A brief introduction to 'How to calculate the embodied carbon of facades: A methodology'

Introduction

The facade has a significant impact on the total embodied carbon of a building. Until now, there has been no industry standard to align facade embodied carbon calculations at every stage of a design. The CWCT's new facade-specific embodied carbon methodology provides this guidance to bring the required consistency and level of detail needed for accurate and comparable facade embodied carbon assessments.

This document provides a brief introduction and overview to the CWCT guidance entitled *'How to calculate the embodied carbon of facades: A methodology'* (1). The methodology and associated Worked Example are available to download on the CWCT Sustainability webpage.

The methodology has been developed and written over the course of 11 months by the CWCT's sub-committee on embodied carbon. A peer-review of the document was undertaken in 2022 with input from over 30 industry organizations including industry-bodies, consultants, architects, contractors and suppliers mainly located across the UK and Europe, but also with some reviewers located in the United States.

This document briefly describes the inputs, process, and outputs required for facade embodied carbon calculations following the CWCT methodology as summarised in Figure 1.

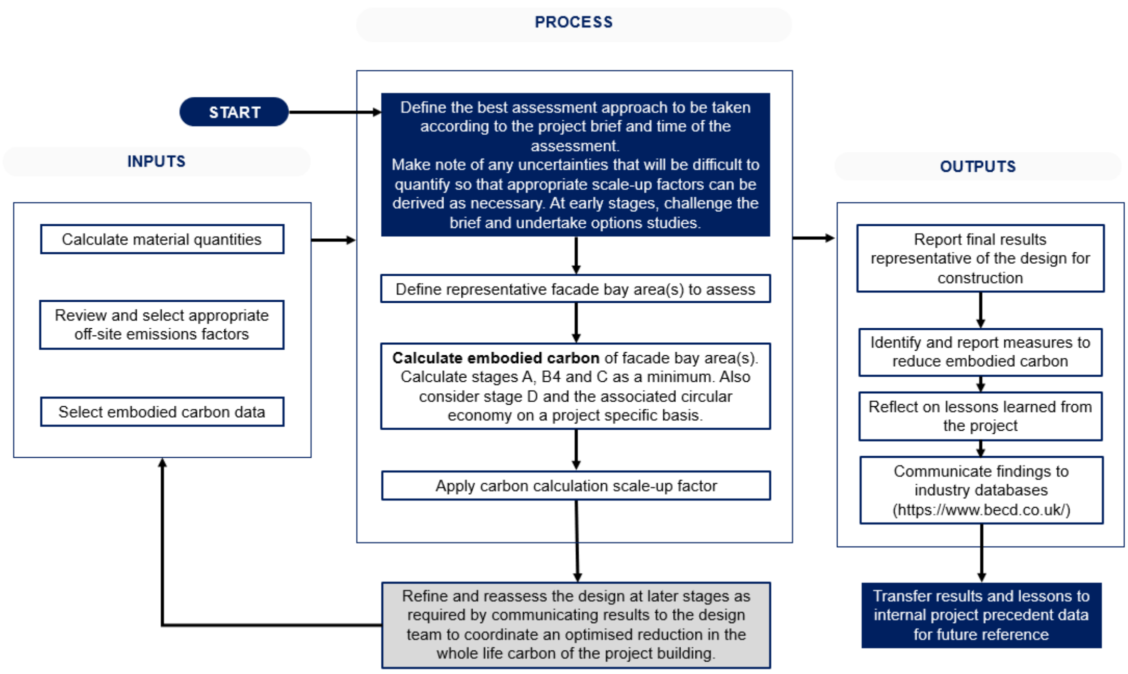

Figure 1 – Calculating facade embodied carbon process overview (adapted from The IStructE (2))

The CWCT methodology aligns with the calculation method set out in BS EN 15978 (3) providing specific guidance and interpretation for life cycle assessment (LCA) of facades and cladding systems. The methodology also aligns with other industry specific documents including:

- RICS Professional Statement (RICS PS): Whole Life Carbon assessment for the built environment (2017) (4)
- IStructE: How to calculate embodied carbon 2nd Edition (2)
- CIBSE TM65 Embodied carbon in building services: A calculation methodology (2021) (5)

It is anticipated that the results of assessments undertaken using the CWCT's methodology will feed into broader project-wide whole life carbon assessments. To this end, the methodology provides a degree of consistency with other industry guidance as referenced above.

While writing the methodology, the CWCT have recognised that there are various limitations as well as important tasks that must be carried out in the future to reflect the latest knowledge and experience on this subject. Therefore, it is intended that the methodology will be updated over time. Where appropriate at this time, the methodology presents default assumptions to address data gaps in order to provide improved consistency.

Methodology scope

This methodology concerns the assessment of facade systems, commonly referred to as an external wall or part of a building envelope. All components required to meet the functional, technical, and aesthetic performance of the facade must be considered. The complete assembly of the facade is to be considered in LCAs.

Within RICS guidance (4), the facade is to be considered within the "Superstructure" building element group in whole life carbon assessments. More specifically, this includes the building elements '2.5 External Walls' and '2.6 Windows and External Doors' within this group as listed in Table 3 within the RICS guidance.

Life cycle stages and modules

Life cycle stages are used to define the different stages during a facade material or components[1] life in which there can be a contribution to global warming. This includes embodied carbon as a global warming potential indicator used to quantify this impact. Each stage is then further broken down into modules as shown in Figure 2. The assessor must be familiar with each stage and module which will require a specific set of calculation requirements to assess the embodied carbon of the facade through its life cycle.

Each life cycle stage and module is described below, and they are referenced throughout this article and the full methodology. For further information on the life cycle framework, modules and their boundaries readers should refer to the CWCT's *life cycle modules explained* guide (6).

[1] The term 'materials and components' is used within this document to refer to the elements that form a facade system. These elements may include monolithic materials and fabricated components. To this extent a facade system may be thought of as an assembly of materials and components.

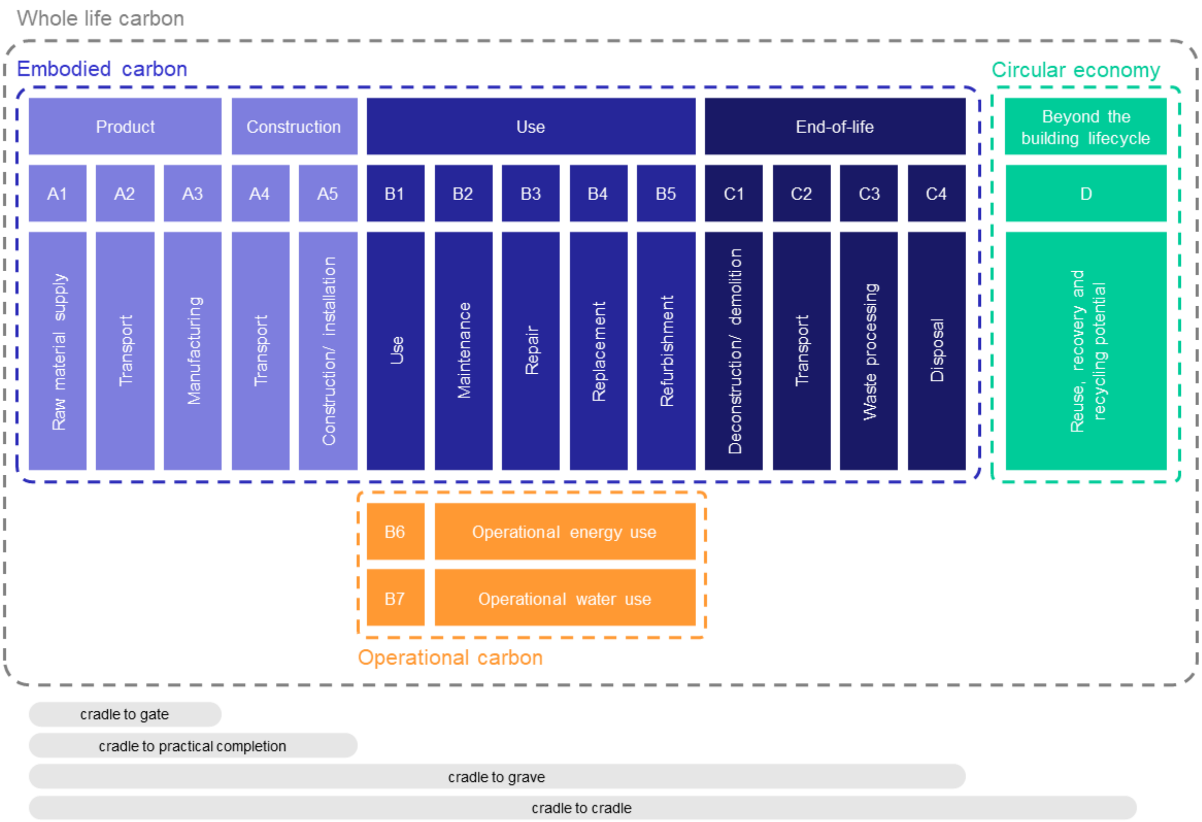

Figure 2 – Life cycle framework defined in BS EN 15978; figure adapted from BS EN 15978

- **Product stage (modules A1-A3):** This stage includes the emissions associated with the raw material extraction, processing, transportation to manufacturer and manufacturing (this includes facade mock-ups and spare materials or products (AKA "attic stock").

- **Construction stage (modules A4-A5):** This stage includes the emissions associated with the transportation to the building site and the installation into the building, including emissions from on-site testing.

- **In use stage (modules B1-B7):** This stage includes emissions associated with the use, maintenance, repair, replacement and refurbishment of the asset. Modules B1 to B5 consider the embodied carbon emissions within the use stage. Modules B6 and B7 consider the operational carbon emissions associated with the operational energy and water use of the asset being assessed.

- **End-of-life stage (modules C1-C4):** This stage includes the emissions associated with the de-construction, transport away from site and end-of-life scenarios.

- **Benefits and loads beyond the system boundary stage (module D):** This stage exists outside the life cycle of the asset and considers the emissions and sequestration of carbon associated with recycling, recovery and reuse of materials.

The scope the CWCT methodology is limited to embodied carbon and therefore does not include operational carbon modules B6 and B7.

Calculation process

The following sections provide an overview of the process required to calculate embodied carbon for facades. This includes the different approaches that can be taken according to the design stage of the project, and how to address various uncertainties associated with the design.

Calculating embodied carbon

A key principle to calculating embodied carbon emissions entails multiplying the quantity of each material and component by the respective embodied carbon factor (ECF). Each ECF has a global warm potential (GWP) in units of $kgCO_2e$ per unit quantity (i.e. kg or m^2) of material or component.

Assessors must consider as many life cycle modules as possible in assessments. As a minimum, life cycle modules for product [A1-A3], construction [A4-A5], replacement [B4], and end-of-life [C1-C4] must be included in facade assessments.

To calculate A1-A3, it will require assessment of off-site emissions associated with facade production. However, some off-site emissions may not be applicable to a specific system under assessment and therefore must be considered accordingly.

Assessment approach

The design stage of the project will influence the level of detail and certainty in the facade design, where at early stages of a design, there is a greater level of uncertainty typically relating to quantities and sourcing of materials and components.

To address this, three approaches are defined to guide how embodied carbon can be assessed whilst addressing any gaps and limitations in information at the time of the assessment regarding materials and component quantities. Each approach is described in Figure 3. The accuracy of an assessment is expected to improve throughout the design process moving from RIBA Stage 0 to Stage 4-5 when construction design details are finalised and a facade contractor is typically appointed.

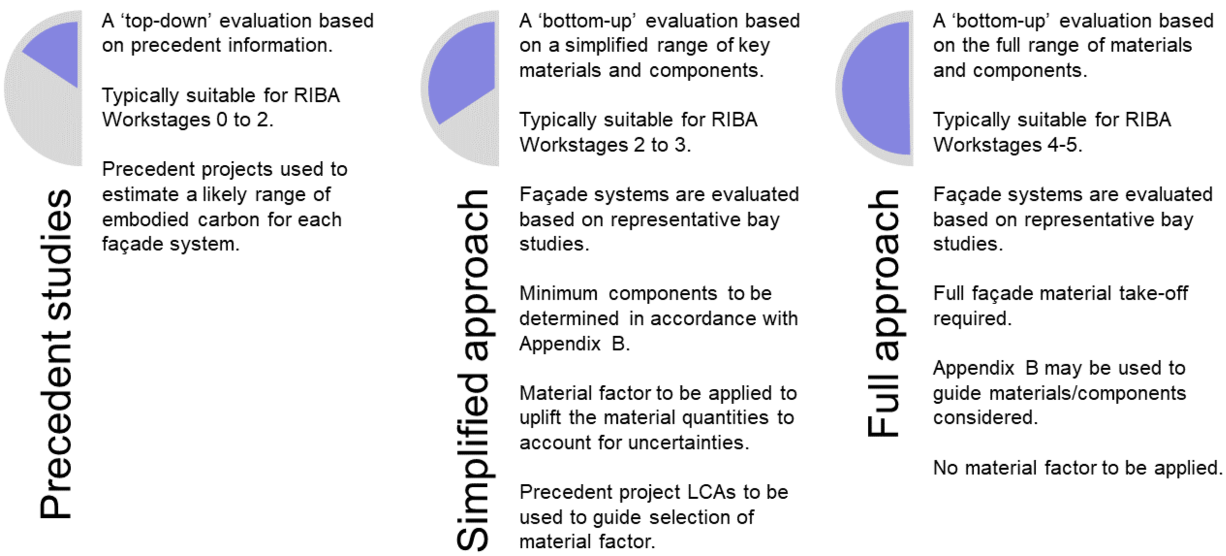

Figure 3 – Assessment approaches at different project stages

The simplified approach is to be used only prior to facade contractor appointment, which is before the full design for construction is completed.

Representative facade bay

A representative surface area of each facade system on a project building (i.e. a standard bay width, or repeating arrangement) is typically defined as the boundary for facade embodied carbon assessments, Figure 4.

The total embodied carbon of the project can then be assessed by multiplying the results of each facade system by the surface area of the building the system is applicable to. This method also facilitates option studies when comparing different facade system strategies.

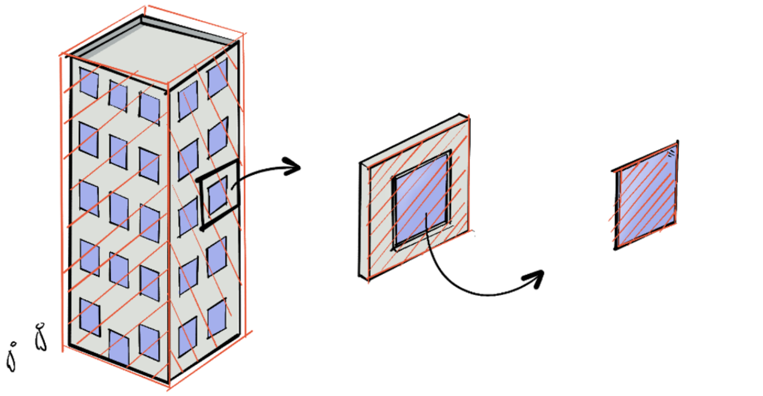

Figure 4 – Illustration of areas

Calculation inputs

Several inputs including quantities and emissions factors are required to calculate the embodied carbon of facades for the different life cycle modules. These inputs are summarised in the following sub-sections.

Quantities

Quantities for facade materials and components can be calculated using a range of methods. The type of method used will depend on the level of detail and tools available at the stage of design. This can include use of the following types of information:

- Project drawings;
- BIM models;
- Previous project experience;
- A Quantity Surveyor's cost plan;
- Bill of Quantities.

Do not let the uncertainty of material quantities prevent an assessment being undertaken. The level of uncertainty in the material quantities will reduce during the project design, this supports the need to repeat calculations at key project stages.

Material factor

The **'material factor'** described for use in the simplified approach is recommended to be applied to material quantities to account for uncertainties associated with the assessed facade elements, as well as providing a provision for unassessed facade elements.

Material factors are multiplied to relevant facade quantities during early-stage assessments.

A1-A3: Product stage ECFs

Embodied Carbon Factors (ECFs) used to calculate modules A1-A3 (ECF_{A13}) of a given material or component will depend on the material specification and the location where the product/material is to be manufactured. There are multiple sources for A1-A3 ECFs. They are predominantly found within Environmental Product Declarations (EPDs) for specific products, and also from open-source databases.

ECFs for A1-A3 are multiplied by the corresponding quantity of a facade material or component to determine product stage emissions.

Off-site emissions

Facade systems assembly and wastage can occur both on-site and off-site to a varying degree which may be the result of the type of facade system and complexity of the supply chain required to fabricate and assemble the facade.

All required off-site emissions associated with producing a facade component must be accounted for in assessments. Off-site emissions should be accounted for within EPD's, however, EPDs may not always include all emissions associated with additional transportation, fabrication, and wastage required. For example, a designer may only find an EPD for sheet metal rather than a cut and formed metal rainscreen panel. The EPD for the sheet metal will not include the emissions associated with the additional transportation, fabrication and wastage that is required to form the panel.

To address these data gaps, the methodology provides an approach to calculate off-site emissions to be used in addition to EPD data as a supplement for data gaps. These emissions include:

- Transportation to off-site factory;
- Off-site fabrication emissions;
- Off-site assembly emissions;
- Off-site wastage rates.

The following terminology in Table 1 includes definitions used to differentiate multiple off-site processes in the methodology.

Off-site terminology	Description
Fabrication	Processing and forming of a component(s). For this reason, the embodied carbon factor is applied at the component level.
Assembly	Assemblage of components into a facade system. These works, and associated emissions, may occur on and off the project site to a varying degree. The embodied carbon factor is applied at the facade system level.
Installation	Works undertaken to the facade on the project site during the construction and for many facade systems is likely to include a degree of 'assembly'.

Table 1 –Terminology used for different off-site processes

ECFs for A1-A3 off-site emissions for <u>transportation</u> to off-site factories, <u>fabrication</u>, and <u>wastage</u> are multiplied by the corresponding quantity of a facade material or component to determine product stage emissions.

ECFs for A1-A3 off-site <u>assembly</u> are multiplied by the representative area of facade assessed.

A4-A5: Construction stage ECFs

A4 transport to site

Calculation of module A4 considers emissions associated with all the transport of products from the factory gate (manufacturing and/or assembly plant) to the construction site, including all interim stops. These emissions are a function of the transportation distance and carbon-intensity of the transport mode.

A4 ECF values will depend on the transportation distance and mode of transportation to transport the given quantity of material. The mode of transport (e.g. road or ship) will have a transport emissions factor (TEF). TEFs can be obtained from *Greenhouse gas reporting: conversion factors'* document published annually by the Department for Business, Energy & Industrial Strategy (7).TEFs may also be available in EPDs, however assessors must ensure the values are representative of project specific scenarios being assessed.

ECFs for A4 are multiplied by the corresponding quantity of a facade material or component to determine transportation to site emissions in the construction stage.

A5 construction / installation

Calculation of module A5 considers emissions associated with the site activities ($A5_a$) and waste ($A5_w$) that occurs during construction and installation of the facade onto a building.

$A5_a$ Site activities:

On-site construction activities result in emissions that must be accounted for. Emissions for site activities can be quantified by monitoring on-site fuel use and electricity consumption. This will require relevant Fuel Carbon Factors (FCFs) and the quantity of fuel consumed. FCFs can be found in the current UK Government *'Greenhouse gas reporting: Conversion factors'* (7) which are specific to the UK. Site-specific fuel source data should be used where possible.

ECFs for $A5_a$ are multiplied by the corresponding quantity of a facade material or component to determine site activity emissions in the construction stage.

Alternatively, where project-specific data is unknown prior to, and during construction, emissions can either be:

- Estimated based on previous similar project data;
- Estimated using the RICS guidance (8) method for calculating A5 emissions.

The RICS guide provides a rate of 1400 $kgCO_2e$/£100,000 construction cost for a whole building for use in estimations using their guidance. A percentage of the facade cost must be estimated when using the RICS method, which will require advise from the project Quantity Surveyor.

$A5_w$ Site wastage:

Waste factors are applied to the manufacture (A1-A3), transportation to site (A4), transportation away from site (C2) and end-of-life (C3/C4) of wasted facade materials and components.

To determine the appropriate waste factor (WF) to apply in calculations, the waste rate (WR) for materials and components must be understood. This can be obtained from product specific EPDs, or from contractor and supplier evaluations. During early design stages, a default waste rate can be provided which is broadly indicative and is provided to achieve consistency in assessments until more detailed analysis of waste rates can be undertaken.

The methodology provides a number of default wastage rates for use which vary according to the processes required for the material. Consultation from a manufacturer or supplier is recommended to determine appropriate waste rates as required in lieu of using default wastage rates.

ECFs for $A5_W$ are multiplied by the corresponding quantity of a facade material or component to determine site wastage emissions in the construction stage.

B1-B5: Use stage ECFs

B1 Use

The materials used within typical facade systems generally have a negligible contribution to module B1 emissions over the life cycle. Designers should consult manufacturers and check assumptions in EPDs for B1 to ensure they are representative of the project scenario.

B2 Maintenance

Calculation of module B2 considers emissions associated with planned maintenance of a facade and includes product stage emissions (A1-A3) and transportation emissions (A4) of the components and equipment used in the maintenance works. Furthermore, it includes emissions resulting from the use of energy and water in cleaning operations. Limited data is available to facilitate the accurate assessment of all facade maintenance operations.

In most typical facades, glazing cleaning operations are likely to represent the most significant contribution to module B2 over the life cycle of the facade. For this reason, guidance is provided on the assessment of the contribution of glazing cleaning to module B2.

ECFs for $B2_W$ are multiplied by the representative glazed surface area within the representative facade assessed.

B3 Repair

Calculation of module B3 considers emissions associated with the repair of unpredicted damage to the facade that occur outside of the typical maintenance regime. Currently, very little data exists to quantify B3 emissions for facades, and the emissions are anticipated to have a limited contribution to the total embodied carbon.

To assess B3, the extent of repairs must be quantified, and emissions from the production (A1-A3) and transportation (A4) of new components required for the repair, transportation (C2) and end-of-life (C3-C4) of the replaced components, and access activities to undertake repairs must all be considered.

B4 Replacement

Calculation of module B4 considers emissions associated with the planned replacement of facade materials and components over the life of the building. This includes an understanding of how many times the facade component will be replaced within the Reference Service Period, and consideration of relevant modules in stages A-C for the production of the replaced components, transportation of replaced components, the replacement process, losses due to waste, and the end-of-life scenario of the removed components.

A 'like-for-like' replacement is assumed for B4, where A-C embodied carbon of the replacement component is equal in magnitude to the component being replaced. This is assumed to provide a consistent LCA approach in accordance with the Greater London Authority *Whole Life cycle Carbon Assessment* guidance (9).

ECFs for B4 are multiplied by the corresponding quantity of the replaced facade material or component to determine replacement emissions in use stage.

B5 Refurbishment

Calculation of module B5 considers emissions associated with a planned major change to the building envelope known at the time of the assessment but not actually being undertaken as part of the works. Module B5 must consider carbon emissions associated with the components used within the refurbishment works, and must include the minimum scope of life cycle modules for facades (A1-A3, A4-A5, B4, and end-of-life C1-C4).

C1-C4: End-of-life stage ECFs

C1 Deconstruction / demolition

Calculation of module C1 considers emissions associated with the deconstruction and demolition of facades. This should include all on-site based activities that are required to dismantle, deconstruct and/or demolish the facade.

At the outset of the facade design, project-specific scenarios for the facade at the end-of-life should be evaluated to determine the optimal solution to mitigate emissions associated with any deconstruction or demolition required. Furthermore, design for disassembly strategies are encouraged to be integrated into designs where possible to minimise emissions associated with end-of-life.

ECFs for C1 are multiplied by the representative area of facade assessed.

C2 Waste / deconstruction transport

Calculation of module C2 considers the emissions arising from the transportation of the discarded product as part of the deconstruction and demolition of the building.

ECFs for C2 are determined in the same method as used for module A4 ECFs, however the project specific end-of-life (EoL) scenario is used as a basis of assumptions used for transportation distances (including interim stops) and modes of transport in addition to the project site location.

ECFs for C2 are multiplied by the corresponding quantity of a facade material or component to determine waste/deconstruction transportation emissions in the end-of-life stage.

Where components are reused or recycled on site, ECFs for C2 may be assumed to be zero.

C3 Waste processing

Calculation of module C3 considers emissions associated with processing inorganic and organic waste materials and/or facade components intended for reuse, repurposing, or recycling. This is specific to waste processes after the materials/components have reached the end-of-life state and before they reach the 'end-of-waste' state as defined in EN 15978 (3), where the materials would have undergone necessary treatment scenarios required to reach this state. After which, the materials are ready for reuse, repurposing or recycling.

In the absence of this data, default assumptions for disposal emissions in module C4 should be used.

ECFs for C3 are multiplied by the corresponding quantity of a facade material or component to determine waste processing emissions in the end-of-life stage.

C4 Disposal

Calculation of module C4 considers emissions associated with disposal of materials and/or facade components. This is specific to waste processes prior to and as a result of final disposal (e.g. landfilling or incineration) of materials/components that are not intended to be reused, repurposed, or recycled.

Any potential environmental benefits from disposal (e.g. landfill sites capturing CO_2 emissions) should be accounted for in module D.

Similar to module C3, ECFs for module C4 can be found in EPD data adjusted to suit project specific EoL scenarios where required.

In the absence of project-specific EoL requirements or relevant EPD data for disposal, or if disposal is reported as '0' in EPD data, default assumptions from RICS (8) and UK government data on waste should be assumed for different processes and types of waste including disposal of inorganic and organic waste, incineration of organic waste (or biogenic carbon transfer), and processing of metallic waste intended for recycling and partial landfilling.

ECFs for C4 are multiplied by the corresponding quantity of a facade material or component to determine waste processing emissions in the end-of-life stage.

D: Benefits and loads beyond the system boundary

Calculation of module D considers the net environmental impacts, beneficial or detrimental, that occur due to the reuse, recycling and energy recovery of materials and components beyond the boundary of the buildings' life cycle.

ECFs for module D can typically be found in EPDs which require the EPD author to make assumptions about the extent of reuse, recycling and energy recovery that can be accrued from the material or product at the end-of-life. These assumptions must be clearly documented within the EPD. Assessors must take care to ensure these assumptions are valid and representative to the design under assessment.

Module D ECFs consider emissions saved insofar as the recovered product mitigates the demand for a new product (substituted products) based on a market average, and the product stage (A1-A3) emissions associated with any processing works required to prepare the reused product (secondary product) for reuse.

Where insufficient data exists to quantify Module D, designers are encouraged to consider Module D qualitatively to promote implementation of circular design strategies within projects.

ECFs for D are multiplied by the corresponding quantity of a facade material or component to determine emission benefits beyond the end-of-life stage.

Module D is to be reported separately to Stages A-C.

Carbon sequestration in timber

Carbon sequestration should be considered within an embodied carbon calculation provided that the timber or timber product originates from a sustainably managed forest with FSC or PEFC (or equivalent) certification and the scope of the calculation includes life cycle stages A to C.

When stages A – C emissions are presented, carbon sequestration in timber should be accounted within life cycle modules A1-A3 and end-of-life emissions and biogenic carbon transfers should be considered in modules C3-C4**.** This typically results in negative A1-A3 emissions (sequestration) being offset by positive C3-C4 emissions (release or transfer) in the A-C total.

Sequestration ECFs for are multiplied by the corresponding quantity of qualifying timber to determine benefits and emissions during the product and end-of-life stages.

Carbon calculation scale-up factor

A '**carbon calculation scale-up factor'** is strongly recommended to be applied to the results of a calculation to account for potential underestimation due to various types of uncertainties that are acknowledged to be more prevalent and inherent during early design stages. This factor is a separate parameter to the material factor previously described above.

The carbon calculation scale-up factor, F, is to be applied to reported results for stages A to C during early design stages. It can be used to represent one or more types of uncertainty identified in a design, which must be reported within assessments. The magnitude of the carbon calculation scale-up factor may be reduced through the design process to reflect changes in the level of uncertainty.

The carbon calculation scale-up factor is multiplied to the A-C results to account for uncertainties.

Calculation results

Outputs of an assessment will include the results of the embodied carbon calculation and a summary of assumptions used for the calculation, such as the type of project, RIBA Workstage, the functional equivalent or technical/performance characteristics of the facade system, modules assessed and excluded, and schedule of components and ECFs applied including sources. Furthermore, opportunities for embodied carbon reductions, and the actions taken to reduce embodied carbon should also be reported. The methodology provides a reporting template and list of recommended reporting requirements that can be followed as a guide.

Assessment results for facades are typically reported by Facade Surface Area (FSA) in the units $kgCO_2e/m^2$ *FSA* for the representative facade area (A). This can be converted to Gross Internal Area (GIA) in units $kgCO_2e/m^2$ *GIA* if the intention is to inform a wider whole building assessment.

Reporting project embodied carbon data to a publicly accessible database is vital to enable the development of benchmarks that can be used to inform embodied carbon targets and improve industry understanding of embodied carbon in the built environment. In the UK, the Built Environment Carbon Database (BECD) is being developed to capture industry-wide project carbon data. The BECD is due for launch in 2022 (10) and designers / assessors are encouraged to contribute.

Additional guidance

The methodology includes appendices with additional guidance to support users. This includes:

- Reporting results template;
- Facade component checklist for a range of different facade systems;
- Glazing embodied carbon methodology to assess glazing build-ups in the absence of project specific EPD data;
- Assessment and reporting of carbon sequestration in timber.

Future work

While writing this methodology, the CWCT have recognised that there are various limitations as well as important tasks that must be carried out to update the guidance within the document in the future to reflect the latest knowledge and experience on this subject. This future work will also aim to provide more useful guidance to users of this document.

At this time, the following items anticipated as future work include:

- Reference values for a range of carbon calculation scale-up factors that can be applied to address different types of uncertainties in assessments;
- Further guidance on the assessment approach to module D, which will be in coordination with the CWCT’s EPD Workstream guidance;
- Additional product specific guidance for selecting embodied carbon factors for use during early design stages and in the absence of project specific data. This will be similar to the glazing appendix included within the methodology;
- Additional emission factors identified as necessary for assessments. And as more data becomes available, refinement of existing factors including methodologies for users to derive different factors;
- Reference facade specific embodied carbon factors from open-source databases;
- Guidance dedicated to assessing existing facade systems.

References

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Disclaimer

These publications are intended for use only by appropriately qualified façade engineers and related professionals (with relevant experience) in each case having regard to the particular circumstances and requirements of each case, and exercising professional judgement including the reasonable skill and care to be expected for a professional of the relevant discipline, in that context.

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