CO2 2.Low carbon

Deriving embodied carbon factors from scratch

James Kitchin describes an approach to calculating embodied carbon coefficients for materials when an environmental product declaration is not available.

Introduction

For many materials and products in many parts of the world, environmental product declarations (EPDs) and 'average' material data (such as the ICE Database[1]) can be used to calculate the embodied carbon present within an element. However, when this data is insufficient, the engineer may have to determine their own embodied carbon coefficients, based on the information available.

This article demonstrates how MASS Design Group calculated embodied carbon coefficients for the Rwanda Institute for Conservation Agriculture (RICA) project, including for earth blocks, and locally made fired-clay masonry. The RICA project is described in more detail on pages 32–37.

Embodied carbon coefficients

Estimating new embodied carbon coefficients through measurements

We begin by providing general advice, a method and an example for estimating embodied carbon coefficients that doesn't require a lifecycle analysis (LCA) to be performed from first principles. This approach should be limited to personal or project interest and should not be published or used in certification schemes.

It is important to understand that actual product coefficients can differ enormously from those calculated, even for verified product-specific EPDs, but this estimate can still be beneficial. Performing these calculations allows you to make quantitative embodied carbon assessments of different materials, identifies the carbon emissions associated with each process, and generally assists in understanding supply chains, manufacturing processes and how EPDs are calculated.

In principle, we follow the carbon flows in and out of the Product Stage, the A1–A3 LCA modules[2]. The first step is to understand the energy and materials used in the processes that produce the packaged product and the waste and emission outputs **(Figure 1)**.

Some emissions are easy to identify and measure, such as burning fuel or using electricity; however, others are not, such as the emissions from chemical processes or those that are released from a product over time. It can be helpful to create a flowchart to identify these emission flows **(Figure 2)**. Energy consumption and emissions by humans or animals are not considered in these calculations because it is assumed that they would be the same even if these products were not made.

The next step is to identify what processes are within the manufacturer's control. Often, the manufacturer will not be in control of upstream processes, such as extracting or transporting raw materials, and downstream processes, such as waste processing. If the responsible party has EPDs available for these upstream or downstream activities, these should be used; otherwise, secondary data can be used.

Whether measured data or secondary data is used, it should ideally be temporally, geographically and technologically representative:

- Temporal: Measured data should be from a recent 12-month period. Secondary data should not be older than 10 years.
- Geographical: Data should be from the correct geographical regions.
- Technological: Data should represent the technology and processes used. Considering future technologies is not recommended.

However, we often perform these calculations because this data does not exist, as shown in the example below.

If recovered materials are used, they enter your product system boundary as they leave the system boundary that made them, so their extraction and processing (modules A1–A3) does not contribute to your product, but any processing that is required to make the recovered material fit for purpose should be included. The processing of waste that does not leave the factory gate with the product should be included as part of the emissions for the product.

Co-products are products made in the same process as the product of interest and that have a marketable value. If a co-product is avoidable but cannot be separated from the assessment, the allocation may be based on the physical relationship. For instance, if a kiln fires bricks and tiles but the data cannot distinguish between the two products, it would be appropriate, but not perfect, to divide the impact based on the mass of the products.

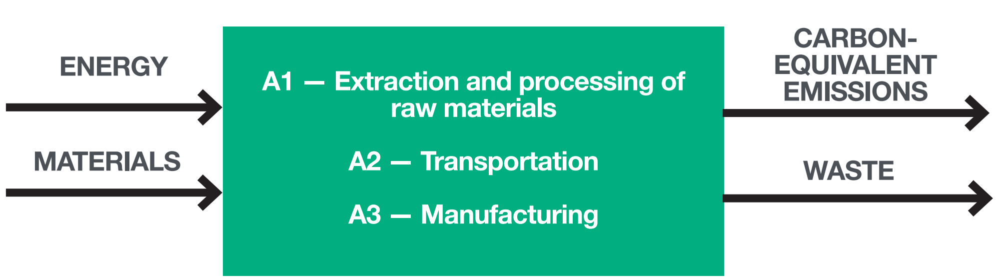
If a co-product is unavoidable, such as slag in steel production, it is more appropriate to allocate the impact based on economic value, because the purpose of the process is not to create the unavoidable co-product.

Co-product allocation can make an enormous difference to the results and it can be difficult to gather economic data from manufacturers.

Example: RICA CSEBs

The following simple example shows

FIGURE 1: Flows in and out of Product Stage



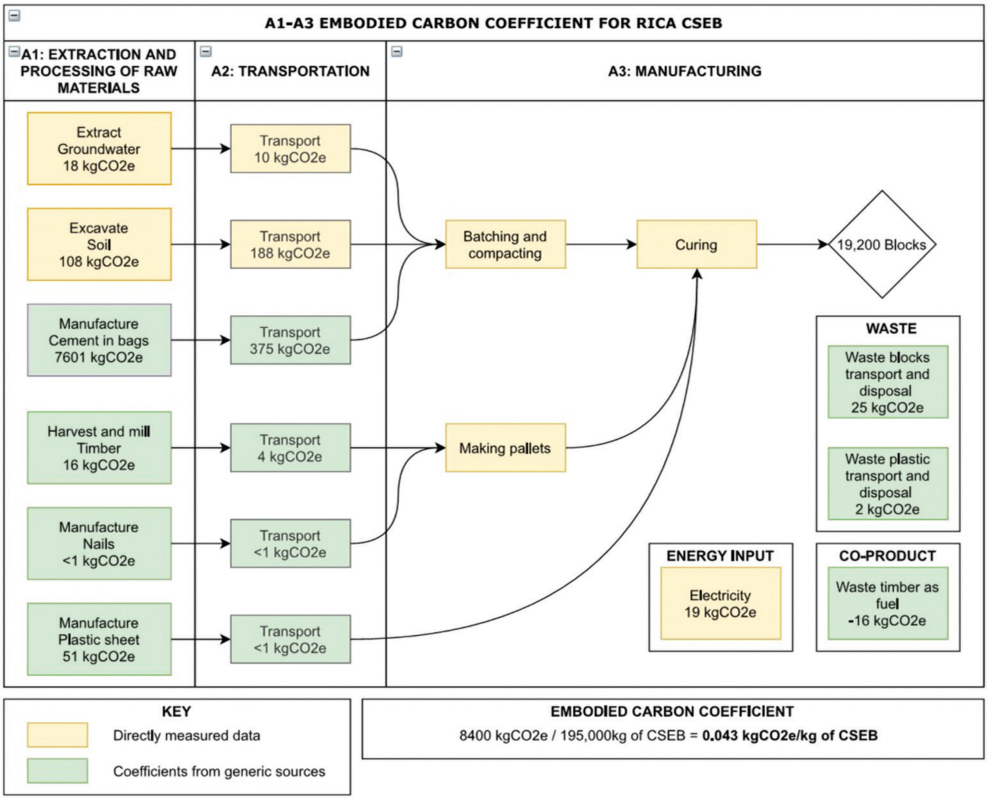


FIGURE 2: Summary of embodied carbon coefficient for compressed stabilised earth blocks (CSEBs)

“DATA USED SHOULD IDEALLY BE TEMPORALLY, GEOGRAPHICALLY AND TECHNO-LOGICALLY REPRESENTATIVE

how the embodied carbon coefficient for the compressed stabilised earth blocks (CSEBs) used on the RICA project was calculated. The contractor makes the CSEBs with earth from site, so we were able to collect data over a four-week period during which 19 200 blocks were made.

Below we present calculations for the carbon emissions from cement manufacturing, soil excavation and electricity use. There are other materials and processes in **Fig. 2** which are calculated in a similar way, but the calculations are not presented here. **Figure 4** shows that 92% of the carbon emissions are from the manufacturing of cement, which helped the team to understand where the greatest carbon savings could be made.

Cement
Manufacturing of the cement is an upstream process outside the CSEB contractor's control. The 32.5N cement is supplied by Cimerwa Cement Ltd, based 307km away from site, and contains 30% pozzolana. The cement does not have an EPD, so we used the ICE V2.0 database for the carbon coefficient. The 30t rigid HGV was fully laden to site but went back empty. 11.5t (57% of HGV load) of cement was used to make the CSEBs.

A1 cement production: 11.5t of cement × 0.66kgCO_2e/kg = 7601kgCO_2e [NB carbon coefficient from ICE V2.0[1]]
A2 transport from cement factory to CSEB manufacturing area: 57% × 11.5t × 307km × 0.12kgCO_2e/km.t + 57% × 307km × 0.77kgCO2e/km = 375kgCO_2e [NB carbon coefficients from DBEIS[3]]

Soil
The soil is excavated from site and transported 2km to the manufacturing area. We measured machine activity time and diesel consumption to estimate how much could be attributed to the manufacturing of CSEBs, because the machines performed other construction activities too.

A1 soil excavation: 40L × 2.69kgCO_2e/L = 108kgCO_2e [NB carbon coefficient from DBEIS[3]]
A2 soil transportation: 70L × 2.69kgCO_2e/L = 188kgCO_2e [NB carbon coefficient from DBEIS[3]]

Electricity
The whole process of making blocks is manual, so the only energy used in the manufacturing process is for lighting. Since these were not on a separate meter, we estimated the energy use from the bulbs and their power.

A3 electricity for lighting: 4nr × 72hr × 100W × 0.66kgCO_2e/kWh = 19kgCO_2e [NB carbon coefficient from DBEIS[3]]

Amending embodied carbon coefficients for different fuel uses
Embodied carbon coefficients are influenced by the fuel used in manufacturing. If the product of interest, say a brick from Rwanda, uses similar

FIGURE 3: Ruliba brick manufacturing process

TABLE 1: Embodied carbon coefficient of Ruliba brick

UK brick[4]			Ruliba brick		
Fuel	**Intensity ($kgCO_2e/kWh$)**	**% of kWh**	**Fuel**	**Intensity ($kgCO_2e/kWh$)**	**% of kWh**
Natural gas	0.183[5]	75%[1]	Biomass	0.013[5]	75%[1]
Electricity UK	0.283[5]	25%[1]	Electricity Rwanda	0.661[5]	25%[1]
Weighted average	0.208	100%	Average	0.175 (84% of UK brick)	100%
GWP from energy	125$kgCO_2e/t$[4]		GWP from energy	*105$kgCO_2e/t$* (84% of UK brick)	
GWP from other sources	88$kgCO_2e/t$[4]		GWP from other sources	88$kgCO_2e/t$	
Total GWP	213$kgCO_2e/t$[4]		Total GWP	*193$kgCO_2e/t$*	

NB Values in italics are calculated.

raw materials and manufacturing processes to another product, such as a brick from the UK, but a different fuel mix, this may be accounted for using conversion factors. Research will be required to identify the emissions due to energy consumption and the fuel mix.

The example in **Table 1** demonstrates how embodied carbon coefficients were amended for a fired-clay brick made by a local manufacturer, Ruliba, using data from UK sources. The Ruliba brick **(Figure 3)** is made using a similar process to UK bricks, and so it was possible to factor the UK brick emissions down in line with the estimated carbon intensity of the energy used to fire the Rwandan bricks.

It was assumed for this basic study that other emissions sources (e.g. raw material extraction) remained the same, which is considered valid because 95% of the emissions in brick manufacturing come from the firing and factory operations[6].

Conclusion

While the above examples are for products on a project in Rwanda, the principles can be applied to many other materials or products, such as nail-laminated timber or precast concrete, that do not have EPDs. It is also worth noting that the decision to use CSEBs as the primary walling material was based on a coefficient of 0.061$kgCO_2e/kg$[1] at concept stage, which is good enough to make major, impactful decisions early on in the project.

It is difficult to investigate why the CSEBs made for RICA have 30% less embodied carbon than the generic product in the ICE V2.0 database, because the background information is not provided, but this was one of the reasons we wanted to perform the assessment in the first place.

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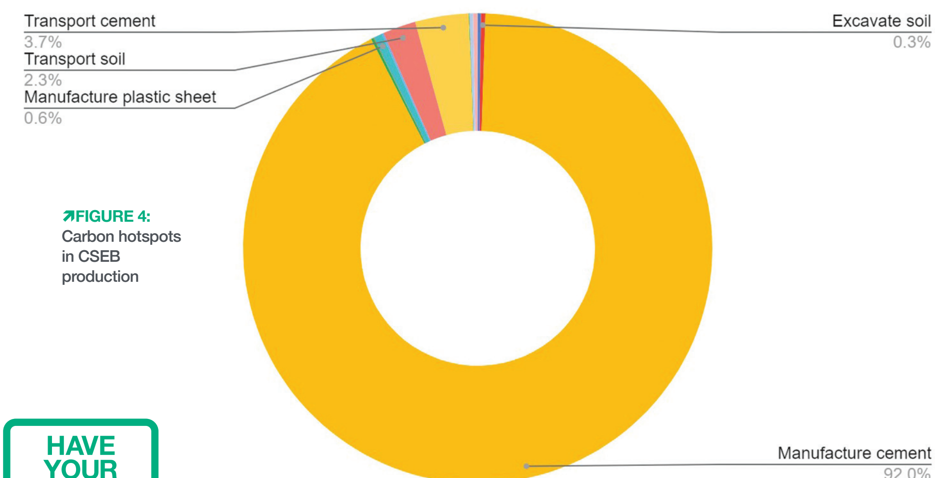

FIGURE 4: Carbon hotspots in CSEB production

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REFERENCES

1) Jones C. and Hammond G. (2011) *Inventory of Carbon & Energy Database* V2.0, Bath: University of Bath

2) British Standards Institution (2011) *BS EN 15978:2011 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method,* London: BSI

3) Department for Business, Energy & Industrial Strategy (2018) *Greenhouse gas reporting: conversion factors 2018* [Online] Available at: www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018 (Accessed: June 2021)

4) BRE Global (2015) *Environmental Product Declaration – BREG EN EPD No. 000002*, Watford: BRG Global

5) Takahashi K. and Louhisuo M. (2021) *IGES List of Grid Emission Factors*, version 10.10 [Online] Available at: https://pub.iges.or.jp/pub/iges-list-grid-emission-factors (Accessed: June 2021)

6) Carbon Leadership Forum (2019) *Embodied Carbon in the EC3 Tool: Beta Methodology Report* [Online] Available at: https://carbonleadershipforum.org/download/4739/ (Accessed: June 2021)