Assessment of embodied impacts – Incorporation of the approaches of IEA Annex 57 into the overall context of environmental performance assessment

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Abstract: After decades of focusing exclusively on the use phase, life cycle approaches get more and more attention in design and decision making in the building sector. In this sense, the assessment of embodied impacts is currently in focus as part of the impacts analysed within a life cycle assessment. Such discussions are no longer only part of the scientific debate, but they have now found their way into practice to assist in variant comparisons and investment decisions. Additionally, the availability of data and the development of tools provide new possibilities. Therefore, it is discussed, how the embodied impacts assessment can be part of a comprehensive assessment of the environmental performance, how the indicators and system boundaries can be defined and which actors follow already specific approaches. Results are presented that were developed by the authors as a preliminary work on the currently ongoing project IEA Annex 57.

Embodied environmental impacts, greenhouse gas emissions, embodied energy, cumulative energy demand, environmental performance

Introduction

The efforts undertaken to implement sustainable development principles in the construction and real estate industry have led in recent years to various activities. These include, among others, the further development of design methods and tools, the development and testing of net zero building (NZB) concepts, the use of innovative products and technologies, the development and application of methods of life cycle analysis, the ongoing standardization for sustainability assessment of buildings or the development and application of systems for describing and certifying the sustainability of buildings.

One current trend is the description and assessment of embodied impacts of buildings, representing the energy and mass flows as well as emissions resulting from all the processes related to the production of construction products and the creation, maintenance and end-of-life of the building. This trend has its roots in experiences and results mainly from the 1970’s and 80’s [1]. Questions concerning the further development, standardization and application of principles related to the description, assessment and influence of the embodied impacts, are the subject of the currently ongoing project, IEA Annex 57 “Evaluation of Embodied Energy
& Embodied Green House Gas Emissions for Building Construction”, in which the authors actively participate.

The various stakeholders/actors involved in the building process have different perspectives on embodied impacts and need to cope with diverse problems within their daily decision-making situations. Some actors (building designers etc.) may have lot of experience for the embodied impacts due to the requirements of sustainable design. On the other hand, some others (e.g. investors) might have limited knowledge of these issues. The discussion of this topic was driven by the increased demand for sustainability assessment of buildings and green public procurement. This fact is also reflected in the literature, where these issues are being integrated more and more into the procurement and practice in comparison to the past.

In this context, it is important to provide a uniform basis for the description and assessment of embodied impacts and place them within the context of environmental performance assessment. In this sense, the objective of this paper is to provide an overview by discussing the following questions:

a) How are embodied impacts described in the existing life cycle oriented standards (e.g., ISO/TC 59/SC 17, CEN TC 350 etc) and initiatives to assess the cumulative energy demand and carbon footprint?

b) Are embodied impacts considered in the design and sustainability assessment?

c) What is the current state of data availability, data supply and data quality in selected regions (including Europe, Asia, America)?

d) How can and should the transparency and traceability of results related to embodied impacts be improved?

e) What is the status of the application by selected groups of actors and what recommendations can be developed?

Embodied impacts as part of environmental performance assessment

There is a demand to reduce the environmental impacts related to the energy consumption and greenhouse gas emissions (GHG) coming from the building material production, as well as construction, refurbishment and demolition of buildings. These elements make up the “embodied energy” and “embodied GHG emissions” of the building. Within a whole lifecycle approach to dealing with buildings, embodied energy and embodied GHG emissions data can be either used as single indicators, or addressed as part of a wider set of environmental impact indicators. Life Cycle Assessment (LCA) is a methodology used to measure and assess all significant environmental impacts associated with a product, system or service, over its entire life cycle, from extraction of raw materials, through processing, manufacturing, transportation, and use, to eventual disposal or recycling. Therefore, it covers a broad range of environmental issues. Within the context of LCA embodied GHG emissions would normally be expressed as part of the environmental impact category climate change or global warming potential (GWP) and embodied energy would be expressed as a part of the cumulative energy consumption, alongside other environmental indicators (e.g. acidification, eutrophication,
etc.). An LCA should be always carried out in accordance with the standards ISO 14040:2006 and ISO 14044:2006.

Considering the current standardization activities also the sustainability assessment of buildings should be based on life cycle thinking. Thus, the current standards elaborated by the ISO TC59 /SC 17 at an international level, and the CEN TC 350 working group at a European level, require Life Cycle Assessments (LCA) to be carried out in the course of a environmental performance assessment as part of sustainability assessment. Within this group of standards the ones including the assessment of embodied energy and embodied GHG emissions in buildings are ISO 21929-1:2011 and EN 15978:2011, while ISO 14025:2006, ISO 21930:2007, and EN 15804:2012 are the ones to be used for calculating the impacts at construction product level and defining environmental product declarations (EPD) based on product category rules (PCR). These standards include a long list of indicators, some of them used for describing environmental impacts and others for describing resource use.

However, some building practitioners and decision makers choose to focus on a single issue rather than a long list of environmental impacts. This single issue is climate change and a great deal of attention has focused on measuring this specific impact using “carbon footprint”, as being an easy to understand indicator among stakeholders coming mainly from real estate industry. Different methodologies have begun to emerge to measure a carbon footprint, either at an organisational level or a product level, in a standardised way. Examples include the ISO/TS 14067:2013, Greenhouse Gas Protocol, or the BSI PAS 2050 specific to UK. In this case, “embodied carbon” can be considered as a partial carbon footprint.

Therefore, there are both international and European standards for the assessment of energy consumption and GHG emissions of buildings. The same applies to the production of standardized data and information for construction products. In this regard, these standards can also be applied for determining “embodied energy” as part of the cumulative primary energy demand, and “embodied GHG emissions” as part of the total GWP or carbon footprint. In particular, the uniform basis for the development and publication of environmental product declarations (EPDs) has contributed significantly to the improvement of the data availability for construction products related to “embodied energy” and “embodied GHG emissions”. IEA EBC Annex 57 considers both “embodied energy” and “embodied GHG emissions” as important indicators that provide the different stakeholders with useful information to be incorporated into their decision making, as well as a first step into the subject of energy resource use and associated effects on the environment caused by the manufacture, construction and use of buildings. However, for giving a complete picture of the life cycle environmental impacts of a building, these two indicators must be supplemented by others and be part of a full life cycle assessment.

**Consideration of embodied impacts in design and sustainability assessment**
Architects are increasingly interested in reducing the environmental impacts of the buildings they design. Additionally, they are increasingly concerned about the embodied impacts, due
to the increasing number of NZB, comparing to previous years when they were only concerned for operational impact of buildings. A larger segment of this group of actors and other decision makers procuring new buildings are choosing to use sustainability assessment systems as a tool to support decision making in this direction. In this field, a rapid movement from qualitative to predominantly quantitative approaches is observed, as well as an elevation of the importance of Life Cycle Assessment (LCA) in an attempt to comply with the recent standardization activities.

For example, some of the existing certification systems already consider LCA for their assessment criteria (e.g. LEED v4, GreenStar, etc.), while many of them (e.g. CASBEE) are still focused on operational energy use and associated environmental impact ignoring the issue of embodied energy and embodied GHG emissions (table 1). One of the reasons for this might be the lack of available data. Nowadays, there are freely available national databases, among others, that can provide detailed life cycle data on environmental impact and energy for building products and systems. These national databases can be easily integrated into the respective national sustainability assessment systems. Specifically, the newly released versions of US LEED and Australian Green Star integrate LCA for building product level only, while the German BNB/DGNB and the Swiss SNBS for the whole building. In addition, in Switzerland also design goals for embodied energy have been formulated [2].

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* qualitative assessment of Global Warming Potential
** both qualitative and quantitative assessment of Global Warming Potential
*** quantitative assessment of Global Warming Potential

Table 1. Coverage of assessment of global warming potential along the building life cycle by selected building sustainability assessment systems as an example.

Data availability
The most important prerequisite for the assessment of embodied impacts of a building is that there is an availability and accessibility of LCI data of building materials. Nowadays, the availability of environmental product declarations (EPD’s) for construction products, as well as the provision of accessible databases and tools can be considered as a progress towards this direction. For example, there are already comprehensive collections of construction product related EPDs from different countries that can be found catalogued on the web, such as the International EPD system [3], the IBU in Germany [4], or the Green Book Live in UK [5].

However, the availability of life cycle inventory data is more limited in Asia or America than it is in Europe, where LCA is practiced more widely. The deficiency in present databases in such countries leads to collection of data from other sources, such as product manufacturers (first party data, instead of third-party data). Another possibility for closing data gaps offers the I-O analysis [12]. The lack of readily available data makes the task of conducting LCA difficult for the architect or even for an LCA practitioner [13]. Also the assessment of the quality of the data set to be used is very important. For example, the report of GHG Protocol “Product Life Cycle and Accounting and Reporting Standard” lists important questions to use when selecting a database. Also a quality control of the secondary data chosen from the selected databases is necessary and can be achieved through the use of various quality indicators [14]. The analysis and evaluation of all these issues are part of the activities of the authors. Further information will be available on the website of Annex 57 (www.annex57.org).

Transparency and traceability of results
In many cases, the results of various embodied impact assessments cannot be directly compared with each other, as they might be based on different methodologies, assumption, boundaries, and calculation principles. Particularly it is even more difficult to compare the results when this information is not transparent or is only partially transparent. Especially in relation to the selection and application of indicators and system boundaries, there are still various views and approaches. One of the key tasks of IEA Annex 57 is to develop specific recommendations aiming at providing more transparency and traceability regarding different parameters influencing the results. One consistent way of defining the system boundary in terms of the included life cycle stages is by referring to the stages described in EN 15804:2012 and EN 15978:2011 (figure 1). The authors recommend that, where possible, embodied impacts from all life cycle stages should be considered (Cradle to Grave) for the building level. As a sub-information, the system boundary “Cradle to Handover” should be used. This can be also a minimum requirement, as it represents the initial embodied impacts of the building. Benefits and loads beyond the system boundary may be reported. If so, they shall always be reported separately.
The authors recommend the use of three different indicators for the quantification of embodied impacts: a) the consumption of primary energy non-renewable in MJ, b) the consumption of primary energy total (renewable + non-renewable) in MJ and finally c) the greenhouse gas emissions in kgCO$_2$eq. However, this alone is not sufficient to guarantee comparability of results. Additional information on the character and scope of each indicator is required, as for example information on the different sources of energy included in the first two recommended indicators, or the different GHG emissions included in the kgCO$_2$eq. For this purpose, specific tables have been developed by the authors to provide a detailed description of the definition and system boundaries of each recommended indicator. Specifically, the tables include the following information: (1) name of the indicator inside Annex 57, (2) also known as (different names used in literature), (3) name in LCIA (4) metric (5) target (6) definition (7) system boundaries (8) included modules in detail, and (9) unit. Furthermore, a specific reporting template has been designed providing the minimum documentation requirements for case studies in order for them to be comparable. Besides the database and data used for a case study, also the building components and products included, their service life, the method of materials quantification used, the reference study period and the different scenarios and assumptions made are considered important requirements, among others, that should be transparently documented.

**Recommendations for selected groups of actors**

To further improve the situation, the following recommendations are made by the authors:

- The architects should discuss intensively the topic as well as the use of tools and databases.
The methods of Life Cycle Analysis should be integrated into the education and training of designers in a more effective manner. It should be explained to them that they do not have to perform an LCA in the narrow sense, but rather just to combine information from the materials quantification with information from databases and interpret the result.

The scientists should evaluate and publish more case studies. There is a need for the development of reference values and benchmarks.

The industry should develop and publish EPD’s in parallel with the development of new products.

In the area of standardization, there is still a need on clear - adapted to the needs of the construction industry - definitions and system boundaries;

The developers of sustainability rating systems should integrate LCA based methods and benchmarks. The consideration of embodied impacts is a good starting point.

The description and assessment of embodied impacts requires the determination and listing of the type and quantity of materials needed for the building construction. This information can be re-used for the building file.

Procurement (e.g. green public procurement) and funding programmes should incorporate more than ever before embodied impacts considerations.

Summary and conclusions
Nowadays, the current international and European standards form the basis for a quantitative assessment of embodied energy and embodied GHG emissions. At the same time, the increasing integration of LCA into sustainability assessment systems and building labels, such as DGNB, SNBS or Green Star, helps to spread life cycle thinking even more among investors and architects. The consideration of embodied impacts in terms of energy and GHG emissions in the design and decision making process is the first step towards this direction. This is also propelled by the current availability and accessibility of appropriate data and the development of EPD’s. Comparing to the past the assessment of embodied impacts is now less time and cost intensive as a lot of information is already collected and stored in national databases worldwide. Besides data availability, transparency and traceability of the assessment results are important in order to ensure comparability of the results. This leads to the establishment of new requirements for all stakeholders in the construction industry to secure, on the one hand, the information flow and, on the other hand, the inclusion of embodied impacts in their decisions.

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References


