Potential energy savings and economical impact of residential buildings considering different efficiency scenarios. Catalan case study.

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Abstract

The main goal of this paper is to evaluate the potential of energetic savings of the dwellings in Catalonia and its economical impact, according to different scenarios of efficiency that have been defined according to the different regulations at state and autonomic level.

13 typologies of dwellings have been defined in order to categorize the buildings in Catalonia following these criteria: climatic zone, orientation, year of construction and type of dwelling, i.e., detached house or multifamily building.

Simulations with LIDER software has been done in order to obtain the heating and cooling demand for each typology of dwelling in each climatic zone and for each orientation. It has also been studied the economical impact of each scenario.

The mainly conclusions are the following: the best normative scenario is the one where the limitations imposed by the state regulations are fulfilled, CTE. With this scenario a reduction in emissions of 6.4% would be achieved with respect to the emissions that would be produced to 2015 without carrying out any measure of rehabilitation in the existing buildings. The investment in the entire park of buildings of Catalonia would be in 3.600 M€ (spared 0.45 €/kg CO2 / year considering a time of useful residual life of the building at 40 years). The saving in emissions would suppose 32,3% of the reductions foreseen in the Plan of the Energy in Catalonia for 2015 for the domestic sector.

1 Introduction

Energy consumption in buildings accounts for a significant percentage of total world energy consumption, with values that range from 40% in Europe and USA [1] [2] to 30% in some Mediterranean countries and regions [3] [4] [5]. In recent years, increasing energy import dependency rates and environmental impacts of fossil fuel consumption (the most important being global warming due to anthropogenic CO_2 generation) have raised unprecedented efforts to reduce fossil energy consumption and mitigate its depletion. Directives like 2002/91/EC [1] and 2010/31/EU [6] have been issued by the European Union in order to mitigate the environmental and economic impacts of energy consumption in buildings.

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The national transposition of such directives have generated national and regional regulations for setting minimum requirements on the energy performance of new and existing buildings that are subject to major renovations.

A regional regulation is fully justified if it is more restrictive than the national one and includes the characteristics of the territory. That is, it should improve the state regulations. In the case of buildings, such regional regulations must give a bonus for buildings that are constructed in this area in particular.

The coexistence of regulations that have the same scope and purpose it may be counterproductive if it is not clear which one is more restrictive in its entirety.

In some cases, an architect or engineer responsible for the design of a building must take into account the two regulations. The fact that coexist two rules that are defined according to different criteria and parameters, creates confusion in the professionals who have to apply them. At best, it can cause confusion and a greater investment of time in the correct definition of the building. At worst, it can lead to malpractice either through ignorance or lack of confidence in the regulatory system.

In order to check this behavior, this paper analyzes this, for Catalonia, a particularly autonomous region in the north east of Spain, where energy issues are particularly relevant. In the case of Spain, and the autonomous region of Catalonia particularly, the transposition is twofold: Technical Code of Buildings (CTE) for Spain [7] and Ecoefficiency decree (DEC) for Catalonia [8].

For example, the Catalan regulation requirements are not defined according to climatic zones, and the national regulation consider climatic zones. It means that for some climatic zones of Catalonia, the national regulation are more restrictive than Catalan, but not for all of them. The solar factor of the windows is not limited according to the percentage of glass in Catalan regulation, as it is proposed for the state regulations. The Catalan regulations, unlike the state, only limited insulation of facades and the quality of the windows, shedding the isolation of other closures such as the roof or the slab in contact with the ground.

Energy efficiency is expected to play a key role in meeting the European target in accordance to the Kyoto commitments to reduce CO_2 emissions in an economic way.

In the area of residential buildings, and to ensure that these regulations are efficient, (a) the actual contribution in terms of GHG (greenhouse gases) emissions in this sector and the savings that will be achieved with these regulations are estimated, (b) It elaborates the methodology used to determine the potential savings of energy and emissions and also to establish the characterization of the building stock of the studied region (i.e., Catalonia), and (c) offers the opportunity to extrapolate this methodology to other regions. The overall approach may be applicable to other countries or regions facing similar problems.

The rest of the paper is organized as follows. Section II describes the methodology followed for this study. Section III analyzes the results obtained and in section IV the most important conclusions are indicated.

The main goals were to estimate the contribution of heating and cooling of housing to energy consumption in Catalonia and the equivalent carbon dioxide emissions associated with these uses. To estimate the energy savings and emissions reduction obtained in 2015 according to different energy conservation scenarios at different climatic zones. These scenarios are defined according to the Catalan legislation, Ecoefficiency Decree (DEC) and State legislation, Technical Code of Building (CTE). To estimate the economic impact that would mean the implementation of the measures proposed in each scenario at different climatic zones.

2 Methodology

To estimate the contribution of heating and cooling of housing to energy consumption and emissions of CO_2 in Catalonia, the following methodology has been followed:

1. Characterization of building stock of Catalonia
    - To define the types of building considering its geometry and thermal parameters
    - To find the number of buildings by climatic zone
2. Estimation of Energy demand
    - Energetic simulation using LIDER software
3. Estimation of Energy consumption
    - To establish data about heating and cooling systems and energy source
4. Estimation of CO_2 emissions
    - To find the percentage of use of heating and cooling systems
    - To establish the emission factors for each energy source

The base scenario represents the state of demand, consumption and emissions associated with the building stock in 2005, just before the national regulation came into force.

In order to determine the potential savings of energy and emissions for each normative in 2015 and the economical impact, the following methodology has been followed:

1. Definition of scenario
    - Thermal requirements for each scenario: Base (2005), DEC (Regional regulation acronym), CTE (National regulation acronym)
    - Estimation of number of buildings in 2015 (for each category)
2. Estimation of energy demand and consumption and emissions for each scenario
    - Technical potential savings considering 100% of rehabilitation
    - Potential savings considering 2% of rehabilitation
3. Economical impact of each scenario
    - Total investment for each category
    - Total investment for all the stock of buildings.

The calculation of heating and cooling demand has been carried out with version 1.0 of the software LIDER. The LIDER application is the implementation of Spanish normative Limiting energy demand (HE1), established in the Basic Document of Habitability and Energy of the CTE [7]

Lider is not an energy simulation program itself, but verification of compliance of the normative, although dynamic simulation of the energy demand of the building is done. There are settings, such as the use factor, that are not modifiable by the user. This fact does not invalidate the use of this software as it is really interesting that this parameter was constant for all buildings because they do not interfere with the final result. Therefore, the proposed by LIDER is as valid as any other.

3 Results and discussion

In this section, the following results will be presented: characterization and estimation of energy consumption and related emissions for the base scenario (2005); energy and emission savings due to regulation scenarios and economical impact of each scenario.

3.1 Energy consumption and related emissions of stock buildings in Catalonia at 2005 (base scenario)

The following subsections present an overview of the relevant data for the Catalan dwellings stock, energy consumption and emissions of CO2 for base scenario.

3.1.1 Characterization of building stock of Catalonia

It has been classified all the buildings of Catalonia in a total of thirteen categories that combines the old character house or flats with the factor of whether they are isolated or not isolated. [9]

Number of buildings of each category was estimated based on the available information of the 2001 census and the construction activities after 2001 until 2005 [10]. Each dwelling has been defined according to parameters that are important in their energy performance such as geometry of buildings (see table 2) and heat transfer coefficient of closures and openings (see table 3).

Climatic zones correspond to the adaptation of four climatic zones defined in the regulations on thermal insulation Catalan [11] under the new zoning defined in the CTE. The following figure indicates climatic zones by region.

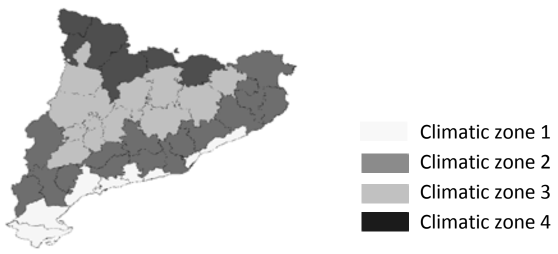


Figure 3 Map of the distribution by climatic zones of Catalonia. Source: [12]

The climatic data from different geographical areas are automatically generated by the LIDER software. The methodology used to calculate this data is explained in the model [13].

The breakdown of the Catalan building stock for different periods of constructions and climatic zone is illustrated in the table 1

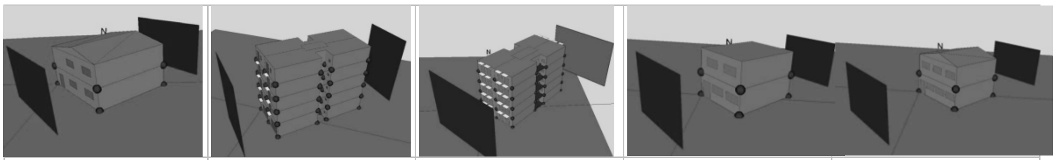
Table 1. Breakdown of the Catalan building stock at 2005.

Year of construction	**Detached/ Multif.**	**Code**	**Climatic Zone**				**m^2/ home**	**TOTAL**
			CZ 1	**CZ2**	**CZ3**	**CZ4**		
Until 1940	Detached	T1 Rural dweling	26.425	46.993	23.894	0	115	**97.312**
	Multifamily	T2 old town	85.474	61.215	24.949	0	60	**171.638**
	Multifamily	T3 “Eixample "	103.809	0	0	0	100	**103.809**
From 1940 to 1980: post civil war	Detached	T4 Post civil war	53.585	124.399	37.993	0	108	**215.977**
	Detached	T5 Mountain dwelling	0	0	0	10.982	112	**10.982**
	Multifamily	T6 Post civil war town	701.032	421.780	48.777	0	80	**1.171.589**
	Multifamily	T7 Mountain building	0	0	0	17.951	91	**17.951**
From 1980 to 1990: post thermal legislation NBE – CT – 79 (stately)	Detached	T8 Detached post 79	20.832	46.950	10.398	0	124	**78.180**
	Multifamily	T9I Isolated Post 79	2.768	3.232	580	0	92	**6.580**
	Multifamily	T9 NI Not isolated Post 79	52.590	61.406	11.024	0	92	**125.020**
From 1990 until 2001: post thermal legislation NRE-AT-87 (regional)	Detached	T10 Detached post 87	65.602	76.798	20.762	0	129	**163.162**
	Multifamily	T11I Isolated Post 87	12.050	7.569	1.392	0	90	**21.011**
	Multifamily	T11NI Not isolated Post 87	228.959	143.824	26.433	0	90	**399.216**
TOTAL			**1.353.126**	**994.166**	**206.202**	**28.933**		**2.582.427**

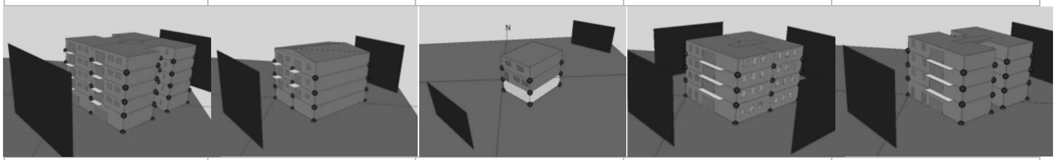
60% of dwellings were built in Catalonia during the period from 1940 to 1980, before thermal regulation (14) came into force. Furthermore, 75% are multifamily residential buildings.

The following tables present the geometry of each type of building and the heat transfer coefficient of closures and openings.

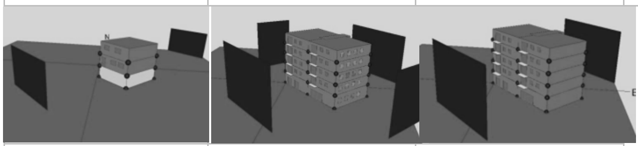
Table 2. Geometry of each type of building.



T1	T2	T3	T4	T5



T6	T7	T8	T9I	T9M



T10	T11I	T11NI

Table 3. Heat transfer coefficient for each closure and for each type of building

Escenario 0	**Heat transfer coefficient, U (W/m²K)**												
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9I**	**T9NI**	**T10**	**T11I**	**T11NI**
Facade	1,82	1,75	1,75	0,66	1.30	1.06	1.50	0.97		0,76	0,90		0,76
Cover	0,11	0,10	0,11	0,11	0,11	0,70	0,11	0,46		0,46	0,48		0,45
Walls	4,74	4,86	4,86	4,74	4,27	4,60	4,27	4,60	na	4,60	4,27	na	4,60
Partitions	1,52	1,87	1,39	1,62	1,69	1,96	1,60	1,81		1,63	1,81		1,63
Forged	1,91	1,43	1.59	1,44	1,68	1,99	2,65	1,96		2,03	2,58		2,37
Base	5,20	n/a	n/a	5,20	5,20	n/a	n/a	n/a		n/a	n/a		n/a
Windows	5,06	5,06	5,06	5,38	5,38	5,72	5,38	5,73		5,73	3,52		3,52
Shutters	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	exterior shutter (White colour)				

na: not available.

3.1.2 Estimation of energy demand for heating and cooling of building stock of Catalonia

In this subsection, the estimation of energy demand for heating and cooling for each category of dwelling and for all buildings of Catalonia is presented.

Table 4. Energy demand for heating and cooling. (kWh/m^2/year). (Base scenario 2005)

Category	**ZC 1**		**ZC 2**		**ZC 3**		**ZC 4**	
	Heat	**Cool**	**Heat**	**Cool**	**Heat**	**Cool**	**Heat**	**Cool**
T1 Rural dweling	72,1	4,3	96,6	3,8	96,3	12,1		
T2 old town	64,1	5,4	87,4	3,6	87,6	10,9		
T3 “Eixample "	74,7	7,8						
T4 Post civil war	67,2	7,5	92,0	6,3	92,5	16,1		
T5 Mountain dwelling							158,5	0,0
T6 Post civil war town	42,4	4,4	60,2	3,1	61,0	8,8		
T7 Mountain building							134,1	0,0
T8 Detached post 79	36,2	10,8	55,1	7,6	57,0	18,9		
T9I Isolated Post 79	49,7	7,3	71,0	5,3	71,2	12,9		
T9 NI Not isolated Post 79	34,5	3,4	48,4	2,3	50,0	7,8		
T10 Detached post 87	26,4	7,9	39,9	6,2	42,2	15,8		

T11I Isolated Post 87	42,5	4,8	66,4	3,9	67,3	10,6		
T11NI Not isolated Post 87	27,9	3,8	50,4	2,3	51,4	7,2		

Considering the number of dwellings of each category at 2005, we can conclude that, taking into account all assumptions considered, energy demand for heating and cooling in the residential sector in Catalonia is around 14,000 GWh / year.

3.1.3 Estimation of energy consumption for heating and cooling of building stock of Catalonia.

To calculate emissions of carbon dioxide is necessary to determine the consumption associated with heating and cooling energy demand. Different systems and equipments are used to meet this demand, and they have a specific energy yield.

With the existing data on energy performance of equipment and its degree of use in Catalonia supplied by Institut Català de l'energia (ICAEN), it was able to estimate the final consumption of heating and cooling of a dwelling and around the park buildings Catalonia according to the number of dwellings of each type in each climate zone [16].

The following table presents data about distribution of heating systems in Catalonia.

Table 6 Heating systems distribution in Catalonia at 2005.

Heating system	%	Equipment	%	Energy source	%
central heating (building)	2,1	Boiler	100,0	Natural gas	66,7
				diesel	25,5
				propane	4,0
				electricity	3,8
central heating (dwelling)	68,3	Boiler	86,0	gas natural	76,4
				diesel	17,8
				propane	1,8
				electricity, coal, firewood	3,7
		Other (heat pump,…)	14,0		
modular heating fixed	13,2	Electric radiators and convectors	39,0		
		Heat pump	20,0		
		Fireplace	9,0		
		Other: (heat accumulator, gas wall heaters , etc)	32,0		
modular heating mobile	16,4	Catalytic heater (butane stove)	43,0		
		Other (electric stoves)	57,0		

There are no detailed data for cooling. In fact, according ICAEN 2005, only 28% of dwellings had the cooling system. So, for calculation purposes, it was considered that 28% of homes have the cooling system with a COP of 2.5. [15]

Energy final consumption of heating and cooling for building stock of Catalonia were found to be 13.500 GWh/year (Base Scenario 2005). Note that the energy consumption associated with the amount of heating and cooling of buildings is lower than the demand. Although this might seem contradictory, it is easily explained because only 28% of homes have refrigeration system. This means that there are 72% of homes that, despite having cooling demand, they don't have systems associated with this demand.

According to data from other studies [17] [18], the overall domestic consumption is around 26,300 GWh/year. It means that heating and cooling are approximately 47% of global consumption of buildings, as indicated by different authors [19] [20] and institutions as ICAEN or IDAE. Based on the assumptions made, the consumption in heating and cooling of housing in Catalonia in 2005 represented 50% of global consumption of housing.

Thus, the results obtained and contrasted with other sources indicate that the results obtained by the methodology used are consistent. Therefore, it is considered that the methodology was valid to perform simulations of policy scenarios.

3.1.4 Calculation of CO2 emissions associated with energy consumption for heating and cooling of building stock of Catalonia

Finally, to determine the CO_2 emissions associated with energy demand of housing in Catalonia is necessary to know the sources of energy used for each use. The following table indicates the percentage of use of different energy sources for heating and cooling. [10]

Table 7. Energy sources used by heating and cooling in Catalonia. Source: [10]

Energy source	Heating (%)	Cooling(%)
Coal	2,0	0,0
Firewood	0,4	0,0
Butane	29,0	0,0
Diesel	12,0	0,0
Oil	0,0	0,0
Propane	0,0	0,0
Natural gas	29,0	0,0
Electricity	26,0	100,0

It is also necessary to know the emission factors associated with each of the energy sources.

Table 8. Emission factors for each energy source. Source: [4] [21]

Energy source	**kg CO_2 / kWh**
Coal	0,347
Butane	0,235
Diesel	0,264
Fuel	0,282
Propane	0,235
Natural gas	0,202
Electricity[2]	0,184

The way of calculating CO2 emissions is well known by the following equation:

$$Emissions = \sum C_{heating} \cdot u_i \cdot F_e + \sum C_{cooling} \cdot u_i \cdot F_e$$

Equation 1

$C_{heating}$: Heating Consumption (kWh/year)
$C_{refrigeració}$: Cooling consumption (kWh/year)
u_i: Use (%)
F_e: Emission factor (kg CO_2 / kWh)

Therefore, the heating and cooling of the housing in Catalonia, suppose the emission of more than 2.800 kt of CO_2 each year. These estimates may be even higher, as both the building stock as the percentage of homes that have a cooling system is increasing. In Catalonia, the CO_2 emissions in 2005 were 43800 ktCO_2 [17], the Energy Plan of Catalonia, located in 41457 kt CO_2 for 2003 [18]. That means 6.5% of CO_2 emissions are due to consumption in heating and cooling of the housing.

3.2 Estimation of energy, emissions savings and economical impact due to thermal regulations at 2015

The following subsections present results of energy and emission savings and economical impact at 2015 due to bring into force energy regulations DB-HE1 (CTE) and Ecoefficiency Decree (DEC).

3.2.1 Definition of regulation scenarios

As mentioned above, there are 2 different scenarios that aim to reduce CO_2 emissions by reducing energy demand of buildings. The regulation scenarios are based on reducing energy demand, reaching smaller heat transfer coefficient values (U). This is achieved by using insulation and construction solutions that ensure the desired thermal coefficients. For the purpose of reducing demand and the economic calculation has been considered that the decrease of U has been achieved by adding insulation material in the case of closures, and changing the type of glass in the case of the openings.

[2] According to energetic catalan mix. Source: [17]

These measures are different in each scenario because each one of them covers different aspects and energy constraints. The following table indicates the limits established by the regulations for each climate zone.

Table 9 Limit values of U (W/m^2K) for each scenario and climate zone.

Scenario	**DEC**	**CTE**			
	All the climate zones	**ZC1**	**ZC2**	**ZC3**	**ZC4**
Facade	0,70	0,73	0,73	0,66	0,57
Cover	n/a	0,41	0,41	0,38	0,35
Walls	n/a	1,00	1,00	1,00	1,00
Partitions	n/a	1,20	1,20	1,20	1,20
Forged	n/a	1,20	1,20	1,20	1,20
Base	n/a	0,50	0,50	0,49	0,48
Windows	3,30	*	*	*	*
Solar Factor	0,35	n/a	n/a	n/a	n/a

* : The U and Solar Factor of windows depend on climate zone, the orientation and the percentage of glass surface on the total area of facade. Thus, the limit values are indicated in the following table:

Table 10 Limit values of U (W/m^2K) for each category and climatic zone CTE.

Category		**ZC1**	**ZC2**	**ZC3**	**ZC4**
T1	**20 – 30% glass**	2,90 – 4,30	2,90 – 4,30	2,50 -3,50	2,60 – 3,10
T2					
T4					
T5					
T7					
T3	**30 – 40 % glass**	2,6 – 3,9	2,6 – 3,9	2,2 – 3,40	2,20 – 3,10
T6					
T8					
T9A					
T9M					

Related to the solar factor, for these climatic zones and the percentages of glass surface on the total area of the facade, there is not any limitation.

Each of the categories studied for each climate zone according to the requirements of each scenario have been simulated. The reduction of energy consumption and global emissions of CO_2 achieved in 2015 has been calculated. It has been assumed an annual growth of the park building of 50,000 homes per year and an annual percentage of rehabilitation equal to 2%

According IDESCAT [10] projection of housing in 2015 is projected to be equal to 2.9 million homes if a trend scenario is followed and 3.15 million if a higher scenario is followed. So the average between these two scenarios is 3.025 million homes. Therefore, the forecast made by IDESCAT corroborate the annual growth figure of 50,000 new homes per year.

In relation to the percentage of rehabilitation, the annual report on the housing sector which annually publishes the Housing Department of the Environment also reports on the number of homes that have received grants for rehabilitation. Given these data, the average of buildings rehabilitated corresponds to 1.7% of total annual building. However, it should be noted that rehabilitation within the construction sector is projected to be one of the key activities in the coming years. In the current period of crisis, where the construction of new housing has fallen dramatically, Euroconstruct report envisages a recovery from 2010 [22]. In this case we have used an annual rate of 2% of rehabilitation.

3.2.2 Savings of energy demand, consumption and emissions for each scenario

Applying corrective measures indicated by the regulation scenarios to minimize energy demand in all dwellings in Catalonia, the maximum reduction in energy demand will be obtained. This hypothesis of rehabilitation of all dwellings in Catalonia corresponds to an ideal case. The calculation was performed to determine the maximum savings that could be achieved, thus obtaining the technical potential savings for each scenario.

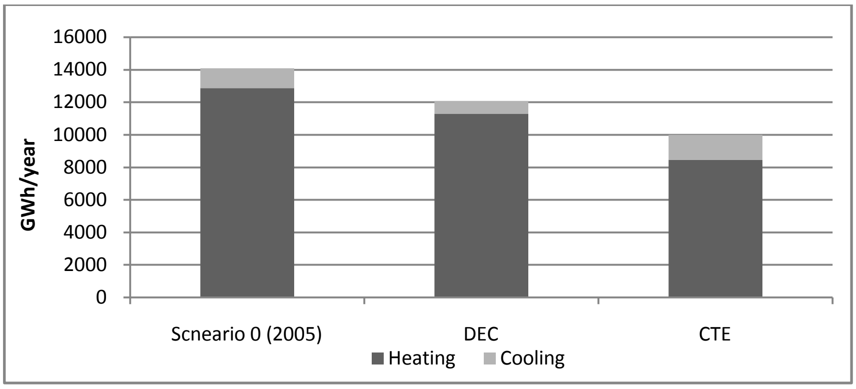


Fig. 4 Heating and cooling energy demand for each scenario. Technical potential savings.

The potential energy saving obtained by scenario CTE is 29% of the global energy demand of the base scenario (2005). On the other hand, the potential saving for DEC scenario is 14.3%. It means that, considering all the measures, CTE is better than DEC, at least for global energy demand. If only cooling demand is considered, then DEC is better than CTE. The reason is because of the limitation of solar factor of windows. For DEC scenario, solar factor is limited to 0.35 for all the year. It is a good solution for cooling demand, but not for heating because solar gains are reduced.

According to the data of equipments installed in Catalonia to produce heat and cool in buildings and the energetic mix, the technical potential saving in emissions if both scenarios were accomplished are as follows:

- DEC scenario: 358 ktCO_2/year, ie., a 12.4% of the total emissions for base scenario.
- CTE scenario: 970 kt CO2/year, ie a 33.7% of the total emissions for base scenario.

Once our technical potential has been evaluated, we can face more realistic assumptions on percentage of rehabilitation and number of housing built from 2005 to 2015.

The growth of housing in Catalonia is 50,000 new homes per year. This means that from 2005 until 2015 there is an increase of 500,000 homes on the most modern types, namely T10 and T11, spread over four climatic zones in the same proportion as the existing buildings. The new homes have been built under the limitations imposed by 3 scenarios of the study, from 2006, this is the year when the different regulations came into effect.

The percentage of rehabilitation considered is 2% of the homes for the current year. The rehabilitation process began in 2005 and has 10 years in which rehabilitation has occurred, this means that by 2015 will have restored 20% of households in 2001. It applies the same rules to both houses of the rehabilitated and new construction.

The following figure shows the savings obtained for energy demand for each scenario if these hypotheses are assumed.

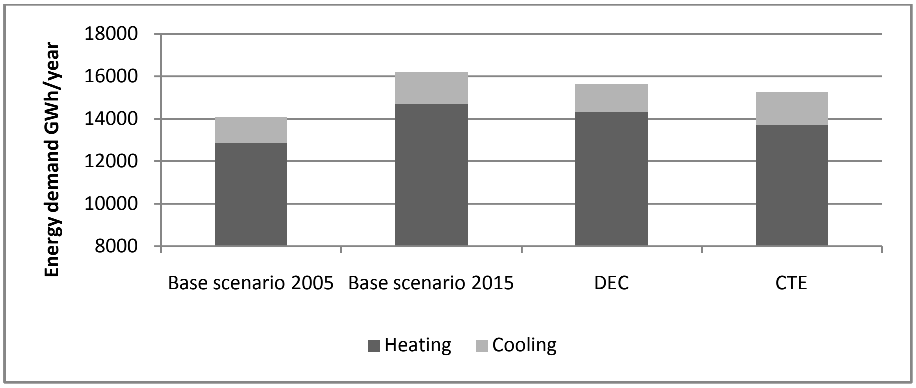


Fig. 5 Heating and cooling energy demand for each scenario. Year 2015

The energy saving obtained for the energy demand by scenario CTE is 5.6% of the global energy demand of the base scenario for 2015, i.e, the energy demand if there were not any thermal regulation. The potential saving for DEC scenario would be only 3.3%. In addition, the increase of housing from 2005 to 2015, without any corrective measures for rehabilitation, would mean an increase of 15% of the global energy demand.

To determine the energy consumption is taken into account the same considerations as in the calculation of consumption in 2005. It also takes into account 5% of increase of cooling equipment installed until 2015.

According to the Energy Plan for Catalonia 2006 - 2015, we expect a reduction in the domestic sector in 2015 of 660 ktCO_2/any. This means that only if 2% of the dwellings were rehabilitated (since 2005) and following the regulatory requirements of:

- DEC scenario, it can be achieved a reduction of 92 kt CO_2/year, ie, 14% of the expected savings in Energy Plan for Catalonia from 2006 to 2015 by 2015.

- CTE scenario, it can be achieved a reduction of 213 kt CO_2/year, ie 32.3% of the expected savings in Energy Plan for Catalonia from 2006 to 2015 by 2015

4.2.3 Economical impact

The demand reduction and energy consumption involves environmental and economic benefits. On the one hand, the reduction of emissions of carbon dioxide associated with energy consumption and secondly, reduction in energy bills. However, this reduction in energy demand is achieved by improving the thermal characteristics of walls and windows. These actions have a cost that must be evaluated.

This section takes into account the direct costs of rehabilitation of the closures and windows, according to data from the database BEDEC - ITEC [23]. The calculation of the economic application of corrective measures for each scenario is calculated for each building category. The following figure presents the investment that should be applied in every dwelling. This value was obtained by dividing the investment costs for the building by the number of dwellings in each building.

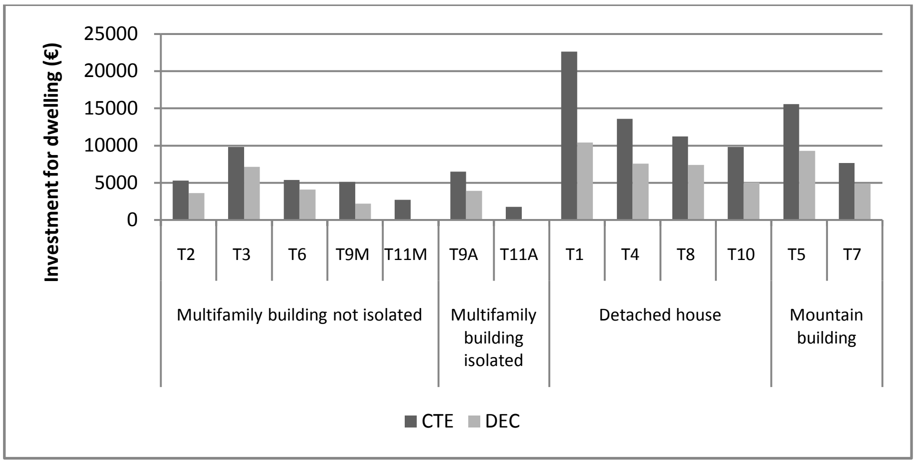


Fig. 6 Investment per dwelling category and scenario

The results, considering 2% of all dwellings in Catalonia until 2015 were rehabilitated following the regulatory requirements of the CTE and the DEC, are indicated in table 11

Table 11. Investment, emissions of CO_2 saved per year and the cost of each kg of CO_2 saved.

Scenario	Investment (M€)	Emission of CO_2 saved per year (kt CO_2 /year)	Cost of kg CO_2 saved (considering residual useful lifetime of building 40 years) (€ /kg CO_2)
CTE	3600 M€	213	0.45
DEC	2070 M€	92	0.55

The cost to save a kg of CO_2 is higher if you follow the Catalan rules. It would be desirable that Catalan regulation consider the most restrictive requirements of national regulation and consider the economical efficiency of them.

4 Conclusions

We conclude that, under the hypotheses considered, the global CO_2 emissions in the residential sector in Catalonia due to the energy consumption of heating and cooling are 2 800 kt CO2 / year for 2005 building census. This means 6.5% of global emissions of carbon dioxide in Catalonia. According to reviewed literature [17] CO_2 emissions in 2005 were 43800 and 41500 kt CO_2/year in 2003[18].

In terms of emission reduction scenarios studied can be concluded that:

- If you do not apply any measures, according to the 2015 trend scenario, emissions will increase by 16.5% compared to emissions in base 2005.

If a rate of 2% is considered in the rehabilitation of existing buildings annually from 2005 to 2015:

- The best scenario in terms of reducing emissions is named CTE scenario, which meet the constraints imposed by state regulations Technical Code of Buildings. This scenario would achieve an emission reduction of 6.4% of emissions that would occur in 2015 without carrying out any action for rehabilitation of buildings. The total investment in all park buildings in Catalonia would be equal to 3600 M € (0.45 € / kg CO_2 saved / year considering a residual useful lifetime of the building equal to 40 years). The savings in emissions would be 32.3% of the reductions provided for in the Energy Plan for Catalonia for the domestic sector by 2015 [18].

- The DEC scenario, corresponding to comply with the limitations established in the regional regulations, Ecoefficiency Decree, achieved savings of 2.8% of emissions that would occur in 2015 without carrying out any action rehabilitation of buildings. The total investment in all park buildings in Catalonia would be 2070 M € (0.55 € / kg CO_2 saved / year considering a residual useful lifetime of the building equal to 40 years). The savings in emissions would be 14% of the reductions provided for in the Energy Plan for Catalonia for 2011 for the domestic sector [18].

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