Relevant factors in Spanish buildings energy certification process.

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ABSTRACT

European directive EPBD (2003) and Kyoto protocol (1997) obligated the signer countries to implement an energy certification process of buildings in their laws. In Spain, the government established (RD 47/2007) two certification options: a simplified certification (that does not permit to obtain the best certification results) or a simulation process based on the Lider and Calener tools (DOE-II based simulators adapted to Spanish norms). In this work we report the results of a large number of residential building simulation and certification processes, obtained during years 2007, 2008 and 2009. Architectural factors that may improve or affect the certification result are identified and discussed by comparative analysis. Residential buildings investigated are grouped in tree typologies: familiar house, little dwellings block (minus than 10 dwellings) and medium dwellings block (between 10 and 30 dwellings). For each group the more relevant architectural factors are discussed. All the buildings locate in the Autonomic Community of Catalonia, in a Mediterranean climate. At the end of the work a discussion between the different groups is conducted. Finally, certification process is critical discussed, especially thinking in the repeatability of the results and in the capacity of the analysed tools to express an architectonic result, in terms of geometrical distribution, form, magnitude of the buildings. Alternatives to the actual Lider and Calener simulation process are also critically discussed.

1. INTRODUCTION

Certification process established in Spain as obligated by the European Directive EPBD is in use since 2007. These first tree years have seen an interesting discussion about the certification techniques and the first building's results. Especially, in Catalonia the public promoter INCASOL (Catalan Institute of Ground) provide to certificate all its new residential buildings promotions. These certifications were obtained by dynamical performance study with the Lider and Calener VYP tools. Main author of the paper participate to various public reunions with the INCASOL and ICAEN (Catalan Institute of Energy) Institutes, trying to identified which are the more relevant parameters of the Lider-Calener simulation over the final result (the CO_2 emissions estimation). Results of these discussions lead to the application of a strategy in the simulation. With this strategy were analysed the following buildings. Strategy consist in accord the values of the more important parameters, in order to obtain at least the "B" classification. However, some buildings obtain the "A" classification and other buildings obtain the "C" classification. Only a building obtains a "E" classification, but this case is a retrofit and the strategy was not applied. Each building has a form, a volume and an orientation, but this may be not the cause of the different results, because simulation compares the analysed building with a reference building with the same form and orientation. The reason is investigated in this work by grouping tree different typologies of dwelling.

2. CASE STUDIES AND SIMULATION METHODOLOGY

2.1 Climate

The climate of the studied cases is in general Mediterranean, with little differences between the towns. The majority of the locations is close to the Mediterranean Sea. General urban density is low. Radiation levels are high to very high. Precipitation is different between the locations. Temperature profile is also little different, especially between the sea localities and the others. Figures 1 and 2 show the regions and the climates of Spain and Catalonia, where place the studied buildings.

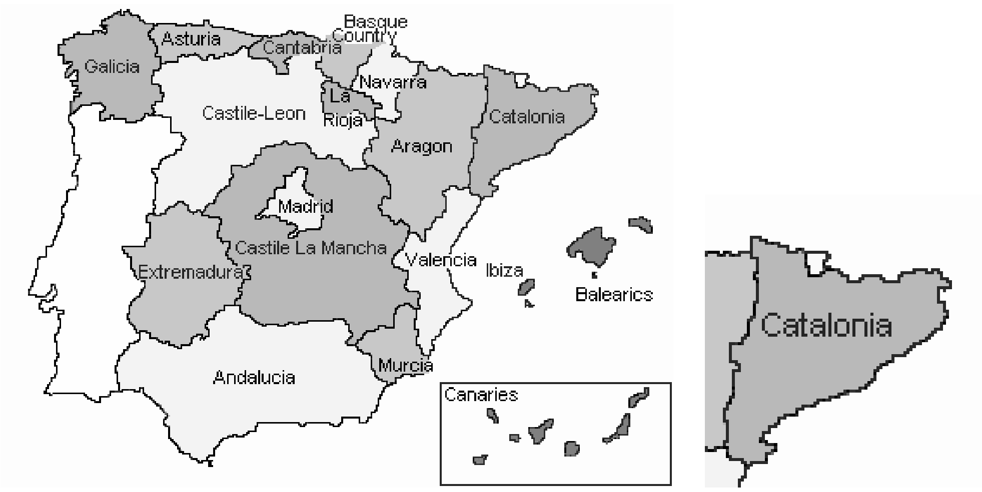


Fig. 1: Regions of Spain

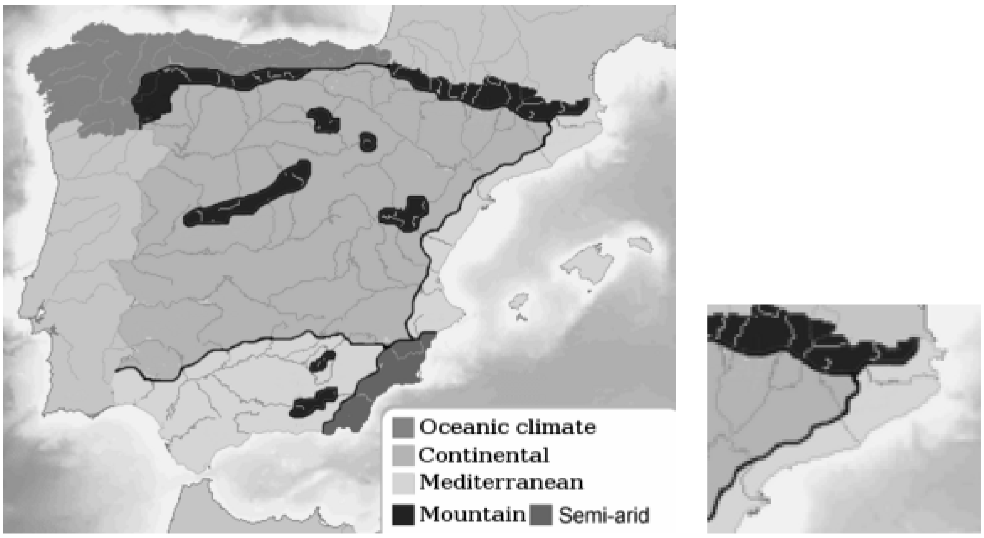


Fig. 2: Climates of Spain and Catalonia

Figure 3 shows the localization of the studied buildings in the Catalan Community.

Figure3: case studies localization

Town of Cambrils and Blanes are very close to the Sea. Figueres, Llinars and Les Franqueses place 50-100 km far away. Manlleu, Campolier and Mas Torrent place more than 100 km far away to the Sea. Familiar houses studied locate in Llinars, Mas Torrent and Campolier towns. Little dwelling blocks locate in Les Franqueses and Mannleu towns. Medium dwellings blocks locate in Cambrils, Blanes and Figueres. Climate of the groups seems to be sufficiently uniform. Especially the medium blocks locate all close to the Sea.

2.2 Tool's characteristics

Simulation and certification are done with the Lider and Calener tools. These tools use in the evaluation a reference building with the same form, orientation and the same climatic emplacement. Energy etiquette is assigned by comparison of the object building and the reference building that has the normative value of the transmittance of glass and walls. Lider and Calener tools permit to insert different parameters in the simulation. Parameters can be classified in different ways. In this work are classified as climatic, user-dependent, characteristic of the building and system-dependent, using the classification scheme proposed by Palme (Palme 2010). Table 1 shows the Lider Calenr parameters typology-grouped and the correspondent units.

Table 1: Parameters of the Lider-Calener simulation

TYPOLOGY	PARAMETER	UNIT
Climatic	Climatic zone	/
	Altitude	m
	Air renewal coefficient	1/h
User-dependent	Glass heat loss corrected by use of blinds in winter	%
	Solar factor by use of blinds in summer	%
	Boiler typology	/
	Boiler efficiency	%
	Boiler power	kW
System-dependent	Combustible typology	/
	Final unit typology	/
	Final unit power	kW
	Solar contribution to hot water	%
	Building use	/
	Internal humidity production	/
	Orientation	/
	Linear thermal conductivity of materials	W/mK
	Specific heat of materials	J/kgK
Building characteristics	Water diffusion resistance	/
	Glass solar factor	%
	Glass transmittance	W/m^2K
	Fixed protection transmission	%
	Fixed protection absorption	%
	Density of materials	kg/m^3

Altitude is the only climatic variable directly editable by tool's user. Others climatic data are obtained by libraries. The system dependent variables that more influence the final result are the power of the boiler and the combustible typology. The majority of the buildings use natural gas and the boiler power is 24 kW (flat of a block) or 50 kW (familiar house). Analysed buildings have all the same reference values of the important parameters related with the use of the building (air renewal coefficient, solar factor in summer due to user's actions over the blinds, transmission night coefficient of the windows due to action over the blinds).

2.3 Buildings description

Analysed buildings are grouped in tree categories: familiar house, medium size block and little size block.

2.3.1 Familiar houses

Familiar houses analysed are very different in form, materials, and renewable energy integration. Campolier house is a retrofit of an old house, principal materials are stone and wood. It has no insulation, single glass windows and high thermal inertia in the walls. Solar thermal panels have been installed for hot water production. Mas Torrent house is very well insulated, has especial low-transmittance windows, solar thermal system for hot water. Llinars house is well insulated, has double glass windows, but has not thermal panels for hot water production. Table 2 shows the characteristics of the tree houses.

Table 2: familiar’s houses characteristics

	Campolier	Mas Torrent	Llinars
Number of floors	3	2	2
Area [m^2]		240	200
Wall transmittance [W/m^{2}K]	2,80	0,42	0,48
Main orientation	SW/NE	S/N	S/N
South windows	3	8	2
East windows	7	1	4
West windows	2	1	5
Ventilated roof	no	no	no
Ventilated façade	no	no	no
Balcony	0	1	2
Heating system	radiators	radiators	radiators
Mobile solar protection (blinds)	yes	yes	yes
Fixed solar protection (shutters)	no	no	no
Window transmittance [W/m^{2}K]	3,3	1,7	2,8
Combustible	natural gas	natural gas	GPL
Boiler type	condensation	condensation	condensation
Boiler efficiency	95%	95%	95%
ACS solar panels (solar fraction)	50%	50%	0%

2.3.2 Little dwelling blocks

Little dwelling blocks are not very different each other. Alta cortada block has a transmittance value a little higher and Miriana block a transmittance value a little lower than the Les Franqueses block, that can be assumed as reference for a well-insulated building. Les Franqueses block is a block of small dwellings, while the others no. Alta cortada building has only two external façades. Miriana building has the façade ventilated to extract humidity and heat in summer. Other significant difference is the number of floors, respectively 4, 3 and 2. Table 3 shows the characteristics of the tree buildings.

2.3.3 Medium dwelling blocks

Medium dwelling blocks are different in orientation: E/W for the Figueres building, S/N for the Blanes building and SW/NE for the Cambrils building. Wall transmittance is better in the Cambrils case. Cambrils flats are smaller than the others building’s flats. Solar contribution for hot water is higher in the Cambrils case, because of the different climatic emplacement. For the same reason, this building has the roof ventilated. Table 4 resumes the building’s characteristics.

3. RESULTS

Following pages show the energy label of the analysed buildings, grouped by category. Spanish energy etiquette resumes the heating/cooling demand and the heating/cooling/hot water CO_2 emissions, calculated by final energy and primary energy consumption evaluation. Final energy evaluation consider the system efficiency, primary energy calculation consider the cost of energy production and transportation. CO_2 evaluation is done using transformation coefficients established by the government.

Table 3: little dwelling blocks characteristics

	Alta cortada	Miriana	Les Franqueses
Number of floors	4	3	2
Flats per floor	1/2	1/3	7
Average flat area [m^2]	65	80	30
Total number of flats	7	7	14
Wall transmittance [W/m^2K]	0,65	0,33	0,48
Number of stairways	1	1	1
Main orientation	S/N	SW/NE	SW/NE
South windows	19	23	20
East windows	0	0	0
West windows	0	0	0
Ventilated roof	no	no	no
Ventilated façade	no	yes	no
Balcony	16	12	0
Cooling system	no	no	no
Heating system	radiators	radiators	radiators
Mobile solar protection (blinds)	yes	yes	yes
Fixed solar protection (shutters)	no	no	no
Window transmittance [W/m^2K]	2,8	2,8	2,8
Boiler type	conventional	conventional	condensation
Boiler efficiency	85%	85%	95%
ACS solar panels (solar fraction)	50%	50%	50%

Table 4: medium dwelling blocks characteristics

	Cambrils	Figueres	Blanes
Number of floors	4	4	4
Flats per floor	11/13	6/8	8
Average flat area [m^2]	37	75	65
Total number of flats	50	30	32
Wall transmittance [W/m^2K]	0,48	0.52	0,57
Number of stairways	1	2	2
Main orientation	SE/NW	E/W	S/N
South windows	84	6	40
East windows	7	72	6
West windows	8	72	6
Ventilated roof	yes	no	no
Ventilated façade	no	no	no
Balcony	39	24	48
Cooling system	no	no	no
Heating system	radiators	radiators	radiators
Mobile solar protection (blinds)	yes	yes	yes
Fixed solar protection (shutters)	no	no	no
Window transmittance [W/m^2K]	2,8	2,8	2,8
Boiler type	condensation	condensation	condensation
Boiler efficiency	95%	95%	95%
ACS solar panels (solar fraction)	70%	50%	50%

3.1 Familiar houses

Figures 4 to 6 show the familiar house's labels.

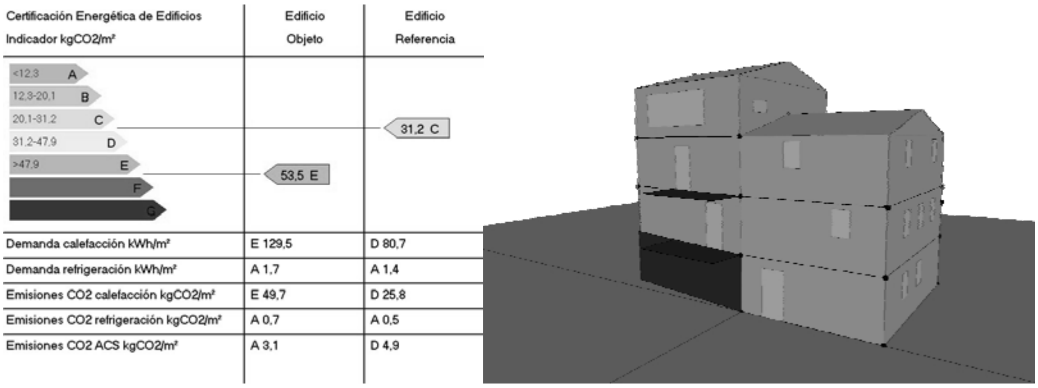


Figure 4: Campolier building and energy label

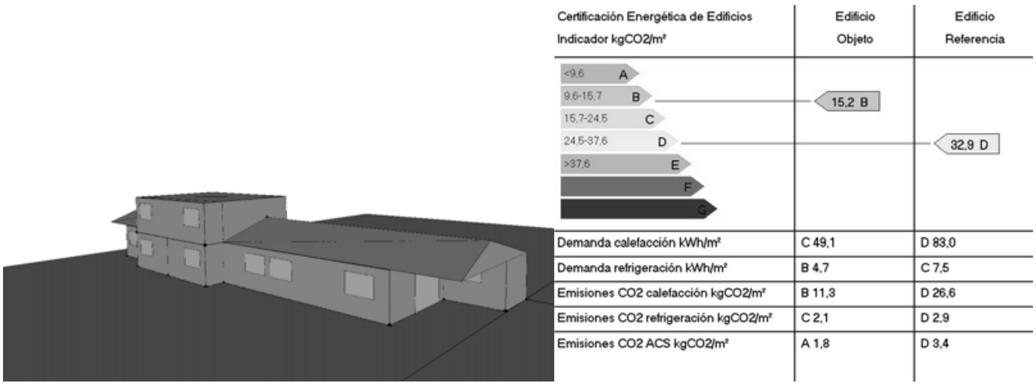


Figure 5: Mas Torrent building and energy label

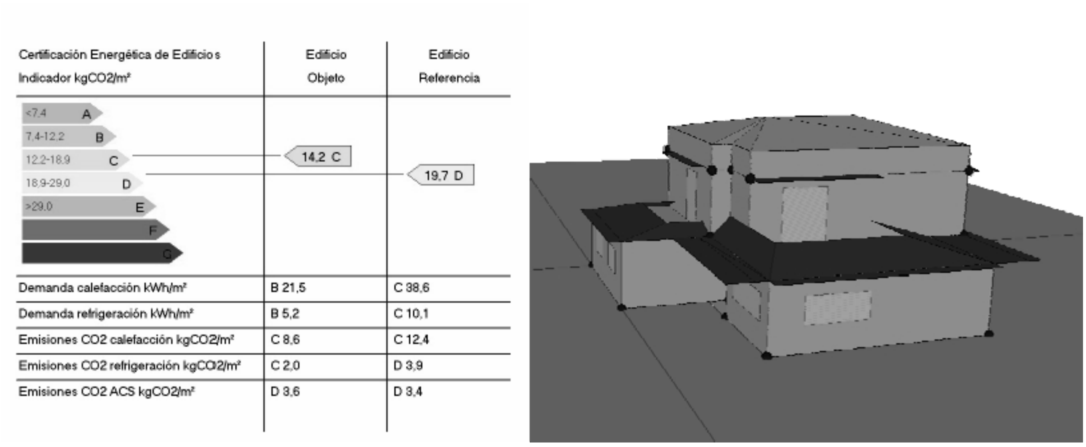
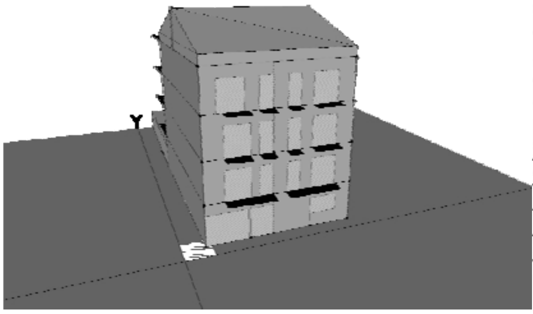


Figure 6: Llinars building and energy label

3.2 Little dwelling blocks

Figures 7 to 9 show the little dwelling blocks energy labels.



Certificación Energética de Edificios Indicador kgCO2/m²	Edificio Objeto	Edificio Referencia
<9,7 A		
9,7-14,8 B	12,7 B	
14,8-22,1 C		
22,1-33,0 D		23,2 D
>33,0 E		
F		
G		
Demanda calefacción kWh/m²	C 47,4	D 64,3
Demanda refrigeración kWh/m²	-	-
Emisiones CO2 calefacción kgCO2/m²	B 10,0	D 20,6
Emisiones CO2 refrigeración kgCO2/m²	-	-
Emisiones CO2 ACS kgCO2/m²	D 2,7	D 2,6

Figure 7: Alta Cortada building and energy label

Certificación Energética de Edificios Indicador kgCO2/m²	Edificio Objeto	Edificio Referencia
<8,0 A		
8,0-13,1 B		
13,1-20,4 C	17,3 C	
20,4-31,4 D		27,4 D
>31,4 E		
F		
G		
Demanda calefacción kWh/m²	D 62,9	D 70,2
Demanda refrigeración kWh/m²	C 3,7	D 6,1
Emisiones CO2 calefacción kgCO2/m²	C 13,3	D 22,5
Emisiones CO2 refrigeración kgCO2/m²	D 1,4	E 2,3
Emisiones CO2 ACS kgCO2/m²	D 2,6	D 2,6

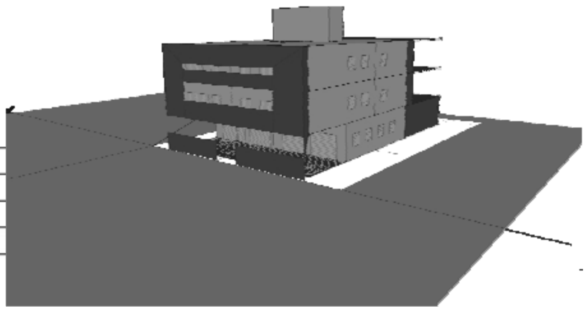
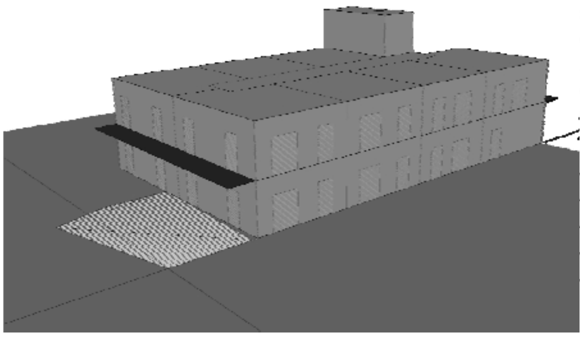


Figure 8: Miriana building and energy label



Certificación Energética de Edificios Indicador kgCO2/m²	Edificio Objeto	Edificio Referencia
<5,0 A		
5,0-8,1 B	5,3 B	
8,1-12,6 C		
12,6-19,4 D		16,9 D
>19,4 E		
F		
G		
Demanda calefacción kWh/m²	B 14,0	D 35,5
Demanda refrigeración kWh/m²	A 1,4	D 7,9
Emisiones CO2 calefacción kgCO2/m²	B 3,4	D 11,4
Emisiones CO2 refrigeración kgCO2/m²	A 0,5	E 3,0
Emisiones CO2 ACS kgCO2/m²	A 1,4	D 2,5

Figure 9: Les Franqueses building and energy label

3.3 Medium dwelling blocks

Figures 10 to 12 show the medium dwelling blocks energy labels.

Certificación Energética de Edificios Indicador kgCO2/m²	Edificio Objeto	Edificio Referencia
<3,7 A		
3,7-7,1 B	4,2 B	
7,1-12,0 C		
12,0-19,3 D		16,7 D
>19,3 E		
F		
G		
Demanda calefacción kWh/m²	B 5,4	C 16,5
Demanda refrigeración kWh/m²	B 6,7	E 24,8
Emisiones CO2 calefacción kgCO2/m²	A 1,0	C 5,3
Emisiones CO2 refrigeración kgCO2/m²	B 2,3	E 9,5
Emisiones CO2 ACS kgCO2/m²	A 0,9	D 1,9

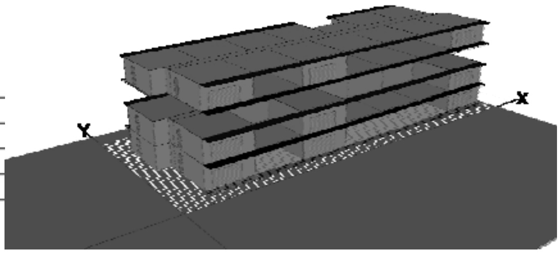
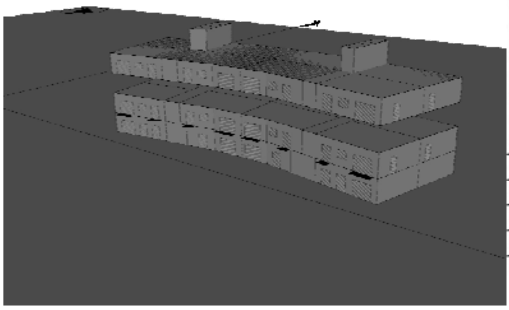


Figure 10: Cambrils building and energy label



Certificación Energética de Edificios Indicador kgCO2/m²	Edificio Objeto	Edificio Referencia
<5,0 A	4,9 A	
5,0-8,1 B		
8,1-12,6 C		
12,6-19,4 D		14,1 D
>19,4 E		
F		
G		
Demanda calefacción kWh/m²	B 10,8	C 24,3
Demanda refrigeración kWh/m²	B 4,1	D 10,1
Emisiones CO2 calefacción kgCO2/m²	A 2,5	C 7,8
Emisiones CO2 refrigeración kgCO2/m²	C 1,6	E 3,8
Emisiones CO2 ACS kgCO2/m²	A 0,8	D 2,5

Figure 11: Blanes building and energy label

Certificación Energética de Edificios Indicador kgCO2/m²	Edificio Objeto	Edificio Referencia
<6,5 A		
6,5-10,6 B	9,5 B	
10,6-16,5 C		
16,5-25,3 D		17,0 D
>25,3 E		
F		
G		
Demanda calefacción kWh/m²	C 28,9	C 37,5
Demanda refrigeración kWh/m²	B 3,0	D 6,6
Emisiones CO2 calefacción kgCO2/m²	B 7,1	C 12,0
Emisiones CO2 refrigeración kgCO2/m²	C 1,2	E 2,5
Emisiones CO2 ACS kgCO2/m²	A 1,2	D 2,5

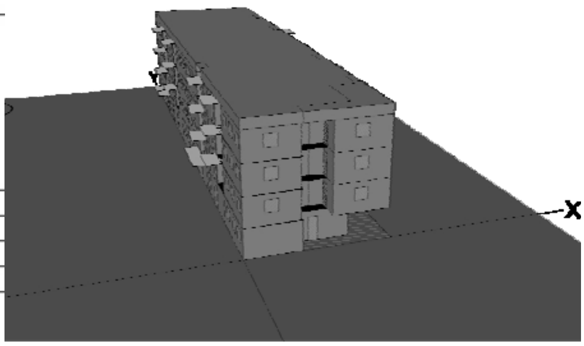


Figure 12: Figueres building and energy label

4. DISCUSSION

4.1Familiar houses

Result of the familiar houses analysis shows that Campolier house has a performance clearly lower than the minimum established. The reason is clear: this retrofit doesn't use the actual standard of sustainable construction. Especially, wall and window transmittances are high. Heating energy demand result to be 129.5 kWh/m^2year, while reference building has a value of 80.7 kWh/m^2year. Good boiler efficiency cannot solve the problem, and the resultant label is "E". Comparison between Mas Torrent and Llinars buildings show the importance of the combustible typology: the "C" result of the Llinars building can be explained considering the GPL use (while Mas Torrent uses natural gas) and the absence of solar panels for hot water production. Other goal of Mas Torrent construction is the heating/cooling demand reduction, which is considerably lower than the reference building in the same climates. Table 5 resumes the building demand and emissions results.

Table5: Familiar houses demand and emissions results

	Heating demand (kWh/m^2)	Cooling demand (kWh/m^2)	Heating emissions ($kgCO_2/m^2$)	Cooling emissions ($kgCO_2/m^2$)	Hot water emissions ($kgCO_2/m^2$)
Campolier	129.5	1.7	49.7	0.7	3.1
Mas Torrent	49.1	4.7	11.3	2.1	1.8
Llinars	21.5	5.2	8.6	2.0	3.6

4.2 Little dwelling blocks

Result of the little dwelling blocks analysis shows that Les Franqueses building has a better performance respect to the others. Emissions result of this building is 5.3 $kgCO_2/m^2$year, while 5.0 is the "A" qualification limit. Most important factor is in this case the boiler typology (condensation), while others building have a conventional boiler with a lower efficiency (85%). Difference between Alta cortada en Miriana building (in the same town of Manlleu) has to be searched by the west and east façades of the Miriana construction, that have windows exposed to solar radiation. Another relevant factor is the total external surface exposed, that increases the losses. This fact is not directly detected by software, that compares the building with a reference building with the same form, but is increasing the importance when pass from a "C" label to a "B" label is required. Table 6 resumes the buildings results.

Table 6: Little dwelling blocks demand and emissions results

	Heating demand (kWh/m^2)	Cooling demand (kWh/m^2)	Heating emissions ($kgCO_2/m^2$)	Cooling emissions ($kgCO_2/m^2$)	Hot water emissions ($kgCO_2/m^2$)
Alta cortada	47.4	0.0	10.0	0.0	2.7
Miriana	62.9	3.7	13.3	1.4	2.6
Les franqueses	14.0	1.4	3.4	0.5	1.4

4.3 Medium dwelling blocks

Medium dwelling blocks analysis show that Blanes block has a better performance with a final result of 4.9 $kgCO_2/m^2$year, that signifies the only "A" label obtained by the analysed buildings. Keys of this result are the good summer problem resolution (with the blinds use) and the insulation level (relatively high in this climate). Figueres building and Cambrils building obtain the same "B" qualification, but real consumption and CO_2 production is really different: 4.2 $kgCO_2/m^2$year in the Cambrils case, and 9.5 $kgCO_2/m^2$year in the Figueres case. This fact shows the principal problem of the Spanish certification methodology: the comparison between the analysed building and a reference building with the same orientation, that is very bad in the Figueres case. Cambrils energy label is very close to the "A" upper limit, while Figueres label is closer to the lower "C" limit. Table 7 resumes the analysed building performances.

Table 7: Medium dwelling blocks demand and emissions

	Heating demand (kWh/m^2)	Cooling demand (kWh/m^2)	Heating emissions ($kgCO_2/m^2$)	Cooling emissions ($kgCO_2/m^2$)	Hot water emissions ($kgCO_2/m^2$)
Cambrils	5.4	6.7	1.0	2.3	0.9
Blanes	10.8	4.1	2.5	1.6	0.8
Figueres	28.9	3.0	7.1	1.2	1.2

As a final consideration, is necessary to observe that the architectonical factors are often not considered in the certification process. Geometry, factor of form, orientation are important parameters of the architecture, and can be used to improve sustainability. However, actual certification process in Spain doesn't permit to evaluate really the energy goodness of a building. It is more focused on system efficiency. Moreover, as noted by García Casals (Garcia 2004, 2009), systems in Calener VYP tool are defined by a nominal power and by an efficiency, but at the moment of certification, only the power is really taken into account. This means that is very easy to falsify the results selecting a low power boiler or HCAV system. Certification experts reunions, that taken place in Barcelona in 2009 confirm the strong dependence of the actual certification method on the system dimension parameters. It will be interesting to consider other ways of analysis, more focused on the architecture, as sensitivity qualification. Sensitivity certification focused on global volumetric parameters as loss coefficient, thermal mass and thermal effusivity. All the parameters consider orientation and distribution factors, in order to permit architectural consideration and selection between different construction typologies. Sensitivity certification can be conducted by estimation of sensitivity vectors or global thermal effusivity. A discussion of how insert sensitivity analysis in the Spanish certification process can be found in the work of Palme (Palme 2010). Table 8 resumes the emissions and the etiquette of the studied buildings and its references buildings.

Table 8: emissions and labels of the studied buildings and its references buildings

	Studied building emissions ($kgCO_2/m^2$)	Studied building energy label	Reference building emissions ($kgCO_2/m^2$)	Reference building energy label
Campolier	53.5	E	31.2	C
Mas Torrent	15.2	B	32.9	D
Llinars	14.2	C	19.7	D
Alta cortada	12.7	B	23.2	D
Miriana	17.3	C	27.4	D
Les franqueses	5.3	B	16.9	D
Cambrils	4.2	B	16.7	D
Blanes	4.9	A	14.1	D
Figueres	9.5	B	17.0	D

Table shows clearly that energy efficiency improves as the block size improves. The other relevant result is the comparison among the label of Blanes, Figueres and Les Franqueses. All these buildings have a comparable reference building (16.7-17.0 $kgCO_2/m^2$) and the same final result “B”. However, the CO_2 productions of Les Franqueses and Blanes buildings are the half than the Figueres building. Finally, it has to be remarked that a square meter evaluation can not be the best: an evaluation per person seems to be more realistic thinking on the occupation density problems, as showed for example by Pagés (Pagés et al. 2008) and Palme (Palme et al. 2006).

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