The Regulation Frame in view of Buildings Energetic Certification

(Session number: IAQ T2S2)

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ABSTRACT

A comparative study was organised in the scope of a recently finished master's dissertation between three European country's legal frames: France, Spain and Portugal paying special attention to the Portuguese case. The results of the three studies were compared in order to identify the potential of each regulation in terms of the building's energetic efficiency whose conception is based on solar passive parameter application. Some of the improvements that were applied are not clearly shown in the results, namely inertia increase (using other solutions and calculus methodology) and different solar orientation. Because of this, a tool for energetic efficiency evaluation of housing buildings is presented that takes into consideration it's constructive solutions and local climatic characteristics.

The results taken were evaluated according to passive solar parameters, for example, thermal inertia and storage specific capacity in relation to the constructive elements. The insignificant impact on results caused by the improvements mentioned implies the need of implementing an evaluation methodology for building's passive solar performance capable to qualify them in line with the existing regulatory application that leads to the existence of minimum values granting acceptable comfort conditions and energy consumption. This proposed methodology, according to a qualitative analysis of several parameters classified according to pre-established qualitative levels, becomes, in fact, an available tool for the buyer's choice and an argument to the seller or investor. This paper describes briefly the main aspects of the thermal regulation referred above and, then, it presents and discusses the proposed methodology for the qualitative evaluation of passive solar performance of buildings.

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1. INTRODUCTION

Since the Industrial Revolution, technological developments with repercussions on the construction sector led to a progressive detachment in the ancient connection between the construction and the surrounding environment.

A new paradigm seems to be winning more and more followers: terminologies like "bioclimatic", "passive solar", "renewable" and "sustainable" are currently being used and make a new approach possible based on the building's energetic efficiency.

The new approach, worked out under a new sustainable development point of view, contributes to an increase in preoccupation about the application of constructive solutions that reach satisfactory interior comfort levels. This will minimize the use of traditional energetic sources to fill the need of heating as well as of cooling.

Joining the solar passive principles and the thermal codes, will contribute to the decrease of the buildings energetic consumption and will aid the person in charge of the project to assume a new options. After that, the analysed codes, the extracted thermal parameters of the passive solar principles and the evaluation method will be presented in order to relate theses approaches.

2. THERMAL CODES

2.1. Portuguese Code

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The code is applied to each independent area of the building and aims, firstly, to assure the thermal comfort conditions reducing the energy consumption and, secondly, to prevent the pathologies that occur due to the condensations in the constructive elements (RCCTE 1991).

The study is attached to the attainment of values that are concerned with heating nominal needs in winter (NIc) and the cooling in summer (NVc). This are characterized, respectively, for the amount of heat that will need to be provided and the excessive amount that should be removed, to maintain the comfort conditions mentioned in the Code of the Buildings' Thermal Behaviour Characteristics (RCCTE), i.e. the maintenance of an internal temperature of 18ºC in winter and of 25ºC in summer.

$$N_I = \frac{1{,}3 K_{fr} A_f + K_{hr} A_h + K_{env} A_{env}}{A_p} + 0{,}34\, P_d \quad (0{,}024)\, GD \tag{1}$$

Where:

N_I	–	Heating nominal needs	$KWh / m^2 . year$
A_f	–	Opaque surface area	m^2
A_h	–	Cover area and pavement area in contact with the exterior air	m^2
A_{env}	–	Glazed area (maximum: 15% de A_p)	m^2
A_p	–	Useful pavement area	m^2
K_{fr}	–	Reference coefficient of thermal transmission to the outside walls	$W / m^2 . ºC$
K_{hr}	–	Reference coefficient of thermal transmission to the covers	$W / m^2 . ºC$
K_{env}	–	Reference coefficient of thermal transmission to the glazed area	$W / m^2 . ºC$
P_d	–	Height	m
GD	–	Heating degrees-days	ºC . day . year

$$N_V = \frac{0{,}36\,(1{,}3 \Delta T_f K_{fr} A_f + \Delta T_h K_{hr} A_h) + G_{ref} A_{ref}}{A_p} \,.\, M \tag{2}$$

Where:

N_V	–	Cooling nominal needs	$KWh / m^2 . year$
A_f	–	Opaque surface area	m^2
A_h	–	Cover area and pavement area in contact with the exterior air	m^2
A_{ref}	–	Glazed area (maximum: 15% de A_p)	m^2
A_p	–	Useful pavement area	m^2
K_{fr}	–	Reference coefficient of thermal transmission to the outside walls	$W / m^2 . ºC$
K_{hr}	–	Reference coefficient of thermal transmission to the covers	$W / m^2 . ºC$
ΔT_f	–	Effective temperature ratio in the opaque surfaces in summer project days	ºC
ΔT_h	–	Effective temperature ratio in the covers in summer project days	ºC
G_{ref}	–	Reference solar gains through the glazed areas	$kWh / m^2 . month$
M	–	Effective durability of the cooling season	months

The calculated values according to the building characteristics and the fulfilment of the calculations sheets (Fernandes and Maldonado 1990) will be compared with the regulation values of N_I and N_V, which were established in each case in agreement with the formulas 1 and 2.

2.2 Spanish Code

This code is applied to all the buildings that demand the execution of a project and establishes the demanding thermal conditions of the constructions, as well as the data that regulates its determination (CE 1999).

The buildings are defined under the thermal point of view through some characteristics of their exterior surface, namely:

- The global heat transmission, defined by the K_G coefficient;
- The heat transmission through its elements, according to the K coefficient values of each of them;
- Its thermal-hygrometric behaviour;
- Its air permeability.

The K_G coefficient corresponds to the considered average of the K transmission coefficients of the exterior surface and it is supported by the following formula:

$$K_G = \frac{\sum K_E \,.\, S_E + 0{,}5\sum K_N \,.\, S_N + 0{,}8\sum K_Q \,.\, S_Q + 0{,}5\sum K_S \,.\, S_S}{\sum S_E + \sum S_N + \sum S_Q + \sum S_S} \qquad (3)$$

Where:

K_G	– Global heat transmission coefficient	$W / m^2 . ºC$
K_E	Thermal transmission coefficient: – Vertical surface in contact with the exterior – Inclined vertical surfaces with more than 60º with the horizontal line and built under open spaces	$W / m^2 . ºC$
K_N	Thermal transmission coefficient: – Dividing surface towards other buildings or isolated areas – Vertical or horizontal surface under closed, non-isolated areas with a height of 1 meter or more	$W / m^2 . ºC$
K_Q	Thermal transmission coefficient: – Cover or terrace surface – Inclined vertical surfaces with more than 60º with the horizontal line	$W / m^2 . ºC$
K_S	Thermal transmission coefficient: – Dividing elements with the ground – Thresholds or covered up walls – Built under an air-space with the height inferior to 1 meter	$W / m^2 . ºC$
S_E	– Elements surface in contact with the exterior	m^2
S_N	– Dividing elements surface with other buildings or non-isolated spaces	m^2
S_Q	– Elements surface of covers and terraces	m^2
S_S	– Dividing elements surface with the ground	m^2

The parameters just described are confronted with the maximum values established by the code:

- The maximum established K_G regarding the form factor (F) of the climate zone where the building will be located and the type of energy to be used in heating;
- K values to each one of the elements of the exterior surface regarding its constitution and localization (climate zone).

2.3. French Code

The French rule subdivides the comfort conditions and the terms of its application according to the occupation for which a particular construction is destined. In this study the rules applied to the housing buildings were considered. According to the general calculation principles, we proceed to calculate the waste by transmission through the envelopment (D_t) and the losses through the renovation of the air (D_r) (CSTB 1977; CSTB 1989)

$$GV = D_r + D_t \qquad (4)$$

Where:

GV	– Total losses	W / ºC
D_r	– Air renovation losses	W / ºC
D_t	– Transmission losses	W / ºC

Considering the two parameters determined above, we will proceed to the calculation of the GV coefficient (Formula 4). This consists of the sum of the losses by renovation and transmission in the building and by the difference of 1ºC between the interior and exterior temperature, i.e., in the amount of heat that needs to be supplied in order to maintain a constant interior air temperature.

It is possible to calculate the heating needs that are needed for the determination of the BV coefficient from the GV coefficient (CSTB 1988):

$$BV = GV(1 - F) \tag{5}$$

Where:

BV	–	Annual Heating needs	W / ºC
GV	–	Total losses	W / ºC
F	–	Profit of the free gains	

The obtained BV coefficient value is compared with the BV value reference (BV_{ref}) calculated according to constant values of the regulation. The building will be regulated if BV ≤ Bv_{ref}.

2.4. Codes Synthesis

The French and the Portuguese codes adopt a similar analysis methodology of the buildings' performance as a whole, with a basis of envelopments calculation of losses and the value of the current gains in the incidence of solar radiation. The major differences are that firstly, the analysis must be made for the whole year and, secondly, it must be made for two different seasons, i.e., heating and cooling.

The Spanish code presents a different philosophy by analysing the building as a whole, i.e. a volume that produces heat and loses heat through contact between the surface and spaces that present inferior temperatures. The form factor is a fundamental parameter in this application and penalizes buildings with shape that are too exposed.

3. ANALYSIS OF THERMAL PARAMETERS

3.1. Quality criteria

The parameters presented in Table 1 were analysed according to their contribution to the global thermal efficiency of a constructive solution whose objectives are the optimization of the energetic wastes (Ramos 2002).

Table 1
Criteria which was used

	Criterion:	
1 -	Heating nominal needs	N_{IC}/N_I
2 -	Cooling nominal needs	N_{VC}/N_V
3 -	Base temperature	Tb
4 -	Gross solar gains / Heating Gross needs	GLR
5 -	$K_{solution}$ and K_{ref} ratio	K/K_{ref}
6 -	Delay factor	φ
7 -	I_t calculation without maximum values	I_t
8 -	Accumulator surface / Glazed surface	S_a/S_{env}
9 -	Thermal bridges – external wall and roof slab	P_{ext} e L_{roof}
10 -	Thermal bridges – external wall and intermediate slab	P_{ext} e L_{int}
11 -	Thermal bridges – external wall and floor slab	P_{ext} e L_{floor}

Each one of this eleven elements will be analysed in a way that enables its performance to be accessed in the building, according to the quality levels, that flow from: N_0= -4, N_1= 0, N_2= 2, N_3= 3 and N_4=4. This score allows the attribution of a final grade to the building as a whole, through the average of these elements.

3.2. Evaluation of the thermal parameters

3.2.1. Ratio between N_{IC}/N_I and N_{VC}/N_V.

From the RCCTE application in a building with two different solar orientations, an evaluation of the ratio between the calculated energy nominal needs, considering the real constructive features of the building, and the maximum energy needs, calculated according to reference regular values can be proposed. By comparing the results and relating them to quality levels, it is possible to produce Table 2.

Table 2
Nominal needs

Quality levels	$X = \frac{N_{IC}}{N_I}$	$X = \frac{N_{VC}}{N_V}$
N_0	X > 1,0	X > 1,0
N_1	0,85 < X ≤ 1,0	0,75 < X ≤ 1,0
N_2	0,75 < X ≤ 0,85	0,6 < X ≤ 0,75
N_3	0,60 < X ≤ 0,75	0,4 < X ≤ 0,60
N_4	X ≤ 0,60	X ≤ 0,40

3.2.2. Base temperature and Heating degrees-days.

The base temperature consists of a constant value to be kept in an autonomous space, i.e., buildings. To determine the base temperature reached in the interior of a building it is necessary to proceed to the alteration of the mathematical expression of N_{IC}, equals N_{IC} and N_I and isolating the heating degrees-days (Costa 1995). The following formula is therefore obtained:

$$GD = N_I + \frac{GSU}{Ap} \quad / \quad \frac{Total..losses}{A_p} \; X0.024 \tag{6}$$

Where:

GD	–	Heating degrees-days	ºC . day
N_I	–	Heating nominal needs	KWh / m^2 . year
GSU	–	Use solar gains	KWh / year
Ap	–	Useful pavement area	m^2

The application of this formula allows calculating the degrees-days value according to the losses and useful solar gains, and it also allows the classification of the performance based in Tb (Table 3):

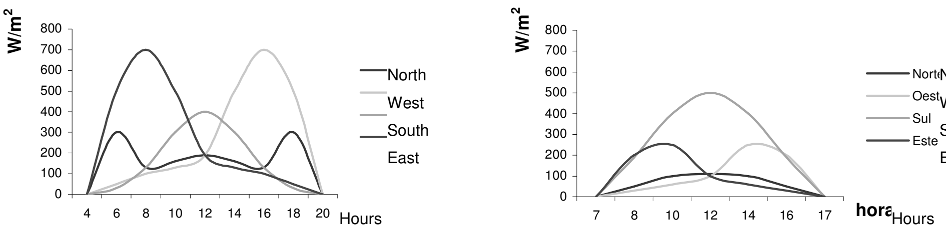
Table 3
Base Temperature

Quality levels	Inside temperature obtained with the heat system (Tb)
N_0	Tb < 15 ºC
N_1	15 ºC ≤ Tb < 16 ºC
N_2	16 ºC ≤ Tb < 17 ºC
N_3	17 ºC ≤ Tb < 18 ºC
N_4	Tb ≥ 18 ºC

3.2.3. Solar gains contribution.

The useful solar gains are quantified in the Portuguese code according to the factor of using the gains, η, that alternates between zero and one. The value of one is a result of buildings with very little or no solar incidence. The envelopments that interfere in the gains determination are: those oriented to the South quadrant, i.e., South, South-east, South-west, if they are vertical, and the horizontal envelopment, normally by the use of skylights. It is extremely important the radiation amount that is received in the different orientations, considering vertical surfaces, in the two possible situations: summer and winter, as shown in Figure 1.

The Figure clearly shows the difference between the levels of radiation received by the glazed area in all orientations. For example in the Summer, although the incidence level is bigger and lasts longer, it is relatively simple to proceed to the shadowiness during the hours in which this incident energy is unpleasant, making use of diverse types of applied devices in each situation.



Summer Winter

Figure 1
Incident solar radiation (W/m^2) in windows with different orientations

The qualification of the solar gains will be done having in mind the value of GLR, that expresses the relation between the gross solar gains and the gross heating needs, and, consequently, in the factor of gains use. This relation will be qualified according to Table 4.

Table 4
Gross solar gains and gross heating needs ratio

Quality levels	$GLR = \frac{\text{Gross solar gains}}{\text{Gross heating needs}}$
N_0	1,2 < GLR / GLR < 0,2
N_1	0,2 ≤ GLR ≤ 0,5
N_2	0,5 < GLR ≤ 0,8
N_3	0,8 < GLR ≤ 1,0
N_4	1,0 < GLR ≤ 1,2

3.2.4. The thermal transmission coefficient.

The Constructions Physic Laboratory (LFC) published a Technical Information Note (Freitas and Pinto 1997) with the purpose of revealing a methodology able to evaluate, through objective criteria, the performance of thermal isolating materials. This methodology gives quality levels according to the relation between the value K of the envelopment elements and the value of the reference thermal transmission coefficient previously described and established in the RCCTE (Table 5).

Table 5
$K_{solution}$ and K_{ref} ratio

Quality levels	$X = \frac{K}{K_{ref}}$
N_0	X > 1,0
N_1	0,9 < X ≤ 1,0
N_2	0,7 < X ≤ 0,9
N_3	0,5 < X ≤ 0,7
N_4	X ≤ 0,5

In Silva (2000) the thermal transmission coefficient classification in quality levels according to the relation between K and K_{ref} can also be found. The N_0 that consists in the non-fulfilment of the established criteria of the Portuguese code was added to these quality levels. Table 5 presents this qualification.

3.2.5. Damping (μ) and Delay (φ) factors.

These parameters consist of two elements directly related with the thermal inertia of construction and with the value of the thermal transmission coefficient of their solutions. They characterize the variation of the heat flow that goes through the dividing element in contact with contiguous spaces of different thermal characteristics.

The delay factor should be enough to make the heat flow reach the interior during the hours in which heating is more necessary, which means that it can be considered to have an ideal value of φ of roughly 8 hours. The constructive solutions used in this work have a delay factor from 6 hours to 10 hours, which consists in a damping factor, between the moment in which the heat flow reaches the exterior surface until it goes through the interior space, acceptable according to the ideal value considered. So, it can be assumed that the use of a strong thermal inertia, with materials used in the Portuguese traditional construction, guarantees acceptable results to the attainment of interior comfort.

Table 6 classifies the elements according to the value of its delay factor. This factor can be used as a reference in relation to the deadening of the heat flow. The use of K values compatible with the quality levels expressed in point 3.2.4., indicates a good performance (as far as the element delay in relation to the exchanges is concerned). This leads to inferior values of the deadening heat flow to 0,2, which can be considered to be good characteristics' parameters of the behaviour under thermal actions.

Table 6
Delay factor

Quality levels	φ (hours)
N_0	$2{,}0 > \varphi$
N_1	$2{,}0 \le \varphi < 3{,}5$
N_2	$3{,}5 \le \varphi < 5{,}0$
N_3	$5{,}0 \le \varphi < 7{,}0$
N_4	$\varphi \ge 7{,}0$

3.2.6. Thermal inertia and Specific capacity of thermal storage.

The concept of specific capacity of thermal storage (qa) consists of the amount of heat that a construction element is able to store by square meters when its temperature rises in 1ºC (Wh / m^2 . ºC). This value is obtained according to the following formula:

$$qa = \rho \times c \times e \qquad (7)$$

Where:

qa	–	Specific capacity of storage	Wh / m^2 . ºC
ρ	–	Density	Kg / m^3
c	–	Specific heat	Wh / Kg . ºC
e	–	Thickness	m

The results reveal that the materials with major specific capacities of storage are also those that have the highest values of density, because the value variation of the specific heat is not relevant. In this way, it can be concluded that the materials with highest thermal inertia are those that can store a major amount of heat.

Figure 2 shows that the thermal inertia values can be related when considering the results of the RCCTE methodology without the maximum limits imposed by the different situation of the elements: the results variation is linear.

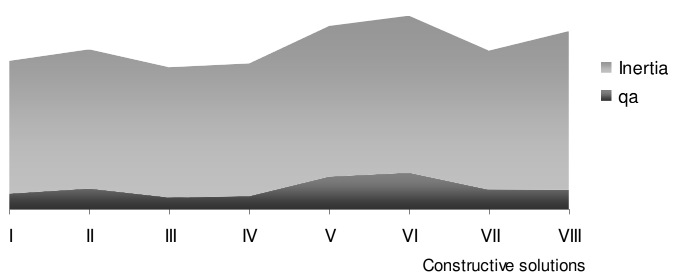


Figura 2
Relation between the inertia values and the specific capacity of thermal storage

A qualification methodology of a specific capacity of thermal storage can be defined in a basis of a parallel parameter to the thermal inertia, as shown in Table 7:

Table 7
Thermal inertia (without maximum values)

Quality levels	I_t
N_0	$150 > I_t$
N_1	$150 \leq I_t < 400$
N_2	$400 \leq I_t < 600$
N_3	$600 \leq I_t < 800$
N_4	$I_t \geq 800$

3.2.7. Relation between the storage surface and the glazed surface.

The glazed areas are fundamental elements as far as the thermal comfort of a space is concerned. This is because, firstly, they are responsible for the major or minor capture of solar radiation necessary for the heating of the storage mass and, secondly, because they are responsible for one part of the thermal losses for fenestration. This is why correct orientation and measuring are important. The increase of the gains and consequent reduction of losses can be obtained through the use of glazed areas with the minimum of apertures and with a rationalization of ventilation openings.

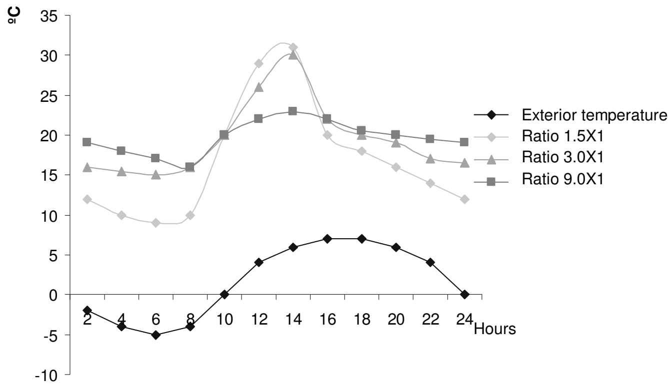


Figure 3
Thermal amplitudes related to different storage capacities

Figure 3, adapted from Moita (1985), presents the thermal amplitudes verified in the interior of a room. It considers three different situations: firstly, a relation between a storage surface and a glazed surface of 1.5 / 1 where an amplitude of 22ºC is reached; secondly, a relation of 3.0 / 1 where an amplitude of 14ºC is registered; and, thirdly, a storage mass with nine times the surface of the glazed area, i.e., a relation of 9 / 1, in which the amplitude is about 7ºC. The measuring of the glazed surfaces oriented to the South quadrant should be related to the space storage capacities. A large glazed surface without the correspondent storage mass is pointless.

In this way, the measuring of the glazed and storage surfaces can be qualified according to the Table 8:

Table 8
Storage surface and glazed surface ratio

Quality levels	$X = \frac{Storage\ \ surface}{Glazed\ \ surface}$
N_0	$X < 1,0$
N_1	$1,0 < X \leq 3,0$
N_2	$3,0 < X \leq 5,0$
N_3	$5,0 < X \leq 7,0$
N_4	$X \leq 7,0$

3.2.8. Thermal bridges

The thermal bridges are located, mainly in the connections between the exterior envelopment and the structural elements of the building. The attributed levels, presented in

Figure 4, refer to: N_4 to the non-existence of thermal bridges in these connections, through the use of exterior continuous isolation. N_2 represents the quality level when there are thermal bridges, but considering that they were corrected according to DTU 20.1. Finally, the quality level N_0 corresponds to any case where there aren't any types of treatment in the areas where there are thermal bridges (CSTB 2001).

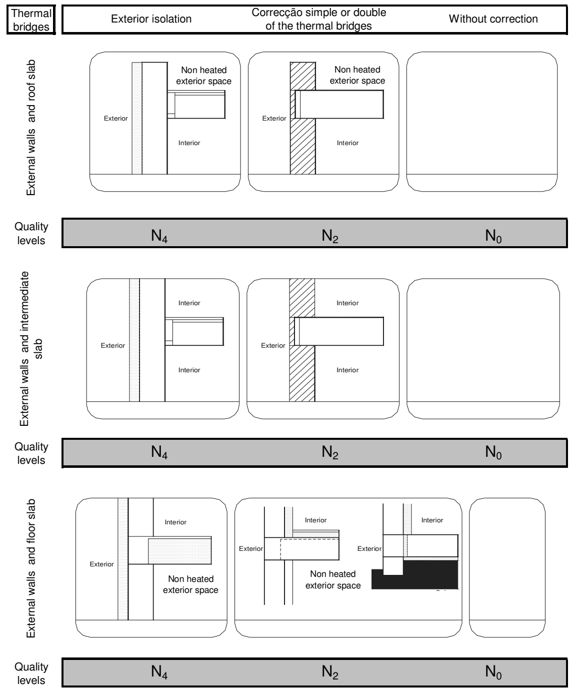


Figure 4
Thermal bridges

4. EVALUATION METHOD

With a basis of the analysed elements it was possible to elaborate a synthesis table to show the global behaviour of the building under two aspects: through a graphic and an attributed global grade (Ramos 2002).

	Evaluated Parameter		Quality Level N_4	N_3	Average level	N_2	N_1	N_0	Points
1	Nominal needs (R.C.C.T.E.)	N_{IC}/N_I	□	□		□	□	□	
2		N_{VC}/N_V	□	□		□	□	□	
3	Base temperature	Tb	□	□		□	□	□	
4	Gross solar gains / Heating gross needs	GLR	□	□		□	□	□	
5	$K_{solution}$ and K_{ref} ratio	K/K_{ref}	□	□		□	□	□	
6	Delay factor	Φ	□	□		□	□	□	
7	I_t calculation without maximum values	I_t	□	□		□	□	□	
8	Accumulator surface / Glazed surface	S_a/S_{glaz}	□	□		□	□	□	
9	Thermal bridges - external wall and roof slab	P_{ext} e L_{roof}	□	□		□	□	□	
10	Thermal bridges - external wall and intermediate slab	P_{ext} e L_{int}	□	□		□	□	□	
11	Thermal bridges - external wall and floor slab	P_{ext} e L_{floor}	□	□		□	□	□	
	Global evaluation:	____	Good			Satisfactory		Weak	
			Performance						

Figure 5
Final table of evaluation

The final table shown in Figure 5, is simple and consists of the previous parameters after the analysis, in which each one of the different indicators owns the necessary requirements for the attribution of quality levels to mark the respective quality levels to each one of these indicators. These points will be joined by lines in order to be able to proceed to the graphic elaboration. The analysis consists of observing in which zone the largest area of the graphic can be found. This task is easier if different colours are used. It should be kept in mind the cases that reach the darkest area, which defines a weak performance in any parameters (to which a negative grade is attributed). This evaluation compromised the efficiency of the system as a whole.

5. CONCLUSION

There is a real need to find tools that are able to control and to evaluate the energetic consume that allows the consumer to gain knowledge about the necessary expenses to have in order to maintain their house with minimum comfort levels. The presented methodology relates the main thermal factors that are determinants of the efficiency, in terms of comfort, of the housing building. One of the arguments for the sale should be about the efficiency of the whole, and not only about the materials and the applied constructive techniques. This should be a indication to the consumer of minor wastes in a country that can take advantages of a mild weather in opposition to the rest of Europe.

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