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Strategies for optimizing the environmental profile of dwellings in a Belgian context: A consequential versus an attributional approach

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ABSTRACT

To date, many tools and guidelines to reduce environmental impacts from a life cycle perspective are available concerning the construction sector. However, basically all of them are modelled according to an attributional approach and there is a lack of studies that develop strategies for improvement based on a consequential LCA. The goal of this paper is to analyze to what extent the results differ when both models are applied on the same case, a representative dwelling located in Niel, Belgium. A conceptual optimization scenario for insulated exterior cladding has been added as well to examine to what extent different models affect the ranking of improvement strategies. For both approaches, the same foreground data and energy calculations are used, but the underlying structure of the models is different. The starting point is an attributional scenario, based on a Belgian guidance document 'Environmental profile of building elements' (EPBE) published by the Public Waste Agency of Flanders. The results of the entire life cycle indicate differences between the approaches, in direct relationship to the underlying modelling assumptions. The discrepancy becomes more pronounced when looking at the separate materials so the effect is not damped as a consequence of the aggregation in life cycle phases. Especially the three most contributing materials (steel, concrete and brick) show clear differences. The optimization scenarios underline previous statement, since the ranking of the different solutions is not equal according to both approaches. This research points out the emergence of a discrepancy between results when different modelling approaches are applied. The consequential model that complements the attributional EPBE study is therefore a useful addition to provide information for decision-makers. This way, the right information is available for all type of decisions.

1. Introduction

1.1. General

The growing environmental awareness of the last decades resulted in identifying the construction sector as one of the major targets for improvement. The building sector is responsible for nearly 40% of the global energy consumption, 30% of raw material use, 25% of solid waste production, 25% of water use, 12% of land use, and 33% of the related global greenhouse gas (GHG) emissions (United Nations Environmental Programme and Sustainable Buildings and Climate Initiative, 2010, 2009). This awareness resulted in Europe in energy regulations such as Energy Performance of Buildings Directive (EPBD) 2002/91/EC and the revised EPBD 2010/31/EU issued by the European Union (European Parliament, 2010, 2002). But attention for the improvement of the environmental profile of construction materials and their waste treatment emerged as well and resulted for example in the development of Construction Product Regulations and the implementation of the European Waste Framework (European Parliament, 2011, 2008). But before any conclusions can be drawn about the environmental profile of buildings or their components,

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the environmental impact of the entire life cycle has to be investigated, based on the methodology of a life cycle assessment (LCA). This methodology is a commonly accepted way to assess the environmental impact of products or services. Despite the fact that LCA takes the entire life cycle into account, still many assumptions and methodological choices have to be made throughout a study, which can lead to different outcomes. Traditionally, attributional LCA (ALCA) and consequential LCA (CLCA) are considered to be the two main approaches, however, only in the last decade CLCA is becoming better known and more implemented (Zamagni et al., 2012). Over time, many definitions emerged describing the differences between ALCA and CLCA (Curran et al., 2005; Ekvall and Weidema, 2004; Weidema, 2003). In the general, ALCA is defined by its focus on describing the environmentally relevant flows within the chosen temporal window, while CLCA aims to describe how environmentally relevant flows will change in response to possible decisions. So in the case of ALCA, contributions are traced backwards in time, making use of data on specific or market average suppliers at a certain point in time. In the case of multifunctionality, impacts are allocated over the different outputs according to a certain ratio representing the relevant underlying causal relationship (EC-JRC-ies, 2010). CLCA on the other hand is market based and only takes the actual affected suppliers into account (Weidema, 2003; Weidema et al., 2009). Since economic forecasting involves a lot of uncertain factors, a scenario based approach is appropriate to provide robust results. This can be done on micro- or macro-level, where in the first case only the existing production capacity is affected while in the second case also changes in capital goods might occur (Weidema et al., 2009). The market based reasoning is also applicable on processes with multiple outputs. By-products are eliminated by including the counterbalancing products they substitute on the market, so allocation can be avoided by means of system expansion (Schmidt, 2015). This is also applicable on the end-of-life phase, with the discussion on how to take the benefits of recycling and reuse into account. In CLCA, the benefits are assigned to the end of the life cycle when recycled products replace other products on the market (recycling potential). In ALCA on the other hand, the benefits are often assigned to the selected materials (recycled content) (EC-JRC-ies, 2010). Since both approaches have their strengths and weaknesses, it is relevant to apply both, depending on the type of research questions.

1.2. Current LCA practices in the built environment

To date, multiple tools exist to support house owners, designers, architects and policy makers by providing information on the environmental profiles of dwellings and materials. Some of them are descriptive based rating tools that only follow the LCA methodology to a certain extent e.g., BREEAM (UK) (BREEAM International, 2013), others provide more detailed performance based environmental information on commonly used materials, e.g., Ecolizer 2.0 (BE) (Public Waste Agency of Flanders (2015)) and Nibe (NL) (Haas and Blass, 2015). All previous examples rely on the attributional approach, just like the most elaborated study in Flanders to date, 'Environmental profile of building elements' (EPBE) published by the Public Waste Agency of Flanders (Debacker et al., 2013a). The purpose of the latter is to assist designers, architects and building owners to reduce environmental impacts of a building over the entire lifetime at the design phase of the construction process by providing data on building components. EPBE (Debacker et al., 2013a) describes with an attributional modelling approach the current environmental profile of 115 building components. For identifying products that are on average produced with the lowest environmental profile, the approach of this tool makes sense. Provided that the allocation is done according to the drivers of the relevant environmental impacts. However when it is used for eco-design (so changes in future production are involved) or serves as basis for policy-making, the nature of the functional unit changes and it is necessary to take the consequences of such a decision into account. Especially in the Belgian context, but also in a broader international context, there is a lack of consequential studies concerning the construction sector to support the decision making (Blengini and Di Carlo, 2010; Buyle et al., 2013; Earles and Halog, 2011; Finnveden et al., 2009; Ramesh et al., 2010; Sharma et al., 2011).

Independently of the modelling approach, buildings however are special products that differ thoroughly from more controlled (industrial) processes. In the construction industry, a LCA study is therefore on average much more complex and uncertain because of multiple issues such as the long lifespan of the entire building, in combination with a shorter lifespan of some elements and components, the use of many different materials and processes, the unique character, design and geography of each building, the evolution of functions over time due to maintenance and retrofitting, etc. Therefore results of previous studies are not directly comparable, however still trends can be identified.

An overall trend is the dominance of the use phase, mainly with respect to space heating and cooling demands (Adalberth, 1997; Asif et al., 2007; Chau et al., 2015; Marceau and VanGeem, 2006; Matasci, 2006; Ortiz-Rodríguez et al., 2010; Peuportier, 2001). This is directly related to the long life span of buildings. Additionally, in low energy buildings also lighting and auxiliary energy can have an important contribution to the use phase (Blengini and Di Carlo, 2009; Debacker et al., 2013b). Most of the optimization scenarios focus on improving the level of insulation, complemented with high-performance technical installations. Blengini and Di Carlo investigated a low-energy dwelling in Italy and found that although the operational energy was 10 times lower compared to the reference standard house, the total environmental impact was only reduced by a factor two. Additionally, when the level of insulation and energy efficiency increases, the share of material related impacts increases, both in relative and absolute terms (Blengini and Di Carlo, 2009). Buyle et al. (2015) analyzed the influence of building type, level of insulation and different technical services in order to improve the environmental profile of Flemish dwellings. It was found that taking into account the current energy regulations, multiple non-hierarchic actions for improvement were relevant. A combination of a compact building design with one of the two following possible ways to reach a similar environmental optimum: firstly by following the current regulations for insulation complemented with the most efficient technical services, and secondly by an extensive reduction of energy losses - entailing a reduced (but not negligible) influence of the efficiency of technical services on the results. Himpe et al. (2013) come to similar conclusions for the Belgian situation by performing a LCEA. Another recent Belgian study by Stephan et al. (2013, 2012) pointed out that a passive house was preferable to a standard one, even if the embodied energy exceeds the operational energy in the passive scenario.

So when energy consumption is reduced, the reduction of impacts related to materials deserves more attention. However, there is no consensus on how this should be achieved, on neither of the level of materials or structural systems. For example, some studies assign a lower impact to dwellings composed of renewable materials such a wooden timber frame structures, while others conclude that because of the higher land use of wood, massive structures (brick, concrete, steel) have a lower environmental impact (Bawden et al., 2015; Feiz et al., 2015; Gerilla et al., 2007; Marceau and VanGeem, 2006; Mithraratne and Vale, 2004). Also building