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Analysing methodological choices in calculations of embodied energy and GHG emissions from buildings

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ABSTRACT

The importance of embodied energy and embodied greenhouse gas emissions (EEG) from buildings is gaining increased interest within building sector initiatives and on a regulatory level. In spite of recent harmonisation efforts, reported results of EEG from building case studies display large variations in numerical results due to variations in the chosen indicators, data sources and both temporal and physical boundaries. The aim of this paper is to add value to existing EEG research knowledge by systematically explaining and analysing the methodological implications of the quantitative results obtained, thus providing a framework for reinterpretation and more effective comparison. The collection of over 80 international case studies developed within the International Energy Agency's EBC Annex 57 research programme is used as the quantitative foundation to present a comprehensive analysis of the multiple interacting methodological parameters. The analysis of methodological parameters is structured by the stepwise methodological choices made in the building EEG assessment practice. Each of six assessment process steps involves one or more methodological choices relevant to the EEG results, and the combination potentials between these many parameters signifies a multitude of ways in which the outcome of EEG studies are affected.

1. Introduction

Buildings are responsible for more than 40 percent of global energy used, and as much as one third of global greenhouse gas emissions [1]. The environmental impacts from buildings are of operational as well as embodied character, where embodied energy and greenhouse gas emissions (EEG) from buildings concern exchanges with the environment from processes that take place in relation to the life cycle of the building materials, for example the production processes of cement clinker which requires heating energy and which emits CO2 from energy conversion as well as chemical processes. It is increasingly recognized that EEG can constitute more than half of the total life cycle impacts from new buildings and is thus a key element to address when working towards a more sustainable building sector [2].

On a regulatory level, focus from international, as well as, from regional political bodies may act as a driver for national development of measures to reduce EEG from buildings [1,3]. Preliminary steps towards regulatory guidelines and/or requirements are thus seen in several countries [4–7]. This regulatory attention follows an already existing focus within the building sector itself, where voluntary initiatives include EEG considerations as part of holistic evaluations of the sustainability of buildings, e.g. as practiced in various certification schemes.

Furthermore, methodological improvements have been made in developing and harmonising the life cycle assessment (LCA) method by which the EEG is quantified. Building and construction related standards include the international standard ISO 21931-1:2010, which specifies the framework for methods of assessment of the environmental performance of construction works, and the European standard EN 15978:2011 which specifies a calculation method for assessing the environmental performance of a building. In parallel with the standardisation development, a number of international research projects have focused on LCA and EEG in

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Table 1
Summary of Annex 57 case study properties for case studies analysed in this paper.

Total number of case studies	59
Study origin (country)	Austria (AT), Switzerland (CH), Germany (DE), Denmark (DK), Italy (IT), Japan (JP), South Korea (KR), Norway (NO), Sweden (SE), United Kingdom (UK)
Number of databases employed	19
Range in applied reference study period (RSP)	20–150
Number of applied system boundary combinations	18
Building types	Office, residential, school

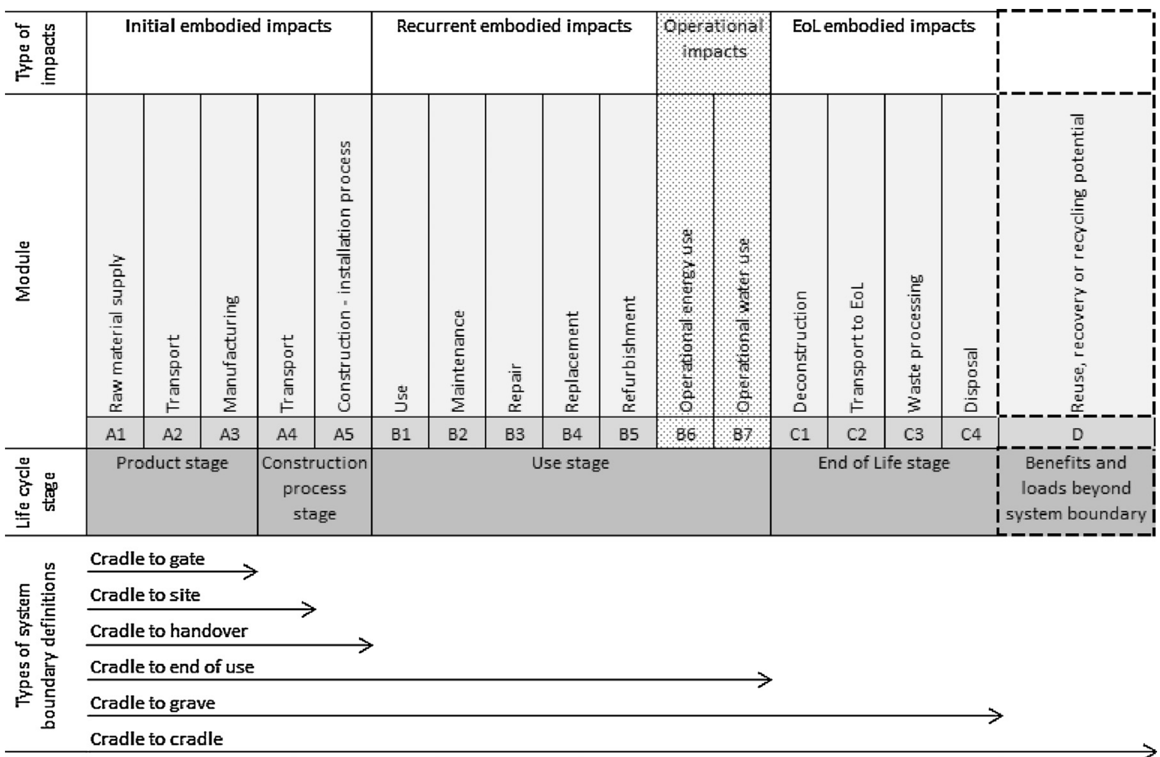

Fig. 1. System boundaries definitions in relation to the life cycle stages of a building [30,29,18].

the building sector. These activities are carried out e.g. in a European context [8–10], but also in an international context through e.g. the International Energy Agency's Energy in Buildings and Communities Programme (IEA-EBC). Relevant IEA-EBC research work include, most recently, the Annex 57 on EEG in buildings (2011–2016) [11].

In spite of all the attention towards EEG and the efforts in harmonising a methodological approach, research has pointed to the lack of consistency in the ways building LCAs are carried out, both in terms of system boundary definition and in terms of the indicators and the background data used for calculating the embodied impacts [12–15]. Thus, reported EEG of buildings display large variations in numerical results as well as inconsistent and insufficient reporting formats [16].

Knowledge on how to reduce EEG through certain design strategies can be drawn from the experiences and analyses of the, so far, mostly individual case studies. This can guide building designers, as well as, policy developers targeting reductions of EEG. However, it is highly important that the methodological reasons for differences in EEG results is fully understood. Conversely, incorrect conclusions may be drawn and used for creating and validating EEG-reducing design strategies, although these may not actually have the desired reduction potential. Existing literature, mainly in reviews, has described methodological parameters of importance, further explained in Section 1.2. However, the parameters treated in existing literature appear randomly sought out and thus do not provide a systematic overview that links directly to the EEG assessment practice.

The aim of this paper is to add value to existing EEG research knowledge by systematically explaining and analysing the methodological implications on the quantitative results obtained, thus providing a framework for reinterpretation, more effective comparison and understanding of reduction potentials in quantitative terms.

The systematic approach of this paper includes the consideration of the already scientifically addressed methodological parameters, which are presented in the literature review in Section 1.2. The method Section 2 introduces a structured framework for analysis based on the practical assessment process of the EN 15978 standard. Furthermore, Section 2 describes the collection of over 80 building case studies from the IEA-EBC Annex 57 project, an international collection of EEG assessments that are reported in a consistent and organised manner and thus provides detailed and illustrative examples of methodological implications. The results and discussion Section 3 uses the quantitative as well as the qualitative properties of the Annex 57 case studies to analyse and empirically validate the methodological parameters that affect the outcome of EEG studies, and the section presents a comprehensive and structured overview of these.