Life Cycle Analysis of the SNRG Demonstrator Module

Transforming Timber

CONTENTS

OVERVIEW

The built environment is responsible for 39% of global greenhouse gas emissions and similar shares of global final energy demand, resource use, and waste generation [1]. These impacts will only grow due to global population growth and urbanisation trends [2]. Biobased construction is one solution that can mitigate these effects because it relies on biomass that sequesters CO_2 in a cycle from plant growth through use and reuse [3]. Life Cycle Assessment [SH1] (LCA) is key to understanding the positive environmental implications of buildings constructed from biogenic offsite manufactured (bio-OSM) timber.

This summary describes findings from a study that determined the carbon footprint of Scotland's first homegrown mass timber house: the SNRG demonstrator module. The building totals approximately 80 m^2 of floor area over two storeys, is modelled as a 2-bedroom detached house (with an additional mid-terrace scenario), and the core, roof, internal partitions, and façade are included. The model consists of a customisable, modular kit of parts designed for deconstruction and reuse. The LCA revealed that the carbon storage potential of the SNRG module is highly significant, vastly outweighing the impact associated with raw material production, transport, and manufacture. [SH1]In milestone 44, LCA is written out as life cycle analysis; whereas here it is life cycle assessment. Don't know which is preferred, but it should be consistent.

COMPONENTS OF THE LCA STUDY

Built for display at Cop26 in Glasgow, the 2-bedroom module was designed as a detached house for standard residential occupancy according to CIBSE guidelines with an expected life span of 60 years, and was built to provide a thermally and acoustically insulated living space according to the Scottish Building Standards for domestic dwellings. The Functional Unit (FU) for the study was 1 m2 of floor area.

ISO 14040:2006 stipulates the following phases for an LCA study: 1) goal and scope definition, 2) inventory analysis, 3) impact assessment, and 4) interpretation. Where primary data was unavailable for any of these areas, representative proxy data was obtained from Environmental Product Declarations (EPDs), peer-reviewed literature, the Ecoinvent database, and personal communications with the design team. The LCA is based on information for four different life cycle stages that impact a building assessment: Product Stage, Construction Process Stage, Use Stage, and End of Life stage. For more information on these see BS EN 15978. Some elements were beyond the scope of this LCA and they are explained in the full report.

1. Goal and scope

This LCA includes a cradle-to-grave analysis. All raw materials and energy inputs related to core, roof, internal partitions, and façade of the FU are included. Operational impacts of the use phase have been considered based on a generic energy consumption profile.

2. Inventory analysis

The life cycle inventory (LCI) comprises the material quantities (in kg, m3 or m2) and transport distances (in km) required to build one SNRG module. As opposed to regular construction where products are manufactured in a plant, travel to the site, and then are assembled, installed, or erected on site, in offsite construction some products are manufactured but then serve as raw materials for offsite operations, and therefore contribute to different impact stages.

3. Impact assessment

Life cycle impact assessment (LCIA) provides additional information that helps assess a system's LCI results to better understand their environmental implications. All the EPDs used to compile an impacts database adhere to BS EN 15804:2012. These were used to generate an impact profile that accounts for the embodied impacts across the supply chain, transport of raw materials or pre-manufactured products to the manufacture site, and construction of the modular elements onsite.

The carbon sequestration potential of the SNRG module was calculated from data included in the impacts reported in the EPDs or by following the formula provided in BS EN 16449.

For operational energy use, a generic energy profile was developed based on the potential orientation of the SNRG module when installed on a real site and by factoring in all the relevant end uses required in a dwelling. This calculation also assumed the whole energy demand would be provided by grid electricity, and the methodology accounts for both direct and indirect GHG emissions.

As a result, some consideration should be given to the continued decarbonisation of the UK electricity grid, so even though current standards do not require this, six decarbonisation scenarios were considered in the LCIA based on those recommended in the Tyndell Centre for Climate Change Research report.

In terms of the end-of-life stage, even though it is not possible to predict the fate of the SNRG module 60 years in the future, a complete LCA requires this scenario which is particularly important for assessments containing biogenic carbon that could leave the system boundary and return to the atmosphere. A description of how the study managed these uncertainties and possibilities is given in the full report, but reuse was assumed for the timber elements, recycling for the glazing and window frames, and incineration for the woodfibre elements.

While it is important to consider environmental indicators beyond global warming potential such as ecotoxicity and resource depletion, here only the carbon footprint of the SNRG module and FU are assessed in line with this study's scope. Thus, the results presented here are not a complete representation of environmental sustainability.

Stakeholders need to maintain an open mind in distinguishing between prescriptive norms and the reality of physical flows of carbon and demand of energy that happen at very different stages across a product's life cycle. The consortium should develop a robust reverse logistic process to track where the SNRG module is and ensure its reusability, recyclability, and permanent carbon storage potential materialises as theorised.

4. Interpretation

Impacts had to be divided between cradle-to-practical completion (which are based on primary collected or derived data and therefore likely to be correct) and cradle-to-grave (which is muddled by the uncertainties around decarbonisation and future EoL options). This highlights the significant difference in the confidence that can be posed over the two numbers. The study shows that the top three elements by mass—timber, bio-based insulation, and bamboo—are also those most influential in determining the life cycle impacts.

The normalised value per FU in cradle-to-practical completion is 162 kg CO2e/m2, which is a very low value in residential building construction. As a comparison, the A++ target (the highest LETI band and two steps above the LETI 2030 Design Target) is reserved for values lower than 100 kg CO2e/m2, meaning the SNRG unit is not far from that exceptional threshold.

From the cradle-to-grave perspective, the impact increases significantly, showing a range from 1,540 to 830 kg CO2e/m2 for the worst and best case operational carbon scenarios. If writing off the biogenic carbon exiting the system were not mandated, the impacts would range from 1071 to 361 kg CO2e/m2, with a normalised impact of 521 kg CO2e/m2. This value is also indicative of great performance since the RIBA 2030 Design Target value for residential buildings from a cradle-to-grave perspective is reserved for those totalling less than 625 kg CO2e/m2. In all scenarios, the share of embodied carbon over whole life carbon is extremely significant and reinforces that embodied impacts are gaining prominence as the most important share of whole life impacts in modern construction.

CONCLUSION

Results indicate that embodied and operational carbon are equally important to successfully design a low carbon building from a whole life perspective, with embodied carbon accounting on average for just over 55% of the whole life impacts for this construction method.

Crucially, the study reveals that if the carbon stored in the timber could be permanently stored at EoL and an equivalent amount of biomass was replanted (sequestering the same amount of carbon stored in the SNRG module), there is scope for carbon-neutral or even carbon-negative construction. For now, the SNRG module represents truly low carbon construction as demonstrated by its superior performance in the bands defined by LETI and RIBA for both upfront and whole life carbon.

REFERENCES

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