction works. Assessment of buildings. Framework for the assessment of environmental performance)*: this standard provides the specific principles and requirements for the assessment of environmental performance of a building (both new and existing) with specific reference to its technical characteristics and functionality. The standard covers a ranges of impact categories including ozone depletion, eutrophication, resource use, in addition to carbon footprint.

An efficient and effective introduction from guidance documents:

- **UK-GBC (2017)** *(Embodied Carbon: A Client Brief)*: this guide is designed to help people write an effective brief to commissioning their first embodied carbon measurement study. It also provides a very good review of embodied carbon and whole life carbon standards and guidance and some benchmark data.
- **RICS guidance note (2014)** *(Methodology to Calculate Embodied Carbon)*: a precursor to the RICS professional statement of 2017.
- **UK-GBC and The Crown Estate (2015)** *(Tackling Embodied Carbon in Buildings)*: a guide on the assessment of embodied carbon in building and advice on how to drive carbon reductions.
- **Construction Production Association (2012)** *(A guide to understanding the embodied impacts of construction products)*: this guide explains how environmental impacts of construction products are typically measured and how this information is used at the building level.

Other guidance notes:

Examples of other guidance notes include, UK-GBC and BRE (2014), WRAP (2011), Defra (2013), Sturgis (2017), BCO (2012), Clark (2013), ASBP (2014), Embodied Carbon Task Force (2014), Institution of Structural Engineers (2011), GLA (2013) and Hammond and Jones (2011). Also, useful review papers include Giesekam and Pomponi (2017) and de Wolf et al (2017).

Overview of data and tools

An over of key tools and data sources for the measurement of embodied carbon and whole life carbon of new buildings is displayed in Figure 4. The SFT tool is compared with other tools on this figure, which is separated by RIBA design stages.

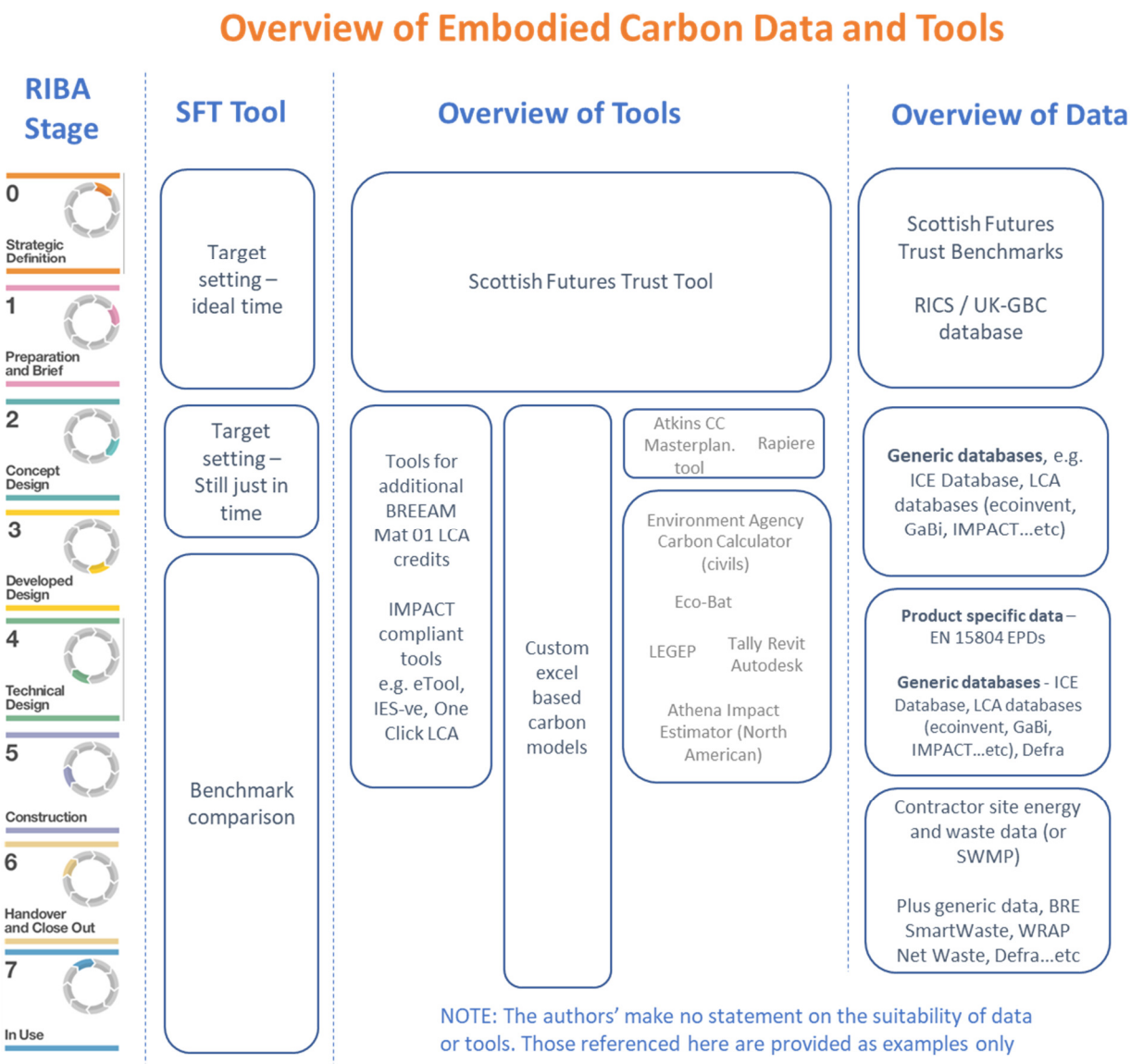

Figure 4 –Tools relating to the measurement of embodied carbon of buildings, sorted by RIBA design stage. (Source of RIBA stage diagram: RIBA).

There is a large choice of tools available, both open-source and proprietary, that allow for the measurement of embodied or whole life carbon of buildings. Links to the tools in Figure 4 are provided in the references section.

In summary, the SFT tool will be useful for benchmark and target setting. Ideally early into the design process. However, later in a project, the SFT benchmarks will be useful for comparing their building to

a benchmark building. The SFT tool also includes useful statistics, to judge uncertainty and where a particular building sits in the overall spectrum.

When it comes to measuring and reducing embodied carbon, wider tools will be needed by the design team. There are a significant number of tools and new tools keep being released. To provide some guidance:

Excel based models: Many embodied carbon experts, e.g. consultants, academics…etc, chose to model embodied carbon in Excel. Either through an inhouse developed Excel based tool, or a custom model, developed for each building. Whilst this may sound inefficient, for experts it still gives the greatest control over modelling, data and results. Software tools have not yet replaced this approach as a main method of embodied carbon assessment for experts. That said, those new to the subject and likely to find a tool easier to work with. New tools are often being released.

IMPACT compliant tools: IMPACT is an embodied impact framework and database from the BRE. There are several tools that are IMPACT compliant. Examples include eTool, IES-ve and One Click LCA. These tools may particularly appeal for projects wanting to score additional BREEAM credits. IMPACT compliant tools can be used to score additional Mat01 credits for BREEAM projects.

Other useful tools: Examples of other useful tools include, Tally, Atkins CC Masterplan Tool, Environment Agency Carbon Calculator (civils), Athena Impact Estimator (North America), Rapiere, Eco-Bat, LEGEP, amongst many others.

Data:

There are several key data sources for embodied carbon assessment. The SFT embodied carbon tool, will be useful to provide data for benchmarks of buildings. However, when it comes to modelling the embodied carbon of a building and design options, data for embodied carbon of materials and products will be required.

Key data sources include:

Inventory of Carbon & Energy (ICE) database: This free embodied carbon database for materials[2] is one of the main data sources for embodied carbon of materials. It was originally created at the University of Bath by Professor Geoffrey Hammond and Dr Craig Jones. The ICE database was being updated at the time of writing, with a new version being released in May 2019. This database is used in many embodied carbon tools.

Defra / BEIS GHG Emission Factors for Company Reporting: These GHG emissions factors are released by every year. They provide an excellent resource for carbon emissions for consumption of fuels, electricity, transport of goods and processing waste. This is an important resource for calculating GHG emissions from construction site energy and for transport of construction materials to site.

LCA databases: LCA databases also offer an important resource for data. The main databases are ecoinvent and GaBi. They are commercially licensed databases. Access to the database directly are only recommended for experts. They require a good level of expertise to apply correctly. However, some of the embodied carbon tools are based upon these databases.

[2] Available from: http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html

Environmental Product Declarations (EPDs): EPDs are rapidly rising in number. In 2012, there were around 500 EN 15804 EPDs. At the start of 2019 this figure had risen to over 6,000[3]. EPDs are produced by manufacturers or material sectors and have become a key data source for the embodied carbon of construction materials and products. These will be useful when the detailed design for a building is more developed.

Contractor site data: To calculate the carbon emissions of construction site energy, e.g. diesel to power generators and equipment, electricity…etc, and construction site waste, which also has an embodied carbon impact, data from contractors is important. In the absence of this data, generic resources can be used, such as the SmartWaste data from the BRE and the Net Waste Tool from WRAP. The latter no longer has support and is a little dated. However, it is still used for many construction Site Waste Management Plans (SWMP).

There are many more data resources. However, the above offers more than enough data for the average project. It is also important to appreciate, that some of the embodied carbon tools have all the embodied carbon data that you will need.

Guidance on Embodied Carbon Reduction and Target Setting

Approach to Embodied Carbon Target Setting

Embodied carbon assessment is best considered as an iterative process. This mentality is also best to apply when setting an embodied carbon target. Some advice when setting an embodied carbon target:

- Appreciate that embodied carbon results vary, much like operational carbon varies from building to building, or CAPEX build costs vary from project to project. Expect a similar level of variation for embodied carbon results.
- If it is the first time setting an embodied carbon target, then don't be too ambitious on the first project. Consider the first project as a testbed for refinement on future projects.
    - Start by selecting an embodied carbon target which is a realistic amount under the appropriate typical benchmark, rather than at the lowest end of the benchmark range.
    - Because the first project will have a learning curve, where all parts of the project team will need to learn about embodied carbon, understand where to focus and what is not important for embodied carbon assessment.
    - For further projects, refine the carbon target based upon feedback of the initial project. Consider gradually making the embodied carbon target more ambitious.

This approach will help to implement embodied carbon target setting and to achieve embodied carbon reductions.

[3] https://constructionlca.wordpress.com

Setting Appropriate Embodied Carbon Targets

The SFT embodied carbon benchmark tool provides an estimate of embodied and operational carbon for your project, which is calculated using the median value of benchmark data (in tCO_2e per m^2) collected from the literature (over 1,200 data points collected and 600 used) and floor area plus building type entered by the user. The potential range of carbon footprints for the project is also provided using 10^{th} and 90^{th} percentile values of the benchmark data per project type.

Even at the strategic definition stage, outputs of the SFT tool provide an estimate of the embodied and operational carbon of a typical building of the same floor area and end-use as your project, and the potential range from the best to worst performing buildings (excluding "outliers"). With this information, targets can be set to either be "better than typical" by aiming for lower than the median values provided (recommended for first project) or for "good practice" by aiming for lower than values generated using lower quartile benchmarks (recommended if reduction initiatives are intended to be a priority from early design stages). Both "better than typical" and "good practice" targets for embodied and operational carbon for the specific floor area and building data entered for your project are provided by the SFT tool.

Once your project is complete, a more thorough embodied carbon assessment can be carried out results to track performance against the target and fed back into the target setting process for the next project.

High Level Embodied Carbon Reduction Advice

There are many ways in which embodied carbon can be reduced on a project. Some of them involve more detailed and project specific embodied carbon assessments. However, there are also some general principles that can be followed to reduce the embodied carbon of a project.

To reduce the embodied carbon of a building consider:

- **Use of natural minimally processed materials:** As a general rule of thumb, the more natural a materials and the less processing steps it has undergone, the lower embodied carbon the material is likely to be. For example, softwood timber from a sustainable resource has a notably low embodied carbon, even without carbon storage benefits.
- **Dematerialisation:** Use less to achieve the same function or purpose. Can the same be achieved by using less materials?
- **Reuse, retention and refurbishment:** Building on the previous item, if parts of a building can be retained or refurbished then it can save a considerable amount of embodied carbon. Likewise, if products can be reused it can save considerable embodied carbon.
- **Lower carbon concrete:** Lower carbon concrete is one of the embodied carbon top wins. There are two main substances that can be added into concrete mixtures, to substitute some of the cement content:
    - **GGBS:** Ground granulation blast furnace slag (GGBS) is a by-product from virgin steel making. Due to its cementitious properties it can replace some of the cement content in concrete, typically around 50% cement replacement. However, there are companies working on up to 95% cement replacement. As yet these extreme replacement levels should be considered as "in development".

- **PFA / Fly Ash:** Pulverised fuel ash (PFA), or fly ash, are waste products from coal fired electricity generation. Often around 30% of the cement is replaced with PFA. Whilst this is not as high cement replacement as GGBS, the use of PFA could offer a real marginal environmental benefit. This is because the demand for GGBS is high, therefore it all gets consumed. Whereas, PFA has been more available.

- **Reduce construction waste:** The embodied carbon of construction waste can be a notable contributor to carbon impacts. Materials that arise as construction waste also had an embodied carbon. The priority should be:
  - Reduce the amount of materials wasted on site as a first priority;
  - Sending surplus and usable materials for reuse; and
  - Finally, send remaining materials for recycling.

Carbon Offsetting

It is typically recommended to reduce emissions, before considering carbon offsetting. However, carbon offsetting is a topic of growing interest. The carbon offset market has developed considerably since the early days. There are now carbon offset standards and verified carbon offset registries, to ensure that they are additional, traceable and verifiable carbon offsets. As a result, the perception of carbon offsetting has changed considerably.

There are also growing initiatives to be carbon neutral. Scotland has stated in the Energy Efficient Scotland Route Map[4], "for all social housing to be carbon neutral as far as reasonably practical".

Generally, definitions of zero carbon are still developing and often do not include embodied carbon emissions. However, that may change over time and as thermal standards improve, the embodied carbon emissions become a larger share of the whole life carbon emissions.

Should carbon offsetting be considered for projects to become carbon neutral, there are financial costs involved of the offsets.

[4] Energy Efficient Scotland, Scottish Government. May 2018. Available from: https://www.gov.scot/publications/energy-efficient-scotland-route-map/

Summary

This project has compiled embodied carbon benchmarks and used these to develop an SFT Excel-based tool for calculating embodied (and operational) carbon of new buildings. This tool is useful for setting “better than typical” or “good practice” targets and defining benchmarks projects. The tool is best implemented early in the design process, however, if used later in the project it can still be useful for benchmark comparison as a learning exercise.

Examples of useful guidance documents and standards have been identified, for further reading along with examples of useful data and tools, which may be of use to the design team.

Finally, it is always worth remembering that embodied carbon is best considered as an iterative field. Iteration is key throughout a project, to sense check the progress against a target, but also the appropriateness of a target. It is also useful to feedback lessons from one project into the next.

References

Standards

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Tools

Athena Impact Estimator

Atkins Carbon Critical Masterplanning tool

Baubook eco2soft

Butterfly tool

ECO-bat

Environmental Agency Carbon Calculator

IMPACT (IES-ve, eTool and Bionova)

LEGEP

Rapiere

Scottish Future Trust – C-CAT

SOM Environmental Analysis Tool

Tally

Others

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