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Influence of the different Spanish climatic conditions in energy efficiency of existing dwellings

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Key words

Climate zones of Spain, residential building, existing dwelling, energy performance certificate, energy efficiency.

1. Introduction

Energy efficiency is considered as one of the most cost effective ways for society to enhance security of energy supply and reduce emissions of greenhouse gases and other pollutants [1].

Buildings are responsible for over 40% of final energy consumption in the European Union (EU), of which approximately 27% correspond to residential ones [2]. About 35% of the EU's buildings are existing buildings over 50 years old [3]. Therefore, improving the energy performance on these buildings could be an important opportunity to save energy.

EU has adopted a number of measures to improve energy efficiency. In particular, in the European Community the energy efficiency in buildings has been the aim of diverse European Directives. The 2010/31/EU Energy Performance of Buildings Directive (EPBD) and the 2012/27/EU Energy Efficiency Directive [4] are the EU's main legislation when it comes to reducing the energy consumption of buildings[5].

Spain, as an EU Member State, has set its own legislation and tools to achieve the EU targets. The main policies related to the energy efficiency in dwellings are: the revision of the Regulations on Building Heating Installations (RITE) [6], the approval and revisions of the Technical Building Code (CTE) [7] and the approval of the Building Energy Performance Certificate for newly-constructed an existing buildings [8].

Additionally, Spain has developed the National Energy Efficiency Action Plan (NEEAP) 2014-2020 [9] under the Energy Efficiency Directive. The NEEAP includes the current situation and the long-term national building renovation strategies.

Energy certification of buildings is a key policy instrument for reducing the energy consumption and improving the energy performance of new and existing buildings [10].

The ''energy performance of a building'' is defined as 'the amount of energy actually consumed or estimated to meet the different needs associated with a standardized use of the building'. The energy performance certificate includes an energy performance rating (from A, the most efficient, to G, the least efficient), also called energy qualification, and recommendations for cost-effective improvements and it is calculated according to a methodology based on the general framework set out by the EPBD [11].

The objective of this paper is to study the influence of the different Spanish climatic conditions in the result of the energy performance certificate. For this purpose, a typical Spanish existing dwelling is placed in the different Spanish climatic zones and certificated in order to analyse the sensitivity of the energy qualification process with respect to the climatic conditions.

2. Methodology

This study was performed using a predefined "standard building", which is representative of the existing dwellings stock in Spain. The energy performance is evaluated placing this building in the different climatic zones of Spain with different climatic conditions.

CERMA software [12] has been used to obtain the energy performance certificate including energy performance rating, primary energy consumption and CO_2 emissions. This software is recognized by the Spanish Ministry of Industry, Energy and Tourism (MINETUR).

Furthermore, some measurements have been implemented in order to improve the energy performance of the building and to meet the minimum CTE requirements for each climatic zone.

After improvements, new energy performance rating, primary energy consumption and CO_2 emissions of the building were calculated and compared with results obtained before improvements.

A. Standard Building Definition

The “standard building” has been chosen as a representative building of the existing residential building stock in Spain. It was selected using data available from the Energy Diversification and Savings Institute (IDAE) and MINETUR and statistics from National Statistics Institute (INE) related with geometry, materials used in construction of the enclosure and thermal installations.

The “standard building” has the characteristic summarised in Table I.

Table I: - “Standard building” characteristics

“Standard building” definition		
Multi-family building (8 dwellings)		
Geometry	Living area	$896\ m^2$
	Conditioned volume	$3{,}136\ m^3$
	Floors	4 (2 dwelling per floor)
	Distribution	Master bedroom, single bedroom, kitchen, living/dining room and bathroom
Constructive solutions		Thermal transmittance U ($W/m^2 \cdot K$)
	Facade	1.58 (4 facades with the same characteristics)
	Roof	1.60
	Floor	2.65
	Windows	5.70
Thermal installations	Heating	8 Conventional boiler 24 kW performance: 75% (Natural Gas)
	DHW	8 Conventional Boiler 24kW performance: 81% (Liquefied petroleum gases)

B. Climatic conditions

According to the CTE, in Spain there are 12 climatic zones. For the test, a representative city of each one has been selected (Table II).

Table II. - Spanish climatic zones

Climatic Zone	Representative city
A3	Cádiz
A4	Almería
B3	Valencia
B4	Sevilla
C1	Bilbao
C2	Barcelona
C3	Granada
C4	Toledo
D1	Lugo
D2	Zamora
D3	Madrid
E1	Burgos

The standard building is placed in these different locations applying the specific climatic conditions of each one.

C. Energy performance assessment

CERMA software was used to obtain the energy performance, the energy demand and CO_2 emissions of the building.

For existing residential buildings the energy performance is expressed as an energy label. The label is based on the carbon dioxide (CO_2) emissions per square meter generated by the building in one year. It is expressed as a letter ranging from A to G [13,14].

The C_1 labelling index refers to new residential buildings or refurbishment ones and it is calculated according to Eq. (1):

$$C_1 = \frac{\left(\frac{I_o}{I_r} \cdot R\right) - 1}{2 \cdot (R-1)} + 0.6 \qquad (1)$$

where,
Io, are the CO_2 emissions generated by the building
Ir, is the energy performance regulation benchmark and corresponds to the average CO_2 emissions in residential buildings that strictly meet the requirements stated in the Technical Building Code
R, is the ratio between Ir and the CO_2 emissions corresponding to the 10th percentile of residential buildings that strictly meet the requirements stated in the Technical Building Code

The C_2 labelling index refers to existing residential buildings and it is calculated according to Eq. (1):

$$C_2 = \frac{\left(\frac{I_o}{I_s} \cdot R'\right) - 1}{2 \cdot (R'-1)} + 0.5 \qquad (2)$$

where,
Io, are the CO_2 emissions generated by the building
I_S, is the building stock benchmark and represents the average CO_2 emissions in existing residential buildings in 2006.
R’, is the ratio between I_S and the CO_2 emissions corresponding to the 10th percentile of the existing residential building stock.

Table III shows the correspondence between values of C_1 and C_2 and the energy performance letter.

Table III – Energy rating for residential buildings

Energy label	Residential buildings
A	$C_1 < 0.15$
B	$0.15 \leq C_1 < 0.50$
C	$0.50 \leq C_1 < 1.00$
D	$1.00 \leq C_1 < 1.75$
E	$C_1 > 1.75$ and $C_2 < 1.00$
F	$C_1 > 1.75$ and $1.00 \leq C_2 < 1.50$
G	$C_1 > 1.75$ and $1.50 \leq C_2$

D. *“Standard building” improvements*

The improvements are selected in order to upgrade the energy performance of the building to the energy label “D” (qualification D) and to meet CTE requirements in each climatic zone.

Energy saving measures in existing buildings can be divided into three categories: energy savings due to the thermal performance of the building envelope (reducing energy demand), savings by upgrading thermal installations (reducing energy use) and energy savings due to supplying part or the total energy demand by renewable sources (reducing primary energy use) [15].

The measurements were chosen taking into account the energy consumption distribution in dwellings and the efficiency measurements proposed for the building sector by IDAE and MINETUR in the NEEAP 2014-2020 (Table IV).

Table IV – Selected improvements

1) Facade Insulation (add 4 or 6 cm insulation)	Thermal Envelope
2) Roof insulation (add 6 or 8 cm of insulation)	
3) Window replacement (better glass and frame)	
4) Heating/DHW boiler replacement	Thermal Installations

Depending on the climatic zone one or more measures are necessary to achieve letter “D” and to meet the CTE requirements.

3. Results and discussion

Energy performance rate, CO_2 emissions and energy demand are calculated using CERMA for the different climatic zones and for the building before and after improvements.

A. *Energy performance rate and CO_2 emissions results*

The result of the energy qualification (letter) and CO_2 emissions of the “standard building” before improvements are shown in Fig. 1.

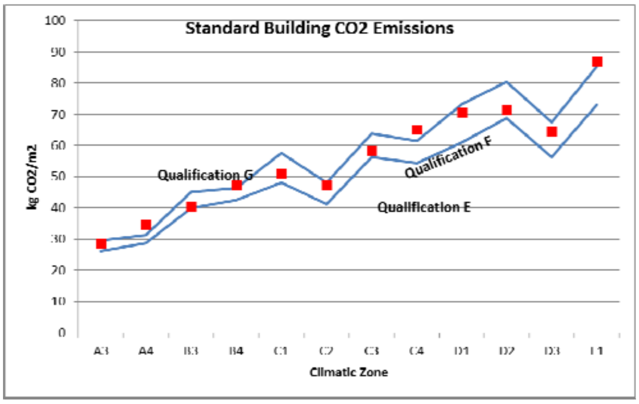

Fig. 1. – Energy performance rate and CO_2 emissions in the different Spanish climatic zones

The qualification is very similar in the different climatic zones, F (A3, B3, C1, C2, C3, D1, D2, and D3) and G (A4, B4, C4, E1). However, CO_2 emissions have important differences for the same qualification letter. For example, zones A4 and E1, both have G qualification, but the CO_2 emissions are 34.6 and 87 kg CO_2/m^2. year, respectively.

B. *Energy performance rate and primary energy consumption results*

The results of energy qualification and primary energy consumption of the building before improvements are shown in Fig. 2.

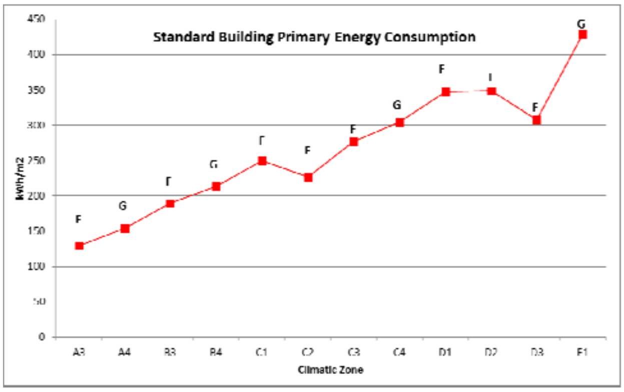

Fig. 2. - Energy performance rate and primary energy consumption in the different Spanish climatic zones

Results show that identical qualification does not correspond with the same primary energy consumption in the different climatic zones. In some cases, less primary energy consumption match to a worse qualification (A4 corresponds to a worse qualification with less primary energy consumption than B3)

C. Results after improvements

The effects on the energy performance due to improve the thermal envelope and/or thermal installations of the “standard building” have been studied. In order to achieve “D” qualification and to meet the CTE requirements, the minimum improve measurements have been applied for each climatic zone.

Fig. 3 shows the building qualification and CO_2 emissions before and after improvements. CO_2 emissions have been considerably reduced and differences among climatic zones have decreased.

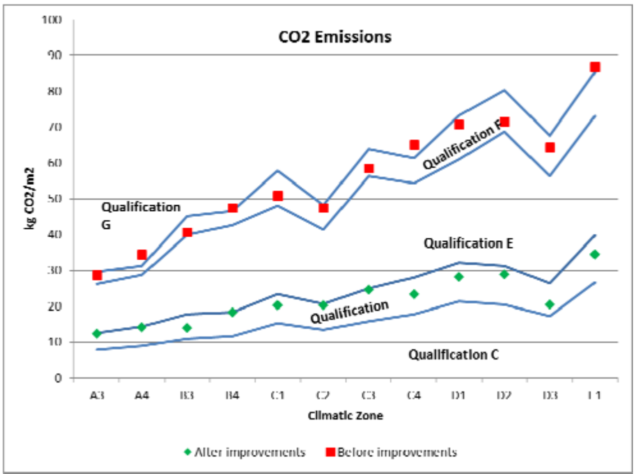

Fig.3. – Energy performance rate and CO_2 emissions before and after improvements in the different climatic zones

Fig. 4 shows how primary energy consumption has been also considerably decreased.

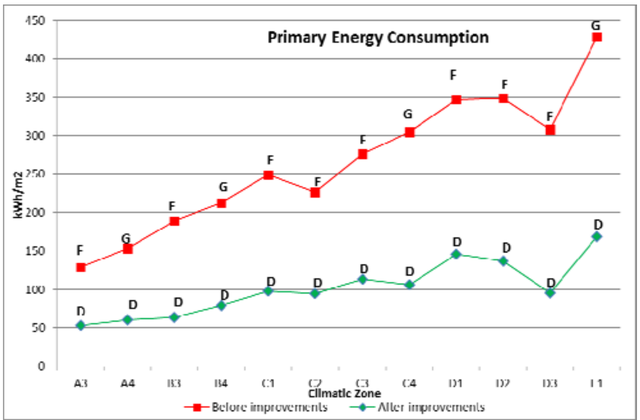

Fig. 4 – Energy performance rate and primary energy consumption before and after improvements in the different Spanish climatic zones

4. Conclusion

The energy performance analysis of a standard existing building placed in the different Spanish climatic zones has been carried out.

The “standard building” energy qualification (letter) is similar in the different climatic zones. However, the values of CO_2 emissions and primary energy consumption are really different among the zones.

The minimum necessary improvements for the different zones that allow to meet the CTE requirements and to achieve “D” energy label have been considered. After improvements, both CO_2 emissions and primary energy consumption have been considerably reduced and the differences in the obtained values have decreased among the different climatic zones.

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