An Embodied Energy Analysis of Social Housing in Brazil: Case Study for the "Program My House My Life"

Sposto, R.M. Paulsen, J.S.

***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 embodied energy 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. 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. 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.**

***Index Term*— Embodied energy, case study, social housing, Brazil**

I. 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].

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.

Sposto, R. M. is a professor doctor at Department of Civil Engineering, University of Brasília, Brazil. E-mail: rmsposto@unb.br.

1.2. The situation in Brazil

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 [5].

There is a currently deficit of homes, around 7,2 million [6], however, because of an expected increase in population the deficit in the coming decade could be expected to be far over this number [7]. 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 planned to be constructed primary for the group of families with income under 5 SM per month.

Some national studies of embodied energy in social housing (included a prototype building) [8], and energy in housing in five different types of standard houses [9] 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, scope and limitation

The goal of this paper is to visualise the energy use for a Brazilian house in the low-income segments. Only the first part of the life cycle will be considered (pre-use phase) together with materials used for maintenance.

The scope of this paper is the embodied energy in the pre-use phase considering the lifetime referring to the various elements of the house. This could indicate if there is a significant improvement potential in any of the building parts 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. The data collection for materials is based on national literature studies. However, even international data has been used when there have been a lack of national data.

II. Concepts about Life cycle Energy Analysis (LCEA)

Several tools exist for analysing and minimizing environmental impacts, one of these are Life cycle assessment (LCA) [10], [11]. However, 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 [12] and [13].

The LCEA is based on the methodology used for Life Cycle Assessment according to the international standards [10], [11]. However, the impact assessment part is reduced to only concern energy use as an environmental impact midway indicator.

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 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).

Energy studies like LCEA provide a basis for further improvement assessment, like choosing materials with less embodied energy.

III. Description of the case study, Minha Vida Minha Casa

An inventory of a real house from the MCMV-program has been performed through a case study realized in the centre of Brazil, near Brasília, provided by a local construction company It is a single-family house (fig 1 and 2) with an internal area of 48 m^2. The house has two bedrooms, a living room, a kitchen and a bathroom. At the back of the house there is a small outdoor service area with a sink. The house has two external doors, three internal doors and five windows. The conventional system would be with ceramic blocks without structural function (but with reinforcements such as small pillars and beams with concrete elements), however, in this case the block has a structural function, removing the need for further structural elements. The main systems like masonry, roof, floor and windows are included according to table 1.

Table 1

The foundation is not included in the study, because it depends of the strength of the soil. Also, the installation has not been included due to lack of data on quantities (cables for electricity, tubes for hydraulic system). However, the quantity of this fraction of materials can be considered quite low because of the sparse installations in this type of housing

Fig 1

IV. Methodology

4.1 Functional unit

The functional unit should be chosen so it is comparable with other studies. In this case a standard house with an internal floor area of 48 m^2 with the service life of 50 years have been studied and used as the reference unit.

4.2. Data collection

Ten material groups has been inventoried, seven with national data [14], [15], [16] and [9] and three with data from Portugal [17].

The data are cradle to gate data, i.e. extraction of raw materials, transports, processing into building product, the gate being the factory gate with a product ready to use.

4.3 Studied system

The studied system includes two phases, which are further divided into 5 stages according to table 2.

Table 2

4.3.1 Pre-use phase

According to table 2, there are 4 stages included in this phase. Stage 1 and 2 are extraction and production of materials and building products including all processes until the factory gate of the manufacturer.

For the construction, the energy use for the rising the building has been regarded as insignificant. These types of building are commonly produced by hand. However, a significant part of the embodied energy can be found in the spillage of materials during the construction process meaning that an extra percentage of materials have to be produced just to be transformed into waste in the construction process. It is assumed that the spillage is transported 20 km to the nearest landfill. Data on spillage in Brazil has been found in [18], [19] and [20] and can be up to 25% depending on type of material. Some of the major reasons for spillage are due to lack of adequate packaging and transportation, and especially for social housing, the storing and management of materials on the building site is a problem [21].

4.3.2 Maintenance

The Embodied Energy from maintenance is during replacement of material and repainting and depends on the maintenance plan and estimated intervals for maintenance. Data from Brazilian building standards have been used to estimate the maintenance intervals expressed as service life for the building products used [22]. The minimum requirements according to the standard are 40 years for external walls, 20 years for internal walls and roof and 13 years for the floor covering. Windows and door are estimated to 40 years.

These service lives require a frequently maintenance of the walls (internal and external). It is estimated that these surfaces need a lighter repainting every 2 years and a more comprehensive repainting every 10 years. The windows and external doors also need a more frequently repainting but the small areas make the impacts insignificant in this context and are therefore excluded from the analysis. The energy use for the working process is assumed to be mainly performed by hand and regarded as negligible.

V. RESULTS

5.1 Embodied energy from material use

In the given case study, the embodied energy from the pre use phase could be estimated to round 184 GJ where the transportation constitute 15 GJ and waste (spillage) 17 GJ. The maintenance had an embodied energy round 183 GJ. Totally, the embodied energy is 367 GJ distributed according to Fig. 3.

Fig 3

The share en the different building parts is shown in figure 4. It can also be seen that the walls contains 57% of the total embodied energy, the roof 26%, the floor 10% and the windows and doors 7%

Fig 4

VI. DISCUSSION

In this case study where the maintenance are carried out according to the building standards, to guarantee the performance of the building it showed that the amount of the embodied energy for maintenance ended up to be in the same range as for the initial embodied energy. This indicates that the planning and performance of the maintenance are very important. For this type of social housing the responsibility for maintenance lies on the house owner but it is still possible to prepare information or a manual for maintenance to increase the likelihood of a good maintenance.

The durability of the systems is very important due to influence of the maintenance. This means that when materials and components are specified with a recognised quality and durability, it results in building elements with a longer use phase, and therefore less embodied energy for maintenance. Obviously, the application of the materials and components has to be considered in their context (exposition for climate, temperature etc.) In this case it is suggested, that the construction is carried out, using components with certification, according to the Assessment System Materials and Components of the Brazilian Program of Quality and Productivity of the Habitat (PBQP-H) [23].

It can also be observed that the majority (57%) of the embodied energy) are to be found in the masonry (37% in the external walls and 20% in the internal walls) including ceramic blocks, mortar and paint. This indicates that the largest potential for reducing the amount of embodied energy can be found in the masonry element.

VII. CONCLUSIONS

The case study showed that the embodied energy (EE) in a Brazilian house from the social program “Minha Casa Minha Vida” is 7,2 GJ/ m^2. Half of the EE is due to material use for maintenance and around 57% of the embodied energy is used in the wall construction. The study indicates that the largest improvement potential for reducing the embodied energy are connected to the walls trough choosing materials and systems with less EE and higher durability to decrease the need for maintenance and substitution of materials. In the future, it could be interesting to carry out analyses on alternative materials in the construction, with less embodied energy. Also, recycling should be considered to see the improvement potential in the results, regarding the magnitude of embodied energy.

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