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Industry CPD

Steel and embodied carbon

This CPD module, sponsored by Steel for Life, examines the embodied carbon credentials of steel and its potential to contribute to a zero-carbon future.

Continuing professional development (CPD) ensures you remain competent in your profession. Chartered, Associate and Technician members of the Institution must complete a specified amount each year. All CPD undertaken must be reported to the Institution annually. Reading and reflecting on this article by correctly answering the questions at the end is advocated to be:

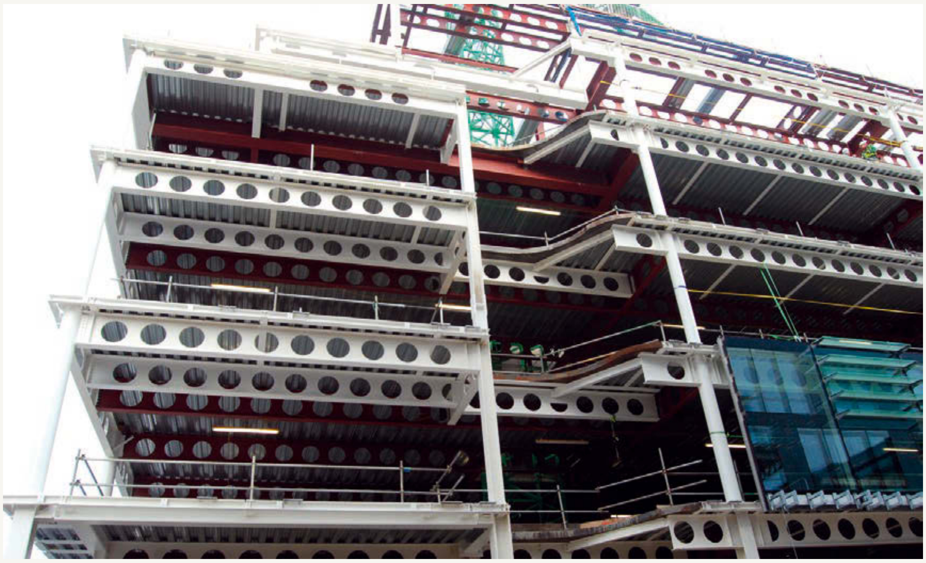
1 hour of verifiable CPD

The construction industry has set itself ambitious targets for reducing its carbon footprint. The World Green Building Council for example, in 2019's *Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon*, has targeted at least a 40% reduction in embodied carbon from new buildings, infrastructure and renovations by 2030 and net-zero by 2050.

Also by 2050, all buildings, including existing buildings, must be net-zero operational carbon.

As the title of the World Green Building Council's report acknowledges, a key milestone on the transition to a zero-carbon future will be ensuring that the embodied carbon content of buildings and other structures is minimised.

To tackle the carbon issue will demand taking account of overall 'whole-life carbon' – defined here as 'cradle-to-cradle' emissions, taking into account reuse or recycling potential – rather than the more simplistic, 'cradle-to-gate' calculations typically used by the construction industry which only account for 'product stage' emissions.



↑Cellular beams are used to accommodate building services within their depth and provide the flexibility to accept any future requirements

What is embodied carbon?

The term 'embodied carbon' refers to the greenhouse gas emissions (expressed as carbon dioxide equivalents – CO_2e) that occur during the manufacture and transport of construction materials and components, as well as the construction process itself and end-of-life aspects of the building.

In recent years, the term 'embodied carbon' of construction materials and products has become synonymous with the term 'carbon footprint'. An embodied carbon or carbon footprint assessment is a subset of most lifecycle assessment studies, i.e. only considering the global warming potential (GWP) environmental impact category.

The embodied carbon and the in-use carbon emissions from the operation of the building (operational carbon) together make up the complete lifecycle carbon footprint of the building.

The scale of the potential threat of global climate change has focused attention on carbon emissions and therefore most construction-related environmental impact studies focus on this impact category. While carbon emissions are clearly an important priority, more thorough environmental assessments should consider a wider range of impact categories; as is routinely done in lifecycle assessment studies.

While recent initiatives to reduce operational carbon have increased the relative importance of embodied carbon as part of a whole-life building assessment, operational carbon of new buildings still makes up most (around two-thirds) of the whole-life carbon emissions over 60 years.

Embodied carbon assessment

Quantification of the embodied impacts of buildings can be more complex than for operational carbon impacts. This is mainly due to different scoping and methodology assumptions, concerning the lifecycle stages to be included within the scope of the assessment.

Conceptually, embodied carbon assessments are quite straightforward, involving the multiplication of quantities of construction products and materials (generally on a weight basis) with embodied carbon coefficients or carbon emission factors. Quantities are generally derived from a 'take off' from construction drawings or directly from Bills of Quantities. Increasingly, design software is being developed to automate the assessment process.

Obtaining a comprehensive and compatible set of embodied carbon coefficients can however be far more difficult. Carbon coefficients are dependent upon a number of factors and assumptions that can significantly influence the final results.

There are several standards that set out how to undertake embodied carbon assessments. These include the ISO 14040 series, standards developed under CEN TC 350, specifically BS EN 15804, BS EN 15978, etc.

Steel and embodied carbon

The steel sector has always advocated the more meaningful lifecycle assessment approach of considering a cradle-to-cradle – or whole-life carbon – approach, which takes account of how, or if, a material can serve a meaningful purpose beyond simply being reduced to hardcore for example, after its original use has ended.

Steel has exceptional circular economy credentials as it is typically either reused or recycled. Steel almost never adds to the construction and demolition waste sent to landfill.

Lifecycle assessment shows that steel's long-proven sustainability advantages are strong when account is taken of what happens to the material when a building or other structure reaches the end of its useful life. Steel is not difficult or expensive to dispose of as it has a continuing value to society – it can be recycled or reused endlessly without detriment to its properties.

The recovery infrastructure for steel recycling is highly developed and highly efficient, and has been in place for decades. Current recovery rates from demolition sites in the UK are 99% for structural steelwork and 96% (on average) for all steel construction products.

Steel is manufactured by two production routes (BOS and EAF), which together comprise a single global system of supply to meet growing world demand. Both production routes include a significant recycled content, the average of which is 60% for structural steel used in the UK according to WRAP. British Steel advise a similar figure; in the European steel industry as a whole, recycled scrap steel accounts for 56% of total steelmaking, being made up of 32% pre-consumer and 24% post-consumer scrap. For purchases of European steel, it is recommended to use a recycled content figure of 56% which reflects the total industry position.

Comprehensive lifecycle assessment data

Assessment of embodied carbon of materials should be based on robust data that is derived using lifecycle assessment as set out in BS EN 15804. This standard gives guidance around core product category rules relating to Environmental Product Declarations (EPDs) for construction products and services.

A key distinction has to be drawn between assessments based on all of the lifecycle stages identified in this standard – which is steel industry practice – and materials that only include some of these lifecycle stages.

These partial and incomplete analyses use data that can be called 'cradle-to-gate', as they only consider the impacts from extraction and manufacturing processes – Modules A1–A3 – ignoring whole-life data.

All the substructure for 100 Liverpool Street was retained, as well as approx. 50% of the original steel frames that extend up to eight storeys high

The steel sector is among those that present data for their products that consider all of BS EN 15804's lifecycle stages **(Table 1)**, sometimes called 'cradle-to-cradle' to reflect the inclusion of reuse and recycling data, and increasingly referred to as whole-life carbon assessments.

A lifecycle assessment study comprises three steps:

1) Compiling an inventory of relevant energy and material inputs and environmental releases (outputs) associated with a defined system. Releases can be solid wastes or emissions to air or water.
2) Evaluating the potential impacts associated with these inputs and releases, e.g. the global warming impact from greenhouse gas emissions.
3) Interpreting the results to help make informed decisions.

A common failing of some studies that try to compare one construction material with another, either at structural frame or whole-building level, is an inadequate appreciation of the importance

TABLE 1: Lifecycle stages and modules

Construction works life cycle information			
Stage	**Module**	**Type**	**Cradle-to-gate with Modules C1–C4 and D**
Product	A1	Raw material supply	Mandatory
	A2	Transport	Mandatory
	A3	Manufacturing	Mandatory
Construction process	A4	Transport	
	A5	Construction/installation process	
Use	B1	Use	
	B2	Maintenance	
	B3	Repair	
	B4	Replacement	
	B5	Refurbishment	
	B6	Operational energy use	
	B7	Operational water use	
End of life	C1	Deconstruction/demolition	Mandatory
	C2	Transport	Mandatory
	C3	Waste processing	Mandatory
	C4	Disposal	Mandatory
Supplementary information beyond construction works lifecycle			
Benefits and loads beyond the system boundary	D	Reuse, recovery, recycling potential	Mandatory

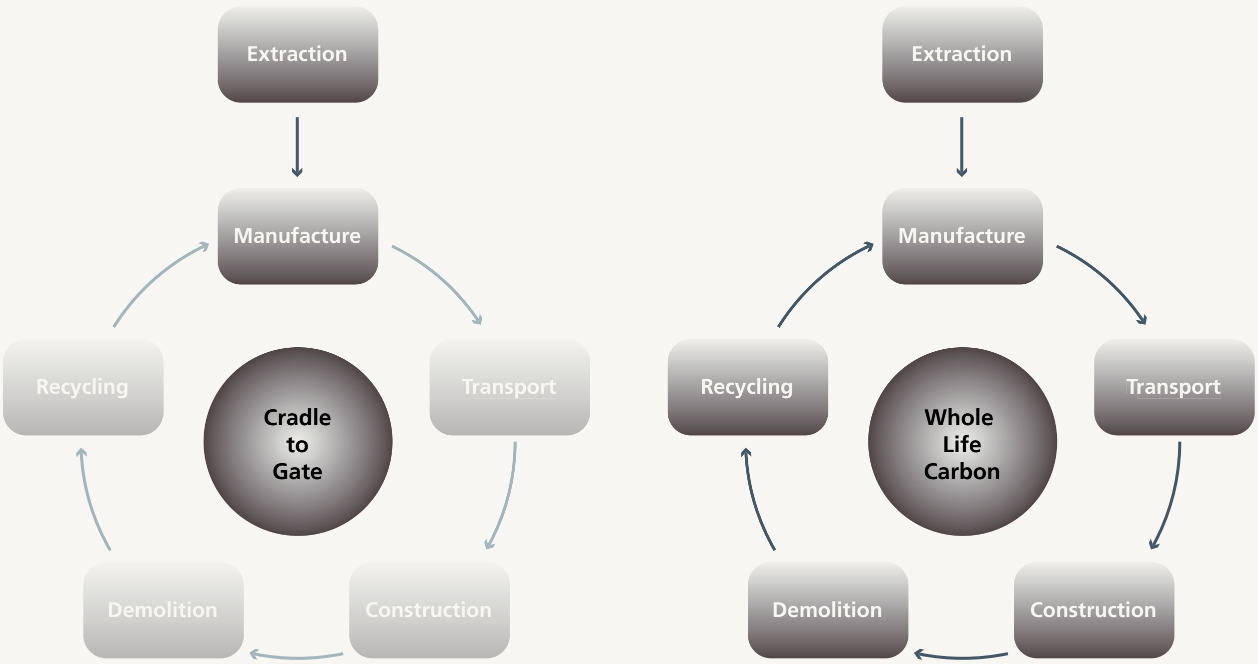


FIGURE 1: Comparison of lifecycle assessment scopes and system boundaries

of system boundaries in the analysis.

System boundaries determine which processes are included or excluded in a lifecycle assessment or other embodied carbon study. EPDs, which are derived using lifecycle assessment, are increasingly used by construction product manufacturers to provide environmental data on their products. Such analyses must be clearly defined and consistent with the system boundaries.

Different scopes and systems boundaries that can be considered, and must be clearly defined, include:

- geographical area
- time horizon, i.e. when the data were collected
- boundaries between the specific system studied and related technical systems, e.g. the production of capital goods used to manufacture a product
- boundaries between the technological system and nature, i.e. which lifecycle stages are included within the system boundary, such as cradle-to-gate and whole-life carbon system boundaries.

Adopting a cradle-to-gate rather than a more comprehensive whole-life carbon approach in lifecycle assessment and carbon footprinting studies has, in the past, been blamed on a lack of sufficiently robust data on what happens to materials during and after demolition, and the fact that such information is an estimate based on current practice – which may of course change in the future. This is the Module C and D information as defined in BS EN 15804. Reporting of Module C and D values is now mandatory in EPDs produced to EN 15804.

The lack of sufficiently robust ‘end of life’ data was addressed for steel by PE International, now called Sphera, several years ago. PE International examined these factors for a range of materials commonly used in building framing systems and derived Module C and D data for steel, concrete and brick/block products.

At the level of individual products it is mandatory in BS EN 15804 to report Module D information, for very good reasons. At the level of an entire building, Module D reporting is not yet mandatory in EN 15978, but this is currently under revision and the two standards are likely to be aligned.

There is a growing appreciation of the need to include building end-of-life impacts (Module C) and Module D benefits from reuse and recycling as part of a robust, whole-life carbon assessment **(Figure 1)**. Limiting the scope to just Module A equates a 100% recyclable building to one which is 100% landfilled when it is demolished.

Landfill avoidance through downcycling construction materials is unsustainable to deliver a truly circular, zero-carbon built environment. As a sector we have to move up the waste management hierarchy and reuse our buildings and their constituent parts.

Environmental Product Declarations

Designers and specifiers looking for evidence that they are making low-carbon selections of products can use the appropriate steel manufacturer’s EPD, assuming that they know where their steel product will be sourced from.

If the source of steel product is unknown, which is generally the case at the design stage, then it is recommended that an average value, reflecting a UK average consumption mix, is used. This is because steel is a globally traded commodity and therefore taking, for example, a UK average production value is not representative of UK consumption.

The most appropriate average value for steel on the European market **(Table 2)** is published by bauforumstahl, the independent steel promotional organisation in Germany. This is based on data collected from the biggest hot-rolled steel sections and plates manufacturers in Europe and includes the most up-to-date

TABLE 2: European average EPD (kg CO_2e/kg)

			EN 15804 Modules			
			Product stage	End of life	Recycling potential	*Whole-life carbon*
Company	**Product**	**Valid until**	**A1–A3**	**C**	**D**	
bauforumstahl	Sections and plates	24/10/2023	1.130	0.002	–0.413	*0.72*

↘Bloomberg's new European headquarters achieved an 'Outstanding' rating against the BREEAM, with a 98.5% score

embodied carbon data currently available.

The Module D figure in the bauforumstahl EPD represents current practice in Europe, that on average 11% of steel is reused at end of life, 88% is recycled and 1% goes to landfill.

EN 15804 states that the figures for the various modules should generally be reported separately, but offers no guidance on how to use the data to make decisions on a project. If decisions are made on a short-term cradle-to-gate or 'product stage' basis, then the figure of 1.13 would be used. However, if a more comprehensive long-term whole-life carbon basis is adopted, then the figure of 0.72 could be used, which is an aggregate of the three reported modules: A, C and D.

Circular economy action plan

The European Union has adopted a Circular Economy Action Plan, one of the main strands of the European Green Deal, the EU's new agenda for sustainable growth.

It refers to the Levels study which recommends the whole-life carbon approach, i.e. including Modules C and D.

The Action Plan incorporates initiatives throughout the lifecycle of products, targeting their design, promoting circular economy processes and promoting sustainable consumption, with the aim of ensuring that the resources used are kept in the EU economy for as long as possible.

The Plan introduces legislative and non-legislative measures targeting areas where action at the EU level brings real added value.

Among other things, the measures aim to make sustainable products the norm in the EU, focusing on the sectors that use most resources and where the potential for circularity is high, which includes construction and buildings.

Questions

To claim your CPD certificate, complete the module online by 10 January 2021 at: www.istructe.org/industry-cpd

1. The World Green Building Council targeted a reduction in embodied carbon from new buildings, infrastructure and renovations of at least what, by 2030?

☐ 20%
☐ 30%
☐ 40%
☐ 50%
☐ 60%

2. Assessment of embodied carbon of materials should be based on data derived using a lifecycle assessment as set out in what standard?

☐ BS EN 15801
☐ BS EN 15802
☐ BS EN 15803
☐ BS EN 15804
☐ BS EN 15805

3. According to WRAP, recycled scrap steel accounts for what percentage of structural steel used in the UK?

☐ 37%
☐ 42%
☐ 49%
☐ 58%
☐ 60%

4. Analyses that include data drawn from only considering the impacts from extraction and manufacturing processes rather than whole-life data are called what?

☐ Cradle-to-grave
☐ Cradle-to-gate
☐ Cradle-to-cradle
☐ Cradle-to-yard
☐ Cradle-to-bed

5. Current recovery rates from demolition sites in the UK are what for structural steelwork?

☐ 59%
☐ 69%
☐ 79%
☐ 89%
☐ 99%

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