Simplified life cycle assessment applied to structural insulated panels homes

Análisis de ciclo de vida simplificado aplicado a viviendas de paneles SIP (structural insulated panels)

Juan Pablo Cárdenas^{1*}, Edmundo Muñoz**, Cristian Riquelme*, Francisco Hidalgo*

* Universidad de la Frontera, Temuco. CHILE

** Universidad Andrés Bello, Santiago. CHILE

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Abstract

As environmental issues become increasingly important, the buildings have focused on energy efficiency and energy needed for the construction and production of material. 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 international databases in order to quantify the energy of each material, and the energy contained in the process relating with structure SIP was determined through measures in a company specializing in SIP construction. For the operational energy, computational models were carried out with Design Builder software, 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 embodied energy 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 masonry houses commonly built in this city.

Keywords: Construction materials, environmental assessment, embodied energy, operational building energy, life cycle assessment

Resumen

A medida que los asuntos ambientales se vuelven más importantes, las construcciones se han enfocado en su eficiencia energética y la energía necesaria para construir y producir los materiales. Esta investigación muestra un estudio de Análisis de Ciclo de Vida simplificado de energía operacional y energía contenida de cuatro viviendas nuevas ubicadas en Temuco, Chile, estructuradas con paneles SIP (Structural insulated panel) para cuantificar la energía en cada etapa de este sistema de construcción. Para obtener la energía contenida, fueron utilizadas dos bases de datos internacionales para cuantificar la energía de cada material y se determinó la energía contenida en el proceso relacionado a la estructura de paneles SIP a través de mediciones en una compañía especializada en construcción de paneles SIP. Para la energía operacional, se llevaron a cabo modelos computacionales con el software Design Builder y se proyectó esta energía con una vida útil de 50 años. El análisis de la información obtenida muestra que la energía contenida por procesos de construcción representa cerca del 1.7% de la energía contenida y mientras que el total de energía contenida representa el 11% de la energía del ciclo de vida total de las viviendas, el remanente 89% representa la energía de operación. Por otro lado, observamos que las viviendas con paneles SIP generan cifras cercanas al 60% en ahorro en demanda energética, comparadas a las viviendas de mampostería estructural normalmente construidas en esta ciudad.

Palabras claves: Materiales de construcción, evaluación ambiental, energía contenida, energía operacional, análisis de ciclo de vida

1. 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 (Zabalza Bribián, Aranda Usón, & Scarpellini, 2009).

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 (Arena & de Rosa, 2003). 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) (Asif, Muneer, & Kelley, 2007).

¹ Autor de correspondencia / Corresponding author:

Departamento de Ingeniería en Obras Civiles, Universidad de La Frontera,
Temuco, Chile

E-mail: juanpablo.cardenas@ufrontera.cl

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 (Thormark, 2002). 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 main-tenance 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 (Zabalza Bribián et al., 2009).

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.

2. Discussion and development

2.1 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 assessment applied to the building sector 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 (Geoff Hammond & Craig Jones, 2008), and New Zealand Building Embodied Energy Coefficients materials database (Alcorn, 1998).

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 greenhouse gas (GHG) was determined separately in the two life cycle stages. For the first stage the equivalent CO₂ associated with the energy content was determined and for the second stage, the emission of CO₂ from the stage of occupation associated with the fuel employed.

Obtaining the equivalent CO₂ was similar to obtaining the energy. The database used for the determination of CO₂ equivalent has the values of CO₂ emissions in kg of CO₂ eq per unit of material. Unlike the energy determination in this case the determination of CO₂ equivalent is done with a single database from the Inventory of Carbon & Energy. 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 construction 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 CO₂ eq 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 CO₂ eq emitted per unit of energy consumed (kg CO₂eq/kWh), so this factor by multiplying the energy consumption of housing delivers annual CO₂ emissions. The factors presented by the software for energy consumption in Chile were:

- » Electricity : 0.685 kg CO₂eq/kWh
- » Diesel : 0.273 kg CO₂eq/kWh
- » LPG y NG: 0.195 kg CO₂eq/kWh

3. Results and discussion

Below, Table 1 shown the results of four homes built with SIP, the first two houses are a typology common in southern Chile, while houses 3 and 4 are modular.

Tabla 1. Energía en cada etapa por vivienda
Table 1. Energy at each stage by house

	Área/Area [m ²]	Contenida/Embodied	Proceso de construcción/Construction process			Operación/Operation
		Materiales/Materials [kWh]	Electricidad/Electric [kWh]	Gasolina/Gas [kWh]	Diesel [kWh]	Calefacción/Heating [kWh/50yr]
Vivienda 1/House 1	75.0	46914.7	625.0	84.8	22.9	438450
Vivienda 2/House 2	60.0	39421.6	500.4	67.8	8.1	368265
Vivienda 3/House 3	35.0	17221.0	291.3	39.6	11.5	155340
Vivienda 4/House 4	50.0	23066.9	417.0	56.5	11.5	233740

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 occupancy 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.

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. Likewise, the energy used by stage is shown in Figure 1.

Figura 1. Energía en cada etapa por vivienda proyectada a 50 años de vida útil
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 normalized heating demand per year associated with the new thermal regulation applied in the country, but also observe their distance a reference like the passive house standard.

Figura 2. Energía Operacional por sistema de construcción
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 (Cárdenas, Muñoz, & Fuentes, 2011).

Emissions are presented for reference in Table 2 and Figure 3. However it is clear that the result depends directly on the emission factors of the country in which the inventory was developed, however we only used in order to see the weight of emissions in operational stage.

Tabla 2. Emisiones en cada etapa por vivienda
Table 2. Emission at each stage by house

	Área/Area [m²]	Contenida/Embodied	Construcciones/Constructions	Operación/Operation
		Materiales/Materials [kg CO ₂ eq]	Proceso/Process [kg CO ₂ eq]	Calefacción/Heating [kg CO ₂ eq/yr]
Vivienda 1/House 1	75.0	12748.4	364.2	523491.0
Vivienda 2/House 2	60.0	12079.2	269.3	457086.0
Vivienda 3/House 3	35.0	5372.6	174.6	222993.5
Vivienda 4/House 4	50.0	6462.0	237.5	282701.9

Figura 3. Emisiones en categoría cambio climático por vivienda proyectadas a 50 años de vida útil

Figure 3. Emissions energy by house projected at 50 years of service life

4. Conclusion

The operation stage is the main phase of life cycle in terms of energy demand. In this sense, the amount of energy in homes and modules represents an average of 5.4 years energy demand in respect of operational energy calculated over 50 years.

Embodied energy is on average only 11% of the all the energy in the life cycle of housing, remaining 89% goes to the energy of operational.

In terms of energy, the construction processes represent a negligible impact. The amount of energy contained in the processes of construction, transport, loading and unloading, is about 2% from the average total energy contained in the materials of the houses and modules.

5. Acknowledgements

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