Embodied energy vs. operating energy in dwellings façade: a case study of Spain

Speaker: Dr Xavier Gabarrell Durany– ICTA (UAB, Barcelona)

Jorge Sierra-Pérez[1,2], Jesús Boschmonart-Rives[1,4], Silvia Guillén-Lambea[2,3], Beatriz Rodriguez-Soria[2], Xavier Gabarrell[1,5]

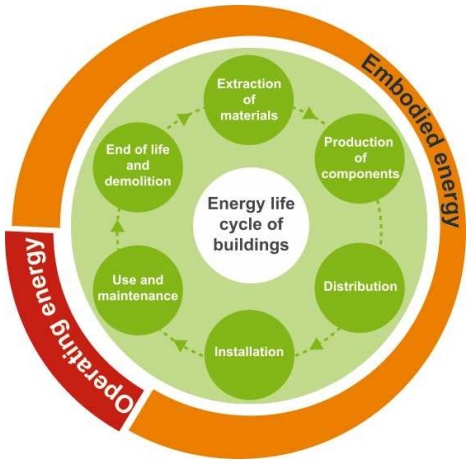
[1]Sostenipra. Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona, Spain
[2]Centro Universitario de la Defensa, Zaragoza, Spain
[3] Aragón Institute of Engineering Research (I3A), University of Zaragoza, Zaragoza, Spain
[4] Inèdit Innovació, S.L. Parc de Recerca de la Universitat Autònoma de Barcelona (UAB), Barcelona, Spain
[5] Department of Chemical, Biological and Environmental Engineering (XBR), Universitat Autònoma de Barcelona.

Introduction / *Energy and buildings*

The European building sector is incorporating the sustainability through the total life cycle energy of buildings to improve its environmental performance.

The total life cycle energy of a building includes the embodied energy and the operating energy.

In an inefficient building, the operating energy represents about 75% of total energy [1].



Introduction / *Operating energy*

The **operating energy** of a building is the amount of energy that is consumed by a building to satisfy the demand for heating, cooling, ventilation, lighting, equipment, and appliances.

The energy consumption for maintaining a comfortable temperature inside the dwelling depends on:

- the external and internal temperature
- the hours of daylight
- the humidity level
- the design of the thermal envelope
- the dwelling orientation
- etc.

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Introduction / *Embodied energy*

The **embodied energy** of a building is the amount of energy in the building materials during the processes of production, the on-site construction, final demolition and disposal.

The value of the embodied energy mainly depends on the existing regulations for each climate zone and the design of the building.

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Objectives

The present study presents a life cycle energy analysis (LCEA) of a dwelling façade located in the different climate zones of Spain, obtaining the relation between the embodied energy and the operating energy related to the energy losses through the walls during a year.

The specific objectives of the study are to analyze the influence of the climatic conditions and the lifespan of the building in relevance of the embodied energy as well as the operating energy.

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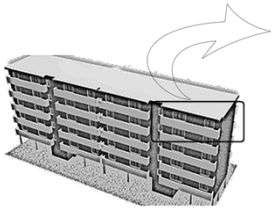
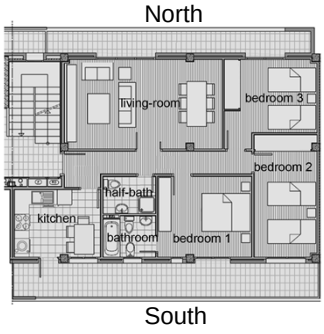
Material and methods

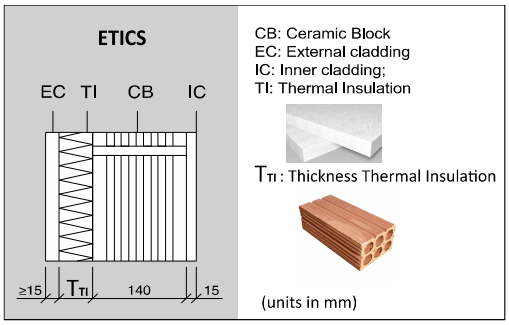
The study considers a dwelling which contains the most habitual percentage of enclosure typologies in the envelope and has a distribution and size coinciding with the typical housing standards defined by the Spanish Institute for Diversification and Energy Savings (IDAE) and the National Statistics Institute of Spain (INE) [2,3].





Material and methods

The constructive system for the external walls is External Thermal Insulation Composite Systems (ETICS).



This type of façade is composed of multiple layers:

- the wall
- the insulation material
- the fixing on the substrate
- the reinforcing intermediate coating
- the reinforcement mesh
- the decorative finish coating.

* ETICS: External Thermal Insulation Composite System

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Material and methods / Declared unit

The Declared Unit (DU) of the LCEA is the production, transport, installation of the necessary quantity of materials to construct the envelope (external walls) and the operating energy related to the use of the material selected.

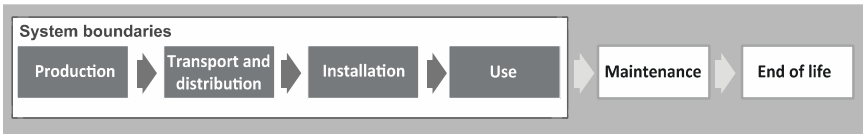

Diagram of the façade life cycle and system boundaries

The operating energy included in the study is the energy losses through the walls during a year, due to the operating energy depending on the construction materials used.
The other amounts of operating energy (ventilation, lighting, equipment, and appliances) are not influenced by the construction materials.

Material and methods / Embodied energy

The embodied energy is calculated according to the environmental product declaration (EDP) for construction products EN 15804:2014 [4] and the Spanish Technical Building Code [2] using the database Ecoinvent 3.1 database [5].

The DU is the production, transport and installation of the necessary quantity of materials to construct the façade of the dwelling façade in each climate zone.

The insulation material selected is the most common in Spain: EPS.

The lifespan of the building is 50 years.

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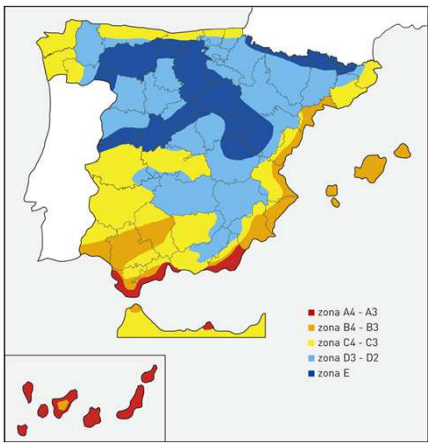
Material and methods / Embodied energy

Table 1 presents the need of insulation material in each climate zone with specific thermal requirements.

				EPS
	Thermal conductivity (λ) (W/m K)			0.035
	Density (kg/m3)			35
	Climate zone	Degrees-per-day	U-value	Quantity (kg)
ETICS	Climate A	1922	0.50	1.83
	Climate B	2729	0.38	2.61
	Climate C	2798	0.29	3.60
	Climate D	3487	0.27	4.22
	Climate E	3868	0.25	1.83

Table 1



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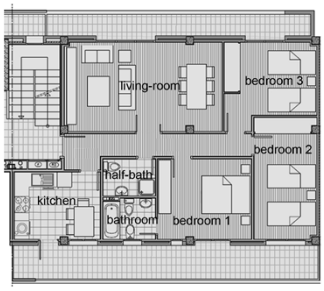
Material and methods / Operating energy

The study takes into account the energy influenced directly by the materials of the façade: the energy losses through the walls. This energy is calculated by using the annual degree-days which indicates the differences throughout the year between the average outside temperature and the inside temperature.

The dwelling has a net area of 81m^2, the ceiling height is 2.5 m.

The external wall area (m^2), for the case of study is 43.15 m^2.

The indoor reference temperature for winter is 18.5ºC and for summer is 25ºC.



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Material and methods / Operating energy

This energy is calculated by using the annual degree-days as the sum of the degree-days for heating and the degree-days for cooling, which indicates the differences throughout the year between the average outside temperature and the inside temperature, by using the equation 1:

$$Q = U \cdot A_i \cdot (\text{degree days per year}) \quad (1)$$

Where:
Q are the energy losses through the enclosure in a year (W),
U is the thermal transmittance of the external wall (W/(m^2 K). The U values used are the characteristics values for external walls recommended on the Spanish regulations depending on the climate zone [6] and are indicated on Table 1.
A_i is the external wall area (m^2).

Results and discussion

The weight of the operating energy is greater than embodied energy in all climate zones, between 76 and 82% (Table 2). The importance of the embodied energy is greater as colder is the zone because of the larger amount of insulation material is needed on the envelope.

	Degrees-per-day (ºC)	Transmittance U (W/m² K)	Total energy (MJ)	Embodied energy	Operating energy
Climate A	1922	0.5	4342.64	17.5%	82.5%
Climate B	2729	0.38	4706.15	17.8%	82.2%
Climate C	2798	0.29	3965.20	23.7%	76.3%
Climate D	3487	0.27	4485.15	21.7%	78.3%
Climate E	3868	0.25	4607.63	21.8%	78.2%

Table 2. Percentage distribution of embodied and operating energy by climate zone

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Results and discussion

The energy losses through the walls are lesser for climate zone C. This is because the recommended transmittance for climate C is more exigent than for the other climate zones.

The results do not follow a linear trend, due to differences in thermal insulation requirements for the different climatic zones.

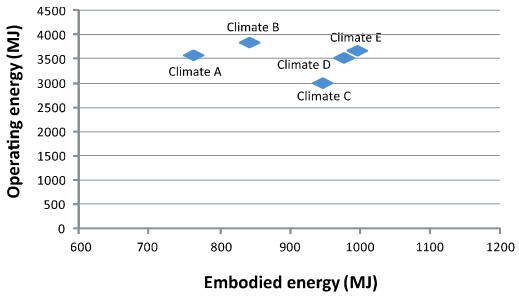
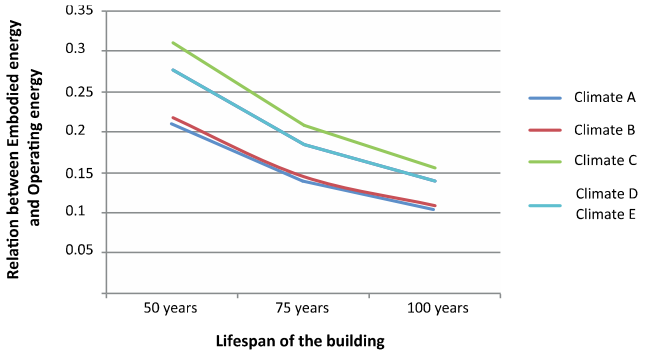


Figure 2. Embodied energy and operating energy of dwelling in each climate zone during a year

Results and discussion

The lifespan of the building is another factor with a great influence in the final results of this study.
The current lifespan used for LCA of buildings is 50 years, but if this lifespan is increased, the weight of embodied energy decreases 50%.



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Conclusions

The results allow us to note the relevance of the operating energy, which is between the 76% to the 82.5% of the total energy depending on the climate zone, for a typical dwelling.

The embodied energy is higher for the coldest climates. This is due to the fact that the recommended transmittance for the coldest climate zone is the lowest.

The reduction of the total energy consumption throughout the life cycle of dwelling will focus on reducing the embodied energy in building, improving the performance of buildings, selecting less energy-intensive materials and extending the lifespan of buildings.

References

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Thank you for your attention!

Dr Xavier Gabarrell Durany– ICTA (UAB, Barcelona)

xavier.gabarrell@uab.cat

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