Analysing the cumulative energy demand of external bearing walls

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Abstract. The assessment of environmental properties of buildings is now commonly using a life cycle analysis (LCA). Due to the rapidly evolving construction industry, LCA research is carried out in many areas, from building materials and components to overall building system. Life Cycle Assessment (LCA) is a tool used to compare environmental impacts along the life cycle of products or services. This paper presents an evaluation and comparing of two external bearing walls of different material compositions regarding the materials’ total energy consumption within the cradle to gate boundaries. Impact categories were calculated by the software SimaPro using Cumulative Energy Demand (CED) method and applying the Ecoinvent database. A renewable (biomass, wind, solar, geothermal, water) and non-renewable (fossil, nuclear, biomass) energies were under consideration. The composition with brick as a core wall material achieved worse results in all categories than the wall composition with aerated concrete block.

1. Introduction

The construction industry and the built environment is important contributor to economic and also social development. These parameters represent a large proportion of capital in most countries and it is a primary source of environmental impacts too. In addition, existing buildings require continuous investments in repairs and renovations [1].

Due to the price crisis, energy analysis of products as well as processes involving the supply of energy itself began to be carried out by scientists at the start of the 70 years. In a publication called 'Handbook of Industrial Energy Analysis' has reached the peak. This handbook consists of energy requirements tables for about 400 industrial processes [2]. Nevertheless, energy consumption as well as pressure on the environment continued to increase. In the late 1960s and early 1970s was stylized the idea of a comprehensive LCA at the American Midwest Research Institute (MRI), while nearly identical ideas were developed in Europe at approximately the same time [3]. Resource and environmental profile analysis: a life cycle environmental assessment for products and procedures [3, 4].

Today, this assessment method is considered an important methodology to quantify the environmental impacts of the life cycle of products and services [5]. Cumulative energy demand (CED) or also primary energy consumption is one of the key indicators that have been solved since the first studies LCA. This impact assessment method is now quantified in studies, which is based on life cycle assessment [6].

The International Organization for Standardization (ISO) 2006a, b) [7] do not require or address the energy consumption indicator. However, the European Standard EN 15643-2 and EN 15978 address the sustainability of construction works (EN 15643-2 and EN 15978) [8, 9] and also the European Standard on environmental product declarations (EPD) deal with energy consumption with 9 indicators (EN 15804) [10]. Although this method is often used, there is no (does not exist) harmonized approach. The
cumulative energy in the above standards and guidelines is defined in a different way [11]. In addition, it is still under discussion whether the CED as an indicator of impacts belongs in the life cycle assessment or only in the life cycle inventory [5].

The paper presents the results of an evaluation of two external bearing walls of different material compositions regarding the materials total energy consumption (CED) within the cradle to gate boundaries.

2. Material and methods
This study focused on evaluation of two material alternatives of external bearing walls (table 1). The first analysed wall (A) consisted of 300 mm thick brick and the expanded-polystyrene thermal insulation with graphite (EPSg), (thickness of this insulation was 120 mm and bulk density 28 kg/m³). The second analysed wall (B) consisted of 400 mm thick aerated concrete block (AC) with the same thermal insulation of thickness of 70 mm and bulk density 28 kg/m³. The other components were the same for both variants. The scheme of the material composition of the walls is illustrated in figure 1.

![Figure 1. Scheme of external bearing wall.](image)

Material composition of the analysed walls are described in table 1.

| Wall alternative | Density [kg/m³] | Thickness [mm] | Weight [kg] | Interior Layer | Core | Thermal Insulation | Exterior Layer |
|------------------|----------------|----------------|-------------|----------------|------|-------------------|----------------|
| Wall A           | 2000           | 15             | 30          | Lime–cement plaster | Brick 300 mm | EPSg | Silicate plaster |
| Wall B           | 2000           | 10             | 20          | Lime–cement plaster | AC 400 mm | EPSg | Silicate plaster |

The impact assessment method Cumulative energy demand (CED), which is available in Software SimaPro was used for the quantification the environmental impacts. This method includes both energies (direct and indirect) that are associated in all life cycle processes of material, i.e. the energy needed to extraction of the material, manufacturing, use phase and disposal. [12, 6].
The functional unit was established of 1m² of the structure. The objective of the LCA was a cradle-to-gate assessment. The idea of sustainable design of buildings, their construction and operation in the management and construction sectors needs improvements adapted to the current demands and requirements at all stages of the building's life. Building life is a set of interrelated processes. The first step is an initial architectural and construction solution that leads to real construction and subsequent maintenance, inspection and, last but not least, renovation or demolition.

In accordance with building regulations on the basis of lifespan, requirements have been generated in terms of the basic spheres of society (social, economic and environmental) issues related to high-efficient energy-saving building systems [1]. In this study, the lifespan was considered of 50 years for the core materials and thermal insulation, and 25 years for both the exterior and interior plasters. In practice, however, the lifetime of construction products is shorter than had been designed for [14]. The calculations were performed using software SimaPro based on LCA analysis and Ecoinvent database [15].

2.1. Cumulative energy demand (CED)
The method was applied to calculate the energy impacts of the constructions. This method has a long tradition. It has been developed in the early seventies after the first oil price crisis [12].

The CED methodology can be understood as a screening indicator for environmental [16]. It is also possible to compare the results of the CEDs with the results of a detailed LCA study that only covers primary energy demand. The plausibility check can be performed based on the final results of the CED. In this case, it is easy to determine if there were any serious errors or not [17]. In the Ecoinvent database, the CED method is divided into eight categories (see table 2), because there are different concepts of perception of this method and also an unclear basis for characterizing the different carriers of primary energy [18]. The table does not contain any aggregate values.

| subcategory        | includes                                      |
|--------------------|-----------------------------------------------|
| non-renewable      | fossil                                        |
|                    | hard coal, lignite, crude oil, natural gas,   |
| resources          | coal mining off-gas, peat                     |
|                    | nuclear                                       |
|                    | uranium                                       |
| renewable          | primary forest                                |
| resources          | wood and biomass from primary forests         |
|                    | biomass                                       |
|                    | wood, food products, biomass from agriculture,|
|                    | e.g. straw                                    |
|                    | wind                                          |
|                    | wind energy                                   |
|                    | solar                                         |
|                    | solar energy (used for heat & electricity),    |
|                    | geothermal                                    |
|                    | geothermal energy (shallow: 100-300m)         |
|                    | water                                         |
|                    | run-of-river hydro power, reservoir hydro     |
|                    | power                                         |

Common to all categories is the thesis that all energy carriers have an intrinsic value. This intrinsic value is determined by the amount of energy taken from nature. The unit of all categories was MJ.

3. Results and discussion
LCA quantification of all impacts of the entire energy supply chain, represented by the cumulative energy demand (CED) for the production of buildings materials in the present study, which were used in the external bearing wall, is presented in figure 2.
The CED method involves the use of both energy sources (renewable and non-renewable). Figure 2 presented the results of the environmental impact of 1m$^2$ of the external bearing wall materials, with brick and aerated concrete as a core material. The figure shown, that the wall composition with brick was in all categories worse, then with using the aerated concrete. This is due to the manufacturing process, because the brick needed more energy and raw materials during extraction and production phase. In the category non-renewable fossil and renewable biomass show the results bigger differences as in other categories. It means, that these two categories have the greatest impact on overall results. The smallest negative impacts on the environment were recorded in the category non-renewable biomass for both alternatives. The lowest values and therefore the smallest negative impact for environment achieved the category non-renewable biomass.

The comparison of technical parameters (weight and thickness of the analysed walls) and calculated energy indicators of the material alternatives are presented in figure 3. The accessory values are expressed as percentage shares of the overall values.
As can be seen in figure 3, option B was presented as a better option than A, even considering the technical parameters such as weight and thickness.

4. Conclusion

Life Cycle Assessment (LCA) is a tool to better understand the various aspects of product development and its potential impact throughout the product lifecycle, which means from cradle to grave. The cradle-to-grave boundary encompasses all processes from raw material acquisition, processing, production, use and final disposal of materials. The lifetime of a building is influenced by several factors. This factors includes market demands and lifetime of building materials be it reconstruction or demolition, which results in a reduction in the life of the building. The lifespan in this paper was considered of 50 years for the core materials and thermal insulation, and 25 years for the plasters. A LCA study of the environmental impacts of the construction of external bearing wall with brick (A) and aerated concrete block (B) were compared in this paper. Based on the results, the option B was shown as a better alternative than A.

5. References

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