Analysis of the determining parameters of energy efficiency on residential buildings in the Mediterranean climate

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Abstract

In order to maintain a reasonable standard of living and comfort, society is dependent on using very high levels of energy. The challenge is to pursue sustainable development while maintaining the level of activity, transformation and progress in every productive sector. In this paper, the influence of every parameter that determinates the energy requirements of heating and cooling in residential buildings will be studied, evaluating the thermal performance of building solutions, the treatment of gaps, control and reduction of solar radiation devices, thermal bridges and ventilation, etc. In addition, there will be an analysis of the factors that optimize the performance of heating, ventilating, air conditioning and domestic hot water systems and integration of renewables in every one of them. Finally, an economic feasibility analysis of building improvements will be performed at both construction and design of facilities.
Keywords: building, energy requirements, energy consumption, CO_2 emissions, cooling, heating, hot water system.

1 Introduction

Concern about the environment and climatic change is forcing governments of the world to research capable solutions and to correct it. The consequence of this issue is the Protocol of Kyoto, in which countries of EU have engaged to obey.

WIT Transactions on Ecology and the Environment, Vol 144, © 2011 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/ECO110331

One recommended measure to achieve the aims proposed is the encouragement of saving and energy efficiency in all sectors. Energy consumption, as much in Spain as in the EU, is mainly satisfied by fossils fuels, emitting compounds to the atmosphere that cause a big environmental impact and, although the energetic production of renewable origin is gravely worthwhile, its percentages of contribution on a global level are not representative because of its low amount.

The consequence of energy consumption, especially those of fossil origin, is one of the main agents responsible for the destruction of the environment by means of the broadcast of greenhouse effect gases. Through the gases which are contemplated in the Protocol of Kyoto, CO_2 represents three quarter parts of the total and more than 90% of this has an energy origin [5].

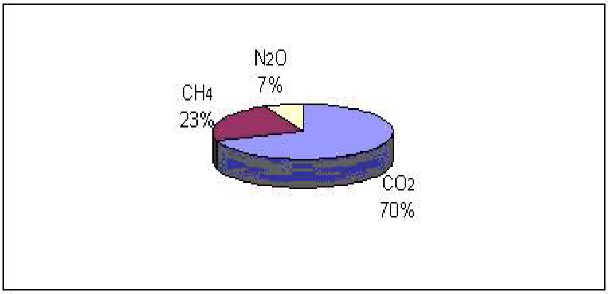


Figure 1: Percentage of polluting gas emissions.

Between the final consumers of energy, the residential sector in Spain occupies third place in importance. But, unlike what happens in the main part of Europe, this sector is found a little bit far from the consumption of industry and transport; it represents 15% of the final energy consumption [1].

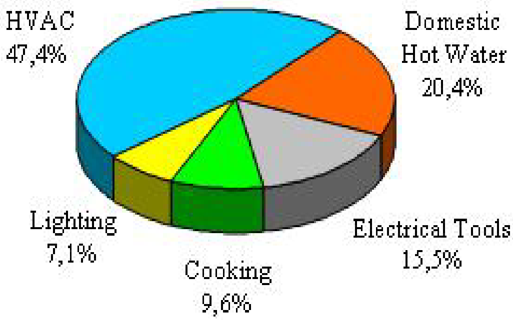


Figure 2: Energy consumption in Spanish housing.

The Spanish rule on the subject of energetic efficiency in buildings, following the European directives, requires the verification of some minimum requirements such as the calculation of energy consumption or indicators associated to this consumption [4]. Both operations require calculation tools to find the energy demand of the building, consumption of its thermal installations and the environmental impact produced by the amount of CO_2 emissions.

The relation between the energetic needs of the buildings, the associated consumption of energy that is supposed, and the CO_2 broadcast produced care related in fig. 3:

$$\frac{Energy\ Demand\ of\ Building}{\eta_{Thermal\ Systems}} = Energy\ Consumption$$

$$\Downarrow Energy\ Type$$

$$CO_2\ EMISSIONS$$

Figure 3: Relationship between energy parameters.

This study will determine which parameters influence the energy efficiency as the method of calculation recognized in the Spanish legislation. A detailed analysis will be carried out of a typical residential building from the Mediterranean area. Starting from these data, some modifications are proposed in order to improve its contributions and reduce CO_2 emissions in this sector.

2 Materials and methods

Figure 4 shows the procedure followed in this study, and in concentrating as much on the constructive levels as well as functional ones, the energy demand is determined. The official simulation tool is employed LIDER [2].

To evaluate the annual energy consumption of heating, refrigeration and sanitary hot water, the simulation of the thermal installations will be carried out. This procedure is done by a simulation application recognized by the Spanish legislation: Calener VyP [3]. This software allows the environment impact value to be calculated according to Fig. 3, showing the CO_2 gas emitted to the atmosphere. Once obtained, the influence of different properties of the building and its installations will be studied.

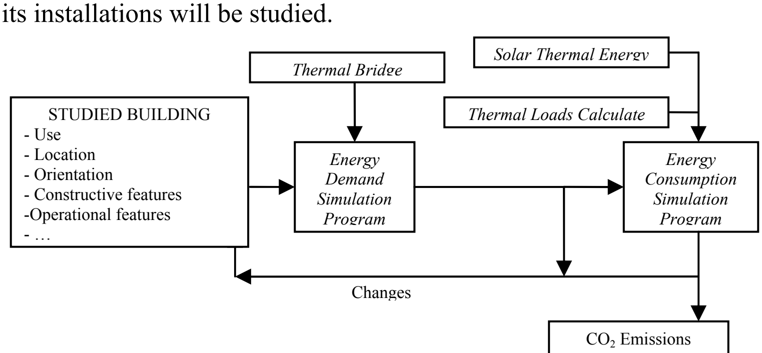


Figure 4: Project flowchart.

2.1 Study of main parameters of the energy demand

The energy demand of the building depends on its constructive and operational characteristics. Several simulations have been carried out in order to analyze the following:

- Orientations of facade.
- Thermal inertia of the exterior closings.
- U-value of the closings. Influence of thermal insulation. Conductivity and thickness.
- Treatment of gaps: Permeability of the carpentries, percentage of gaps occupied by the frame, U-value of frames and glasses, solar factor, dimensional appearances and execution…
- Treatment of the thermal bridges.
- Projection of shadows by outside elements to the building under consideration.
- Air of ventilation.

2.2 Study of the main parameters of the performance of the thermal installations

The properties analyzed at this point do not influence the energy demand. However, the energy consumption of the HVAC and production of sanitary hot water systems are directly affected.

- Type of systems.
- Power, performance and type of the equipment of thermal energy production.
- Type of energy employed by the installations.
- Solar contribution in the production of sanitary hot water.

3 Results and discussion

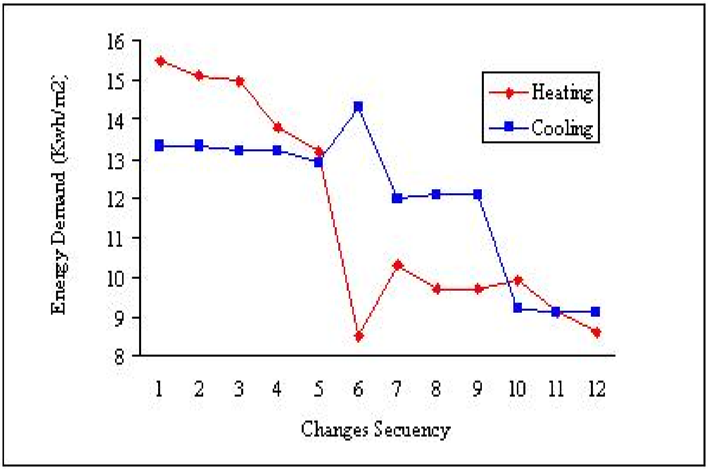
In view of the results obtained in successive simulations, it has been determined that some parameters have greater importance in the energetic behaviour of the building and in the performance of its installations. It will represent the values of the energetic indicators obtained in front of variations in different constructive properties and the working of the systems.

3.1 Evolution of the energetic indicators by modification of influential parameters on the energy demand

After studying each property separately and its relative importance in the demands of heating and cooling, we can proceed to see the energetic evolution of the building under consideration. It maintains the thermal systems at a constant with the aim of reducing its energy needs.

Table 1: Parameter changes in energy demand.

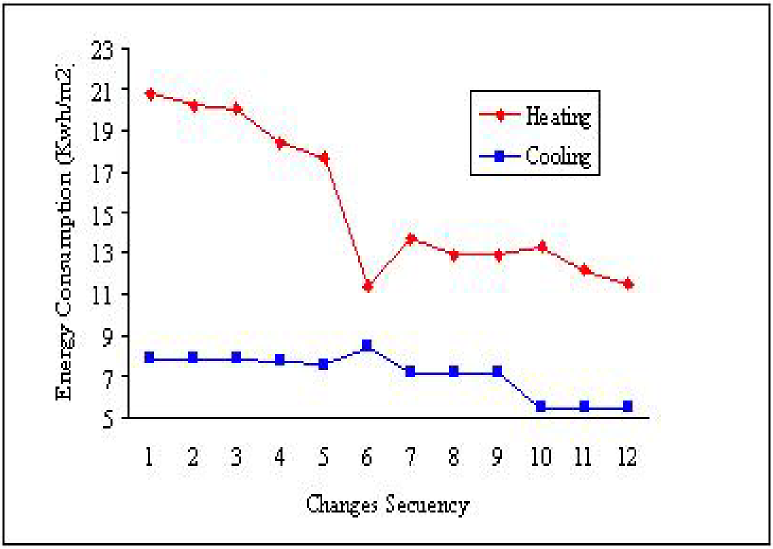
Change Code	Initial Building	Changed Building
1	Initial Conditions	
2	Mineral Wool in Facade (k = 0,041 W/mK)	Mineral Wool in Facade (k = 0,031 W/mK)
3	Exp. Polystyrene on Roof (k = 0,029 W/mK)	PUR on Roof (k = 0,025 W/mK)
4	5cm of Mineral Wool in Facade	10cm of Mineral Wool in Facade
5	4cm of Exp. Polystyrene on Roof	8cm of PUR on Roof
6	Double Glazing ($U = 3{,}3\ W/m^2K$)	Low Emissive Double Glazing ($U = 1{,}4\ W/m^2K$)
7	Glass´ Solar Factor = 0,75	Glass´ Solar Factor = 0,6
8	Metal Window Frame ($U = 4\ W/m^2K$)	PVC Window Frame ($U = 1{,}8\ W/m^2K$)
9	Permeability Carpentries 50 (m^3/hm^2)	Permeability Carpentries 3 (m^3/hm^2)
10	Solar Protection in Summer: 50%	Solar Protection in Summer:70%
11	Ventilation / Hour = 0,8	Ventilation / Hour = 0,76
12	Usual Thermal Bridges	Calculated Thermal Bridges



Sequence of Changes

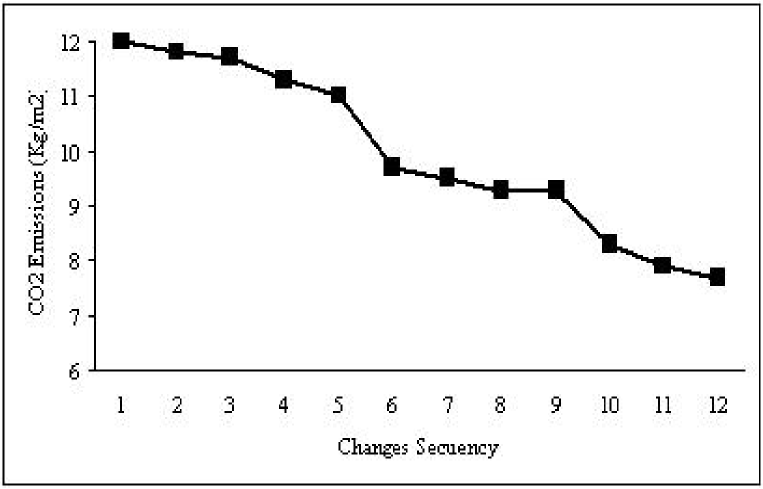
Figure 5: Evolution of energy demands.

The demand of heating is mainly influenced by the heat transfer of the constructive elements and thermal properties. The demand of refrigeration is quite affected in front of parameters dependent on conduction and radiation heat transfer through the gaps.



Sequence of Changes

Figure 6: Evolution of energy consumption.



Sequence of Changes

Figure 7: Evolution of CO_2 emissions.

Improving the thermal properties of closings supposes to reduce the energy needs up to 44,5% for heating and 32% in cooling.

The energy consumption of heating reduces up to 45% of the initial value. The electrical consumption of cooling systems decreases by 30%.

3.2 Evolution of the energetic indicators by modification of influential parameters on the thermal installations

The energy consumption of different installations is evaluated by means of simulating their elements. For this, the previous variations are maintained which affect the energy demand.

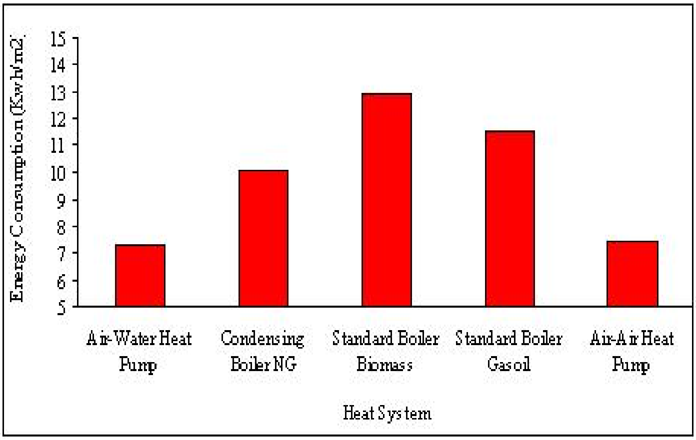


Figure 8: Energy consumption according to heating system.

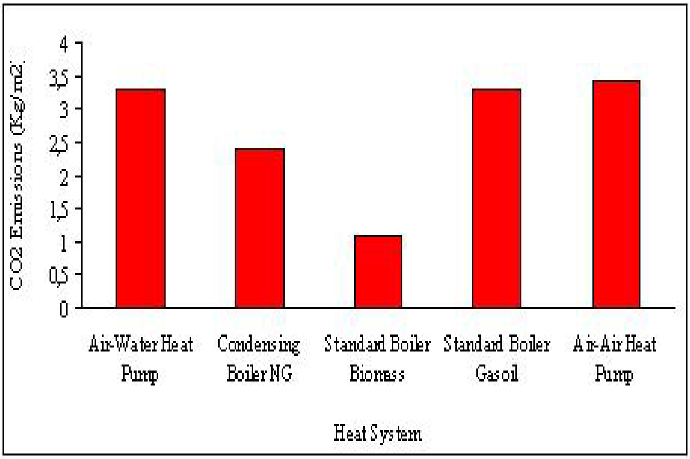


Figure 9: CO_2 emissions according to heating system.

Figures 8 and 9 show how the energy consumption depends on equipment of thermal energy production, such as the principle of working and its performance. However, the broadcasts are more influenced by the type of energy that they employ. For instance, the consumption of electricity, in spite of being minor is more polluted than other energetic sources.

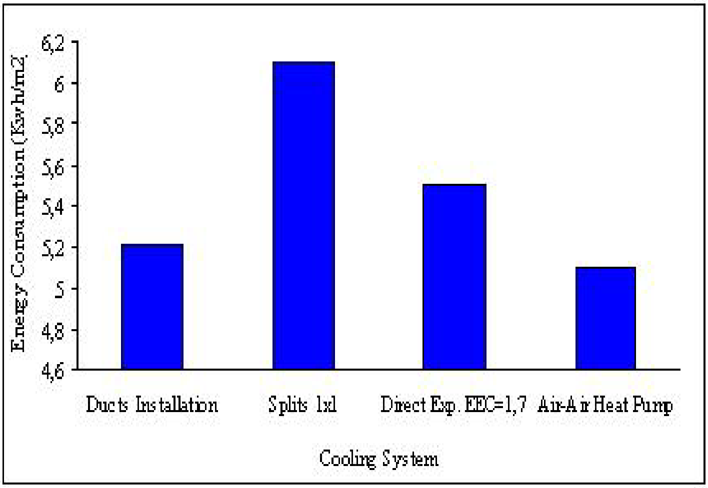


Figure 10: Energy consumption according to cooling system.

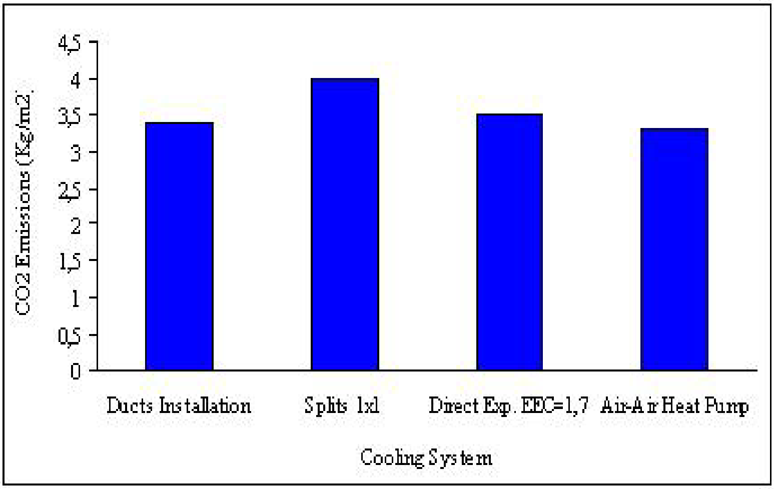


Figure 11: CO_2 emissions according to cooling system.

The cooling systems under consideration are all fed by electrical energy. Therefore, broadcasts and energy consumption will depend on the correct election of the equipment (power, performance, real needs of the buildings…). This fact involves a good engineering project.

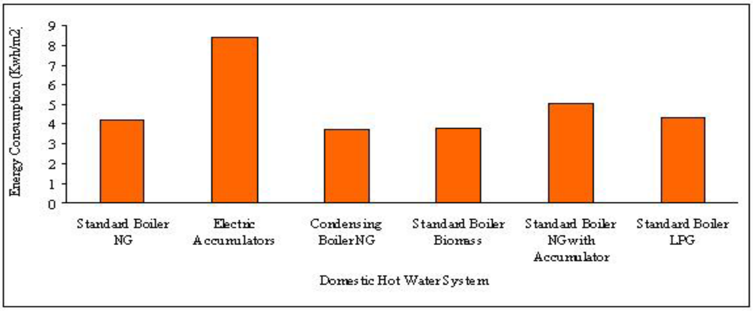


Figure 12: Energy consumption according to domestic hot water system.

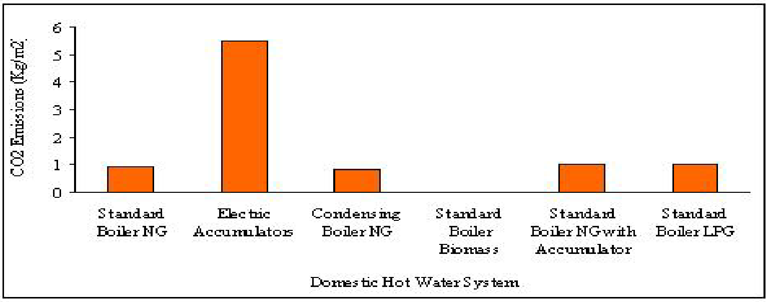


Figure 13: CO_2 emissions according to hot water system.

Figures 12 and 13 show producing hot water using electrical energy is highly inefficient and polluting. On the contrary, the employment of renewable energies, such as biomass, is the best solution from the point of view of the environment.

3.3 Studies of economic feasibility of proposals of improvement the energy efficiency on buildings

Table 2 represents the savings accumulated of a house of 90m^2 if it installs air conditioning systems and sanitary hot water adapted to the real needs.

Table 2: Cumulative economic saves.

Type of System	Cumulative Cost (€)		
	Years		
	5	10	15
Initial Systems	1585,1	3706,4	6545,2
Recommended Systems	950,4	2222,2	3924,3
Economic Cumulative Savings (€)	634,7	1484.2	2620,9

In the calculations, 6% of inflation rate in the price of energy has been considered in order to update the annual values.

From the constructive point of view an analysis of the time needed to amortize an over cost of initial investment because of improvements in the properties of the thermal insulation installed on exterior closings of the building purposed is carried out.

The aim consists of verifying the moment in which the increase of the initial inversion is compensated with the energetic saving associated to the installation of an isolation with minor conductivity and more thickness.

$$Extra\ \ Cost_{initial} = [(\ AnnualPayment)_{Original\ \ Building} - (AnnualPayment)_{\mathrm{Im}\,proved\ \ Building}] \cdot \sum_{year=1}^{year=n} (1+f)^{(n-1)}$$

n = 1,2,…= year of calculation, f = 0,06 = Inflation rate of the price of energy. The approximated values of the isolation cost installed in the Spanish buildings are used to make this analysis [7].

In Fig. 14 it is observed that the time of amortization will be produced starting from 13,5 years for the beginning of the working of the building.

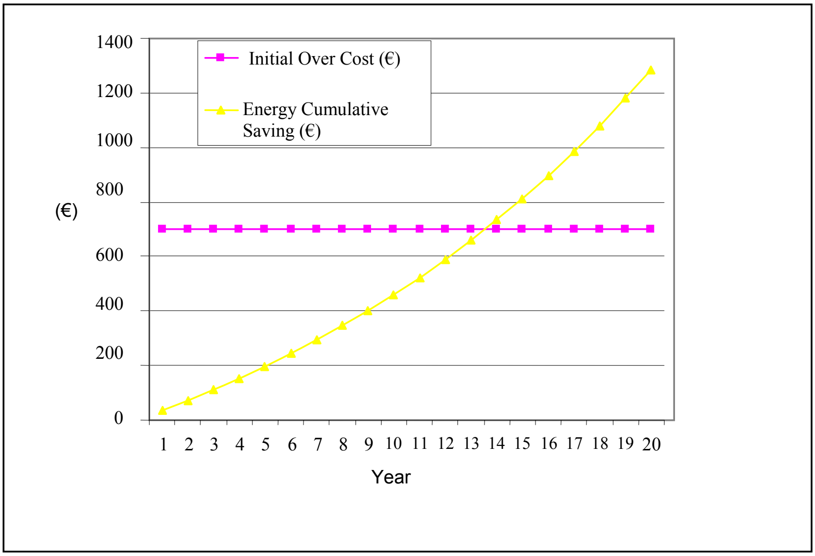


Figure 14: Payback time. Overcost of thermal isolation.

4 Conclusions

Energy efficiency on buildings is influenced from the phase of design until the execution of its closings and installations. Reducing the energy needs in the east of Spain mainly involves limiting conduction heat transfer on closings and solar radiation effects in the gaps.

Besides, the correct execution of the thermal bridges [6], the reduction of infiltrations, detailed calculation of the ventilation, thermal loads and solar protection and correct choice of equipment is necessary.

The type of energy to condition the building is essential to evaluate the environmental impact of the constructions. The improvements in their properties involve some energy saving. Therefore, increasing energy efficiency does not enter in conflict with the economic feasibility of the sustainable construction.

Acknowledgements

The author thanks F. García-Alonso, J. A. Reyes and Y. Villacampa for their technical advising and devotion in the preparation of this survey.

This work has been supported by AIDICO, Technological Institute of Construction.

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