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Affordable Solar Powered Housing for Poor Enclaves as a Possibility Option to Address Rural Housing Deficit

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Abstract

This article presents an affordable house model for rural area, which uses energy conservation and passive solar systems for daytime heating of and dry solar toilet, which reduces the need for water use. This house has a low cost adapted to possibilities of peoples with scarce economic resources and is a candidate to alleviate the rural housing deficit. At the same time, would enable improve expectations in the rural area and reduce migration to urban areas with the consequent increase in poverty in cities.

Keywords: *Affordable Solar Housing, Passive Solar Systems, Dry Solar Toilet*

Introduction

According to the Working Group of the Sustainable Building Alliance (SBA), energy consumption during the operation of a building in middle latitudes is used for several necessary uses, such as to: (a) heat and cool living spaces, (b) provide hot water for sanitation, (c) cook, (d) operate electrical equipment, (e) produce drinking water, and (f) generate non-potable water for other uses [1]. Energy consumption impacts on the environment through the emission of greenhouse gases, the reduction of non-renewable resources of the planet and damaging directly the health of its occupants, when they use firewood as fuel. At this time, the environmental crisis in the planet is evident, both in terms of the destruction of ozone due to the clorofluorcarbonados, and climate change, which creates loss of natural habitats and diversity due to pollution, desertification, deforestation and increased levels of carbon dioxide generated by operating residential sector and other sources (transport and industry) (The European Commission, 2010). Climate change is a global problem with serious environmental, social, economic and political dimensions and poses one of the current main challenges for humanity. Most likely, the worst impact will fall in the coming decades on developing countries. In this context, many of the poor live in situations that depend heavily on the natural reserves and ecosystem services and do not have other financial activities or resources to allow them to adapt to the impacts of climate change, lacking also access to social services and protection (Francisco, 2015). One billion people worldwide have their basic needs unmet. This authors are agree with De Juana, in the understanding that the global priority and the true meaning of globalization should be that developed countries focus their activities to help meet basic needs, according to the culture of each people and their degree of development (De Juana, 2009). As a result, that we live in more developed areas have access to energy networks and to knowledge, we must put our resources and knowledge at the service of those who suffer in order to produce meaningful impact on their lives. The building shape is key aspect which climate exerts its greatest influence. The relationship that best illustrates this relationship is vernacular architecture. In this, the climate is just one of the influences which include socio-cultural, economic, defense, or religious aspects, or even the availability of materials, construction, and technical knowledge that generate the form of architecture. In conditions of low technology (low income) climate plays the main role and become dominant in the solution used (Coch, 1998). To exist a relationship poverty-environment that depends on the area in consideration, for example in isolated rural semi-desertic areas

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there is overexploitation of natural resources (firewood), with the consequent reduction of productivity and elimination of native flora. In these places youth have two alternatives or overexploiting resources or move to marginal areas (cities, neighboring areas to small towns, etc.). Urban poverty suffer environmental problem like inadequate or non-existent sanitation, lack of drinking water or fuel to cook, to heat the home or to heat water. They are subject to pollution, discharge of waste, etc. While no doubt that lack of resources tends to result in excessive pressure on the natural system fragile and low productivity in marginal built environments, all that it can do to alleviate the situation of extreme socio-economic difficulties of these peoples has priority above the problems caused by pollution. It is important to introduce and expand technology and habits to make social systems more controllable by the same people, in a way that life does not depend on non-renewable sources. In Argentina as in Latin America, there is a configuration of socio-economic and infrastructure characterized by uneven growth in terms of profitability, efficiency and access to water, energy, raw materials, building materials, etc. Table 1, shows the percent of urban population in Argentina and in Mendoza province for the period 1895-2010.

Table 1. Percent of urban population in Argentina and Mendoza

	Urban population in Argentina (percentage)								
Year	1895	1914	1947	1960	1970	1980	1991	2001	2010
Total of the country	37,4	52,7	62,2	72	79	82,2	87,1	89,3	91
Mendoza province	24,4	32,1	49,2	60,4	66,2	68,9	77,8	78,9	80,9

Ref.: INDEC - Data for Human Development. Http://www.indec.mecon.gob.ar

The percentage of the country's overall population is higher (influenced by the Federal Capital -100%, and the province of Buenos Aires -96.2%). In Mendoza it turns out to be lower, but there is also an increasing trend. However, in the province of Mendoza, there is still a 19.1% who live in the rural and/or isolated areas, far from sources of supply, with expensive access to energy and consuming other sources such as biomass (firewood), which require several hours a day to collect (Esteves et al., 2014). Data from the 2010 census, indicates that, - approximately 2.3 million people in almost 466.000 homes and 7,000 public buildings (schools, health center, police stations, etc.) live in rural areas in Argentina. The cost of energy is $ 0.96/kWh for LPG (liquefied gas of petroleum) and 0.86/kWh for firewood. This cost of fuel is 3 to 6 times more expensive is that in urban areas with network of supplies, without mentioning the difficulties that exist in food supply and the availability of devices with higher performance. This paper presents a house designed and built to provide a solution to the very difficult situation of a family of 5, the mother and her 4 children of young age, who did not have a place to live. In that sense, from the AAFME – Mendoza Association for Family Support, the Foundation El Goel, Juan Paul II prayer group and several people selflessly made contributions to both allow the acquisition of the land and build the mentioned housing.

Situation of the Land

Figure 2 show the land to build the house. It is very large in N-S direction 31,68 m and 8.86 m in E-W direction. This determines the location of the building in direction N-S. Because is required future expansion of the street Laureano Nazar by Highway Administration the land it is reduced. Terrain has electricity but do not have drinking water or sewer network. Fig. 2 shows the relative position of the same respect to National Route 7 which connects it with the city of Mendoza.

Figure 1. Location of the Land to Build the House and Picture of Laureano Nazar Street and Soil Characteristics

Figure 1 shows an aerial view of the land, predominantly rural, between cultivation of olive trees to the West and the street Laureano Nazar and cultivation of vineyards to the East. Is noteworthy that these endeavors are the source of work for many inhabitants of this area, among which, includes Teresa Pacheco the mother and family support. The soil is sandy with presence of gravel and stones (see Fig. 4a). The phreatic level is quite deep.

Climate

The climate of the area of Fray Luis Beltrán, Maipú Department is semi-desert, but the area occupies part of the Oasis North of the province. Reign cold winters, hot summers and middle period with temperatures from cool to cold in the morning and pleasant evenings. The averages and absolutes monthly temperature are indicated in Fig. 2 (left). The temperatures are very low in June and July (winter), with 0° C average minimum and 32° C average maximum in the month of January (summer). Heating degree-days (base temperature = 18° C) are 1490 °C.day/year. With respect to the solar resource are high values of radiation given by most clear days in every month (see Fig. 2 right). This draws attention to trying to use energy conservation systems, at the same time, incorporate solar systems for heating, heating water, cooking, etc.

Architectural Project

A study of possible projects with emphasis on the calculation of the minimal envelope surface respect to surface of the building, FAEP Factor (Esteves et al., 1997), in order to give the requirement of the minimum cost of the building. Figure 3 shows a plant of the house with stage 1 and 2 indicated.

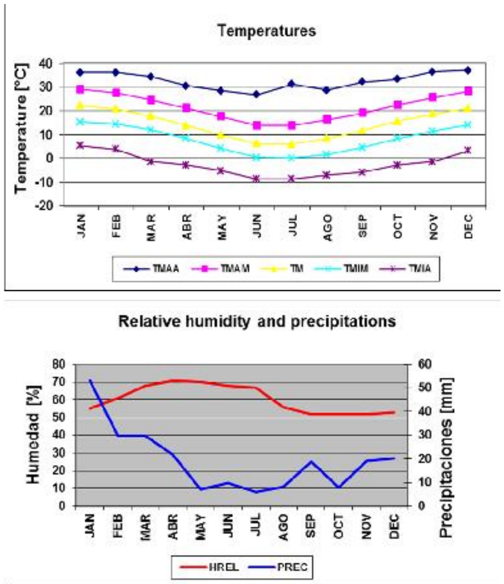

Figure 2. Climate in F.L. Beltrán - Maipú, Mendoza – Argentina. Temperatures: TMAA highest; TMAM avg. max.; TM=mean; TMIM=avg. min.; TMIA= lowest; Relative Humidity (HREL) and precipitations (PREC)

The architectural project was developed jointly by Inestudio Architecture and members of the Chair "Procedures and Techniques of Sustainable Design, specifically students Denise Lara. The final draft was completed by Arq. Matías Esteves (from IADIZA) and Dr. Gustavo Barea (from INCIHUSA), who also occupied the municipal management; Eng. Pablo Gantuz complete the calculation and seismic verification of structure and Alfredo Esteves driving and construction management. Solar systems have been designed by staff of the INCIHUSA: María Victoria Mercado, Fernando Buenanueva, Roberto Sosa and Alfredo Esteves too.

The project consists of a first stage of 32 m^2, including two bedrooms, one minimum to accommodate a bunk bed (that would be occupied by 2 boys) and the other with 3 beds to accommodate the 3 women (mother and 2 daughters). The dining room is located in the end N and with the kitchen is located in the passage to the bathroom. The planned expansion is a kitchen-dining room of 4 m x 7.5 m (see Fig. 3). Analyzing the shape, the FAEP Factor = 2.5 m^2/m^2 ; Form Factor = 0 9 m-1, envelope surface to volume ratio (Goulding et al., 1994).

Building Technology

Building technology is due to speed of light construction features of the remote location and risks of theft or theft of the place. Also it have adopted the premise of incorporating energy conservation and solar systems.

Structure of logs, columns of eucalyptus impregnated with copper sulfate to prevent moisture from the ground could degrade it (Fig. 4b). This columns are placed also anchored in the floor burying it in a given of cyclopean concrete of 0.70 m and depth of 0.40 x 0.40 m. The structure of foundations is completed with beams of 0.20 x 0.20 mm linking the posts at the level of sub-fl oor (Fig. 4 c). Once full concrete foundation beams, completed the smoothing underlayment (Fig. 4d). Beams materialize with logs without impregnating and edged 0.20 m and 0,10 m to close the openings and to support the roof (Fig. 4e).

Roof was constructed with tongued and grooved panels of 5/8" thick pine, vapor barrier with asphalt emulsion paint which simultaneously serves as a binder of the EPS of 0.05 m in thickness and finally 4 mm of aluminum membrane attached with spray contact cement (Fig. 4f).

Opaque walls was made with 12.5 mm thick of cement board in the exterior, thermal insulation of 0.05 mm thick of glass wool between the structure of support plates, materialized with 0.05 m thick poplar frames; vapour barrier using a sheet of 200µ polyethylene and 12.5 mm thick gypsum rock plate (see Fig. 4g).

Frame of windows are made with structural steel pipe and the windows are with pine wood (fruit of a donation like the doors) are have been adapted to provide adequate ventilation and lighting and they result with simple contact with weatherstrip and simple glass. The wood doors also have simple contact and weatherstrip too.

Table 2: Thermal Transmittance K of Envelope Elements

Element	K [W/m2.°C]
Roof	0,664
Wall	0,578
Windows	4,5
Fundation	0,72

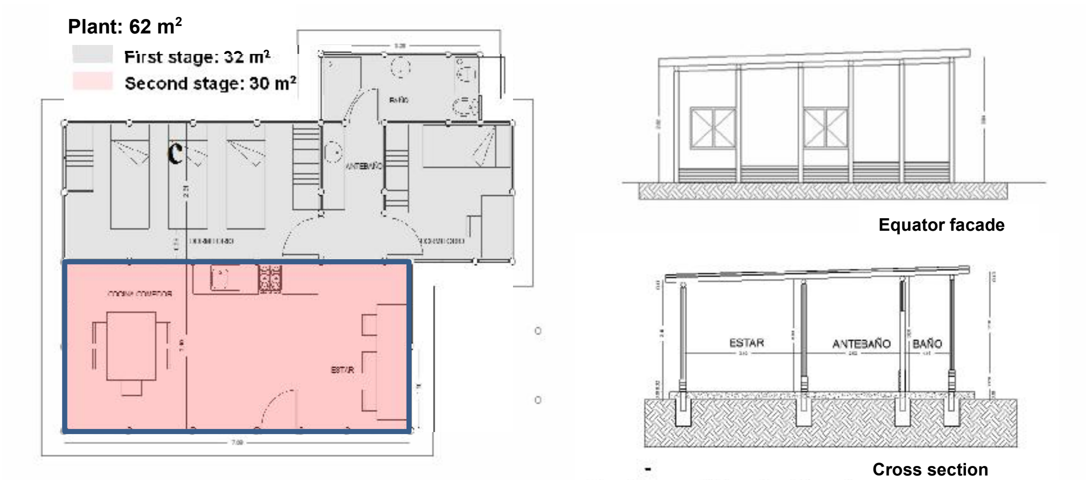

Figure 3: Plants of 1° and 2° Stage, Cross Section and Equator Facade.

Figure 4: Housing Construction Steps

Figure 5: Children Helping to Seal Joints and Inside View of the House.

The construction work has been interspersed with involvement of future users, taking into account that had tasks that could be performed by futures users. In the case of the left Figure 5 you can see children sealing the joints between plates and logs of wood, because in some cases, it was necessary to seal cracks. In the same Figure 5 der. inside the house, and the space built without ceiling to add Solar passive heating system – SIRASOL (Mercado et al., 2013) to gain heat and daylight from the North and over the ceiling is observed.

Solar Systems

The solar energy technology refers to the use of systems that allow incorporating heating at times of the day, take Mercado design called SIRASOL system. It was incorporated two SIRASOLs, one in dining room and in the bathroom the other. Another systems are solar water heater and dry solar toilet system. Daytime heating system SIRASOL adapts to these cases when is the housing long in direction N-S and do not have facade to the Ecuador available in large enough (Mercado et al., 2013). It has been designed to incorporate 2 systems (see Figure 6), one over the dining room seen from the inside and another on the shower in the bathroom seen from the outside.

Solar Technology in Bathroom

In order to save water, since there is no potable water network in the zone, a system of dry solar toilet was installed (Serrano, 1992). Figure 7 shows pictures of the bathroom, and installation of this system. Dry toilet systems are systems used in different places. In San Juan, Argentina, Blasco Lucas mentions the construction of a dry toilet, which uses two cameras (Blasco Lucas, 2013). These toilets have a devices that anatomically separates the liquid effluent from the solids. Those seep into a well and solids pass to a chamber of dehydrated. The process considers the addition of ash or dry earth to keep dried the surface of the solids in the first time. In this chamber solids are subjected to a stream of hot air which produces dehydration.

Figure 6: System SIRASOL A) Over Dining Room from the Inside; (B) Over Bathroom from the Outside

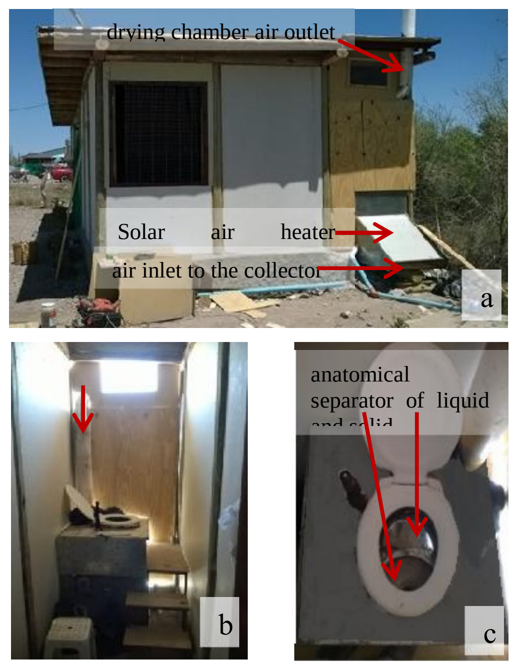

Figure 7: Technology Used in Bath Room: A) North Façade of the House with Solar Collector of the Dry Solar Toilet System; (B) Toilet Seeing from Interior of Bathroom with Staircase of Access; C) Anatomical Device to Separate Solids and Liquids

The stream of hot air it is produces in a solar air collector materialized by an alveolar polycarbonate cover 8 mm thick which allows the entry of solar radiation to the dehydration´s chamber. Because since 75% of solids is composed of water and 25% of solid substance composed 30% are bacteria deceased, 10 to 20% is fat, 10 to 20% are inorganic substances, 2 to 3% proteins and remaining are portions not digested (Barbosa, 2013). Once solids are dehydrated they occupy very little volume. The amount of solids is 135 to 270g for individual to the day, after the drying determines around 88 to 97% of organics substances and the final weight is only 75g 33.75g to 67.5g for individual to the day. The volume of dehydration´s chamber is 0.8 m3. This volume is sufficient to keep the dry product of 1 year for the 5 people who inhabit the housing

Economic Analysis

The economic analysis is carried out on the basis of values for December 2014 in table 3. As you can see, total construction results with a total cost of U$S 10065, 9. (U$S 312/m2). It is possible to compare with traditional construction, that in Mendoza have a cost of U$S 543.5/ m2. The traditional construction is composed of foundations of cyclopean concrete, reinforced concrete structure, walls of solid brick and similar roof but finished with tiles or sheet steel. The rest of components are similar. It is noteworthy the benefit which means the construction of multiple dwellings instead of a single unit, since the scale factor would allow us to lower the values of the materials.

Table 3: Cost of Materials and Workmanship for the House Construction in Arg. $ and U$S for December 2014.

Item	Cost [Arg.$]	Cost [U$S]
Design and proyect	2795	303,8
Wall	19075	2073,4
Floor	2491	270,8
Roof	6520	708,7
Windows (adaptation)	558	60,7
Electrical installation	15000	1630,4
Plumbing	17500	1902,2
Workmanship	28700	3119,6
Total	**92639**	**10069,5**

Conclusions

The society must build sustainable settings in order to controlling and make their future less dependent of non-renewable resources and at the same time, improve the quality of life of the population, especially that of most low-income. This paper presents a model of minimal, economic housing with energy conservation and economic and effective solar systems that can reduce both the cost of construction and the operating cost of the same.

The house has been built between August and October 2014, and immediately the family was moved to it, given the conditions of instability and insecurity in building that occupied so far.

The present represents one of the many possibilities that have renewable energies (solar energy in this case) to spread the use and grow in homes of the rural area. It is also a solution to the current housing deficit which is very high.

Acknowledgement

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