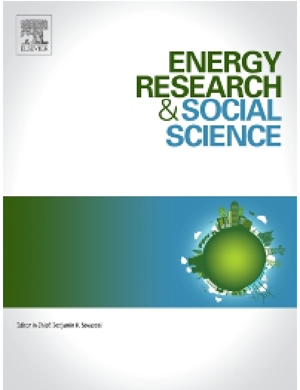

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The merits of making energy costs visible: The sustainability benefits of monetizing energy efficiency certificates in Spanish rental homes.

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Highlights

- A methodology is proposed to provide the financial cost of the energy bill.
- The collected data are used to obtain the economic certificate for the apartment.
- If the landlord/lady knows the energy cost, the rental prices will be affected.
- The energy cost represents between 5% and 62% of the rental price in Spain.
- A significant impact on energy savings is obtained with a minimum effort.

Abstract

Reducing energy consumption in the building sector is a priority issue in European policy. The aim of legislation on energy certification is to provide incentives for the energy renovation of buildings. To help achieve this goal, a methodology is proposed to provide information on the economic cost of the energy bill, in addition to the current indicators of energy consumption and CO_2 emissions. By applying this methodology, it can be seen that energy costs account for between 5% and 62% of the price of renting a house in Spain. Making this information available to the consumers would have a direct impact on rental prices. The landlords who carry out the energy renovation of their home could charge a higher rent, which would allow them to recover the investment made. Also, tenants of homes with more expensive energy bills would benefit from having their rent reduced. Landlords who renovate their home and tenants who access a home without energy renovation would benefit from making energy costs visible. This simple legislative measure would help to overcome the added difficulty that owners of rental homes have - they pay for the energy renovation while the tenants enjoy the savings after the improvement of the property. With a minimum of additional effort, a significant impact on an important issue could be achieved.

Key words

Energy certification, Energy bill, Rental houses, Energy renovation, Energy saving policies.

1. Introduction

The fight against the environmental crisis and climate change demand a profound transformation of the mentality and daily lifestyle from society. In the medium term, education will play a crucial role in achieving these goals, but in the short term, the legal measures related to energy policy have to drive a change in the behavior of society. Monetary incentives have great power to influence economic decisions. Specifically in the field of real estate, it is important to ensure that builders, owners, landlords and tenants are sensitive to the need to maximize energy efficiency in buildings, making it the most profitable decision. Investments aimed at minimizing energy use by improving comfort are costly at first, but later become beneficial both for users and for society as a whole. Hence the importance of regulation facilitating its implementation.

In 2017, households, or the residential sector, represented 27.2 % of final energy consumption in the EU [1]. Buildings offer the greatest potential for reducing energy consumption, a goal expressed by nearly every developed country [2]. Moreover, reducing the buildings' energy consumption would reduce energy dependence and increase energy security [3], increase purchasing power by lowering energy bills, increase property values, increase comfort and improve indoor environment [4].

Further action is needed to achieve the energy goals by 2030. Reducing energy consumption in the residential building sector is one of the elements on which efforts should be focused [5].

This article focuses on a further added difficulty, which is typical of rental housing: the disincentive for the owner to pay for energy renovation whilst the tenant profits from the savings. If there are already difficulties with energy renovation in the case of owner-occupied housing, in the case of rented housing a clear and specific incentive must be found to nudge the owner to overcome the pitfall of spending a significant amount of money with little or no return.

To overcome this difficulty, Royal Decree (RD) 235/2013 that approves the procedure for the certification of a buildings’ energy efficiency [6] establishes the obligation to make available to tenants (or buyers) an energy efficiency certificate with information on the energy efficiency of a building so that tenants (or future owners) can compare and evaluate its energy efficiency. This is intended to encourage investments in energy saving. In the case of renting, to facilitate those investments, the energy class of the dwelling to be rented should have a direct impact on the rental price. More efficient housing could increase the rental price, while less efficient housing would have a lower rental price as it would be penalised by a higher energy bill, as is the case with domestic appliances. Thus, the investment to improve efficiency made by means of an energy renovation of the apartment could be compensated in some way by the surcharge for the incoming rental.

Unfortunately, the real estate market is not responding in the way that RD 235/2013 intended. When announcing the rental of a flat, the common practice is filling in the energy certificate box with the phrase "in process". Palma reckons that only 3% of the flats for rent, in the sample studied, offer such information when advertising [7]. Marmolejo in his study attains the figure of 12% [8]. In any case, energy certification is perceived by most as just other formality that must be carried out when the contract is signed, but which does not have the effects on the rental price as the lawmaker intended. The price setting system in the rental market does not work efficiently, since it does not reveal the final cost that the tenant has to pay taking into account the rental price together with the energy costs involved in living in the apartment. This loss of economic efficiency in the setting of rental prices leads to a loss of their ability to incentivize the energy efficiency of rental apartments.

In Spain, the percentage of apartments for rent is lower than in Europe [9]. Most of society prefers to buy an apartment [10]. A high number of those who choose to rent in Spain are young people with limited resources or families of immigrant workers whose work is highly precarious. Most of the dwellings in Spain have an individual heating installation, so that the tenants pay for their consumption directly to the utility company.

To reduce energy consumption in the building sector, it is pertinent to modify the legislation to make the energy costs of living in an apartment visible before renting it.

The dwellings that show the energy efficiency certificate provide the information required by the regulations: energy consumed in kWh/m^2 and CO_2 emissions. They do so qualitatively by means of a scale of letters that ranges from A for the best performing homes to G for those whose performance is worse, and quantitatively by showing the attained figures. The information provided is very technical; therefore assessing the consequences brought about by these data becomes a very difficult task for anyone who is not a specialist in the field.

This paper addresses whether it is possible to complete the information provided to offer in addition the economic cost that the landlord/lady would have to pay for energy consumption in the house to be rented. If the RD 235/2013, together with the technical data, made it obligatory to provide economic data, it could reach what it is aiming at: that the energy class of the apartment would exert a real impact on the rental price in such a way that it would encourage investment in energy renovations since it is going to make it possible to increase the homeowner´s income, so that he or she can make profit of his or her investment. Otherwise, the energy renovations would only be an expense for the owner, while the reduction in the energy bill and the improvement in habitability, consequences of energy renovation, would be enjoyed by the landlord/lady. The incentives carried out in Spain to date have been insufficient [11].

The aim of this research is to propose a methodology for completing the information in the energy performance certificate with economic data, with the intention that the information provided should have more impact on market prices and can encourage the energy renovation of rental dwellings.

2. Background

The European Commission has published three directives whose aim is to improve the energy performance of buildings (EPBD).

Directive 2002/91/EC on the energy performance of buildings [12] aims to achieve an improvement in the energy efficiency of the building stock. To do this, it creates, among other measures, the energy efficiency certificate for buildings.

Directive 2010/31/EU on the energy performance of buildings [13] develops the energy efficiency certificate and the type of buildings that must obtain it be expanded.

Directive 2018/844/EU on the energy performance of buildings [14] requires the drafting of long-term energy renovation plans for the building stock.

The EU is promoting policies aimed at renovating the building stock. At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient [15]. This means that a large part of the energy used goes to waste [16]. At the same time, only about 1% of the building stock is renovated each year [15]. It is necessary to increase the rate of renewal of the building stock.

The EU’s policy of renewing the building stock is part of the European Green Deal. It aims to take further action and create the necessary conditions to scale up renovations and reap the significant saving potential of the building sector [17].

In June 2020, after the first covid-19 crisis, the Spanish government is considering investing 2,000 million euros for the renovation of the building stock [18]. This is a measure that tries to bring the country's economy back to life and create jobs. Although to achieve this, sufficiently attractive incentives would have to be considered, since, the incentives carried out in Spain to date have been lacking [11].

The Housing State Plan 2018-2021 previously provided for a programme to promote the improvement of energy efficiency and sustainability in housing with a maximum amount of 8,000 euros per house and 40% of the energy renovation budget, provided that the demand for energy be reduced by between 20% and 35% depending on the climate zone in wich the apartment building is located [19]. Due to the covid-19 pandemic, the period for granting aid has been extended until December 31, 2022.

It is important to pay attention to the governance of actions. Cost-effective energy efficiency measures are not always implemented. Different barriers have been identified: Organizational problems like power, culture and agency; behavioral difficulties like bounded rationality, form of information, credibility and trust, and inertia; economic market failures like principal agent problems, split incentives, adverse selection, moral hazards and imperfect / asymmetric information; and economic non-market failures like market heterogeneity, hidden costs, access to capital and risk [20]. Various investigations propose other agents to lead these interventions such as cooperatives [21] and corporate social responsibility [22].

Incentives need to be attractive enough to overcome the difficulties involved, in order for this type of aid to be effective and to mobilize the rest of the private capital essential for its implementation. One of those difficulties is the managerial problem in apartment buildings. Neighbourhood communities often show lack of cohesion and diverse opinions about the need to invest a significant amount of money in energy renovation. Especially when talking about vulnerable neighbourhoods, where the scarcity of economic resources presents a greater challenge. Another difficulty is the lack of information.

In 2007 the first regulation requiring the energy efficiency certification of new buildings was published in Spain [23]. Ruá already pointed out the flaw of making use of the CO_2 emissions indicator, since it favoured those buildings featuring low emissions due to the use of renewable energies such as biomass, despite their very high energy consumption [24].

A second regulation was published in 2013 extending the obligation to carry out energy efficiency certification to existing buildings that are to be sold or rented as well [6]. The final energy consumption indicator was included to fill the previously detected gap.

In June 2020, the Spanish government started working on a draft Royal Decree to partially transpose EU Directive 2018/844 which will regulate the energy certification of buildings. This is the appropriate time to make amendments in the law such as the new indicator proposed in this article in order to correct the detected flaw, as had been done in the previous revision process.

As regards the influence of energy certification on prices, Palma states that the energy rating does not have a significant impact on the price of housing in Spain [7].

Other authors have reported price differences according to energy class. In Anglo-Saxon countries, price differences can be as high as 10%. In Ireland, A-labelled homes are sold at a price premium of 9.3% as compared to similar homes with the intermediate D-label and are rented at a price premium of 1.8% [25]. A difference in the capitalisation rates of energy efficient properties between owners and tenants is noted. In England, A-labelled homes are sold at a price premium of 5% as compared to similar homes with the intermediate D-label, and dwellings with a G-label are sold at a discount of 7% [26].

Similar figures are attained in other European countries as well. In the Netherlands, A-labelled homes are sold at a price premium of 10.2% as compared to similar homes with the intermediate D-label, and dwellings with a G-label are sold at a discount of 5% [27]. In Germany, a 1% increment in energy consumption in dwellings decreases a building's rent by 0.08% and the market value by 0.45% [28].

The attained figures are also similar in Spain. A-labelled homes are sold at a price premium of 9.8% as compared to similar homes with the intermediate D-label [29]. In Barcelona, A-labelled homes are sold at a price premium of 9.6% as compared to similar homes with the intermediate G-label [8].

According to the literature reviewed, actual energy savings are not fully incorporated into the sale or rental price premiums. In some cases, such savings are partially incorporated with a greater incidence in homes for purchase and sale than in homes for rent.

In Europe, only 1% of buildings undergo energy efficient renovation every year [30]. In Spain, between the years 2017-2019, 80,000 residential buildings have been rehabilitated [31]. In order to reach the goal of energetically renovating 1,200,000 apartments set by the National Integrated Energy and Climate Plan 2021-2030, the number of home improvements for energy savings carried out would have to be multiplied by 4.5 times. One of the barriers to the renovation of residential buildings, detected by the 75% of the replies collected by the Stakeholder consultation on the renovation wave initiative [32] is the different interests between house owner and house occupant. The proposal presented in this paper could help mitigate this barrier so that the Renovation wave could be more successful among rental homes.

Marmolejo concludes that, in Spain, the energy rating has no practical impact when a home is sold or rented. Consequently, he points out that national policies should make an effort to clarify the impact of the energy rating on operating costs [8].

It is presupposed that before renting a flat, the landlord/lady researches all associated costs and who pays them: residents' association, property tax, central heating fees, etc. Knowing the expenditure required to maintain the comfort conditions could help to decide when choosing which property to rent, and this would have a real impact on the price.

One could object that the cost offered by the energy efficiency certification will differ from the cost reflected in the bills once the house is used, contrary to what happens in Sweden, where the energy certificate is made based on energy bills [33]. However, the same objection could be made about the value of the energy consumption currently offered. There is a difference between the theoretical consumption provided by the energy efficiency certificate and the real energy consumption that takes place in the apartment. The aim of RD 235/2013 is to establish comparisons between the behaviour of different homes and to do so it establishes a standardised procedure. Actual consumption depends on how the user uses the building and on the thermal conditions the building is maintained. The price will be affected in the same way. Reporting the price associated with energy consumption does not introduce greater uncertainty than prevailing at present.

It would be necessary to be clear when explaining the information that is obtained by means of the housing energy certification: the consumption necessary to maintain certain conditions of the dwelling´s inner environment with a certain usage profile. Regarding economic expenditure, it would also be useful to clarify the economic expenditure which would be necessary to meet these needs that have been standardized by legislation.

If the price that a landlord/lady can demand for renting his/her apartment really varies in relation to the cost to the tenant for maintaining it in comfortable conditions, the economic incentive for the landlord/lady to carry out the energy renovation would be the same as if he/she lived in the dwelling, which would cancel the difficulty in undertaking an investment for others to take advantage of and, in addition, it would become an easier house to rent because it would reach the conditions of comfort more quickly. It would be better appraised by tenants who would be willing to pay more for the rent of the house knowing that they will pay less for the energy consumption and that they will have better living conditions.

3. Methodology

The methodology proposed in this article is described below. Its purpose is to calculate the price that the householder in Spain must pay for the energy usage inside the dwelling. To do this, the different steps of the methodology used, including the different variables and formulas are shown in table 1 are used.

Table 1. Steps of the methodology used, including variables and formulas used to calculate the cost of energy consumption in households.

Step	Description		ENERGY USE				
			Heating	**Cooling**	**Domestic hot water (DHW)**	**Cooker**	**Home appliances, illumination**
1	D: Demand (kWh/m^2; kWh/person)		Climate zone			-	-
			Energy rating		-		
2	P: Average seasonal performance (%) [34]	Electricity (ELE) (Heat pump)	116	131	-	-	-
		Electricity (ELE) (Joule effect)	99	-	99	-	-
		Gas (GAS)	73	-	79	-	-
		Diesel (DIE)	65	-	81	-	-
		Liquefied petroleum gases (LPG)	70	-	77	-	-
3	EPI: energy performance index (kWh/m^2; kWh/person)		EPI = D / P			-	-
4	UR: Unit of reference (m^2; person)		S: Surface (m^2)		Np: Number of persons	-	-
5	Cn: Consumption (kWh) [35, 36]		Cn = EPI · S		Cn = EPI · Np	GAS: 941	ELE: 2570
						ELE: 1081	
6	Pc: Price per consumption (€/kWh) Pp: Price per power (€/kW) Po: Price per other imports (€/day) [37]	Electricity (ELE)	Pc: 0.14754; Pp: 48.38605; Po: 0.05633				
		Gas (GAS)	Pc: 0.05094; Po: 0.40008				
		Diesel (DIE)	Pc: 0.08075				
		Liquefied petroleum gases (LPG)	Pc: 0.08176				
7	Cs: Cost (€)		Cs = $\sum$(Cn · Pc + Rp · Pp + Po) for each energy source				

The meaning of all the acronyms of the table 1 are:

- D: Demand

- P: Average seasonal performance
- EPI: energy performance index
- UR: Unit of reference
- S: Surface
- Np: Number of persons
- Cn: Consumption
- Pc: Price per consumption
- Pp: Price per power
- Po: Price per other imports
- Cs: Cost
- Rp: Rated power

Firstly, the limit values are set, that is, the limit values among the classes of the energy rating scale for the indicators of annual heating demand and cooling demand for apartment buildings located in the different winter and summer climate zones in Spain. For this purpose, the values offered by the official energy certification tools are taken: LIDER-CALENER (HULC) Unified Tool [34]. These are the limit values that imply the change between the seven classes that are named by a letter, class A that includes the buildings that present a lower demand of heating or cooling and class G to which more energy demanding buildings belong. As shown in table 2, these values are different for each of the climate zones present in Spain. The winter climate zones are named with a letter according to climate harshness, with zone A being the mildest and zone E the harshest. The summer climate zones are named with a number according to climate harshness, zone 1 being the mildest and zone 4 the harshest. Additionally, the area α corresponding to the Canary Islands, that are located near the African continent and that enjoy a more benign climate, is included.

Table 2. Limit values among the classes of the energy rating scale of the indicators of annual demand for heating and demand for cooling for apartment buildings located in the different climate zones of Spain in kWh/m2 [34].

Limit values for heating / cooling demand (kWh/m^2 year)		**CLASS**						
		A	**B**	**C**	**D**	**E**	**F**	**G**
CLIMATE ZONE WINTER	α	0.0	0.0	0.0	0.0	0.0	0.0	>0
	A	3.0	7.0	12.2	21.2	46.6	50.7	>50.7
	B	4.6	10.7	19.2	32.2	64.3	70.1	>70.1
	C	7.7	17.9	32.4	54.2	99.8	108.8	>108.8
	D	11.7	27.0	48.7	81.6	144.1	157.1	>157.1
	E	15.7	36.3	65.5	109.6	189.5	206.5	>206.5
CLIMATE ZONE SUMMER	**1**	0.0	0.0	0.0	0.0	0.0	0.0	>0
	2	2.1	3.9	6.6	10.6	12.8	15.7	>15.7
	3	5.5	8.9	13.9	21.3	26.3	32.4	>32.4
	4	7.8	12.6	19.5	30.0	36.9	45.4	>45.4

The heating and cooling demand for each class of dwelling is then established by finding the mean value between the lower and upper limit values of that class. As class G only has a lower limit, this value is adopted as demand, thus adopting a conservative value.

In this way, the heating and cooling demand in each home is obtained, depending on its energy class and climate zone, as shown in table 3.

Table 3. Average values of annual demand for heating and demand for cooling in apartment buildings of each energy class located in the different climate zones of winter and summer in Spain in kWh/m^2. (Prepared by the authors based on data from [34]).

Average values for heating / cooling demand (kWh/m^2 year)		CLASS						
		A	**B**	**C**	**D**	**E**	**F**	**G**
CLIMATE ZONE WINTER	α	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	A	1.5	5.0	9.6	16.7	33.9	48.7	50.7
	B	2.3	7.7	15.0	25.7	48.3	67.2	70.1
	C	3.9	12.8	25.2	43.3	77.0	104.3	108.8
	D	5.9	19.4	37.9	65.2	112.9	150.6	157.1
	E	7.9	26.0	50.9	87.6	149.6	198.0	206.5
CLIMATE ZONE SUMMER	**1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	1.1	3.0	5.3	8.6	11.7	14.3	15.7
	3	2.8	7.2	11.4	17.6	23.8	29.4	32.4
	4	3.9	10.2	16.1	24.8	33.5	41.2	45.4

The annual energy demand for the preparation of domestic hot water (DHW) is calculated according to the following expression [38]:

D_{DHW} (kWh/person) = D_{REF} (l/p·d) · 365 (d) · ($T_{DHW} - T_{CW}$) (°C) · 0.00116 kWh/l·°C

Where:

- D_{REF} = Reference demand of DHW at 60°C. According to table 4.1 of the Basic Document DB-HE "Energy Saving", of the Technical Building Code (CTE) [39], it is 28 litres per person per day in housing.
- T_{DHW} = Temperature of preparation of DHW, 60°C.
- T_{CW} = Cold water temperature. It is obtained from table B.1 of the CTE [39], depending on the climate zone.

Table 4 shows the values of the annual energy demand for the preparation of domestic hot water as a function of the average cold-water temperature in each climate zone.

Table 4. Values of the annual energy demand for the preparation of domestic hot water (DHW) as a function of the average cold-water temperature in each climate zone in kWh/person. (Prepared by the authors based on data from [39]).

Climate zone	Average cold-water temperature (°C)	DHW demand (kWh/person)
α	16	522
A	12	569
B	11	581
C	10	593
D	7	628
E	6	640

To calculate the energy performance index for installations designed to meet the demand for heating, cooling and DHW, the average seasonal performance values set out in Annex IV of the document "Energy Rating Scale for Existing Buildings" [40] are adopted. The average value weighted according to the percentage of square meters in wich each type of installation is used has been adopted, to avoid an excess increase in the number of variables to be taken into account when different values are offered depending on whether it is an individual or collective installation, or other considerations. If the outcome of a specific home is to be known more precisely, the performance value considered should be replaced by the real value. In any case, it would also be necessary to carry out this operation to increase accuracy in the case of not having taken the average values.

For gas-fired cookers, it is taken the average disaggregated consumption value for that use as given in the SPAHOUSEC II report [35]. This report shows that there are hardly any differences between consumption in single-family homes and collective homes. For cookers that use electricity and for domestic appliances and lighting, the disaggregated value of average consumption for usage in apartment buildings it is taken from the SECH-SPAHOUSEC report [36].

Average consumption values have been adopted for gas cookers and for household appliances and lighting. The average consumption value for the electric cooker has been obtained by multiplying the total consumption in the home by the percentage allocated to cooking in collective homes: 644 kWh (8.4% of 7.859 kWh). However, the aforementioned report has not taken into account that 59.6% of households have an electric cooker, so the average consumption in each household with an electric cooker is 644 / 0.596 = 1.081 kWh, a value that has been adopted in this article.

The prices of the different energy sources offered by the National Commission for Markets and Competition obtained in June 2020 [37] are taken. The prices of the most widely used energy sources are collected: electricity, gas, diesel and liquefied petroleum gases. The prices of the different energy sources paid by the final consumer are adopted, as shown in table 1. The price per consumption (Pc in euros/kWh), the price per power (Pp in euros/kW) and the price per other amounts (Po in euros/day) are considered. All taxes are included in the different amounts.

The proposed methodology for calculating the cost of energy consumption within households is a simplified method. It does not seek to know the exact cost, but its purpose is enabling an average cost estimate to be draw out in a quick way in order to establish the cost differences among different dwellings a priori. Hence, it sets certain variables in advance. This streamlines the process, while allowing the definition of other variables, so that it can obtain results to make such a comparison possible. Table 5 shows the different variables that have been defined before carrying out the calculation and those that remain to be defined for carrying out the calculation.

Table 5. Defined variables and variables to be defined in the proposed energy consumption calculation methodology.

<table>
<tr><th>Defined variables</th><th>Variables to be defined</th></tr>
<tr><td rowspan="3">Seasonal average performance of heat, cool and DHW</td><td>Climate zone</td></tr>
<tr><td>Energy rating</td></tr>
<tr><td>Dwelling surface</td></tr>
<tr><td rowspan="3">Energy consumption in cooker, appliances and illumination</td><td>Number of persons</td></tr>
<tr><td>Source of energy used in each application</td></tr>
<tr><td>Percentage of heated surface</td></tr>
<tr><td rowspan="2">Price of different energy sources</td><td>Percentage of cooled surface</td></tr>
<tr><td>Percentage of solar DHW contribution</td></tr>
</table>

All the variables that remain to be defined are variables required to attain the energy rating. Therefore, the proposed methodology does not need any additional data other than those already included in the current methodology.

In order to offer results that allow us to establish the differences in the cost of the energy consumed in the dwellings according to climate zone and energy rating, the calculations are made by adopting the average or most repeated values for all the variables, except for the variables related to the energy sources used in the dwellings, which are studied in the two majority cases: dwellings with gas installation for heating and DHW, with electric cooker and without cooling installations, and dwellings with electric installation for heating, DHW and cooker and without cooling installations, as shown in table 6.

Table 6. Most repeated values of the variables to be defined and alternative values established to develop the calculation that allows the comparison of the cost of energy consumed in a typical apartment [35].

Variables to be defined	Option 1	Option 2
Surface area of apartment building (m^2)	90.2	90.2
Number of persons	2	2
Heating energy source	Gas	Electricity
Energy source in DHW	Gas	Electricity
Energy source in the cooker	Electricity	Electricity
% Heated surface	100	100
% Cooled surface	0	0
% solar contribution DHW	0	0

Once the cost of the energy consumption of the different dwellings has been established, the difference in the monthly cost of the dwellings of each class is calculated with respect to a dwelling with class E, the class obtained by the largest number of buildings [41], located in the same climate zone.

Afterwards, the same difference in cost is calculated between dwellings in the same climate zone with respect to class E homes but considering that they have a cooling system.

Finally, the housing energy cost is related to the rental price. To do this, data is mined in the most expensive, the average and cheapest neighbourhood, of the monthly rental price in two cities in each climate zone: the city with the highest maximum rent and the one with the lowest rentals. The monthly rental prices have been set with the data of May 2020 provided by the Idealista rental platform [42] and are presented in table 7.

Table 7. Monthly rental prices (euros/m^2), and its application to a 90.2 m^2 dwelling (euros/month) in the most expensive, the average and cheapest neighbourhood for the most expensive and for the cheapest provincial capital of each climate zone [42].

Climate zone	Provincial capital	Monthly rental price (€/m^2)			Dwelling rental price 90.2 m^2 (€/month)		
		Maximum	Medium	Minimum	Maximum	Medium	Minimum
α	Las Palmas	11.8	10.5	7.1	1064	947	640
	Santa Cruz	9.3	8.6	7.9	839	776	713
A	Málaga	11.1	10.2	8.3	1001	920	749
	Almería	7.0	6.3	5.5	631	568	496
B	Palma de Mallorca	13.6	12.4	10.0	1227	1118	902
	Castellón	6.7	6.4	6.1	604	577	550
C	Barcelona	19.4	17.6	13.5	1750	1588	1218
	Orense	6.7	5.8	5.3	604	523	478
D	Madrid	19.4	16.8	11.1	1750	1515	1001
	Teruel	6.4	6.1	5.8	577	550	523
E	Burgos	8.3	7.3	6.3	749	658	568
	Ávila	6.1	5.8	5.5	550	523	496

4. Results

Applying the described methodology, the consumption cost of an apartment building depending on the winter climate zone and the energy qualification, has been obtained. Table 7 shows the cost for a dwelling that has gas installation for heating and DHW, with an electric cooker and without air conditioning. Table 8 shows the cost for a dwelling that has electrical installation for heating, DHW and cooker and without air conditioning. As in both cases the dwelling lacks cooling installations, the summer climate zone does not influence the cost since no energy consumption is made to achieve comfort in summer.

Table 8. Cost of the energy consumption of a collective dwelling with gas installation for heating and DHW, with electric cooker and without air conditioning.

Cost (€)		CLASS						
		A	B	C	D	E	F	G
CLIMATE ZONE	α	1000.6	1000.6	1000.6	1000.6	1000.6	1000.6	1000.6
	A	1016.7	1038.7	1067.7	1112.3	1220.6	1313.5	1326.4
	B	1023.4	1057.0	1103.0	1170.7	1312.6	1431.9	1450.1
	C	1034.8	1091.1	1168.8	1283.1	1495.2	1667.0	1695.4
	D	1052.3	1137.3	1253.7	1425.6	1725.8	1963.4	2004.3
	E	1066.6	1180.8	1337.5	1568.2	1958.5	2263.4	2316.9

Table 9. Energy consumption cost of a collective dwelling with electrical installation for heating, DHW and cooker and without air conditioning.

Cost (€)		CLASS						
		A	B	C	D	E	F	G
CLIMATE ZONE	α	927.8	927.8	927.8	927.8	927.8	927.8	927.8
	A	948.0	995.0	1056.9	1152.3	1383.5	1581.8	1609.4
	B	958.7	1030.7	1128.8	1273.3	1576.4	1831.2	1870.1
	C	979.6	1099.9	1265.9	1509.9	1962.9	2329.9	2390.4
	D	1006.5	1187.9	1436.6	1803.6	2444.8	2952.3	3039.6
	E	1033.3	1277.3	1612.0	2104.7	2938.1	3589.4	3703.7

The results of the difference in the monthly energy consumption cost of a collective dwelling with respect to other dwelling located in the same climate zone that has obtained an E class, the class obtained by the largest number of buildings, are shown below.

As can be seen, the buildings located in climate zone α do not vary according to the energy class as the heating demand is zero in this zone.

To facilitate understanding of the figures, table 10 below shows the different combinations of variables that are taken into account in each one of them.

Table 10. Directory of figures.

Figure	Type of energy consumed in the dwelling	Axis Y	Axis X	Depending on
1	Type 1 Heating: gas DHW: gas Cooker: electricity Air conditioning: No	Difference in the monthly cost of energy consumption	Energy class	Winter (α-E) climate zone
2	Type 2 Heating: electricity DHW: electricity			

		Cooker: electricity Air conditioning: No			
3		Type 3 Heating: electricity DHW: electricity Cooker: electricity Air conditioning: Yes			Winter (α-E) and summer (1-4) climate zone
4		Type 4 Heating: gas DHW: gas Cooker: electricity Air conditioning: Yes			
5	Top: Most expensive rent cities	Type 1 Heating: gas DHW: gas Cooker: electricity Air conditioning: No	Percentage of energy costs in relation to the rental price		Winter (α-E) climate zone Most expensive, average and cheapest neighbourhood
	Bottom: Cheapest rent cities				
6	Top: Most expensive rent cities	Type 2 Heating: electricity DHW: electricity Cooker: electricity Air conditioning: No			
	Bottom: Cheapest rent cities				

Figure 1 shows the difference obtained for a dwelling that has gas installation for heating and DHW, with an electric cooker and without air conditioning depending on the climate zone. Figure 2 shows the difference obtained for a dwelling that has an electricity installation for heating, DHW and cooker and without air conditioning depending on the climate zone.

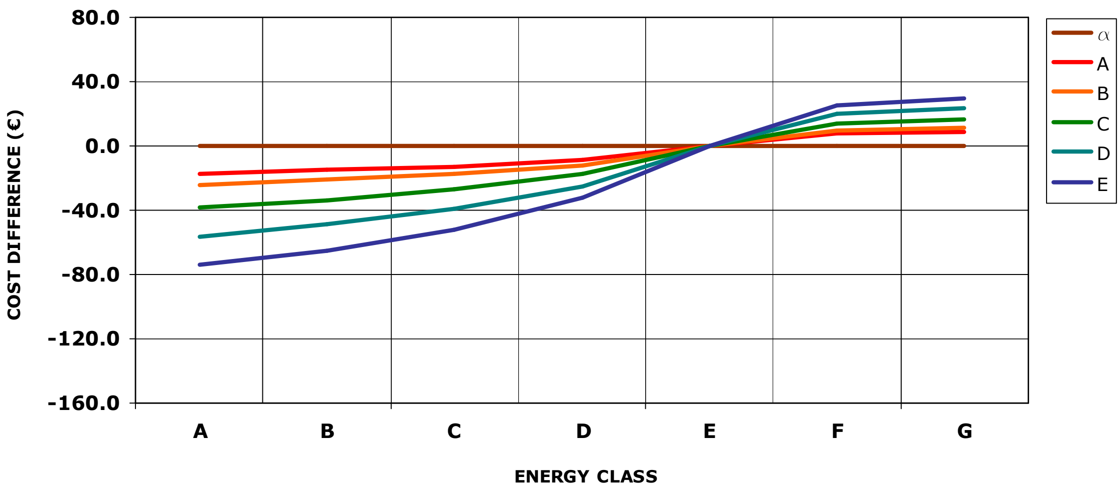


Figure 1. Difference in the monthly cost of energy consumption of a type 1 dwelling.

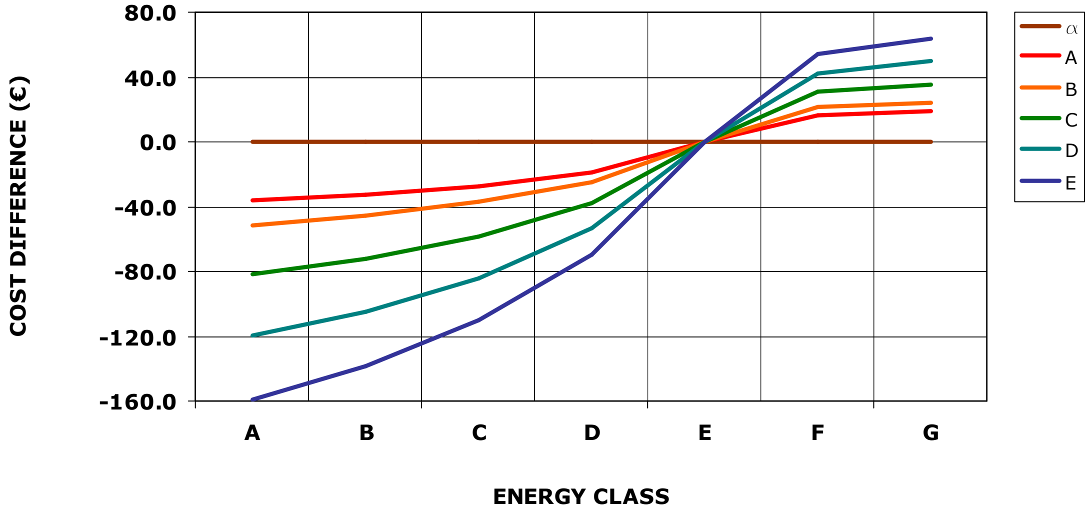


Figure 2. Difference in the monthly cost of energy consumption of a type 2 dwelling.

As the dwellings represented in figures 1 and 2 lack air conditioning, those located in the alpha climatic zone do not present cost differences because there is no demand for heating in the said climatic zone.

Figure 3 shows the difference obtained for a dwelling with gas installation for heating and DHW, with an electric cooker and air conditioning depending on the winter climate zone (α-E), and the summer climatic zone (1-4). Figure 4 shows the difference obtained for a dwelling with electricity installation for heating, DHW, cooker and air conditioning depending on the winter climate zone (α-E), and the summer climate zone (1-4).

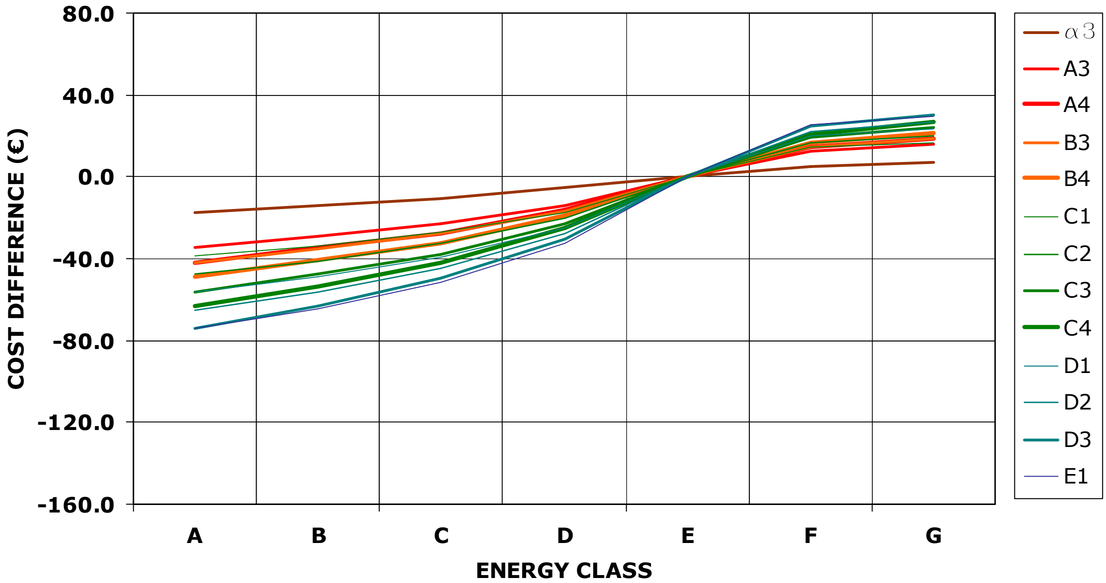


Figure 3. Difference in the monthly cost of energy consumption of a type 3 dwelling.

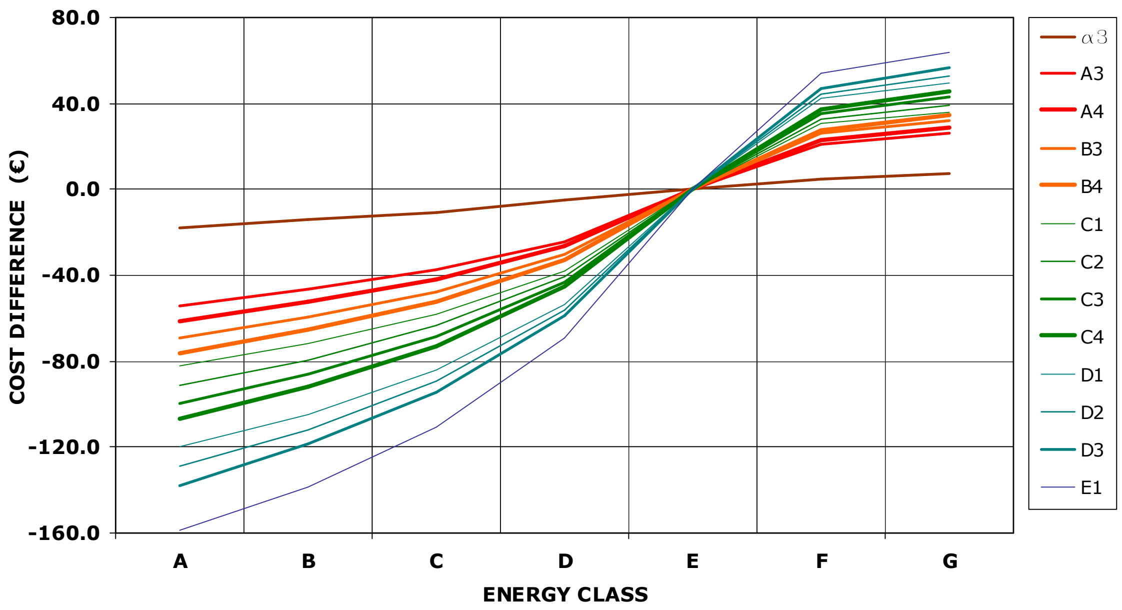


Figure 4. Difference in the monthly cost of energy consumption of a type 4 dwelling.

As the dwellings represented in figures 3 and 4 have air conditioning, it is necessary to differentiate the consumption that occurs in the dwellings located in the different summer climatic zones named with numbers 1-4 within each winter climatic zone named with the letters α-D. Each winter climate zone is represented with the same color. Each summer climatic zone is represented with the same thickness, so that the least severe climatic zone, number 1, is represented by the thinnest line, while the most severe climatic zone, number 4, is represented by the thicker line.

Next, the percentage of energy cost of a dwelling in relation to its rental price, shown in the y axis, depending on the energy class, shown in the x axis, is given.

Each figure consists of two graphs. The dwellings that are located in cities with the most expensive rent are represented in the upper segment of the figure. While the dwellings that are located in cities with the cheapest rent are represented in the bottom segment of the figure.

In each graph, three lines are represented for each climate zone. The thickest line, found in the central position, represents the neighbourhood with the average rent in the city. The thinner line, which is higher than the thick line, represents the most expensive neighbourhood in the city. The thinner line, which is lower than the thick line, represents the cheapest neighbourhood in the city.

Figure 5 presents the results for a dwelling with gas installation for heating and DHW, with an electric cooker and without air conditioning. Figure 6 shows the results for a dwelling that has electrical installation for heating, DHW and cooker and does not have air conditioning.

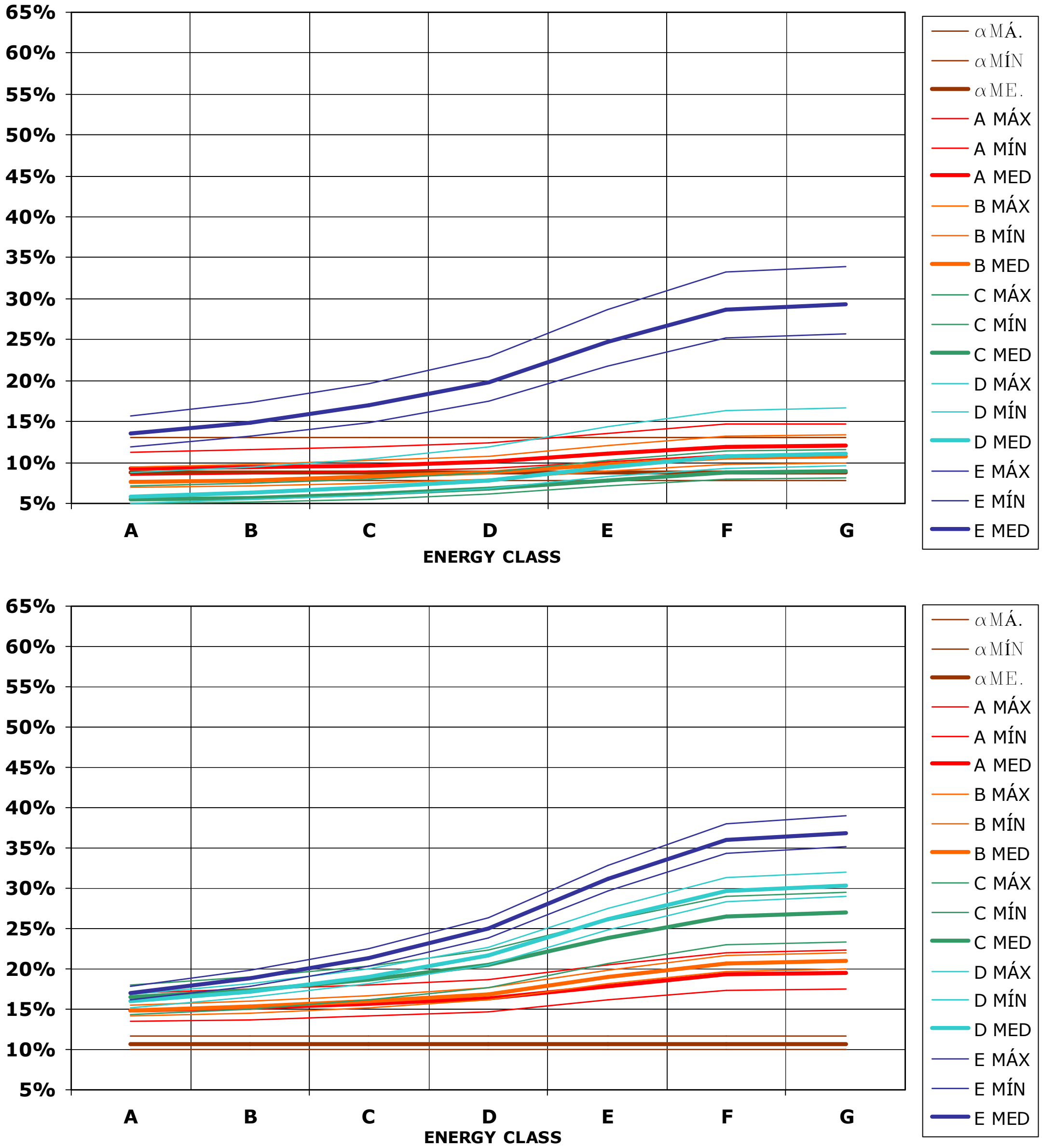
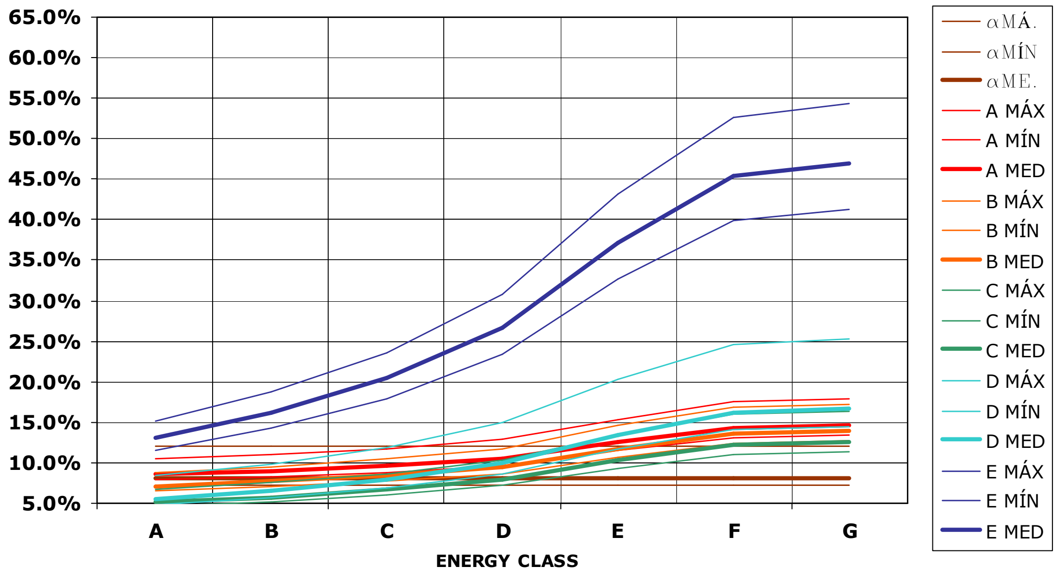


Figure 5. Percentage of energy costs in relation to the rental price of a type 1 dwelling. At the top, the housing is located in the cities with the most expensive rent in each climate zone and at the bottom in the cities with the cheapest rent.



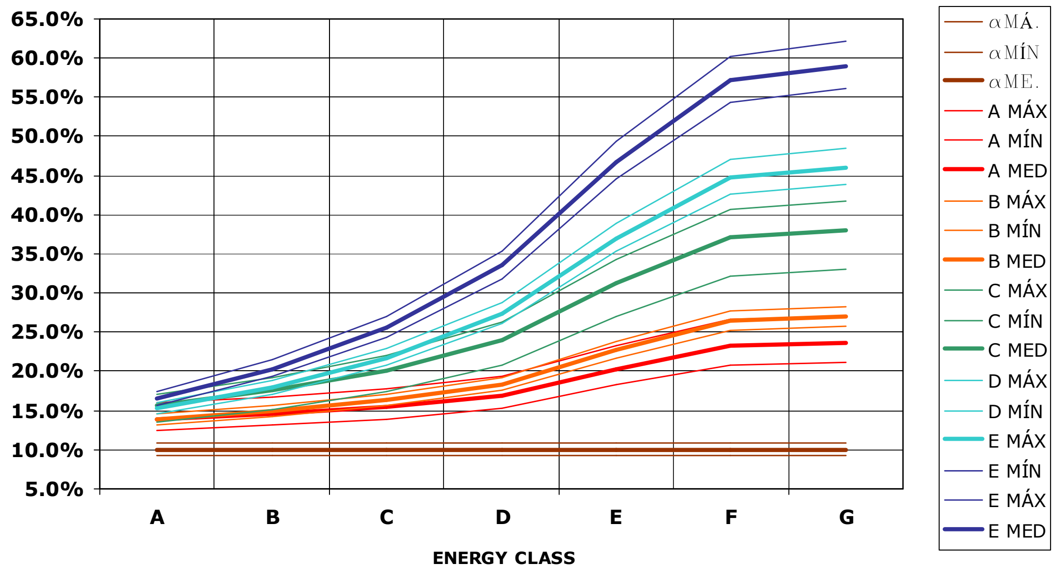


Figure 6. Percentage of energy costs in relation to the rental price of a type 2 dwelling. At the top, the housing is located in the cities with the most expensive rent in each climate zone and at the bottom in the cities with the cheapest rent.

5. Discussion

The values of the demand for heating and cooling have been attained considering that the dwelling is maintained at the following temperatures [43]:

- June – September: 25°C from 7.00 to 23.00 and 27°C from 23.00 to 7.00
- October – may: 20°C from 7.00 to 23.00 and 17°C from 23.00 to 7.00

The consumption values of a specific apartment may differ from the values expressed in this article, since they are average values attained under the aforementioned premises. In the case of varying usage profiles, housing consumption would change as well. This implies that the use that each person makes of the thermal installations, as well as the comfort level they adopt, has a direct effect on the consumption that takes place inside their home. Standard conditions of use and comfort have been considered to establish a comparison among dwellings, but real consumption ultimately depends on the user's behaviour.

Regarding the cost of energy consumption, it can be seen that when a property lacks a cooling system, the summer climate zone does not impact on this cost, since, despite having a different cooling demand in each area, there is no consumption to achieve the comfort conditions in the property. This happens in 74% of the dwellings [44]. Although summer climate zone 1 does not have a cooling demand, the rest of the zones do need an energy input to achieve the comfort that cannot be produced in summer. In these dwellings without a cooling system, the energy consumption cost is lower, although this is at the expense of a decrease in comfort.

On the other hand, in the climate zone to which the Canary Islands belong, there is no demand for heating, so the energy consumption cost remains constant in all types of dwellings.

It can also be seen how it is small the variation in the energy consumption cost depending on the type of dwelling, 5%-8% depending on the type of installations, in class A dwellings, as opposed to 43%-57% in class G dwellings. This is due to the fact that dwellings with a better energy class have a higher quality thermal envelope, which reduces the influence of weather conditions on energy consumption. However, poorly prepared housings are more exposed to the weather.

The difference in energy consumption costs between a home with gas installation and one with electrical installation for heating and DHW is very small, less than 8%, for buildings featuring energy-efficiency and in mild climate zones, whereas for buildings featuring lower energy-efficiency in climate zones with harsher winters, homes with electrical installations pay between 40% and 60% more because it is a more expensive source of energy. The current fee structure discourages, in these cases, the decarbonisation of energy in the residential sector.

As for the difference in the cost of energy consumption according to the type of housing, there is a difference of 26 to 104 euros per month between the best and the worst home depending on the climate zone for homes with gas and 55 to 223 euros per month for homes with electricity. These differences are so significant that, if the landlord had this information before renting the flat, it could have had an influence on the price of the rent. It is not the same for the landlord/lady to know only the rental price information, as it is also to know the price of the energy that he/she is going to consume. Having both data allows him/her to easily make a calculation and thus know the total price that he/she will have to pay while living in the apartment.

The fact of varying only one letter in the class of the house with respect to class E, which is the one presented by most houses at present, has an economic impact of between 8 and 33 euros per month depending on the climate zone for houses with gas and between 17 and 70 euros per month for houses with electricity.

Regarding the difference in energy consumption costs, the milder the climate zone, the less it grows, except in the Canary Islands where it is zero as explained above, and it is even less for homes equipped with a gas installation. In areas of harsher climate, the difference becomes more significant.

For homes with a cooling system, the differences in energy consumption cost are similar to those of homes without a cooling system. Differences of between 9% and 39% are attained within the same winter area, depending on the summer area. In these dwellings, the fact of varying only one letter in the class of the dwelling with respect to class E, does not have a greater economic impact. It varies by between 12 and 33 euros per month depending on the climate zone for homes with gas and between 21 and 70 euros per month for homes with electricity.

Finally, when comparing the energy consumption cost with rental prices, dwellings equipped with gas installation in the locations with the highest rental price in each climate zone show a low value of between 5% and 17%; except in the harshest climate zone where it peaks at a maximum value of 34%. In the areas with the lowest rental price in each climate zone, the value ranges from 10% to 32%, reaching 39% in the harshest climate zone. When the rental price is lower, the impact of the climate zone on the energy consumption cost becomes more significant. This is especially true for less efficient homes.

However, the variation in the percentage of the energy consumption cost compared to the rental price is very similar, when comparing homes located in the most expensive (3%-18%) and the cheapest (4%-20%) locations in the same climate zone. This means that the difference in percentage that can be observed by varying the letter is not greatly conditioned by the price of renting the home.

When the results attained in homes with electrical installations are analysed, by comparing the energy consumption cost with rental prices, in the locations with the highest rental price in each climate zone, they show a moderate value of between 5% and 25%; except in the most severe climate zone where it reaches a maximum value of 54%. In the towns with the lowest rental price in each climate zone, this value ranges from between 9% and 48%, reaching 62% in the harshest climate zone. In homes with electrical installations, the impact of the climate zone on the cost of energy consumption is more significant. This is particularly true in less efficient homes and in the harshest climate zones.

Furthermore, the variation in the percentage that the energy consumption cost entails, compared to the rental price is more noticeable. It reaches values between the houses located in the most expensive locality from 6% to 39% and in the cheapest locality from 9% to 45% within the same climate zone. This highlights that the difference in percentage observed by means of varying the letter is more important than in homes with gas installation.

The percentage that the energy consumption cost represents compared to the rental price is not lower in locations with a milder climate, but rather in those with a higher rental price such as Madrid and Barcelona. If those cities, which have a much higher rental price than the rest, were not to be taken into account, the percentage of the energy consumption cost compared to the rental price would vary depending on the harshness of the climate.

6. Conclusions

Three issues have been addressed throughout this research. Firstly, a methodology has been formulated which allows the cost of energy consumption in a collective dwelling to be calculated by gathering just ten variables which must have been provided in advance for obtaining the energy efficiency certificate. The methodology defined was then applied, adopting fixed values for five variables (surface area of the dwelling, number of people, energy source in the cooker, heated surface area and solar contribution for domestic hot water), alternating two values for three other variables (energy source for heating and domestic hot water and refrigerated surface area) and studying all the possibilities of the other two variables (climate zone and energy class) whose influence was to be analysed. Finally, the energy costs of the homes thus attained were compared with the rental costs of the locations in each climate zone with higher and lower prices, to see the relationship between both prices.

Arising from the aforementioned, the following conclusions have been obtained:

- If the methodology described above were incorporated into the energy certification programme in such a way that it could be replicated by any researcher, the energy consumption cost of a collective dwelling could be calculated in a flexible way.

- The values attained show that, within the same climate zone, the differences in the cost of energy consumption that the homes have to bear are significant, between 26 euros and 223 euros per month, depending on the different characteristics studied.

- The values attained also show that the energy consumption cost makes a difference of between 5% and 62%, compared to the cost of renting, albeit with different reach, depending on the different characteristics studied.

- The information that the energy certification would offer by incorporating the economic data of the dwelling energy consumption, which has been called *economic certification* in the title of this article, would have a greater impact on the market prices.

The explicit incorporation of economic data on the housing energy consumption into the energy certification would mean a clear improvement in the regulatory action of the authorities. With the minimum effort involved in changing the Royal Decree on energy efficiency certification, which is currently being revised in Spain, the behavior of economic agents could be substantially modified.

Its implementation would be necessary to verify the true impact of the measure, since other factors also influence such as the housing market, the financial situation of both the tenants and landlords (landlords still have to invest large sums, the repayment stretches over a long period of time) and the vigorous implementation of the measures (controls, penalty for non-compliance).

The modification we propose would have clear economic repercussions. A market functions correctly when prices reveal to the consumer the relative costs of each good or service. So if the future tenant had easy to process information, that is, he/she could accurately know the economic cost of the energy consumption of the house he/she intends to rent, he/she would choose the house which would be globally cheaper. This behaviour would have a direct impact on market prices, causing a reduction in the rental prices of housings with higher energy costs, given that, if the consumer acknowledges these by means of the proposed legislative modification, those houses would be more difficult to rent. The energy class would cease to be an attribute to which each person attributes a value [45] and would directly become a price without the need for each person to have to make that hypothetical estimate. In this way, the market would provide a more efficient allocation of resources and would encourage, at the same time, a behavior of owners and tenants aimed at improving the energy efficiency of rental properties. That is, the owner could recover his investment through the upward impact on the rental price and the tenant would also benefit from enjoying a more comfortable home without increasing the total price paid for rent and energy consumption.

Definitely, the proposed modification of the Royal Decree on Energy Efficiency Certification could help bring it closer to achieving some of the goals set out in recent international agreements: the reduction of energy consumption in the building stock, the reduction of greenhouse gas emissions in the building sector and the reduction of energy dependence.

Finally, the visibility of the monetary cost associated with the energy certification of buildings could have clear social implications in the scope of energy poverty. If a person knows the amount of energy expenditure before renting a flat, he/she can know if he/she will be able to cope this cost or if, otherwise, he/she will be doomed to incur a situation of energy poverty. Thus, the proposal developed in this paper could be an effective tool to prevent energy poverty.

The results obtained in the present investigation open the field, in a natural way, to other possible investigations, among which we suggest the following three:

- The effective relationship between energy poverty and the lack of economic transparency of energy certificates.
- The possibility of applying the methodological framework of this research to both second-hand and new-build real estate markets.
- The impact that the application of the new electricity pricing system by time bands, recently adopted in Spain, would have on the results obtained in this research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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