Embodied Carbon Analysis

1. Introduction

- The building and construction industry consumes a lot of energy that is accompanied by significant carbon emissions.
- The design and construction of zero-carbon buildings aim at reducing emissions by reducing the embodied energy in construction and operation of the buildings. Therefore developing a standard method of estimating the embodied carbon for a project's whole life cycle is vital.
- The developed estimation method can then be integrated to the design of zero-carbon building for optimum results.

2. Aims and Objectives

- This project aims at developing a standardized estimation method for whole life embodied carbon for building construction projects

Objectives

- To develop standardized methods of estimating the embodied carbon emissions from:
- Activities in construction material production.
- Construction processes.
- During use of constructed building.
- At the end of the builing life.

3. Literature Review

Embodied Carbon Estimation

- Reddy et.al (2018) describes the various life circle stages in embodied carbon assessment with reference to BS EN 15978 and BS EN 15804 standards, which remain important in projecting emissions at each stage of building construction.
- Investigation by Ca (2017) proposes the use of principles of 'cradle-to-grave", "cradle-to-gate "and 'cradle-to-service techniques in embodied carbon estimation while assumption that the carbon factors are in manufacturer's literature which is not always the case therefore not adequate.
- Cole (2016) while estimating the carbon due to waste disposal views such embodied carbon emisions to be insignificant. The impact of these emissions may however be great and should be incorporated in the estimation of total embodied carbon.

4. Methodology

- Identification of empirical equations that are used in the estimation of embodied energy at different phases of building life cycle.

Embodied Carbon Estimation
The estimation involves calculation of carbon by each element of the building which also depends on the type of material.
Embodied Carbon = material quantity x carbon factor

Production Stage Carbon Factors (A1)
Each material has a carbon factor which depends on individual components. The embodied carbon at production stage is given as estimated carbon factors x material quantity

Carbon Sequestration in Timber (A13)
The embodied carbon in timber is treated differently from other materials due to its sequestration nature of growth. The embodied carbon in timber is normally taken as
1.64 Kg CO2/kg

Transport Carbon Factors (A4)
This caters for the carbon emissions during transportation of materials to various construction sites. The embodied carbon is given as transport carbon factors x material quantity.

Construction Installation Carbon Factors (A5)
This accounts for émissions from waste materials in site (A5w) and additional constructions in site like site office (A5a)
A5w = WF x (A13 + A4 + C34)
Where WF - waste factor and C34 - the emission for the processing disposal of waste material assumed as 1.77 kg/CO2

Use and End of life
The use Phase = Use (B1) + Maintenance (B2) + Repair (B3) + Replacement (B4) + Refurbishment (B5)
End of Life Phase = Deconstruction (C1) + Transport (C2) + Waste Processing (C3) + Disposal (C4)

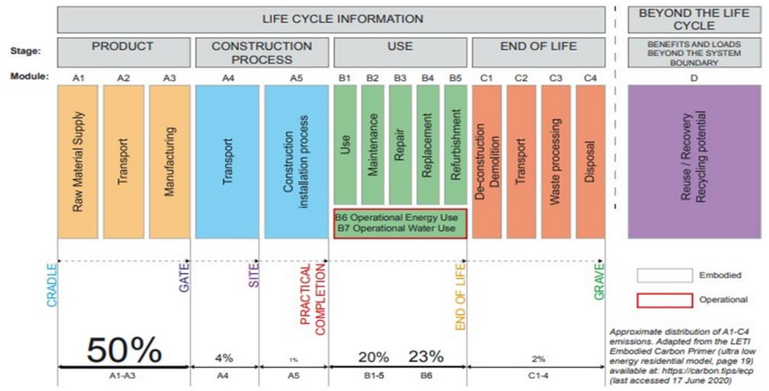

Table 1. Building Life Cycle Phases (Lee, 2015).

5. Results

- The overall embodied carbon for a building life cycle can be estimated effectively by adding all the carbon emissions in each phase of the cycle
- Total Building Embodied Carbon (BEC) = Production (A1-A3) + Construction Process (A4 - A5) + Use (B1-B5) + End of Life (C1-C4)

$$BEC = (A1\text{-}A3) + (A4 - A5) + (B1\text{-}B5) + (C1\text{-}C4)$$

6. Conclusion

- There exists a number of techniques for estimating the resultant embodied carbon in the building life cycle.
- Some techniques may not be effective as they rely on estimations recorded in various inventories like ICE database and literature from material manufacturers.
- Therefore, carrying out a full life cycle carbon analysis at each stage of a building project with focus on materials and designs remains the most accurate method of estimation.

Figure 1: Carbon in Building (Skanska, 2019).

7. Further Work

- Investigate how various factors influence the emission of embodied carbon including:
- Environment factors
- Economic factors
- Social factors
- Investigate the methods available for reducing embodied carbon in building life cycle especially in material production and design process.

8. References

- Cao, C. (2017). Sustainability and life assessment of high strength natural fibre composites in construction. In Advanced high strength natural fibre composites in construction (pp. 529-544). Woodhead Publishing.
- Cole, R.J(2016). Energy and greenhouse gas emissions associated with the construction of alternative structural systems. Build. Environ. 34, 335–348.
- Lee, S., Tae, S., Roh, S., & Kim, T. (2015). Green template for life cycle assessment of buildings based on building information modelling: Focus on embodied environ mental impact. Sustainability, 7(12), 16498-16512.
- Reddy, B.V.V.; Jagadish, K.S(2016). Embodied ergy Build.35, 129–137
- Skanska. (2019). Skanska conceives solution for calculating embodied carbon in construction materials, announces transition to open-source tool.