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Basic building life cycle calculations to decrease contribution to climate change – Case study on an office building in Sweden

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A B S T R A C T

This study examined whether simplified life cycle-based calculations of climate change contributions can provide better decision support for building design. Contributions to climate change from a newly built office building in Gävle, Sweden, were studied from a life cycle perspective as a basis for improvements. A basic climate and energy calculation tool for buildings developed in the European project ENSLIC was used. The study also examined the relative impacts from building material production and building operation, as well as the relative importance of the impact contributions from these two life cycle stages at various conditions.

The ENSLIC tool calculates operational energy use and contributions to climate change of a number of optional improvement measures. Twelve relevant improvement measures were tested. The most important measures proved to be changing to CO_2 free electricity, changing construction slabs from concrete to wood, using windows with better U-values, insulating the building better and installing low-energy lighting and white goods. Introduction of these measures was estimated to reduce the total contribution to climate change by nearly 50% compared with the original building and the operational energy use by nearly 20% (from 100 to 81 kWh/m^2 yr). Almost every building is unique and situated in a specific context. Making simple analyses of different construction options showed to be useful and gave some unexpected results which were difficult to foresee from a general design experience. This process acts as an introduction to life cycle thinking and highlights the consequence of different material choices

1. Introduction

The European Union has agreed upon climate targets to decrease the emissions of green house gases by 20% by 2020 and 50% by 2050 compared with the 1990 level [1]. Over and above that, the Swedish Parliament has decided that fossil fuels for heating purposes must be phased out by 2020 and that emissions of CO_2 must be reduced by 40% compared with 1990 (Swedish National Environmental Objectives) [2,3]. The building and property sector is regarded as an area where there are large possibilities to reduce energy use and contributions to climate change.

In Sweden, the building and property sector (including heating) emits around 15 Mton CO_2eq/yr, which constitutes approximately 20% of the total Swedish green house gas emissions [4]. To date, in some countries such as Sweden, the policies and building sector strategies have focused almost entirely on the building use stage in attempts to reduce the energy use and the contributions to climate change. This priority is supported by many case studies in which environmental impacts throughout the building life cycle have been calculated e.g. in studies studying on new office and residential buildings [5–7] and showed that about 80% of a building's total impact comes from the use stage. However, the variation between buildings is large. A review of case studies by Sartori and Hestnes [8] showed that in conventional new office and residential buildings the use stage accounted for 62–98% of the energy use over the life cycle, while in low-energy buildings, the use stage accounted for 54–91%. In a study on contributions to climate change, Marsh et al. [9] found that the use stage accounted for 40–95% in a number of different new, buildings in Denmark.

However, especially with the recent increase in interest in low-energy buildings, a number of studies have highlighted the importance of the environmental impact caused by construction material production [10–14]. For example, Ding [13] showed that in

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Australian secondary schools the embodied energy amounted to nearly 62% of the operational energy over the building's 60-year life span. Other studies indicate that the embodied energy equals the operational energy in 15–37 years [15–19]. In these studies it is clear that the embodied energy (including both initial and recurrent embodied energy) has a significant impact on the total energy use of the buildings studied. This relative impact increases with shorter calculated life span since the total impact from materials is distributed evenly over the life time. It means that the yearly impact from materials decrease with prolonged life time while the impact from building operation stays the same. The larger the proportional impact of material production is, the more evident their importance becomes and the influence of material choice. When efforts to reduce impacts from building operation have been made the next step to reduce the overall building impact is to reduce impacts from materials which demand an analysis also of the material production stage and starts a process of life cycle thinking.

Green house gasses and especially CO_2 emitted from buildings is mainly related to use of fossil fuels and refrigerants i.e. energy use for heating and cooling. As noted above, energy saving in the use of buildings is often the main focus in policies trying to reduce the contributions to climate change from the building and construction sector. However, depending on the local/national energy system, such a strategy may not always be successful. For example, of the contributions to climate change related to the building and construction sector in Sweden, only 4% are estimated to be related to heating of all buildings in Sweden [4]. The main reason is the extensive district heating network in Sweden, which is now predominantly based on renewable energy sources. Such contexts increase the argument for using a life cycle perspective, not only considering the buildings use stage, when trying to reduce the contributions to climate change from buildings.

So far the inclusion of a life cycle assessment (LCA) in design of new buildings has been not used in Sweden. LCA methodology is often regarded as being too complicated, data- and knowledge-intensive and time-consuming [20]. There is also scepticism owing to the complex results, poor accuracy, problems regarding interpretation of results and the cost of performing LCA [21].

One way to introduce life cycle considerations into the design and management of buildings is by making the analysis more user-friendly and by illustrating how the results can be used as decision support. In the European Union project 'Energy Saving through Promotion of Life Cycle Assessment in Buildings' (ENSLIC), nine countries have been working with developing guidelines and examples on how LCA can be used as decision support in early design phases [21]. Within that project, a basic Excel tool has been developed which calculates energy use and CO_2 equivalents from operational energy and building material production. A certain sheet is devoted to explore gains from different kind of improvements made on an original building design. Production of energy conversion plants/devices are taken into account but not transports and losses at distribution. 21 pre-designed improvements measures are available covering building form (2), building envelop (7), energy saving equipment (5), energy supply (6) and building life time (1). Default values can be applied for electricity and hot water use.

In the present study this ENSLIC tool was used to study an office building in order to exemplify how simplified LCA calculations can provide input to building design and to examine the relative importance of operational stage contra the material production stage in different contexts. The methodology used and the results obtained may be useful for further simplifications of building-related LCA applications.

2. Aim

The aim of this study was to examine how energy use and climate change contributions can be reduced by decisions taken in early building design phases. This was achieved by exploring different improvement measures on an existing building with the basic ENSLIC tool. Special attention was paid to the impact from building materials in relation to the impact from operational energy.

3. Method

The estimation of operational energy use and contributions to climate change in early design phases is illustrated by an example based on a office building from 2009. Additional similar buildings are planned in the same geographical area and the question has arisen of how to increase the energy efficiency and reduce the contribution to climate change in these planned buildings. The ENSLIC tool was used to test potential building improvements.

3.1. *The basic climate and energy tool*

The Excel tool used was originally developed in the European ENSLIC project[1] [21] and a Swedish research project funded by the Swedish Research Council Formas. The version used here is a further development. The aim of the tool development was to include a minimum of what would be necessary to regard it as an LCA, which was expected to include at least two life cycle stages (material production, energy for operation), one impact category (climate change) and service life time. The intent with making a rough tool was also to introduce life cycle thinking and application to building designers. It allows straightforward, calculations of the resulting operational energy use and the contribution to climate change of different technical solutions that may be considered in the design phase. Such calculations can also be useful for setting and evaluating environmental targets in early design phases.

Only the dimensions of the future building envelope and a few basic data (location, etc.) are needed to start exploring how to reduce the operational energy use and the contributions to climate change. The first two options concern changes in the building form while maintaining the same floor area. These are followed by seven options to improve the heat resistance in the building envelope and a further five options to add energy saving equipment. Finally, there are six options available to choose a less polluting energy supply. Sometimes the tool includes pre-set percentage savings for a measure.

The exploration procedure can start with an existing building that is to be retrofitted. If no existing building is available, it is possible to only insert data on the desired net floor area and select a pre-designed construction in wood or concrete in the model. All the construction layers may then be changed if desired. The anticipated life span of the building and its components can be varied.

3.2. *Calculations on the case study building*

3.2.1. *Life cycle stages*

For buildings, the CEN/TC 350 'Sustainability of Construction Works' working group recommends consideration of four life cycle stages: product stage (raw materials supply, transport and manufacture), construction stage (transport and construction–installation of on-site processes), use stage (maintenance, repair and replacement, refurbishment, operational energy use: heating, cooling, ventilation, hot water and lighting and operational water use) and

[1] http://circe.cps.unizar.es/enslic/texto/pub.htm.