Simplified life cycle assessment:
Applied to structural insulated panels homes

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ABSTRACT: As environmental issues continue to become increasingly significant, buildings become more energy efficient and the energy needs for their operation decreases. Thus, the energy required for construction and the material production, is getting of greater importance. This research shows a simplified life cycle analysis study of operational and embodied energy of four new houses located in Temuco - Chile, structured with SIP (Structural insulated panel), in order to quantify the energy at each stage of this construction system. To obtain embodied energy were used two databases in order to quantify the energy of each material, Inventory of Carbon & Energy (ICE), 2008, University of Bath, Inglaterra and New Zealand Building materials embodied energy coefficients database. Volume II – Coefficients, 1998, Victoria University of Wellington, and the energy contained in the panel assembly process, transport and construction of the houses was determined by a data collection company specializing in the construction of houses built in SIP. For the operational energy, computational models were carried out with Design Builder software, with information of the house from thermography and infiltration essays, and this energy was projected at 50 years lifespan. The analysis of the data obtained show that the energy contained by construction processes represents about 1.7% of embodied energy, while the total energy embodied represents 11% of the total life cycle energy of houses, the remaining 89% represents the energy of occupation. On the other hand, we observe that SIP houses generate figures close to 60% savings in energy demand, compared to a common masonry houses with no method of thermal insulation, which were commonly built in this city.

Keywords: Construction materials, environmental assessment, Embodied energy, Operational building energy.

INTRODUCTION

Buildings' construction has a major determining role on the environment. It is a major consumer of land and raw materials and generates a great amount of waste. It is also a significant user of non renewable energy and an emitter of greenhouse gases and other gaseous wastes [7].

The building sector contributes largely in the global environmental load of human activities: for instance, around 40% of the total energy consumption in Europe corresponds to this sector. According to data from the Worldwatch Institute, the construction of buildings consumes 40% of the stone, sand and gravel, 25% of the timber and 16% of the water used annually in the world [3]. The building and construction sector (i.e. including production and transport of building materials) in OECD countries consumes from 25% to 40% of the total energy used (as much as 50% in some countries) [4].

Because global materials such as cement, aluminium, concrete and PVC are used, the energy costs and environmental impact increasing daily. Naturally, one solution is come back to building sector begin, local materials use with low energy costs and low environmental impact.

On the other hand, several studies have shown that operational energy accounts for the main amount of total energy use in dwellings during an assumed service life of 50 years and it is approximately 85–95% of the total energy use [9]. It also represents a major target for improvement, and is generally addressed by most environmental policies. There is a clear interaction between all the stages of a building's life: for example, if less is invested in the construction phase (e.g. using poor insulation), the investment needed for use and maintenance will increase. So the question is: is it better to invest in construction rather than in use and maintenance? The application of a global methodology such as LCA will allow us to answer this question, since this methodology can assess the global environmental impact during the life span of a building [2].

However, there are many methodologies proposed in papers with aims to overcome the existing prejudices of architects and engineers about LCA complexity, the difficulties in understanding and applying the results and the loose link with the energy certification applications. In Chile, the LCA methodology applied on building sector it is a new subject and our work it is focused in incorporate embodied energy concept still.

METHODOLOGY

Goal and scope

The aim of this study was to compare different dwellings available on the building market today in the city of Temuco, Chile, according to their embodied and occupational energy.

Energy

Due to lack of inventory in Chile and that the methodology of life cycle analysis applied to the construction area is still incipient, the analysis was simplified to the calculation of energy in the construction phase as a result of the energy in each material used in the dwelling through two databases: Inventory of Carbon & Energy (ICE), 2008, University of Bath, England and New Zealand Building Embodied Energy Coefficients materials database. Volume II Coefficients, 1998, Victoria University of Wellington.

In order to determine the energy contained in the building process we conducted a survey of data from an assembly of modules and SIP panel housing.

Moreover occupational energy was calculated as necessary to maintain thermal comfort and lighting in the home, designed to fifty years. This study aims to generate a first approximation to the energy issue, a concept not addressed by the construction companies who are incorporating new energy efficiency criteria but only focused on the stage of Occupancy. This form is also meant to see the importance of considering all lifecycle stages of housing construction to move towards a sustainable and certifiable.

Impact assessment- CO2 emissions

The emission of CO_2 was determined separately in the two life cycle stages. For the first stage the equivalent CO_2 associated with the energy content was determined and for the second stage, the emission of CO_2 from the stage of occupation associated with the fuel employed.

Obtaining the equivalent CO_2 was similar to obtaining the energy. The database used for the determination of CO_2 equivalent has the values of CO_2 emissions in Kg of CO_2 per unit of material. Unlike the energy determination in this case the determination of CO_2 equivalent is done with a single database from the Inventory of Carbon & Energy (ICE), 2008, University of Bath, England. This study is based on data generated from the energy, making changes to emission factors from England, related to emissions from fuel used in the process, which is only a first approximation and does not necessarily represent the reality of Chile.

The emission of building process was measured by quantifying the energy of the processes and the emission factor of the fuel source used.

The emission from the occupation phase was generated from the thermal simulation software DesignBuilder®. The calculation of CO_2 was associated with energy consumption of HVAC (heating and cooling) and electricity for lighting calculated by the software. Thus, the software identified a factor for each fuel, which contains the amount of CO_2 emitted per unit of energy consumed (kg CO_2/kWh), so this factor by multiplying the energy consumption of housing delivers annual CO_2 emissions. The factors presented by the software for energy consumption in Chile were:

» Electricity: 0,685 kg CO_2/kWh
» Diesel : 0,273 kg CO_2/kWh
» LPG y NG : 0,195 kg CO_2/kWh

RESULTS AND DISCUSSION

Below are the results and analysis of four homes built with SIP, the first two houses are a typology common in southern Chile, while houses 2 and 3 are modular.

Comparing the results for each dwelling is observed that embodied energy of materials used represents an average 98.3% in the pre occupancy and the energy associated with the construction processes only about 2%. The total energy of the pre occupation on average is equivalent to 5.4 years of heating energy in the phase of occupation, this is explained by the low level of requirements still present in the regulations of Chile, with occupational energy ranges between 89-123 kWh/m2/year.

Table 1: Energy at each stage by house

		Embodied	Construction process			Operation
	Area	Materials	Electric	Gas	Diesel	Heating
	[m^2]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh/yr]
House 1	75.0	46914.7	625.0	84.8	22.9	8769.0
House 2	60.0	39421.6	500.4	67.8	8.1	7365.3
House 3	35.0	17221.0	291.3	39.6	11.5	3106.8
House 4	50.0	23066.9	417.0	56.5	11.5	4674.8

The total energy projected at 50 years of service life varies between 172900 – 486097 kWh, in an average result of 298947 kWh, where the embodied energy in the materials is on average 11% approximately of the total energy. This is shown in figure 1.

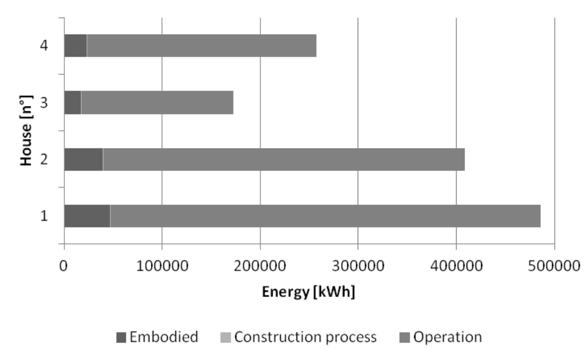

Figure 1: Energy at each stage by house projected at 50 years of service life

Figure 2 shows in general terms the decrease of the heating energy demand associated with the new thermal regulation applied in the country, but also observe their distance from the passive house standar.

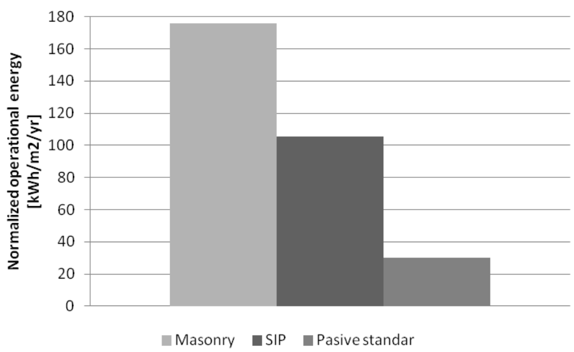

Figure 2: Operational Energy by building system

It is also important to note that housing sip with fewer occupational energy demand, the energy contained in the materials in this comparison is at least 20% average energy contained in a masonry housing [6].

Table 1: Emission at each stage by house

	Area	Embodied Materials	Constructions process	Operation Heating
	$[m^2]$	[kg CO_2 eq]	[kg CO_2 eq]	[kg CO_2 eq/yr]
House 1	75.0	12748.4	364.2	523491.0
House 2	60.0	12079.2	269.3	457086.0
House 3	35.0	5372.6	174.6	222993.5
House 4	50.0	6462.0	237.5	282701.9

Emissions are presented for reference in Table 2, however it is clear that the result depends directly on the emission factors of the country in which the inventory was developed, however we used to see that again the weight of emissions is in step occupational.

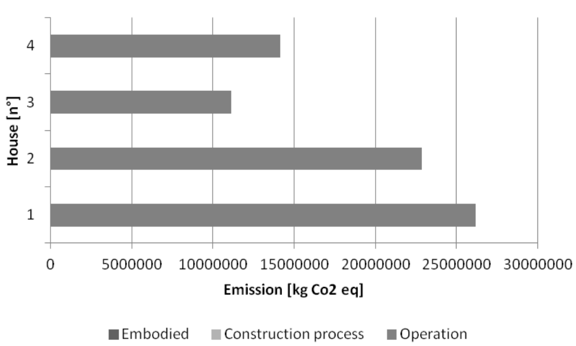

Figure 3: Emissions energy by building system

CONCLUSION

The amount of energy in homes and modules represents an average of 5.4 years energy demand in respect of all occupational energy calculated over 50 years.

The energy is on average only 11% of the all the energy in the life cycle of housing, remaining 90% goes to the energy of occupation.

The amount of energy contained in the processes of construction, transport, loading and unloading, is about 1.5% from the average total energy contained in the materials of the houses and modules.

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