Robustness of social houses in Ecuador facing global warming: prototyping and simulation studies in the macroclimatic regions of Amazons, Coast and Andes.

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Abstract

Ecuador is a small country but has a very climatic variety. Principal macro-climatic regions could be considered as: amazon rainforest, with hot humid climate; tropical coast, with also hot humid climate; highlands, with tropical mountain climate. Actual Government is working on energy efficiency improvement of all kind of buildings. In 2011, the Ministry of Urban Development and Housing (MIDUVI) selected by a design competition, named "Dwellings for the climate change", three social house typologies, one for each macro-climatic emplacements of the country. The winner dwellings were designed considering passive architecture concepts, however some simulation studies conducted by the National Institute of Renewable Energy and Energy Efficiency (INER) in 2014 show that the new design proposals have in many cases poor performance than the standard dwelling typically used in Ecuador for all climatic emplacements. To validate the simulation results, a new set of simulations has been conducted using today weather data. Output searched was the total discomfort sensation instead of the thermal demand or energy consumption (heuristic). In addition, global warming has been taken into account by simulating future situation in A2 scenario proposed by IPCC. Future climate has been modelled by using the Climate Change World Weather Files Generator developed by CISBE. Results show that building design in Ecuador is influenced by standards that come from colder countries. This fact leads to a general poor result in terms of natural cooling performance, even in the actual climate. Global warming and urban development, especially in the coast region, will improve the cooling needs, so building design guidelines for Ecuador will have to be reconsidered, especially focusing on heat evacuation problems, instead of heating demand reduction.

Keywords: global warming, climate change mitigation and adaptation, social housing, Ecuador

1. Introduction

Ecuador is starting to consider climate change as a priority for the country development. Recently, was founded the Sub-secretariat for climate change, and many Ministry started to insert related topic in the political agenda. Particularly, Urban Development and Housing Ministry, MIDUVI, launched in 2011 the competition "Dwellings for climate change" in order to improve the basic social house that is still constructing in all the climates of the country. For instance, Ecuador, even small, has a unique climatic diversity: in the Andes the climate is tropical mountain, in the Amazons is tropical wet and in the Coast is hot, both arid and humid, depending on the specific position. One of the competition goals was to put in evidence the need of different design for each climate, even for social dwellings, that have to be very cheap. The National Institute of Energy Efficiency and Renewable Energy (INER) is also developing some prototypes for the different climates of Ecuador [1]. In this paper, a simulation study has been conducted in order to estimate the discomfort hours (both undercooling and overheating) that inhabitants could feel in the base case (the actual MIDUVI social house) and in the three competition winner prototypes. Simulations have been conducted for the climate of nowadays (Typical Meteorological Year –TMY) and for the future (2050 and 2080) taking into account the global warming effect under the Intergovernmental Panel for Climate Change (IPCC) A2 scenario. Because of in Ecuador heating and air-conditioning systems are used only by a small part of the population (the richer one), the analysis was conducted thinking in naturally ventilated buildings, searching for the total discomfort hours during the year.

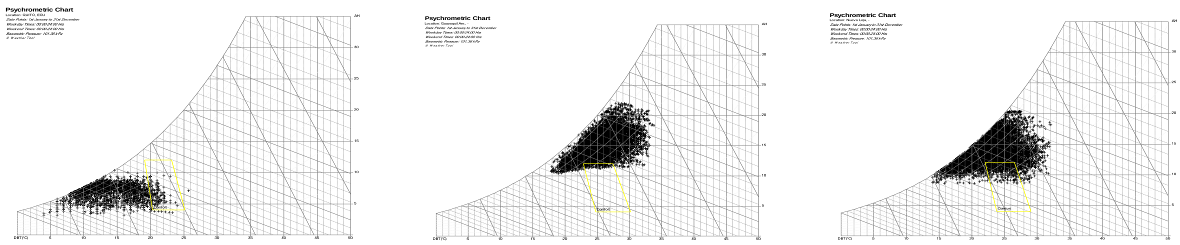
2. Methodology

In this paper IPCC data are used to simulate future energy performance of three types of buildings. Future data (2050 and 2080) are obtained by using the Climatic Change Weather Files Generator developed by Jentsch et al. [2] and typical meteorological years are obtained from the meteorological service of Ecuador INHAMI [3]. The selected scenario to simulate the future is the A2 IPCC scenario. The A2 scenario describes a heterogeneous world, with slow population increase, differences among regions and social classes. The result is a medium-high emissions scenario. Climate description of the considered cities, representative of the macroclimates of Ecuador, is the following:

- Quito (0ºN latitude, 78ºW longitude, 2800 m height) climate is a tropical mountain climate, whit mild diurnal temperature and colder nights both in wet and dry seasons. Radiation levels are high, urban density increases the heat retention effect and breeze is sometimes present.

- Guayaquil (2ºS latitude, 79ºW longitude, 0 m height) climate is hot and wet during all the year. Oceanic breeze, when available, is very important for the natural cooling of the buildings. Urbanization is affecting the temperatures of the city and new constructions in the first costal line are blocking in many cases the wind.

- Nuevo Loja (0ºS latitude, 77ºW longitude, 200 m height) climate is tropical wet, with high humidity and temperature during all the year, and a night – day oscillation a littele higher than in the Guayaquil climate.



(a) (b) (c)

Figure 1 – Givoni chart for Quito (a), Guayaquil (b) and Nuevo Loja (c)

Building typologies analysed are described in the follow:

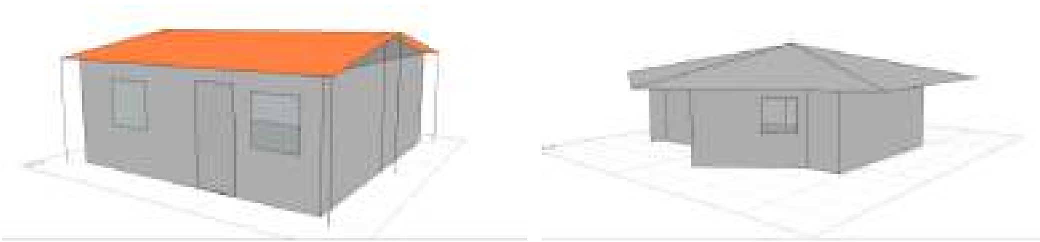
- MIDUVI house is a small family house with external walls made of cement block, with thermal transmittance of 1.8 W/m^{2}K; roof made of metal deck, transmittance 5.2 W/m^{2}K, 15% of transparency on the main façades (simple glass and aluminium, transmittance 5.1 W/m^{2}K).

- Proposed house for Amazon is a family house with external walls of reeds, thermal transmittance 4.5 W/m^{2}K, roof of polipropilene, transmittance 2.7 W/m^{2}K and 10% of glazed surface.

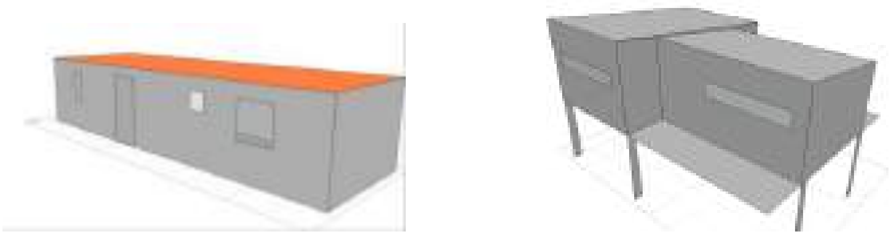
- Proposed house for Mountain is a more compact house with walls of concrete (transmittance 1.8 W/m^{2}K), roof of metal deck (transmittance 5.2 W/m^{2}K) and 20% of glazed surface.

- Proposed costal house is an elevated house with walls of light concrete (transmittance 3.5 W/m^{2}K), roof of steel (transmittance 5.2 W/m^{2}K), 10% of glazed surface.

All the houses have the same occupancy of 10 m^2/person during the 24 hours. Figure 2 shows the models for the dwellings and table 1 resumes the material properties.



(a) (b)



(c) (d)

Figure 2 – Houses models for MIDUVI (a), Amazons (b), Mountain (c) and Coast (d).

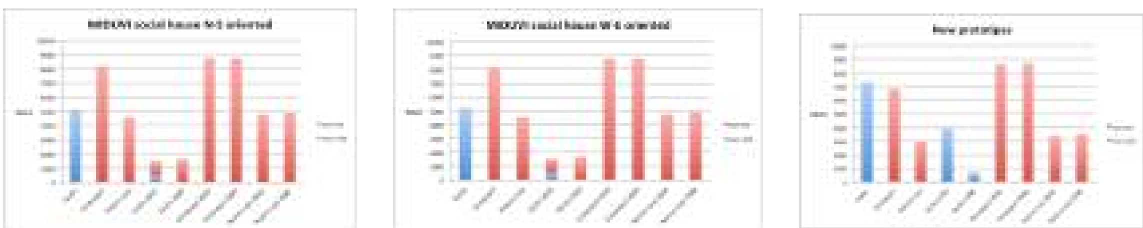
Table 1 – Transmittances and glaze percentage of building typologies

Building	U wall (W/m^{2}K)	U roof (W/m^{2}K)	Glazed surface (%)
Mountain	1.8	5.2	20%
Amazons	4.5	2.7	10%
Coast	3.5	5.2	10%
MIDUVI	1.8	5.2	15%

Simulations have been done using Types 56a (multizone building) in the Trnsys tool (version 16). Climatic TMY files are read in Type 109, sky cloudiness is calculated by Type 69b and psychometric variables by Type 33e. The Jentsch method to generate TMY future data uses "shift" and "stretch" modifications for temperature, "stretch" modification for wind speed and global radiation, "shift" for relative humidity and atmospheric pressure. Fore more detailed information, see the tool manual [4]. The MIDUVI house has been simulated in both main orientations N-S and E-W, whilst the prototypes have been simulated with the recommended orientation, N-S for the Guayaquil case and E-W for the Quito case. It has to be remembered that the latitude 0 means that E and W orientations guarantee the solar gain, whilst the N-S orientation avoid the solar gain during all the year.

3. Results

Figure 3 shows the results in terms of discomfort hours for the MIDUVI house in both orientations and for the new prototypes. Table 2 resumes the discomfort values.



(a) (b) (c)

Figure 3 – Discomfort hours for the MIDUVI house N-S (a), E-W oriented (b) and new prototypes (c)

These results confirm the possible impact of the climate change on the built environment and the need of a new concept thermal regulation for the country. Many research is currently on going in this topic, for tropical, arid and Mediterranean climates, see for example the work of Palme et al. [5]

Table 2 – Discomfort hours in analysed cases

Case	MIDUVI house N-S		MIDUVI house E-W		New prototypes	
	Too hot (h)	Too cold (h)	Too hot (h)	Too cold (h)	Too hot (h)	Too cold (h)
Quito TMY	41	5071	29	5121	0	7315
Quito 2050	1000	487	1009	511	0	3939
Quito 2080	1640	9	1676	9	8	660
Guayaquil TMY	8161	0	8139	0	6810	0
Guayaquil 2050	8760	0	8760	0	8632	0
Guayaquil 2080	8760	0	8760	0	8724	0
Nuevo Loja TMY	4552	0	4536	0	3024	0
Nuevo Loja 2050	4780	0	4776	0	3352	5
Nuevo Loja 2080	4913	0	4898	0	3480	5

4. Conclusions

The present work showed that new design for houses is needed in Ecuador. The climate change will affect the performance of the buildings and for example in the highlands the actual house of MIDUVI will suffer the shift between heating and cooling demand. In Guayaquil and Nuevo Loja, the overheating is the problem and global warming will increase the effect. Respect to the new prototypes, it seems that the different design could reduce the bad performance of the MIDUVI house, but it is not sufficient. Considering the future scenarios, in both hot emplacements (Guayaquil and Nuevo Loja) the overheating sensation will be very high. Only the new prototype for the highlands shows really a better performance in the future (but not with the nowadays climate) respect to the MIDUVI house, avoiding the future overheating sensation. The energy certification of dwellings, under development in Ecuador, will have to focus on heat evacuation in all the climates, including the highlands. To insert since now simplified calculation methods to estimate the potential to naturally cool the buildings seems a priority. At the urban district level, environmental studies to quantify the contribution of the building to the heat island effect and its dependence on the urban form are also needed, as in other climates [6]. The blockage of natural breezes in the case of Guayaquil is also a very important topic to assume as soon as possible as an important issue of debate.

5. References

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