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A life cycle energy analysis of social housing in Brazil: Case study for the program "MY HOUSE MY LIFE"

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ABSTRACT

The Brazilian government has started up a large social housing program for low-income families. Considering the large investment for this program, it is important to analyse the environmental impact to create a base for further improvement assessment. The goal of this paper is to visualise the energy use (embodied and operational) during the life cycle of case study for a house in the social housing program. The case study showed that the embodied energy (EE) is 7.2 GJ/m^2 or 30% of the total energy from the life cycle, the operational energy is 17.5 GJ/m^2. Half of the Embodied Energy is due to material use for maintenance and around 57% of the embodied energy is used in the wall construction. Compared to other international studies (5.8 GJ/m^2 per 50 years), the embodied energy is relative high (7.2 GJ/m^2 per 50 years) whereas the operational energy is only the half (17.5 compared to 36 GJ/m^2 per 50 year). The study indicates that the largest improvement potential for reducing the embodied energy is connected to the walls trough choosing materials and systems with less Embodied Energy and higher durability to decrease the need for maintenance and substitution of materials.

1. Introduction

1.1. Embodied energy and energy use in the construction sector

The concern for the environment and a sustainable future has gained more and more attention the last few decades. The problems like ozone layer depletion, waste accumulation, global warming, among others have become daily topic in all areas of the society. One of the most significant sectors in this context is the building sector because of the large consumption of resources and generation of waste and environmental harmful emissions [1]. To move into a more sustainable direction, there is a strong need to mitigate the use of scarce resources and minimize undesired and harmful emissions.

Energy is one of the most important resources used during a buildings lifecycle, as an example, approximately 50% of the total energy consumption in Europe is accounted for by the building sector [2] and worldwide 30–40% of all primary energy is used in buildings [3]. Energy use often has serious environmental impacts, both locally and globally [4]. This is due to the fact that most energy is generated using fossil fuels, resulting in large amount of emissions of for example CO_2. Therefore, an overall reduction of energy use in the building sector can be seen as an important goal in most places.

1.2. The situation in Brazil

In Brazil, the use of energy have been growing rapidly the last decades and can be expected to increase in the future, following the current development, see Fig. 1 Even though Brazil has a quite clean energy matrix (48% renewable) [5] compared to the world average matrix (17% renewable) [6], it is of concern to reduce the energy use. It can also be seen that the main source for the increase is based on fossil fuels (oil). The building sector in Brazil is not different from Europe when it comes to significance on environmental impacts and energy use. Approximately 44% of the energy and 75% of the natural resources is consumed in this sector [7]. However, the type and composition of the residential houses differ significantly.

Brazil has a rapid developing economy, which also influences the building sector. The sector for building materials can be expected to be doubled between 2010 and 2022 [8]. Further, there is a currently deficit of homes, around 7.2 million [9], mostly for people with a low income (73% of the households in Brazil have an income under 1200 Euro per month [10]). However, because of an expected increase in population the deficit in the coming decade could be expected to be far over this number [8]. To deal with the problem, the Brazilian government has started up a large program for social housing with the name "Programa Minha Casa Minha Vida" (Program my home my life). In the period 2008–2014, at total of 3 million homes is

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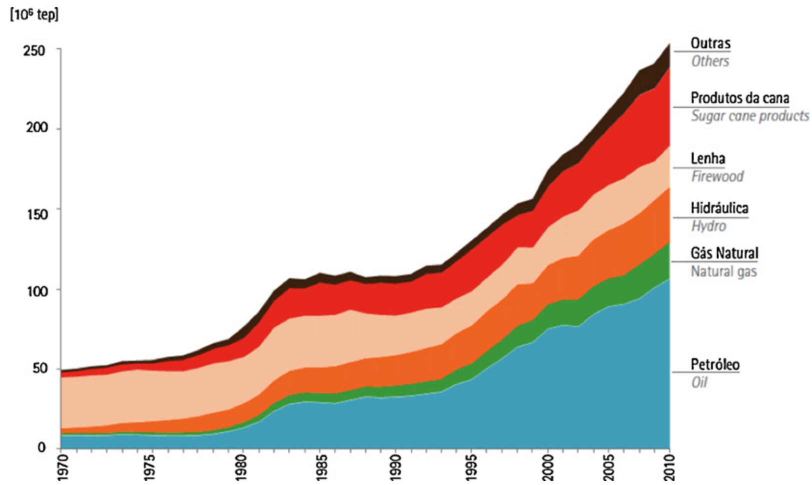

Fig. 1. Energy production in Brazil 1970–2010.

planned to be constructed primary for the group of families with income under 1200 Euro per month.

Some national studies of embodied energy in social housing (included a prototype building) [11], and energy in housing in five different types of standard houses [12] have been carried out. However, there still is a need to develop more research in this area, with focus on social housing and energy use in all the life cycle phases. Considering the large investment for this program it is important to analyse the environmental impact to get an overview of the magnitude and create a base for further improvement assessment.

1.3. Goal

The goal of this paper is to visualise the energy use (embodied and operational) during the life cycle of a case study for a Brazilian house in the low-income segments. The whole life cycle will be considered (pre-use phase, use phase and post-use phase) but the focus would be on the pre-use phase and use phase where most effort and resources has been used to analyse an existing case. The result from this typical Brazilian house from a social housing program will be compared with other international studies to see if it has a significant higher or lower energy use or embodied energy in an international context. This could then further indicate if there is a significant improvement potential in any of the life cycle phases and create a base for further improvement analyses. Sequential, more in-depth analyses along the life cycle could then be carried out in other studies.

2. Concepts about life cycle energy analysis (LCEA)

Several tools exist for analysing and minimizing environmental impacts, one of these are Life cycle assessment (LCA) [13,14]. One of the strengths of the tool is that the whole life cycle is taking into account and thereby minimizing the risk of just moving an environmental impact from one part of the life cycle to another. Unfortunately, the requirement for data is often very comprehensive if the most common impacts have to be included and thereby making it very complex to carry out a full LCA e.g. for a building which normally include an extensive amount of materials. However, several studies have shown that simplifying the study to only analysing the use of energy, as an indicator for environmental impact, is quite effective because it is the energy production that generates most of the emissions and also the use of most non-renewable resources (like coal, oil, gas, etc.). Therefore, life cycle energy analysis (LCEA) are commonly used in the building sector see e.g. [15] and [16].

The LCEA is based on the methodology used for Life Cycle Assessment according to the international standards [13,14]. However, the impact assessment part is reduced to only concern energy use as an environmental impact midway indicator. The LCEA accounts for all the energy inputs to a building in its life cycle including the following phases: Pre-use, use and post-use.

The pre-use phase include all impacts until the building is constructed and ready to use. It normally includes stages like extraction and manufacturing of building materials, transports of materials to the construction site, and the construction process (inclusive waste generation). This part is regarded as the *initial embodied energy*.

The use phase encompasses all activities related to the use of the building. This normally includes stages like maintenance and operational energy. The energy used for maintenance origins predominately from the use of material for substitution or surface treatment and is calculated the same way as for materials in the pre-use phase. The energy use is however placed in the use-phase as *recurring embodied energy*. The embodied energy is the sum of initial embodied energy and recurring embodied energy (which occurs in two different phases of the life cycle). The other part of the use phase is the *operational energy, which* in normal cases represents by far the most significant amount of energy use [15,16], caused by the demands for heating and cooling during the life time of the building.

The post-use phase is the end-of-life treatment of the building, normally including the demolition on site, transportation of waste to landfill and eventually recycling of materials. In this stage it is possible to regain some of the embodied energy by allocating embodied energy in recycled materials into new systems [17,18]. The life cycle energy is finally calculated as the sum of the three phases

Energy studies like LCEA provide a basis for further improvement assessment, like choosing materials with less embodied energy, decrease operational energy, recycling of materials, etc. Knowing the energy use trough the whole life cycle gives a picture of where the most beneficial improvement potential exists.

2.1. Energy calculation in a LCEA

According to the LCA-standards [13,14] it is desirable to calculate all energy as primary energy. Primary energy is the energy form found in nature, which has not been subjected to any conversion or transformation process, like un-extracted oil in the nature.