BENEFITS AND CHALLENGES OF VISUALISING EMBODIED AND WHOLE LIFE CARBON OF BUILDINGS

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ABSTRACT

Embodied and whole life carbon of buildings are increasingly gaining attention. However, embodied carbon calculation is still far from being common practice for sustainability assessment of buildings. Some of its greatest difficulties lie with the long life lifespan of buildings which implies a great unpredictability of future scenarios and high uncertainty of data. To help understand which life cycle stages should get the most attention when considering a building project, this paper proposes a new visualisation method based on Sankey diagrams for whole life carbon that allows one to cluster the carbon emitted in each of the life cycle stages as identified in current BS 15978 standards. With the proposed method, the carbon figures can be further broken down to account for building assemblies and components. Additionally, the method is equally suitable to account for physical quantities of what is embedded in buildings and their components. As such it can supplement some units of existing assessment methods (e.g. metal depletion measured in mass units of Fe_{eq}) and turn it into mass units of embodied steel. With such new metric, a life cycle assessment would include knowledge on flows as well as quantities. Such information could then be linked to the building permanently and smartly to be updated when necessary as the building evolves, changes, and gets upgraded, building on the theoretical foundations of the shearing layers of buildings. As such, this information could be embedded within BIM which is fully suitable to store parametric details for each building component.

INTRODUCTION

Embodied carbon is a significant part of whole life carbon emissions of buildings and with operational energy (and therefore carbon) being continuously reduced, embodied carbon will represent the totality of carbon figures in Zero Energy Buildings (ZEBs). However, both practitioners and academics lament several issues in embodied carbon calculations, as emerged in a research symposium and focus groups on the topic held at the University of Cambridge in April 2016 (CUBES, 2016). Some of the issues that emerged are:

- Lack of uniform and standardised methodologies
- Lack of available data
- Complexity of the calculations
- Difficulty to predict plausible scenarios for future uses and end of life stages of buildings

Whilst some of these issues are certainly technical and require several and plural approaches to be addressed, during the focus groups it seemed that sometimes complexity was perceived even where there was not. To help in such respect, and after evaluating available possibilities, this short paper suggests a new visualisation method for embodied and whole life carbon of buildings that allows one to cluster the carbon emitted at each of the life cycle stages as identified in current BS 15978 standards.

VISUALISING EMBODIED CARBON

Sankey diagrams are widely used to show flows, and are based on the simple but extremely effective idea that the width of the arrows is proportional to the quantity of the flow. They are frequently used in Material Flow Analysis research (Haas et al., 2015) or to track worldwide flows of a specific element (Allwood and Cullen, 2012). Sankey diagrams in building's research are however unusual although they could also help towards embedding circular economy thinking in the built environment. However, this particular aspect is outside the scope of this short paper. For the purpose of showing the visualisation method and discussing the benefits and challenges that go with it, we use numerical results from previous research (Moncaster and Symons, 2013). The objective of this representation is to present embodied carbon figures, and potentially also other environmental impact categories, in an innovative way which plots the life cycle stages according to existing standards (BSI, 2011) for the whole life of the building (Figure 1).

From the diagram in Figure 1 it is immediately noticeable which life cycle stages account for the highest shares of embodied carbon, and which instead are barely noticeable. This representation does not suggest that a certain life cycle stage should be minimised prior to others. Rather it wants to help see where the greatest opportunities for reductions lie. Also, our proposed method includes a time element on the horizontal axis, which helps identify which activities span over a significant time horizon and, as such, might be affected by a lot of uncertainty about what happens over many years (such as the B2 stage of Figure 1). Similarly, it helps visualise uncertainty and variability of what happens distant in the future such as the C stage (end of life of the building). In the latter case the uncertainty is not related to a long time span of the specific activity but rather to the extreme uncertainty of what will happen after decades or centuries if one imagines to use this visualisation tool at the design stage of a new building. In both B and C stages, uncertainty analysis should play an important role in the assessment to ensure that the numbers produced have some meaningfulness – and the diagram in Figure 1 may help to flag this aspect.

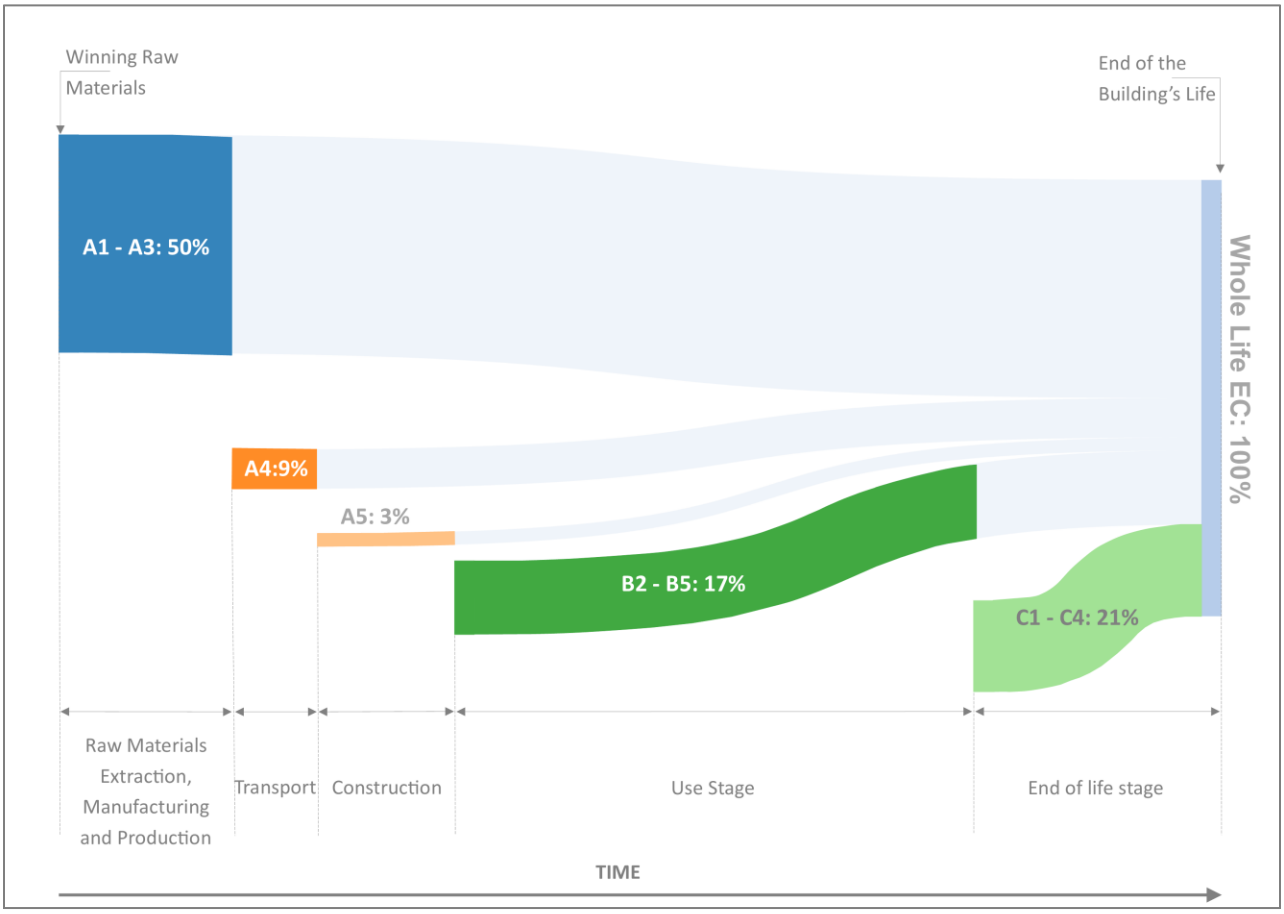

Figure 1 - Sankey diagram of whole life embodied carbon (coding of life cycle stages according to BS EN 15978:2011 - The numbers refer to a specific case and are only used for illustrative reasons here).

With the proposed method, the carbon figures can be further broken down to account for building assemblies and components. In a software environment this could be done – for instance – by double clicking on each stage which would open up a sub-Sankey related to the components and assemblies of that specific stage. This approach could go further down on a tier-by-tier basis and allow to group or detail the level information according to the necessity. A BIM environment seems particularly suitable to do so, due to its parametric approach which goes well with the bill of quantities regularly used in embodied carbon assessment.

Furthermore, the method is equally suitable to account for physical quantities of what is embedded in buildings and their components, to overcome one of the shortcomings of embodied carbon as a single metric, i.e. the risk of neglecting that environmental impacts might just be shifted from one impact category to the another (Pomponi et al., 2016). One example is to enrich some existing units of more comprehensive life cycle assessment (e.g. metal depletion measured in mass units of Fe_{eq}) and further it to become mass units of embodied steel. To keep both pieces of information these diagrams could be used to show the total amount of Fe_{eq} used in a building or one of its components and also how that equivalency figure is split into different metal sources and end-uses.

An example of this new form of metric is given in Figure 2 for a mass unit of a fired brick. The Sankey diagram could of course carry on both ways to reach virgin raw materials on one end and the whole building on the other. With such new metric, a life cycle assessment would include knowledge on flows as well as quantities. Such information could then be linked to the building permanently and smartly to be updated when necessary as the building evolves, changes, and gets upgraded, building on the theoretical foundations of the shearing layers of buildings. Even in this second example, such information could be embedded within BIM which is fully suitable to store parametric details for each building component.

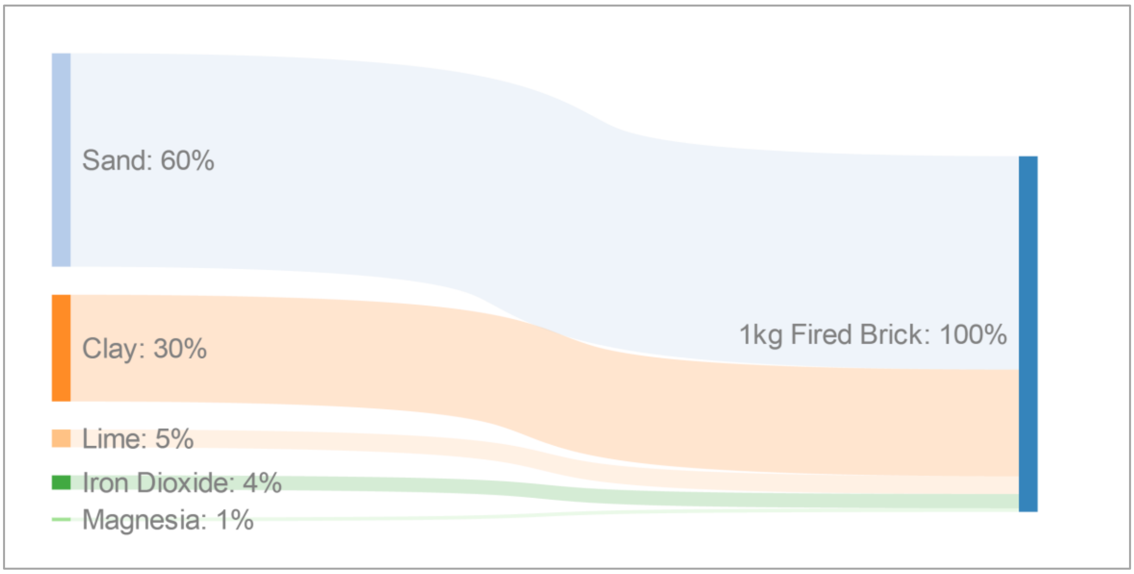

Figure 2 - Proposed metric to enrich embodied carbon as a measure to circularity in the built environment – numbers are solely for explanatory reasons and taken from Punmia et al. (2003)

CONCLUSIONS

This short paper has discussed the idea of visualising embodied carbon as a means to simplify the understanding and use of embodied carbon assessment in buildings and the built environment. In previous research we had indeed realised that both practitioners and academics seemed to ask for simpler and easier ways of communicating embodied carbon results and for visualisation tools that would be richer than a simple pie chart or bar graph. The Sankey-based diagrams that we have proposed include an element of time which helps understand, or at least remember, elements characterised by high uncertainty either because of a long timespan or due to happening in a very distant future. The Sankey chart also quickly allows to identify the life cycle stages which account for the most, thus pointing at where the greatest opportunities for reduction lie. These diagrams could also be developed further to include more comprehensive information (e.g. materials quantities and physical status) for a richer life cycle assessment or to start embed elements of circular economy thinking in buildings and the built environment. As such, collaboration on both initiatives is particularly welcomed.

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