ANALYSIS OF THE ENERGETIC-ENVIRONMENTAL BEHAVIOUR IN APARTMENTS BUILDING IN LA PLATA CITY - ARGENTINA. PASSIVE STRATEGIES FOR A REDESIGN OF LOW ENERGY.

(GREEN-RETROFIT)

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ABSTRACT: *This paper presents a study of the energetic-environmental behaviour in an apartments building in La Plata, which has a mild, warm and humid climate. The detailed analysis started with two audited apartments. The results were transferred to the whole apartments building for its global analysis. As regards the methodology used, the method "Audit-CAD" was used, which allows to measure the thermal and energetic behaviour of the building monthly by means of incorporating the audited information when the formal and energetic indicators are determined. Passive strategies for a redesign of low energy are also suggested (green-retrofit) where concepts of Environmentally Conscious Design (ECD) are involved in order to promote low energetic consumption. The fulfillment of Argentinian standards is verified to ensure its energetic efficacy. For this purpose, "U" values (coefficient of heat transmission) for walls, roofs and openings, superior to the top level of the IRAM standard 11605 about building thermal conditioning are suggested. Subsequently, the accomplishment of the IRAM standard 11900 about labelling energetic efficiency of heat for buildings is verified.*

Key words: *apartments building- energetic efficiency- green-retrofit.*

1. INTRODUCTION

The importance of the topic is related to two current problems: the shortage of resources and the global warming. These are aspects in which the architectonic and urban constructions have a significant level of incidence [1]. The construction industry is one of the most important consumers of raw materials and non renewable resources. This industry implies a remarkable ambiental impact not only during the processes of extraction and elaboration of raw materials but also during the construction of buildings, its use and even later when the building is demolished and recycled [2].

Fossil fuels themselves constitute the main source of energy applied to the built habitat. The energy used to heat in the world represents approximately the 70% of the end-use energy and the 40% of primary energy. The demand of energy for refrigeration on its own is calculated in 8% of the annual generation of power [3]. In Argentina, for example, 96% of electric generation is made by means of mixed-cycle power stations whereas for heating the use of natural gas is intensive [4].

The building analyzed is situated in La Plata (Picture 1) – Argentina (34° 55′ 16″ S, 57° 57′ 16″ W), in a warm area with permanent rainfalls and hot summers (climate *Cfa* – Köppen).

In Argentina warm weather is characterized by not rigorous summers and winters. Its main characteristic is its high level of humidity during a whole year with a temperature range of 14°C. In summer average temperatures oscillate between 20°C and 26°C with maximum temperatures of more than 30°C.

Picture 1: La Plata - Buenos Aires Province (climate Cfa - Köppen)

In winter average temperatures oscillate between 8°C and 12°C, with minimum temperatures between 5°C and 8°C. On the other hand, the average level of humidity varies between 70 and 85%.

60% of the country's population lives in this area, which is near Buenos Aires. The agglomeration in metropolitan areas fosters the effect called "Heat Island", which means an increase in the temperature from 4°C to 6°C [5].

For this geographical region light colours and double thermal insulation are recommended to be used in roofs as regards its walls. Aired facades in big buildings as well as openings with Insulating Glass Units (IGU) and mobile solar protection are also recommended. It is necessary to take advantage of the predominant winds and to protect the openings. The ideal orientation is North-West, North and North-East because it facilitates the solar protection in summer and it allows the sun to enter in winter.

2. AIM

The aim of this paper is to analyse the energetic-atmospheric behaviour of the building standing from a hygrothermal study of the analysed apartments and to suggest means to improve the building envelope in order to save energy. The verification of the Argentinian Standard IRAM 11900 about labelling energetic efficiency of heat for buildings and the comparison with the levels suggested in the IRAM standard 11605 about building thermal fittings are also part of this aim.

3. TOOLS

The whole building was analyzed by "AuditCAD" [6], which allows the monthly analysis of the thermal and energetic behaviour of the building by means of entering the audited information and providing formal and energetic indicators. The characteristics of the building and the information of occupation (lighting, people, and equipment) allow us to determine how much energy is required to maintain the building at a thermostat temperature. The results found are: the power, natural gas, liquefied petroleum gas, distinguishing the demand with and without sun (cloudy days). Later, the results were transferred into Excel to be analyzed.

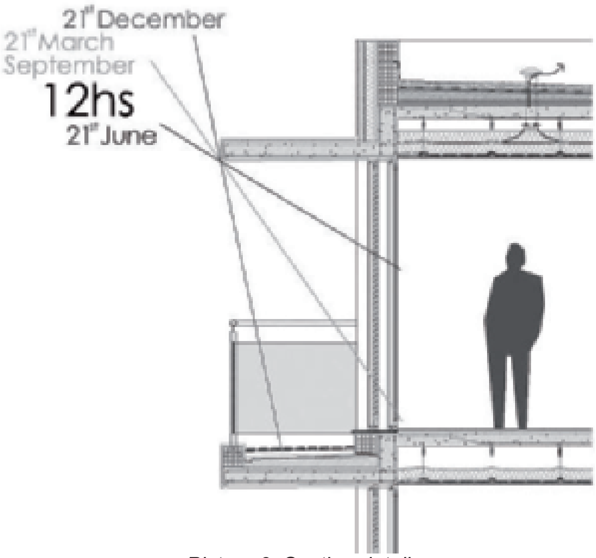
3.1. The building

It was built in 1999 without taking into account the Environmentally Conscious Design. Its constructive technology is conventional with reinforced concrete and exterior walls with air bricks of 18x18x33 without additional hygrothermal insulation (U=1.82W/m^{2}K). Meanwhile, the interior walls were materialized with air bricks of 12x18x33 which separate the apartments among each other and with the community areas, and with bricks of 8x18x33 for the ones that divide the rooms of each apartment. The openings are made of aluminium with simple glass (U= 6.08/m^{2}K) without sun protection. The terrace roof of the building is made of concrete slab with subfloor slope and with an asphalt membrane as an insulating waterproof, without additional thermal insulation (U= 3.82W/m^{2}K). At the same time, the slabs which divide each one of the levels do not have additional thermal insulation. Each one of the apartments has a balanced draft stove of 4,000 calories as part of the heating system. As regards the refrigeration system of the flats, it depends on the owners' personal criteria (Picture 2).

Picture 2: Building Facade

3.2. Green-retrofit

The building envelope is the main element to reduce energy consumption and to guarantee, at the same time, internal hygrothermal comfort [7]. For this reason, we have suggested the improvement of thermal quality of opaque walls (materialized with air bricks of 18x18x33cm) for the redesign of low energy by means of the inclusion of a glass wool felt of 10cm thick with a steam barrier (*R= 1.2m^2·K/W*) and a rigid panel of glass wool of high density 5cm (*R= 0.4m^2·K/W*) over which a fiberglass mesh would be installed to project a mortar with additional water repellent and a concrete covering as high finish. This solution (*U= 0.12W/m^{2}K*) contributes to improve the thermal inertia of the building envelope and at the same time, it avoids taking off centimetres to the room interiors, which are already much reduced. It is recommended the use of openings with IGU (*U= 2.86W/m^{2}K*). At the exterior side of the windows are proposed sliding panels which allow to regulate the sun entrance and to reduce the heat losses during the night. In the space between the slab and the suspended false ceilings, the insertion of a 10cm - glass wool – felt with a steam barrier *(R = 1.2m^2·K/W)* was thought in order to reduce heat transferences among the different levels. To improve the thermal quality of the cover on the last floor the solution of the "inverted roof" was thought. Two glass wool felts of 10cm thick with a steam barrier *(R = 1.2m^2·K/W)* were thought to be inserted in the free space between the suspended false ceiling and the concrete slab. The result of this solution is a thermal transmittance coefficient *U= 0.20W/m^{2}K.* Moreover, ventilation pipes are included in order to avoid heat accumulation in the last floor (Picture 3).



Picture 3: Section detail

3.3 Expenses

In Argentina, this type of building structure costs 800 u$s/m^2 [12]. The openings normally used represent the 8% of the budget of the whole work approximately. A standard aluminium window of 1.20x1.10m with a simple glass of 4mm costs u$s 80 while a high quality one with IGU and with the same dimensions costs u$s 220. By incorporating this type of openings to the construction the cost would be 912 u$s/m^2 and the carpentry system would represent 19% of the budget of the whole work.

The thermal insulation with glass wool costs 6 u$s/m^2 approximately, depending on the density of the material, if it has a vapor barrier, a manufacturer, etc. To apply thermal insulation to the whole building envelope and to the slabs in the mezzanine, according to what ECD suggested that responds to level B of IRAM standard 11900 would imply an increase of u$s 28.500 in the total budget. The “inverted roof” solution would have an additional cost of u$s 5.000. The whole construction would cost 945 u$s/m^2 where the introduction of the thermal insulation would only represent 2.5% of the whole budget.

In terms of expenses, the difference between a building with ECD and a “conventional” one is 18%.

3.4 The measurament campaign

It comprised two periods: summer and winter. HOBO U10-003 data loggers were used to measure temperature and humidity of the rooms as well as a Meteorological Station HOBO ProV2 to measure the exterior temperature and humidity. The solar radiation was registered by the fixed meteorological station Davis “Vantage Pro2”. To process the information generated by HOBOS, “HOBOwarePro” and “BoxCarPro” were used.

During these periods, measurements in the use of natural gas and power were taken in all apartments. On the other hand, two HOBOS were installed in each of the audited apartments: one in the sitting-living room and the other in the main bedroom. 15 minutes was the time interval in HOBOS and in the Meteorological Station (Picture 4). The results were transferred into Excel to be analyzed.

Picture 4: A model of a typical floor in the analyzed building

4. RESULTS

The analysis of the energetic-environmental behaviour of the building started with two apartments where we could have access to. At the same time, a survey was made to determine the variations in the levels of natural gas and power spent on heating and refrigeration respectively. The results of these two cases were transferred to the whole building for a global analysis.

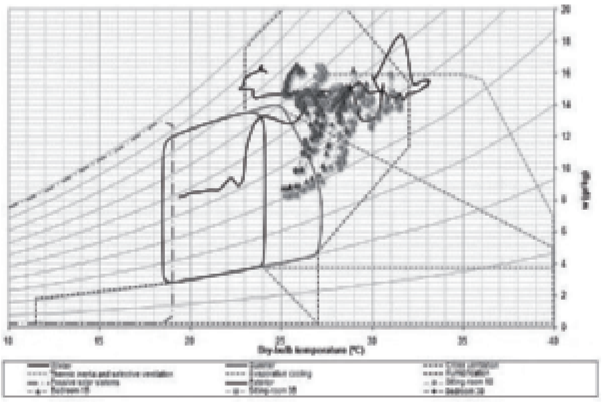
4.1. Analysis of hygrothermal comfort

For the analysis of the variations in temperature and humidity in the different rooms five timetables were chosen. These timetables relate the times of high and low apartment occupation with the sun incidence over the different rooms that are part of each unit.

4.1.1. Hygrothermal performance in summer

The measurement campaign was held from March, 10th to March 16th, 2009. During these days there were no high temperatures, typical of summer days. In most cases, the interior temperatures are over the comfort limits for summer with maximum temperatures higher than 30°C.

For a more detailed analysis of the hygrothermal behaviour of the apartments, a psychometric chart was conducted with the “PsiConf” where reference was made on March, 14th which had the highest temperatures indoors and outdoors. According to Givoni’s climograph (Picture 5) most of the rooms are outside the limits of comfort. According to this diagram, in order to reach those limits, the apartments should add to their design crossed ventilation, thermal inertia, selective ventilation and passive solar systems. On the other hand, some points of the 3rd floor bedroom and some others of the apartment on the first floor are observed within the summer comfort area. However, these points coincide with exterior temperatures which are under 25°C.

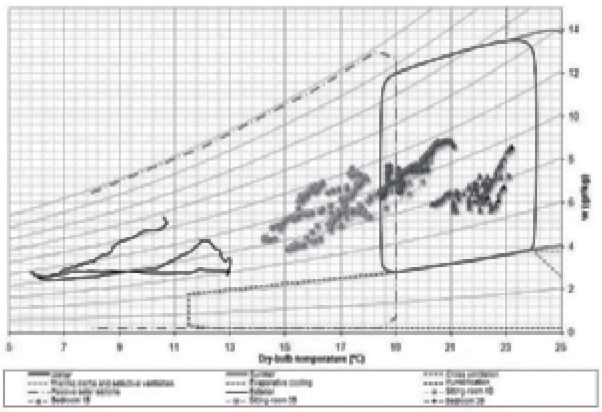


Picture 5: Analysis of the hygrothermal behaviour of the flats (03/14/09)

4.1.2. Hygrothermal performance in winter

The measurement campaign was held from March, 18th to June, 24th, 2009. It shows how the indoor temperature variations occur following changes in external temperature. In this case there is a remarkable difference in the interior temperatures of both apartments; while in the first floor apartment the temperatures oscillate between 18ºC and 25ºC, in the third floor aparment they oscillate between 14°C and 22°C.

For a more detailed analysis of the hygrothermal performance of the apartments, a psychometric chart was conducted using the “PsiConf”. June, 23rd was taken as parameter when the lowest interior and exterior temperatures were registered. According to Givoni’s climograph (Picture 6) only the bedrooms are held within the limits of comfort in winter. The sitting-living room areas are under those limits and only during some moments of the day the sitting room on the first floor reaches that level. According to this diagram, in order to get the winter comfort the apartments should incorporate passive solar systems in their design.



Picture 6: Analysis of the hygrothermal behaviour of the flats (06/23/09)

4.2 Energetic analysis of the building without Environmentally Conscious Design

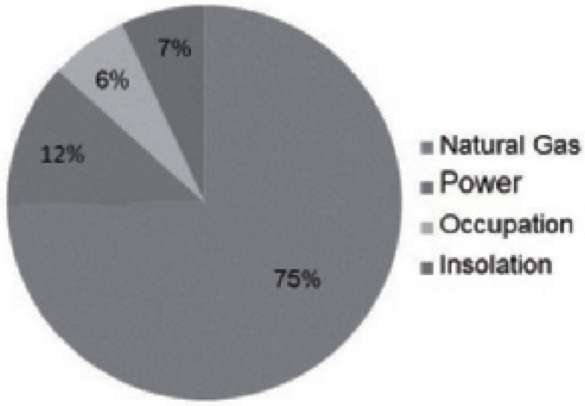
This analysis was done to the whole building audited. The losses through the envelope were distributed in the following way:

- *Roof (U= 3.82W/m^{2}K): 12% (618W/°C)*
- *Air renewal: (2AR): 47% (2326W/ºC)*
- *Walls: (U= 1.82W/m^{2}K): 17% (833W/°C)*
- *Windows: (U= 6.08W/m^{2}K): 19% (922W/ºC)*

When the concepts ECD are applied to the building design the losses through the envelope were distributed in the following way:

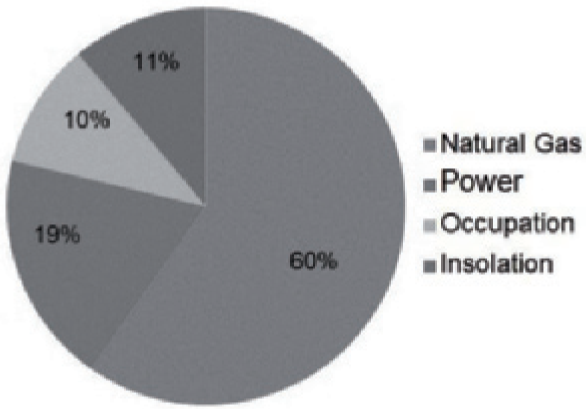
- *Roof: (U= 0.20W/m^{2}K):2% (61W/°C)*
- *Air renewal: (2AR): 74% (2326W/ºC)*
- *Walls: (U= 0.12W/m^{2}K): 2% (54W/°C)*
- *Windows: (U= 2.86W/m^{2}K): 19% (588W/ºC)*

The graphic in Picture 7 shows the “AuditCAD” results for the designed option according to the information taken from reality. The use of natural gas for heating of the building volume represents 75% of the whole income with a necessary use of 110m^3 every day to reach a medium interior temperature of 20°C.



Picture 7: Information processed in “AuditCAD” for the modeled building without ECD

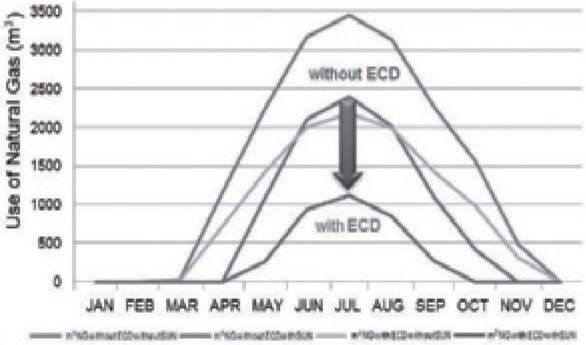
The graphic in Picture 8 shows the necessary energetic contributions for the designed option according to the concepts of ECD. Applying these concepts to the use of natural gas it was reduced to a daily 55m^3 for the volume of the whole building, keeping the other parameters fixed. In other words, the application of the thermal insulation to the whole building envelope and the incorporation of an opening system with IGU helped to reduce the use of gas for heating in 50%, considering in both cases the solar and occupational inclusions.



Picture 8: Information processed in “AuditCAD” for the modeled building with ECD

In both cases, the number of air renewals was 2. This is triggered by the implementation of the regulations of Ente Nacional Regulador del Gas (ENaRGas), Argentina [8].

The graphic in Picture 9 shows the reduction in the demand of natural gas for heating, which can be considered very low even in the coldest months, taking into account the profits made by the sun.



Picture 9: Comparison of the use of natural gas (m^3) with and without ECD, and with and without sun.

4.3 Energetic labelling in heating (IRAM 11900)

We performed the calculation of the energy level of the building with and without ECD. The building constructed according to construction techniques in Argentina today (coefficient "U" similar to that proposed by the lowest level of the IRAM 11605 [9] on thermal conditioning of buildings) reached the lowest level of IRAM standard 11900 [10], which is obtained through the calculation of "τ_m" [Equation 1], which is the weighted average between the interior surface of the building envelope and the temperature of the interior design in Celsius. In this case, "τ_m" showed a value of 7.97°C, much over 4°C, which is the minimum that IRAM standard 11900 suggests to reach "Level H", which is the less efficient one. At the same time, "K'_m" [Equation 2], which is the thermal transmittance weighted average, yielded a value of 2.94 W/m^2·K.

$$\tau_m = \frac{\sum(\tau_i \cdot S_i)}{\sum S_i}$$

Equation 1

$$K'_m = \frac{\sum_1^n (K_i \cdot S_i)}{\sum_1^n S_i}$$

Equation 2

Picture 10 shows the results of applying ECD concepts to the design of the building envelope. In order to reach "Level B" of IRAM standard 11900, the level of thermal insulation added to the building envelope had to be increased at a high percentage, with values of coefficient "U" more demanding than the ones suggested by the highest level of the IRAM standard 11605. For the proposal, according to ECD criteria, the "τ_m" got a value of 1.30°C while "K'_m" [U] got a value of 0.66 W/m2·K.

Types of energetic efficiency	Condition [1]
A	$\tau_m \leq 1$ °C
B	1 °C < $\tau_m \leq 1{,}5$ °C
C	1,5 °C < $\tau_m \leq 2$ °C
D	2 °C < $\tau_m \leq 2{,}5$ °C
E	2,5 °C < $\tau_m \leq 3$ °C
F	3 °C < $\tau_m \leq 3{,}5$ °C
G	3,5 °C < $\tau_m \leq 4$ °C
H	τ_m > 4 °C

[1] τ_m is the weighted averagebetween the interior surface of the shell space and the temperature of the interior design in Celsius

Picture 10: Type of heating energetic efficiency for the building designed with ECD (Level B)

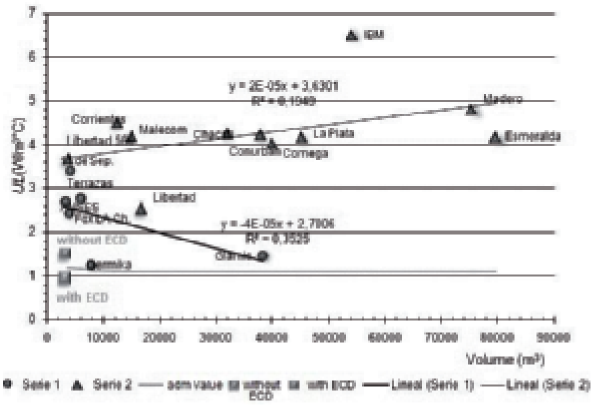
The cart in Picture 11 shows a summary of the different parameters that characterize the energetic behaviour of the building in its versions with and without ECD.

	Unit	with ECD	without ECD
τ_m	°C	1,30	7,97
K'_m [U]	W/m^2•K	0,66	2,94
UL	W/m^3•°C	0,94	1,50
Energy	kWh/m^2/year	95	150

Picture 11: summary of the energetic characteristics of the building with and without ECD.

4.4 Comparison with audited cases

In Picture 12 two samples of high buildings (typical of different periods in the Metropolitan Area, Buenos Aires) are confronted. These examples were taken from a previous work [11].



Picture 12: Comparison of the building with and without ECD with other buildings in the Metropolitan Area, Buenos Aires.

This graphic shows the Global Heat Loss Coefficient "UL" for the selected examples in the previous work and incorporates the building in its two versions, with and without ECD. It can be seen how the edifice built without taking into account the ECD criteria has a "UL" superior to the admissible value. Moreover, while applying the ECD criteria it can be seen that the "UL" of the building decreases, placing it under the line of the admissible values.

5. CONCLUSION

This work allowed us to do an analysis of the energetic-environmental behaviour in an apartments building in La Plata city – Argentina (climate *Cfa* – Köppen) and to suggest, under this analysis, a green retrofit.

From the analysis of the plant, it was possible to infer which are the elements of the envelope that best contribute to improve the thermal and global performance of the building. The incorporation of additional thermal insulation in walls and roofs as well as the incorporation of openings with a more demanding "U" coefficient than the ones that are currently used in Argentina helped to reduce the heat losses in the building envelope. This meant a 50% reduction in the use of natural gas for heating.

Also, an analysis of the weights of the different components in the whole building was made. The inclusion of an opening system with IGU meant 19% of the whole cost of the building while the addition of thermal insulation (including the solution "inverted roof") only meant 25% of the whole cost. While the price of the construction for the "conventional" solution is 800 u$s/m2, the addition of ECD criteria implied a cost of 945 u$s/m2.

The additional cost of a building with ECD compared to one without ECD is 18%.

The Global Heat Loss Coefficient "UL" of the building decreased from 1.50 W/m3•ºC to 0.94 W/m3•ºC, lower to the admissible values, which for this volume is 1.2 W/m^3•ºC. This relation allows a reflection on the quality of the buildings as regards energetic matters, even more if it is taken into account the fact that the analyzed case represents a clear example of the way in which the construction of urban habitat is carried out at present in Argentina. The lack of attention in the selection of materials allows us to see lower quality in the built environment.

However, it is worth mentioning that in order to reach the Level B suggested by the IRAM standard11900, the level of thermal insulation of the building envelope had to be highly increased, surpassing the standards suggested by the highest IRAM standard 11605. This was the only way in which "τ_m" could be reduced from 7.97ºC to 1.30ºC.

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