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# CHALLENGES FOR THE USE OF LIFE CYCLE ASSESSMENT AS A DECISION-MAKING TOOL IN BUILDING DESIGN – THE WÄLLUDEN CASE STUDY

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## ABSTRACT

The construction sector accounts for almost twenty percent of the global carbon emissions, so measures to decrease the carbon footprint of constructions should be introduced during design. A full LCA was conducted for eight different designs for a four-storey multi-family building. The methodology was tailored for a designer's perspective to identify challenges for the use of LCA by non-practitioners. Results show that the selection of building system does not influence the results, as does the use phase energy efficiency or the selection of materials. The production phase becomes more influential with increased use phase energy efficiency. Results suggest that either an increased knowledge of sustainability tools among designers or further simplification of the tools, standards and guides available is required.

## INTRODUCTION

Society is heavily dependent on fossil fuels, with rising concerns about environmental impacts such as climate change (IPCC, 2007). The construction sector is responsible for a large share of society's greenhouse gas emissions. Currently, around 33% of the global greenhouse gas emissions from human activities can be attributed to the building sector (UNEP, 2007). Safe housing is a basic need for mankind, which means there is a strong need to decrease these emissions while still building enough housing for the growing world population and contributing to economic growth. All this calls for measures towards a more sustainable built environment. Environmental criteria should be involved in construction projects as early as in the construction stage. In order to do this, designers have different tools such as standards, software tools such as SimaPro, VIP+ or GaBi, ready-made databases such as Ecoinvent or ILCD, and environmental product declarations (EPDs). Life Cycle Assessment (LCA) is a well-accepted tool for analysing the environmental impact of design alternatives using a life-cycle perspective (Baitz et al, 2013; Guinée et al, 2011). It provides a fair idea of the environmental impacts related to each life cycle stage of a building, which is often used to identify the environmental "hot spots" of a product's life cycle.

## METHODOLOGY

A cradle-to-grave LCA was performed. The methodology of the assessment was tailored for a designer's perspective to identify challenges for the use of LCA among non-practitioners by using easily available data. The production of wood materials was modeled using EPDs inventoried by SP Wood Technology (formerly as Trätek) with the Swedish wood industry. For other materials, external EPDs, literature data (Björklund and Tillman, 1997; IISI, 2001) and existing databases such as Ecoinvent and ELCD were used. The use stage energy requirements were modeled by Linnaeus University (as part of the €CO2 project) using the VIP+ dynamic simulation software and environmental data reported by Växjö Energi AB, the local energy supplier. A square meter of living area was assumed as the functional unit, and a service life of one hundred years was used. Only carbon footprint was used as an indicator.

The effects from concrete carbonation phenomena were included in the analysis, following a methodology developed Lagerblad (Lagerblad, 2005). Ecoinvent data was used to model the waste treatment processes, assuming that 70% of the waste is recycled or reused and the remaining waste goes to treatment processes, while 90% of the wood waste is used for energy production. These carbon implications are explored applying a substitution effect, assuming that the energy produced from the wood waste will replace fossil fuels. The storage of carbon dioxide in wood products is displayed to illustrate the possibility of potential additional benefits from the temporal storage of carbon. Further details for the assessed designs are described in SP's research report 2013:07 (Peñaloza et al, 2013).

## RESULTS

The results for the greenhouse effect impact category are displayed in figures 1 and 2. The contribution from different kinds of materials to the total carbon footprint of the production phase can be observed in figure 1. Meanwhile, figure 2 shows the carbon footprint for the whole life cycle of each of the analyzed designs. The results are distributed per life cycle stage, a distribution which is aligned with the module division in the EN 15978 standard (CEN, 2011). The results displayed under "Module D" correspond to the environmental benefits from the end-of-life scenario in which all the bio-based products are incinerated to produce energy, and this energy replaces energy from coal described in the previous section.

## DISCUSSION

The main differences between the carbon footprints of the evaluated design alternatives come from the selection of materials in the production phase and the use phase energy demand. The completeness of the study ensures that every life cycle stage is included to some extent, and as many processes as possible are included. Identifying these influential aspects is possible during data collection, but this identification requires certain level of expertise in the LCA field. The difference between the evaluated systems is case-specific, as not every decision in the designing process is related with material selection or energy efficiency standards. Other variables such as construction method, selection of suppliers, the level of prefabrication or architectural design may be more important for other cases or circumstances.

Involving every life cycle stage favors the completeness of LCA, but it increases the amount of time and resources required to obtain a result. The evaluation of design alternatives requires often a more practical approach of LCA, a method which provides faster results with minimum input, so as many design alternatives as possible can be evaluated. This is the case especially for buildings, as they are complex systems involving different processes and systems. This is why completeness might not be very relevant for this kind of application of LCA tools. Instead, short and fast LCAs should be applied with focus on the processes and life cycle stages affected by the differences between the evaluated alternatives. Moreover, the use of existing LCA standards in the design process presents a certain challenge, as standards tend to favor completeness over practicality. This is due to the fact that existing standards are made by experts and intended to be used by experts, which excludes designers from using standards as a tool in LCA practice for decision-making.

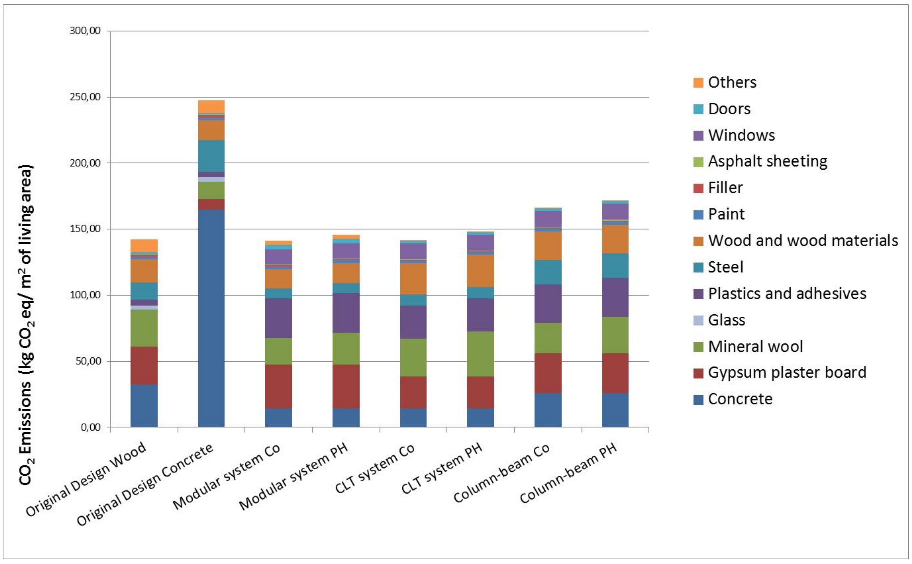


Figure 1. Greenhouse effect for the production phase of the eight design alternatives.

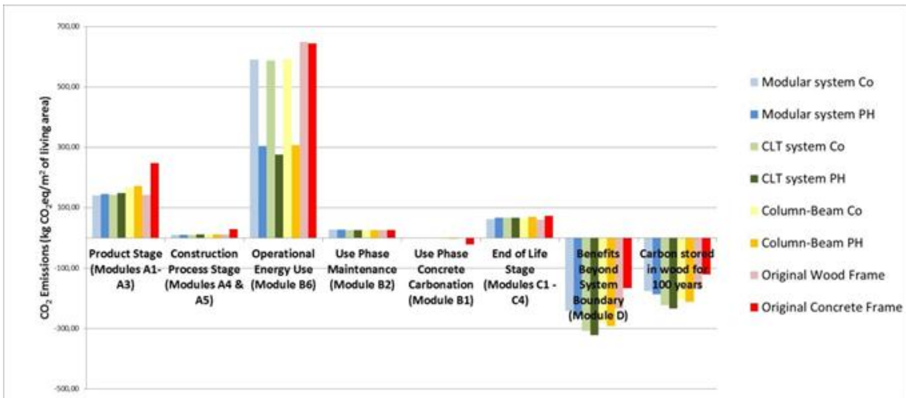


Figure 2. Greenhouse effect for the whole life cycle of the eight design alternatives.

## CONCLUSIONS

In order to use LCA tools for decision-making during the design of construction projects, the scope of the assessment should be defined with focus on the differences between the evaluated alternatives rather than the completeness of the evaluated system. There is currently a gap between designers and the use of LCA during design. In order to close this gap, it is required either an increased knowledge of LCA practice among designer teams or further simplification of the tools, standards and frameworks available for them to use in the process. Other challenges identified for designers are product data availability and interpretation, uncertainties over service life of buildings and materials and the interpretation of results from existing ready-made LCA software tools.

Regarding the LCA results, they show that for more energy efficient building designs or buildings supplied from energy systems with lower carbon footprint, the production and end of life stages are highly relevant. The use of wood and bio-based materials can significantly decrease further the carbon footprint of energy-efficient buildings. This potential can be seen in the production stage, the construction activities and the end-of-life stage. Furthermore, buildings with a higher content of wood materials have higher potential environmental benefits beyond the end-of-life from using them for energy recovery. The choice of wood building system does not seem to have a major influence in the results.

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