Understanding UK average embodied carbon emissions for steel reinforcing bar

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Introduction

Interest in reducing greenhouse gas (GHG) emissions, which drive climate change, is mainstreaming across industry. The built environment and construction sector is no exception with buildings and infrastructure estimated to be responsible for ~35% of total GHG emissions globally. Although this includes operational carbon, at ~27%[i], as this declines over time as heating and cooling becomes more efficient, construction materials (7-9%) are likely to become proportionally more significant. Example data for a medium scale residential building suggests that approximately 50% of life cycle GHG emissions come from construction materials[ii].

Constructional steels and cement manufacture for concrete are the largest sources of construction materials emissions. Steel is traded globally and depending on the production process, the Global Warming Potential (GWP – tonnes CO2 equivalent per tonne of product) can vary dramatically. It is therefore key to have an accurate estimate of embodied carbon emissions for steel at a market level.

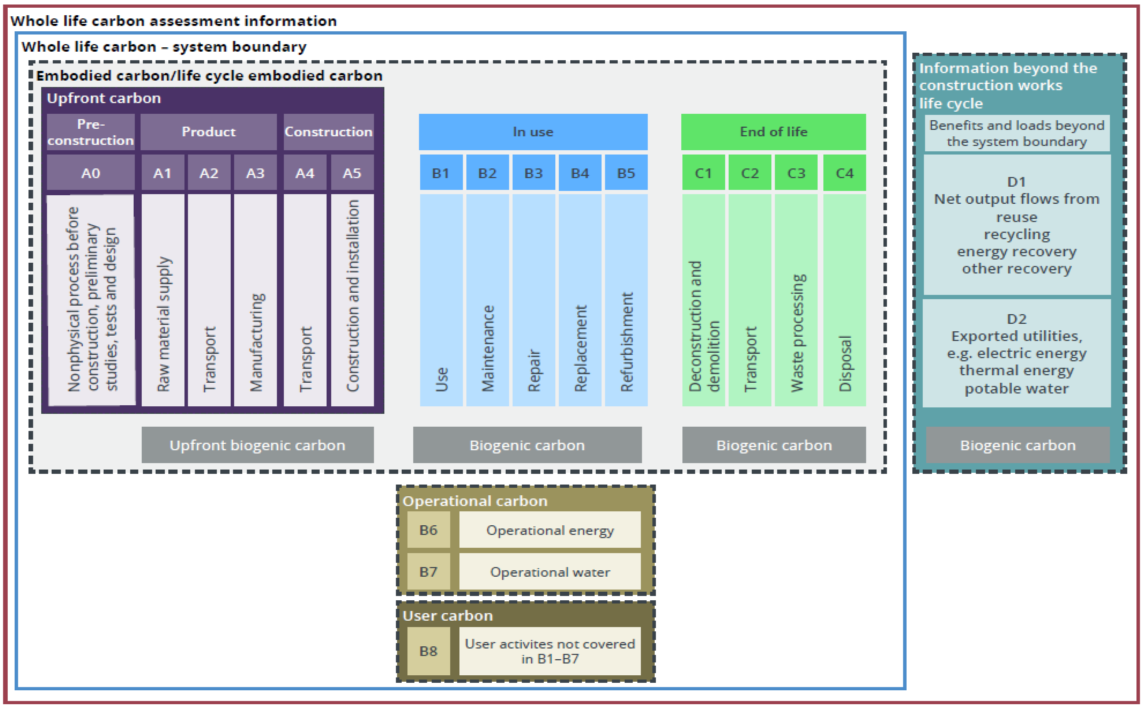
Life cycle assessment and embodied carbon emissions

The impacts of manufacturing and products are typically assessed through a Life Cycle Assessment (LCA). Product Category Rules (PCR) help ensure consistent reporting of LCA information and form the basis of Environmental Product Declarations (EPD). EPD enable companies to make credible and verifiable environmental claims about their products. Embodied carbon emissions are the GHG emissions associated with materials and construction processes throughout the whole lifecycle of an asset and these are typically presented as GWP.

Embodied carbon emissions according to EN 15804:2012+A2:2019 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products, are represented by Modules A1–A5, B1–B5 and C1–C4. Figure 1, from Royal Institution of Chartered Surveyors (RICS) 'Whole life carbon assessment for the built environment (2nd edition)', illustrates this. There are also other sources of Embodied Carbon data for products, for example carbon footprints to ISO

14067 or PAS 2050, Life Cycle Assessments (LCA) to ISO 14044, or The Institution of Structural Engineers (InstructE) ‘How to calculate embodied carbon’, or from a variety of generic databases.

Figure 1. Building and infrastructure life cycle stages and information modules (adapted by RICS from EN 15978, EN 17472 and EN 15643, with additions to illustrate biogenic carbon)



Strengths and weaknesses of Environmental Product Declarations

EPD can be produced using recognised standards, and for construction products, this is mainly to EN 15804:2012+A2:2019 and to ISO 21930 Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services. Jane Anderson, a construction LCA and EPD expert estimates there are 130,000 EPD for construction products globally[iii]. She estimates there are now over 16,000 to EN 15804 and this is the standard most frequently associated with constructional steel products. Although comparability is often sought and by following a standard, assumed to be possible, care needs to be taken as not all EPD are comparable or produced to the same quality level.

An EPD will be produced based on an annual data set. This data will be recorded within a defined LCA tool to produce estimates for the EPD including of GWP. Within the EN 15804 standard, which is typically preferred for constructional steel products however, there is flexibility which can influence comparability for steel products. The key factors include:

- The product, site and production process scope of the EPD. An EPD may cover the same products produced at different steel production sites, for example. Some may cover a broader range of products within a category than others. The same type of products may be produced using different production processes.
- The validity time of the EPD. EN 15804 allows for up to 5 years certification, however many are only valid for 3 years. An EPD valid for 5 years will be using a data set that is at least 6 years old.
- The extent of verification of the source data. Third party verification is often used to provide credibility for EPD; however, some verifications allow for sampling across sites whereas others will be location and product specific.
- Verifier competence. Some verifiers will be on site at least every year, will be steel industry specialists and will have a strong understanding of the operations whereas others may be generalists and not visit the site at all.
- Databases used for life cycle inventories. There are a variety of emissions data associated with production processes and materials. These are generally comparable but specific values can vary across databases depending on the initial research and boundaries used.

There are other factors which influence the accuracy of the GWP in an EPD. This can include the use of estimated data and assumptions. Of course, not everything about a product life-cycle is known when the EPD is created and the calculations require certain assumptions to be made about input materials and other factors. For example, the actual recycling rate (collection and recovery rate) of end-of-life construction steels and the distance from a steel fabricator to a construction site. Therefore, estimates based on research are included. Some emissions are excluded from an EPD as they cannot be easily estimated. For example, transport emissions from a steel mill to a steel fabricator cannot be known when the EPD is produced as future sales are yet to be made and these can vary widely as steel is a global market and many factors influence where steel will be sold and these vary from year to year.

Influencing factors in steel embodied emissions

There are also many factors which influence the GHG emissions embodied in steel products. These include:

- *Production process route:* Global production is ~79% primary ore-based and ~21% secondary scrap-based and the following are worldsteel 2022 average data
    - Primary (~72% of global production): Blast Furnace/Basic Oxygen Furnace (BF/BOF) ~2.3 tCO_2e per tonne (range 1.8-3t)
    - Primary (~7% of global production): Direct Reduced Iron (DRI) into Electric Arc Furnace (EAF) ~ 1.4 tCO_2e per tonne (range 1t gas – 3t coal)
    - Secondary (~21% of global production): EAF ~ 0.7 tCO_2e per tonne (range 0.2-1.1t)
- *Product type:* Historically, in Europe, structural steels tended to be made by BF/BOF, reinforcement bar using EAF, stainless and special alloys using BF/BOF, which typically have even higher emissions (>3 tCO_2e per tonne)
- *Domestic and regional production:* Domestic and regional steel manufacturing process routes vary, regional trade patterns vary, and the associated carbon footprint of the steel supplied will therefore vary
- *Technology:* Process gas reuse and export, use of (green) hydrogen as a reduction agent for iron ore rather than coal, carbon capture, utilisation and storage (CCUS), electrolysis (in future) will all influence emissions
- *Energy sources:* national grid factors for electricity (especially for EAF), use of purchased renewable electricity through contracts (e.g. Power Purchase Agreements) and the direct generation and use of renewables will all impact on the GWP of the products

The nature of the scrap steel used in the process will also influence the actual GWP and is described as "Benefits and loads beyond the system boundary" (Module D) in an EPD. This accounts for the environmental benefits and loads resulting from net steel scrap used as raw material and that has been collected for recycling at end of life. These benefits and loads are calculated by including the burdens of recycling and the benefit of avoided primary production. In reality, pre-consumer (manufacturing) scrap may have come from primary produced steel returned directly to the steel producer and would have more embodied emissions than post-consumer scrap which may have been around multiple use cycles, thereby reducing its embodied emissions.

The UK steel situation

Steel manufacturing in the UK is currently undergoing considerable shifts, with announcements of proposals for key steel making facilities at Port Talbot and Scunthorpe, changing from BF/BOF to EAF to utilise the volumes of steel scrap which originate in the UK, most of which is currently exported. Steel reinforcement bar is currently only made at 1 UK facility, Celsa in Cardiff which utilises scrap based EAF production. Liberty Speciality Steels Rotherham utilises a specialist micro-alloying process and produced a small amount of rebar in 2022 and 2023 but no longer does so.

Considerable volumes of constructional steels are imported into the UK and the specific proportions from different producing countries will vary year on year. UK manufactured steels are also exported. Therefore, to understand the embodied carbon in the reinforcement bar, you must understand the sources of supply. Most reinforcement bar used in the UK is produced by the scrap based EAF route, however, some imports are produced using DRI/EAF production route.

Improving estimates of embodied carbon in rebar used in UK construction

100% of the reinforcement bar used in the UK is certified by CARES - the UK Authority for Reinforcing Steels, an independent, not for profit certification body. A high proportion of this also has third-party verified EPD published which provide the GWP. There are several stages that clients, contractors, engineers and other stakeholders can go through to estimate the GWP of the steels they plan to use and actually use as built. Accurately estimating these at different stages of the construction process can support efforts to decarbonise our built environment.

At RIBA Stages 1 to 4, Concept, Plan & Design: initial embodied carbon analysis can be used to determine the design strategy to reduce carbon emissions. Due to lack of certainty of material specification and procurement, use generic or industry average carbon factors that best represent the product that will most likely be procured for construction at this stage.

CARES produces a sector average EPD[iv] based on steel producers which have been certified to the Sustainable Constructional Steels (SCS) scheme, where it is mandatory for approved firms to have a third-party verified EPD. These EPD are product, site and production process specific, and are not only checked by CARES auditors, but also have an additional level of third-party verification from BRE. The sector average takes all CARES SCS approved firms and averages the GWP.

This is valid for a high proportion of reinforcement used in the UK market. However, to derive a UK consumption average carbon factor for rebar for a particular year, this can be combined with GWP of UK-produced rebar and imports not accounted for in the CARES sector average EPD. Our approach uses a rolling average, typically across 3 years to estimate the UK consumption average embodied carbon factor for rebar. However, the 2021 data was affected by Covid, which disrupted production and led to some data anomalies. Therefore, we have taken the average based on the latest available data for 2022 and 2023 estimated using country of production, tonnes sold into the UK market and GWP estimated by country (utilising CARES knowledge of the steel industry and producers and its EPD). This provides a value of 0.68 tCO_2e per tonne.

Improving this further by accounting for an estimate for the transport associated with the journey the steel takes from the steel mill to the fabricator, an extra 0.04 tCO2e per tonne rebar should be added to the A1-A3 carbon factor for rebar. It should be noted that this estimate is a combination of calculated emissions by a third-party (Sphera) using industry knowledge of the producers, the ports, shipping, train and road transport routes they use, combined with estimates for unavailable, uncalculated sources. The degree of confidence in this transport estimate is lower than for the EPD GWP data.

Combining the estimated additional allowance for transport from steel mill to the fabricator with the UK consumption based average A1-A3 carbon factor, this provides an estimate of 0.72 tCO_2e per tonne for the UK market for 2022 and 2023.

At the As-Built stage: it is important to monitor, measure and report the final overall embodied carbon of the construction materials purchased and used to confirm actual embodied carbon estimates for the as built asset.

As the suppliers will be known at this stage, each should provide an EPD with a reasonably accurate GWP based on the specific production process, site of production and product. Each asset can more accurately calculate the embodied emissions by multiplying the GWP from each reinforcement bar supplier by the mass of rebar procured for the project. Adding these up for all the suppliers (and adding more accurate transport estimates for each supplier) will provide a more accurate estimate of GWP and can be used to assess whether asset level decarbonisation targets have been met.

If you need more information, please contact the CARES team.

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[i] United Nations Environment Programme (2023). 2023 Global Status Report for Buildings and Construction. Nairobi.

[ii] LETI's embodied carbon primer cited in How to calculate embodied carbon (2nd edition) The Institution of Structural Engineers, 2022 edition

[iii] Jane Anderson, ConstructionLCA, 2023 https://infogram.com/constructionlcas-2023-guide-to-epd-1h0n25yvdgz7l6p

[iv] CARES Sector Average EPD, https://www.carescertification.com/content/HtmlContent/d7cc4369-ff70-4b95-8c62-24b076626737/fa959717-302d-4cc1-a0b5-40043d4d7e5f/BREGENEPD000125-CARES-Sector-Average-EPD-Scrap_EAF.pdf