Traditional climate-adapted typologies as a base for a new contemporary architectural approach

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ABSTRACT: Since ancient times, people have adapted dwellings to climate, searching for an efficient shelter that would provide them comfort in an uncomfortable and changing world. The industrial revolution leaded to architectural modern movement, in which, the emphasis was put mainly on the efficiency of the form-function concept, leaving comfort issues to the incorporation of auxiliary devices. As a consequence, the massive use of non-renewable energy to condition spaces, made buildings of the 20th century (and the ones that are still built under the post-industrial paradigm), the ones that are nowadays originating most environmental impacts in cities compromising our present and future. In the same direction, pre-industrial climate-adapted typologies (such as half-patio houses), also need to evolve to answer current inhabitant comfort needs. We believe that good architecture understands the past and rescues still standing values, together with contemporary techniques that allow the development of an energy efficient up-to-date architecture. For this purpose it is studied the thermal behaviour of a bioclimatic house projected by Arch. M. Diez and Eng. F. Esteves in the city of Mendoza, Argentina (32º40'SL, 68º51'WL, 750 masl temperate-continental climate). This house rescues concepts from the traditional half-patio 1900 houses and also incorporates summer and winter passive conditioning strategies. Half-patio houses' roots are found in the mediterranean patio houses, and where brought by Spanish and Italian inmigrants because of climatic similarities. Measurements on site were performed in order to evaluate the thermal behaviour of this present bioclimatic house that has learned its lesson from the past.

Keywords: half-patio houses, temperate continental climate, bioclimatic strategies, new designs

1. INTRODUCTION

During the '70s energy crisis, a new passive solar technology with the objective to benefit from natural energies and to reduce the use of non-renewable energy to run buildings was developed. Nowadays, more than 30 years later, the energy crisis is still current and the implementation of passive technologies is still very poor.

The responsibility leans partly on the industrial revolution principles, that, leaded society to architectural modern movement, in which the emphasis was mainly put on the efficiency of the form-function concept, leaving comfort issues to the incorporation of energetic auxiliary devices. As a consequence, the massive use of non-renewable energy to reach comfort in spaces made buildings of the 20th century (and the ones that are still built under the post-industrial paradigm), the ones that are currently originating most environmental impacts in cities, compromising our present and future.

Also, at the end of the '70s, Aldo Rossi y Giulio Carlo Argan spread the theoretical concept of "typology". As a consequence, a new look over local architectural history recovered the interest in pre-industrial constructions. In Argentina, the "half-patio house" was the focus of architectural debate because of its typological and constructive coherence.

The half-patio house typology, whose roots are found in Mediterranean patio houses, was brought in 1900 by Spanish and Italian immigrants because of climatic similarities between their country of origin and Argentina. It was adapted to the particularities of the urban tissue and therefore, it was split in two by its main longitudinal axis, becoming the HALF-patio house. See Figure 1

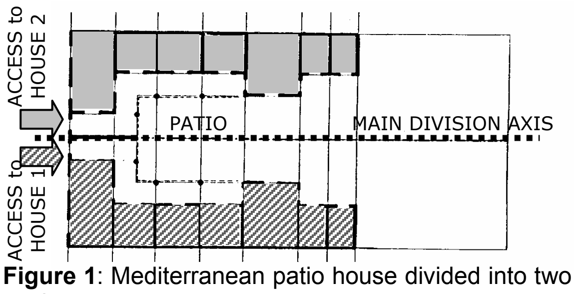

Figure 1: Mediterranean patio house divided into two Half-patio houses

Nevertheless, the repetition of vernacular or regional pre-industrial solutions does not suppose an answer to the lack of natural comfort problem in our houses today. Users' needs and necessities have evolved and, therefore, architectural answers must be appropriate to the present. If the current concept of habitability is not addressed, then, occupant's expectations are not fulfilled. Because of this, they will continue looking for their own answers in the market. And those will result in more auxiliary energy equipment use and higher non-renewable energy consumption.

If we are capable to rehabilitate buildings or city-areas from the past turning them into contemporary architecture, we also pretend to be capable to construct *ex novo* rehabilitating VALUES from the past or from other cultures and assuming them into our architectural creation… From this point of view, it is not strange that the History of Architecture is being read again and that the *bioclimatic achievements* of architectures from the past are being pointed out; and, with that, the possibility to incorporate them in our own design processes… If these architectures were fascinating or exemplary was precisely because their perfect adaptation to environmental circumstances. Material resources and constructive techniques were conditional but not determinant of the architectural form. [1]

We believe that good architecture understands the past and rescues still standing values; and also, it incorporates contemporary techniques that allow the development of a new energy efficient up-to-date architecture. For this purpose the thermal behaviour of a bioclimatic house projected by Arch. M. Diez and Eng. F. Esteves is studied. This house rescues concepts from traditional half-patio 1900 houses including current summer and winter passive strategies and concepts.

The half-patio house typology adapts properly to urban bioclimatic constructions and when oriented East/West makes possible to have excellent solar access in all the house's North length (towards the Equator in the Southern Hemisphere). It leans on one longitudinal neighboring limit of the ground (South), while articulating patios, galleries and pergolas towards the opposite limit of the ground (North) .

Figure 2 describes characteristics of the half patio house typology possible to be considered in new projects, that could benefit from the opportunities it presents to achieve comfort by natural means.

2. CLIMATE: CITY OF MENDOZA, ARGENTINA

The city of Mendoza is located at 32° 40' South Latitude, 68° 51' West Longitude and 823 metres above sea level. The average climatic characteristics define a continental temperate climate: Degree-day (base temperature 18°C) 1384°C.day/year, Solar radiation on horizontal surface annual average: 17.9 MJ/m2.day, been 25.7 MJ/m2.day in summer (January) and 9.1 MJ/m2.day in winter (June).

Figure 3 shows the calendar of exterior average temperatures for each month and hour of the year.
The lightest area is the comfort zone between 21ºC and 27ºC. The darkest area represents temperatures above the comfort zone, and middle gray colours, are temperatures bellow comfort.

In winter, an important need of heating is observed. May, June and July present temperatures near 0ºC between 6 to 8 hours a day and only the 2 hours of the solar mid-day (between 13 and 14 official hour) temperatures can rise up to 18ºC.

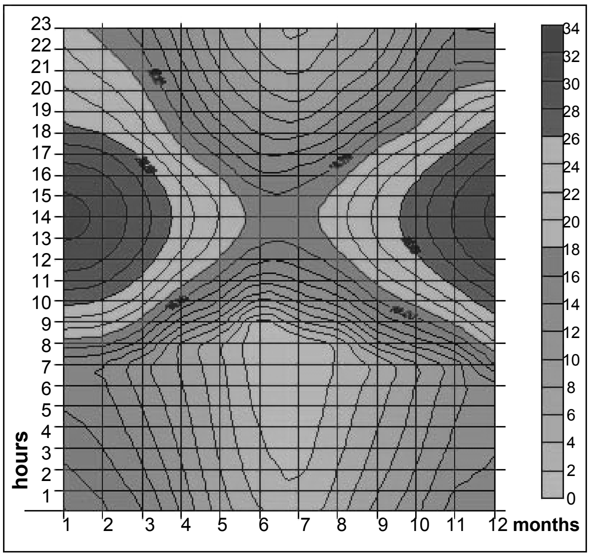

Figure 3: Calendar of exterior average temperatures for each month and hour of the year for Mendoza

3. BIOCLIMATIC HOUSE DESCRIPTION

The bioclimatic house presents an open typology, interior-exterior articulation, equal orientation in all main spaces, a flexible envelope and the presence of intermediate spaces. These characteristics that lead to the resultant morphology (See Figure 4) are learned from the traditional typology (See Figures 1 and 2).

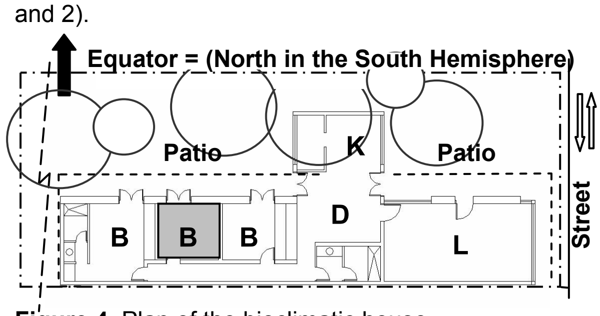

Figure 4. Plan of the bioclimatic house.

	CHARACTERISTICS	DESCRIPTION	OPORTUNITIES
1	Open typology.	To each m3 of interior volume corresponds half m2 of envelope in contact with the exterior	Interaction with the climate
2	Interior- exterior articulation	Zoning of the exterior space. Development of patios with different character and use.	Creation of an exterior microclimate surrounding the house. More control over it.
3	Equal orientation and solar access in all main spaces.	Disposition in a row. Every main interior space has the same orientation.	Oriented towards the Equator. Full benefit from the climate.
4	Flexible envelope.	Opening windows, external blinds, eaves, louvers; internal curtains, etc.	Adaptability to daily and seasonal climatic variables.
5	Presence of intermediate spaces	Transition interior-exterior: access with double door and buffer space, galleries, pergolas, bowers of grapevines, patios, etc.	Adaptability to daily and seasonal climatic variables. Generation of a microclimate around the house.

Figure 2: Characteristics of the half patio house typology possible to be considered in new projects.

Designers also incorporated elements and strategies from the bioclimatic technology to enrich the envelope: Direct Gain with double glazing; Indirect Gain with Trombe-Michel walls, insulation in walls and roofs and also weather strips and prevention of thermal bridges to reduce infiltration and thermal losses for adequate energy conservation.

The transformation of the envelope of the dwelling in a polyvalent membrane for climatic moderation allows it to respond with growing flexibility to variable meteorological conditions.[2] The regulation of interior-exterior selective exchanges of energy through the envelope is fundamental. The envelope must be continuously adjusted in a very changing environment such as in this temperate continental climate, in order to reach comfort in internal spaces.

Traditional external insulation systems for façades and "solar walls" are used to enhance the envelope of dwellings.[3] The North façade (towards the Equator in the South Hemisphere) has an envelope articulated in modules. Each module comforms an interior space in itself. In the case of the main bedroom, an extra half module is incorporated for the en-suite bathroom. Figure 5 shows an exterior image of the North façade and a graphic that facilitates the identification of the repeated modules and its elements. In this Figure, the proportions of the different elements that compose the module are also detailed. Each module has 25% of surface of Trombe-Michel walls, 25% of openings with double glazing, and the remaining 50% with insulated opaque walls.

3.1 Energy Conservation

Energy conservation is achieved with:
- Insulation in walls and roofs. The insulation material chosen was "*Alierita*" which is an expanded volcanic granulate with a thermal conductivity of 0.054 W/mK
- Reduction of heat losses by double glazed windows with external blinds and interior fabric curtains.
- Reduction of infiltrations in openings with double-contact frames and weather strips.
- Prevention of thermal bridges with careful constructive details in junctions.

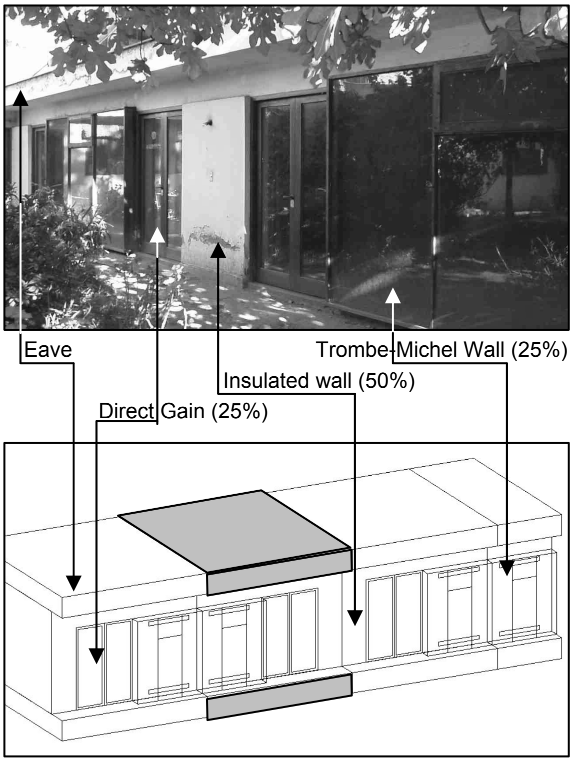

Figure 5. Exterior image and graphic of the North façade. Identification of modules and elements.

3.2 Passive Energy Gain Strategy

Internal temperature during the day is favoured by the solar radiation that enters through the double glazed panels in openings and provide immediate heat to the space.

During daytime, the air inside the solar space of the Trombe-Michel Walls rises close to 35ºC. This air is in contact with the homogeneous, 0.20 m width, massive brick wall. This element is painted black in its exterior face to increase its heat absorption. The collected heat, slowly goes into the mass of the wall and reaches the interior space with a 6 hours delay.

By the time the heat enters the interior, windows are no longer the source of heat by direct gain. This indirect heat maintains the temperature at night, until the morning brings new direct radiation to the space.

The Trombe-Michel wall also presents openings that permit the direct entrance of hot air into the interior to supply extra-heating during daytime, when needed. At night time, the inverse thermo-circulation does not occur because the openings in the Trombe-Michel wall can only be open in one direction: from the solar wall to the interior, preventing heat losses.

Figures 6 and 7 illustrate and describe the elements and the functioning of this articulated envelope in winter.

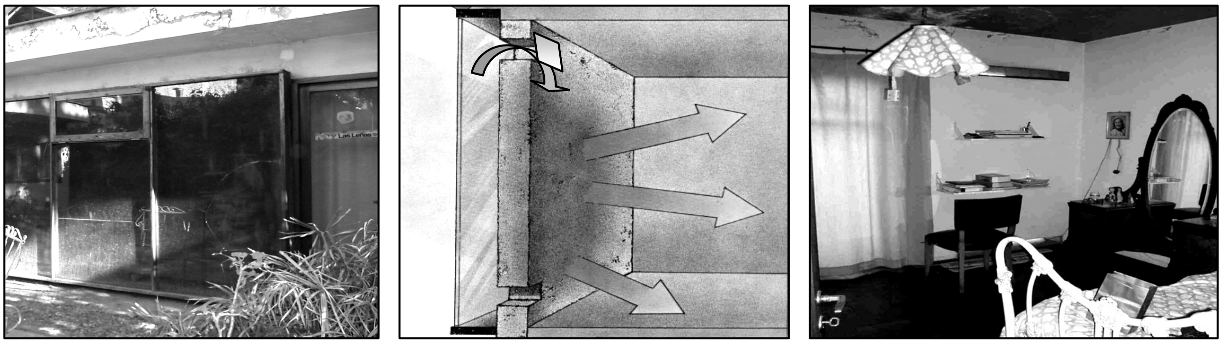

Figure 6. Illustration of the functioning of the articulated envelope in winter

	ENVELOPE ELEMENTS	DESCRIPTION	RESULTS
1	Insulation in walls and roofs	Higher resistance to heat exchange. Less thermal conductivity.	Maintenance of interior temperatures especially at night time and in cloudy days.
2	Reduction of thermal bridges and infiltrations	Less unwanted heat exchange between interior and exterior.	Maintenance of interior temperatures specially at night time and in cloudy days
3	Double glazed windows	Entrance of direct solar radiation through windows. The floor is dark and massive, and therefore it absorbs and collects heat.	Immediate heat during daytime (sunny day) and collection with delay, preventing temperature drops at night time.
4	Trombe-Michel walls	The air within the sun space in the trombe Michel walls rises to very high temperatures. The wall is dark and massive, and therefore it absorbs and collects heat.	Differed heat. The heat arrives through the mass wall to the interior delayed, preventing temperature drops.
5	Openings in the Trombe Michel walls.	Flow regulation of the direct entrance of the heated air in the sun space of the Trombe Michel wall, to the interior space. Flexibility.	Optional immediate heat during daytime to the interior space.

Figure 7: Description of the elements and the results of their application in this articulated envelope in winter

Though the described functions the envelope acquires flexibility in the climatic regulation. For this reason, the management that occupants perform over the elements of the envelope has a big incidence in the thermal behaviour of the house.

4. THERMAL BEHAVIOUR: MEASURED RESULTS

4.1 Measurement methodology

In situ temperature measurements were performed in the Bedroom indicated in Figures 4 and 5 with HOBO data loggers H8 every 15 minutes.

There were placed four data loggers:

1- In the centre of the space, named: “Centre”.
2- In the upper opening of the Trombe Michel wall, named “Trombe Up”.
3- In the lower opening of the Trombe Michel wall, named “Trombe Low”.
4- In the exterior protected from the direct radiation and without the influence of the proximity of mass, named “Exterior”.

Incident radiation data in the horizontal plane was collected in the same period and with the same frequency with a Solarimeter CM 5 Kipp y Zonen. In the figure named: Radiation

It was selected for the analysis the period between June, 17th, 2005 and June 28th, 2005, because it presented an interesting series of clear and cloudy days to evaluate the performance of the Energy Conservation – Direct Gain – Trombe Michel Wall combined system in the North façade of the envelope. It is clear the comparison between the interior temperatures in the less favourable days with the temperatures achieved when the systems arrives to its maximum expression. It must be taken into account that the registered temperatures did not receive any auxiliary heat, nor by mechanical means, nor by presence of people. Figure 8 shows the registered measurements in the Bedroom.

4.2 Measurements analysis

Between June, 18th and June, 21st there is a series of very cloudy days in which the system without solar input stabilizes at 15ºC. The system stabilizes when the gains and losses are equivalent. The exterior temperatures present an average of 7ºC, and therefore the internal temperatures stabilize 8ºC above the exterior temperature. Again, we need to take into account the lack of influence of the registration by any internal gain or auxiliary heat.

In the period between June, 22nd and June, 25th the system starts to function by gaining heat, and arrives to maximum temperatures of 22ºC and minimum ones of 18ºC with a daily variation of 4ºC. At sundown, the temperature descends 2ºC from the maximum reached after the solar noon (13:40 official time). During the nigh temperatures drop another 2ºC but it remain stable so that people go to bed and get up the next morning with a very subtle variation.

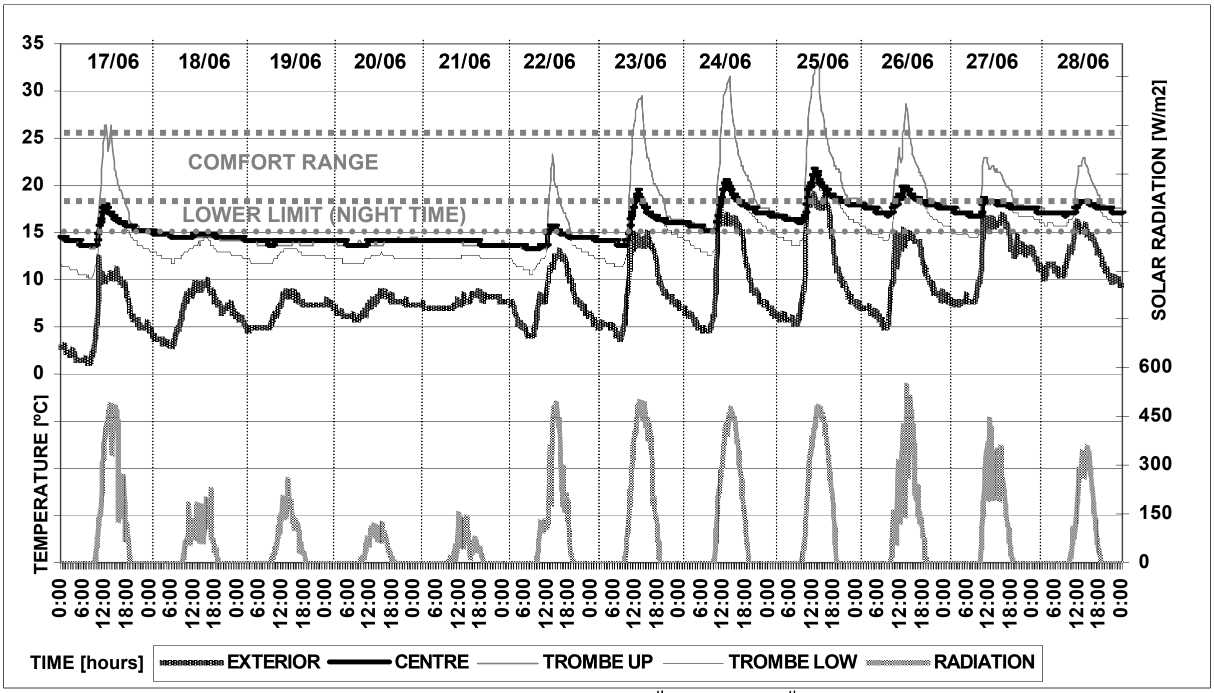

Figure 8: Temperature and radiation measurements. June, 17th to June 28th, 2005.

Givoni suggests that the comfort temperature range in acceptable still air conditions, for people that inhabit developed countries, is 20°C-27°C for the 80% of persons in comfort with 1 cló and 1 met of activity. [4] For countries in development (such as Argentina) the author suggests the flexibility of 2ºC of the limit temperatures, that is 18ºC -25ºC in winter, and 22ºC-29ºC in summer. The author refers as developed countries, to inhabitats used to central conditioning. Inhabitants of spaces without this type of thermal conditioning tolerate higher thermal variations. These data give us adequate criteria to evaluate the comfort situation in the measured spaces. [5]

During the night the inferior limit of the temperature can be accepted as low as 15ºC taking into account that occupants is Argentina are used to heavier clothes in winter (about 2 cló).

The measured system presents a Solar Saving Fraction (SSF) is 60.3% calculated with the Methodology of the Load Collector Ratio (LCR).[6] [7] The calculated auxiliary energy need to reach comfort all year long is 50.4 KWh/m2/year. This data is equivalent to the one registered, in 2004 with the house in use, by the Natural Gas Company that was 49.6 KWh/m2/year.

4.3 Variations in the proportion of the system: Energy Conservation – Direct Gain – Trombe Michel Wall

The existent case obtains a LCR of 7.17 W/m^2.ºC and a total SSF of 60.3% from the proportion: 50% Opaque Wall, 25% Trombe Michel Wall (with an individual SSF of 22.6%) and 25% Direct Gain (with an individual SSF of 37.8%).

In Figure 9 are analysed and compared three proposed variables of the proportion of the system.

	SSF Indirect Gain	SSF Direct Gain	LCR / SSF total	KWh /m2/ year
Existent Opaque: 50% Trombe: 25% Direct Gain: 25%	22.6%	37.8%	7.17 / 60.3%	50.4
Variation 1 Opaque: 33% Trombe: 33% Direct Gain: 33%	25.2%	44.2%	5.37 / 69.4%	38.8
Variation 2 Opaque: 25% Trombe: 50% Direct Gain: 25%	35.9%	30.3 %	4.78 / 66.2%	42.9
Variation 3 Opaque: 25% Trombe: 25% Direct Gain: 50%	18.0%	60.6%	4.78 / 78.5%	27.2

Figure 9. Proposed variations in the proportions of the system. Analysis and Comparisons.

The first Variation analyses the case in which the three elements of the façade have in the same surfase area (33% each) obtaining a LCR of 5.37 $W/m^2.ºC$. This figure is lower than the existent due to the increment of the solar gain area that increased from 50% to 66% (Direct and Indirect). The SSF obtained is 69.4%, (25.2% corresponds to the SSF of the Trombe wall and 44.2% to the SSF of the Direct Gain) improving the general performance of the system.

Variations 2 and 3 present the 75% of the area with solar gain (Direct and Indirect) and a 25% of isolated opaque wall. Because of that the LCR lowers to 4.78 $W/m^2.ºC$. The results are: Variation 2: a SSF is 66.2% if the proportion of the system is 50% Trombe Michell Wall (with an individual SSF of 35.9%) and 25% Direct Gain (with an individual SSF of 30.3%).
Variation 3: a SSF is 78.5% if the proportion of the system is 50% Direct Gain (with an individual SSF of 60.6%) and 25% Trombe Michell Wall (with an individual SSF of 18%).

5. CONCLUSIONS

5.1 Strong and weak points
The bigger the solar collector area, the higher the Solar Saving Fraction (SSF) depending on the performance of the collection system. Direct systems have higher performance than indirect systems. This can be observed in Variations 2 and 3. Both cases have the same Load Collector Ratio (LCR =4.78 $W/m^2.ºC$) and equal collector area (75% of the North Façade). Nevertheless, the SSF vary significantly. (66.2% y 78.5% respectively).

The bigger the solar collector area, also the higher the risks of overheating in summer and in intermediate seasons. In summer the correct aplication of shading devices to avoid non desired heat gains is possible. Intermediate seasons are more complex due to the continuos variability in the energetic needs by alterned cold-hot periods. The flexibility and the possibilities of envelope adaptation and its adecuate management by occupants became imperative.
Strong points of Direct Gain are the higher performance of the system obtaining high SSF with an smaller collector area, that implies a lesser cost. Weak points are presented in the intermediate seasons and in summer in which the necessity of a adecuate and adaptable solar protection can increment substancially initial costs. This also leads to a higher demand in the management of the system by users. The glazed surface to the exterior can also be considered as a decrease in house security and privacy.
Strong points of Trombe Michel Walls are lesser exposure to the exterior, (that directly translates into security and privacy) and higher control in the direct entrance of the solar radiation without an intense demand of management from occupants. In particular by the self-regulated system of openings in the solar wall. The principal weak point is the lower performance of the system compared with the direct gain and therefore the necessity of bigger dimensions in the collection areas to obtain an acceptable result.

5.2 The built solution
The adopted solution in the studied bioclimatic house assumes a compromise with the environmental regulation through the possibilities that offers the envelope. Leaves in the hands of users 50% of the skin in the North Façade and mantains the internal comfort conditions stable without the need of regulation in the other 50%. As a result, the energy comsumption obtained is whithin the accepted standards equivalents to 50 KWh/m2/year [8] and the overheating risks in summer are moderated.
From the understanding of regional pre-industrial typologies and the knowledge of post-industrial bioclimatic technology it is possible to develope energy efficient and environmentally aware projects that lead to the better quality of life of the inhabitants that live in cities.
Half-patio houses from the beginning of the 20th century, adapted from millenary Mediterranean houses, have valuable characteristics that enable a better thermal behaviour of interior and exterior spaces. In combination with bioclimatic strategies are close to reach natural comfort most of the year. An example is the particular case of the house that is presented in this study that achieves 60% of Solar Saving Fraction in an standard urban ground between houses.
The enrichment of the envelope with different elements of protection, gain, collection and conservation of energy, especially in the North façade, contributes to the improvement of the thermal behaviour of the house. These solutions give flexibility to the building and more control over the management to the occupant. More over, the benefit to the image of the dwelling is also interesting from the architectural point of view. This makes it easier for inhabitants to accept and adopt this new architecture that has learned its lessons from the past.

Next step to pursue will be to asses the summer behaviour of the bioclimatic house that is at the moment in evaluation.

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