PASSIVE COOLING TECHNIQUES FOR BUILDINGS. POTENTIAL OF USE WITHIN VENEZUELA´S CLIMATIC ZONES.

M.E. Hobaica[1], F. Allard[2], R. Belarbi[2] and L. Rosales[1]

[1] *Instituto de Desarrollo Experimental de la Construcción, Facultad de Arquitectura y Urbanismo, Universidad Central de Venezuela, Los Chaguaramos, Caracas, 1040-A, Venezuela*
[2] *Laboratoire d´Étude des Phénomènes de Transfert Apliqués au Bâtiment, Université de La Rochelle, Av. Marillac, F17042, La Rochelle, France.*

ABSTRACT

The current paper presents the first outcome of a study dealing with thermal quality of buildings in a context of rationalized energy spending. It takes into account the significance of an integral treatment of the building's envelope through the previous knowledge of the effects of specific passive cooling techniques. Simulations aimed to evaluate the climatic potential of some of these techniques where made, as a way for sitting down the bases for their application in accordance with Venezuela's varied climate. The firsts estimates provided promising results on the use of some of these techniques in order to complement design strategies for obtaining suitable levels of comfort while reducing energy spending. The methodology follows a simplified procedure based on valuation indexes developed by the University of La Rochelle in the framework of the European projects Pascool/Joule [Santamouris, M. et al. (1995)] and Altener/Sink [Alvarez, S. et al. (1997)]. This procedure gives the necessary information for developing design tools that could be use to improve indoor comfort at reasonable energy costs. The first of these tools should be a map of Venezuela in which designers could identify the best technique for each region.

ENERGY SPENDING AND BUILDING DESIGN IN VENEZUELA

As seen in Figure 1, Venezuela has the highest energy spending level per habitant in Latin America. Indeed it is one of the highest of the world. The very hot city of Maracaibo has by its own probably the highest of all. This is in part because of rather low prices of electricity for all consumers due to the country's condition of big oil producer and together with a traditionally paternalist regime.

In addition, after years of population growth and stagnation of public investments in the electrical sector, the demand starts to overcome the offer and regular cuts begin to be clearly noticeable. To overcome this, some strategies where set up in order to increase the offer of electrical energy together with a campaign for making aware the consumer about the importance of saving electricity. But taking into account that buildings are the principal energy consumers (approximately 50% of the total), it is essential to go deeper by means of action aimed to improve the energy efficiency of buildings. Actually any national program of energy rationalization should consider buildings as a fundamental object.

A first evaluation of Venezuela's energy spending practices in buildings [Sosa, M.E. et al (2002)] shows that the rise of the electrical energy demand is mostly a result of inadequate energy spending patterns, incompatibility between architecture and climate, lacking of construction standards, over-designed equipment, use of obsolete or second-rate equipment and absence of maintenance strategies for building equipment

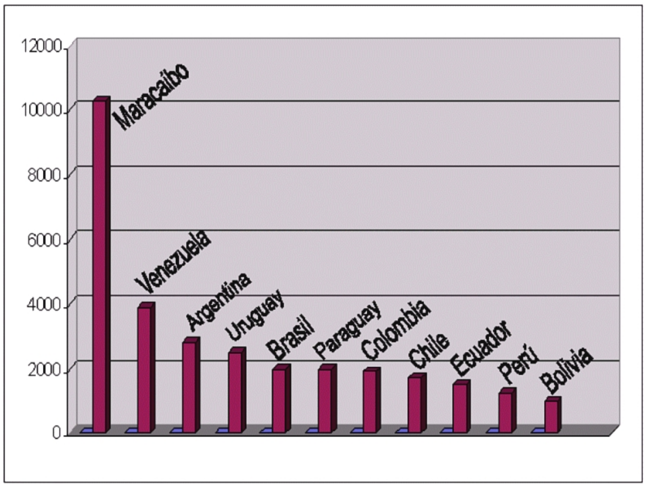

Figure 1: Energy consumption per habitant in Latin America in kWh [Sosa, M.E. et al (2002)]

ENERGY SAVING AND DESIGN STRATEGIES FOR VENEZUELA

In Venezuela, in most cases, the climate allows to achieve appropriate levels of thermal comfort through the year without using too much electrical energy. Depending on the use of the building and the geographical location, one can work with three types of approaches:

- Active techniques, in which the indoor ambiances are only treated by means of air conditioning systems or similar. In spite of the effectiveness for bringing comfort of such techniques, they normally demand large amounts of energy.
- Passive techniques, in which the design take advantage of the climatic conditions in order to produce indoor atmospheres of thermal quality, without using air conditioning systems or similar. Natural ventilation is for example an important technique, because it allows, in an easy way, to diminish the indoor temperature and humidity.
- Hybrid techniques, in witch comfort is achieved by a mixture of active and passive techniques. Hybrid techniques should be used when climatic conditions make insufficient the use of pure passive techniques. Despite the use of air conditioning, the architectural approach contributes significantly to reduce the required cooling load.

Taking into account that natural ventilation was examined quite deeply for many years through numerous researches, the present study deals concretely with the following less known passive techniques [Florenza, R., Roura, H. (1995)]:

- Evaporative cooling: Evaporative cooling is based on the thermodynamic process of evaporation, in which a specific quantity of energy (latent heat) is needed and taken from the air (sensible heat). The amount of sensible heat absorbed depends on the amount of water that can be evaporated according to humidity levels. When evaporation occurs openly, the air temperature descends, but the humidity rises, which is known as direct evaporative cooling. When occurs inside a heat exchanger, the water content of the cooled air remains the same, which is known as indirect evaporative cooling.
- Radiative cooling: Radiative cooling is based on the heat loss by long-wave radiation emission from a body towards another body of lower temperature, which plays the role of a heat sink. In the case of buildings the cooled body is the building and the heat sink is the sky, since the sky temperature is lower than the temperatures of most of the objects upon the earth.

- Ground cooling using buried pipes: Ground cooling is based on the dissipation of the building heat toward relatively deep areas underground whose temperature is smaller than that of the atmosphere. Cooled air is injected into the building that has been previously cooled through buried pipes and taken by means of simple fans.

CLIMATIC ZONES FOR VENEZUELA

Venezuela is located within the tropics, characterized by a high solar radiation, relatively high temperatures, rather soft winds and elevated humidity on the oceans and less elevated inside the country. In order to define climatic zones associated with passive cooling techniques, a methodology was conceived that provided five climatic zones [Sosa, M.E. et al (2002)], characterized by the correlation between the altitude and the following climatic parameters: dry bulb temperature, wet bulb temperature, solar radiation, precipitation, wind speed and wind direction. The methodology is based on the fact that it is possible to establish a relationship among the humidity, the temperature and the altitude by means of a "Virtual Temperature", defined as the temperature that would take a volume of air after all the vapor content is condensed, according to it's latent heat.

Figure 2 shows the 5 climatic zones. It also summarized the main characteristics of each zone.

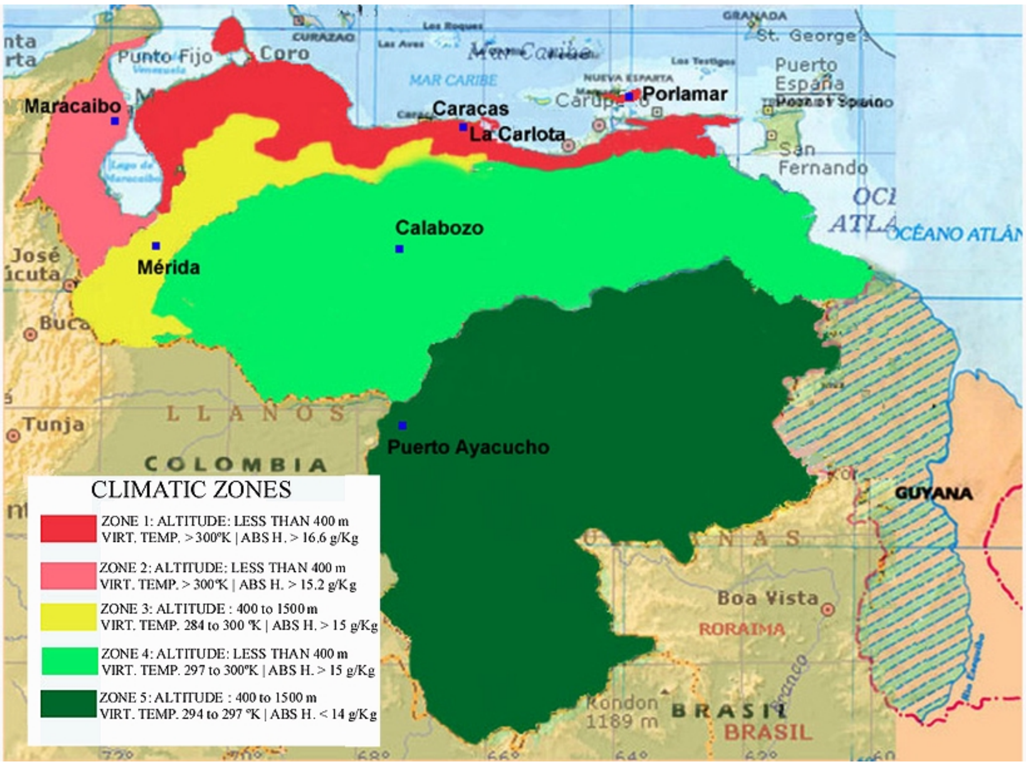

Figure 2: Climatic zones for Venezuela defined through correlations among virtual temperature, absolute humidity and altitude.

CALCULATION HYPOTHESIS

For a long-time, simply qualitative procedures where used to predict the potential of passive cooling techniques of buildings. In recent times, as part of the European projects Altener/Sink [Alvarez, S. et al. (1997)] and Pascool/Joule [Santamouris, M. et al. (1995)] a simplified method was developed by the University of La Rochelle for a quantitative analysis of the cooling potential of different passive cooling techniques for different types of climates.

The potential of any cooling technique depends basically upon the difference between the heat sink temperature and the design or comfort temperature. That difference, integrated along the period of the cooling procedure, gives a first theoretical estimate of the cooling potential of the technique for a particular climate. In order to wrap all the useful information for practical means, the methodology defined several additional indexes: an index of available potential, an index of useful potential, an index of requirements and a covering factor.

SIMULATION RESULTS

Simulations where carry out for six cities distributed among the five climatic zones shown before. These cities where: Calabozo, Caracas, Maracaibo, Mérida, Porlamar and Puerto Ayacucho (See Figure 2). For each city the potential of direct and indirect evaporative cooling, radiative cooling and buried pipes ground cooling where determined for design temperatures going from 24 to 28ºC. The data used consisted on hourly values of all climatic parameters taken by the respective meteorological stations during the years 2000 and 2001.

The index of theoretically available energy shows that the best potential for all climatic zones is the radiative technique, followed by the buried pipes technique, while it seems a lot less practicable the evaporative techniques, either direct or indirect.

When analyzing the index of useful potential for a design temperature of 26ºC (See Figure 3), which takes into account the real effectiveness of the technique, the radiative and buried pipes techniques seems to have a comparatively bigger potential in warm regions, while presenting little interest in colder regions with high altitudes. On the other hand, the evaporative techniques can be considered in a much smaller measure as only able to collaborate to a certain extent in improving comfort.

The requirements index (See Figure 4), witch quantifies the sensible cooling requirements to guarantee a comfortable microclimate, indicates almost no need of air conditioning in Caracas as well as in the Andes region for all design temperatures going from 24 to 28ºC.

The covering factor defines the relationship between the useful potential index and the requirements index during a certain period of time for a specific design temperature. The simulation made for a design temperature of 26ºC (See Figure 5) indicates that the radiative and buried pipes techniques could cover the requirements for 100% of the country if the design temperature goes between 26 and 28ºC, and in a important degree if it is even of 24º. The evaporative techniques, no matter if direct or indirect, have a lot smaller covering percentage, ranking from 20 to 30% for all zones, specially the warm ones.

The simulation also shows that the covering factor is the most appropriate index, while the theoretical potential index is the most limited because of the lack of information involved. Therefore, the methodology, broadly used in Europe, must still be adjusted in order to carry out in a better way the evaluation of the diverse cooling techniques for all Venezuelan climatic zones. Furthermore, the methodology will be incorporated into a general building thermal analysis code [Belarbi, R. (1998)].

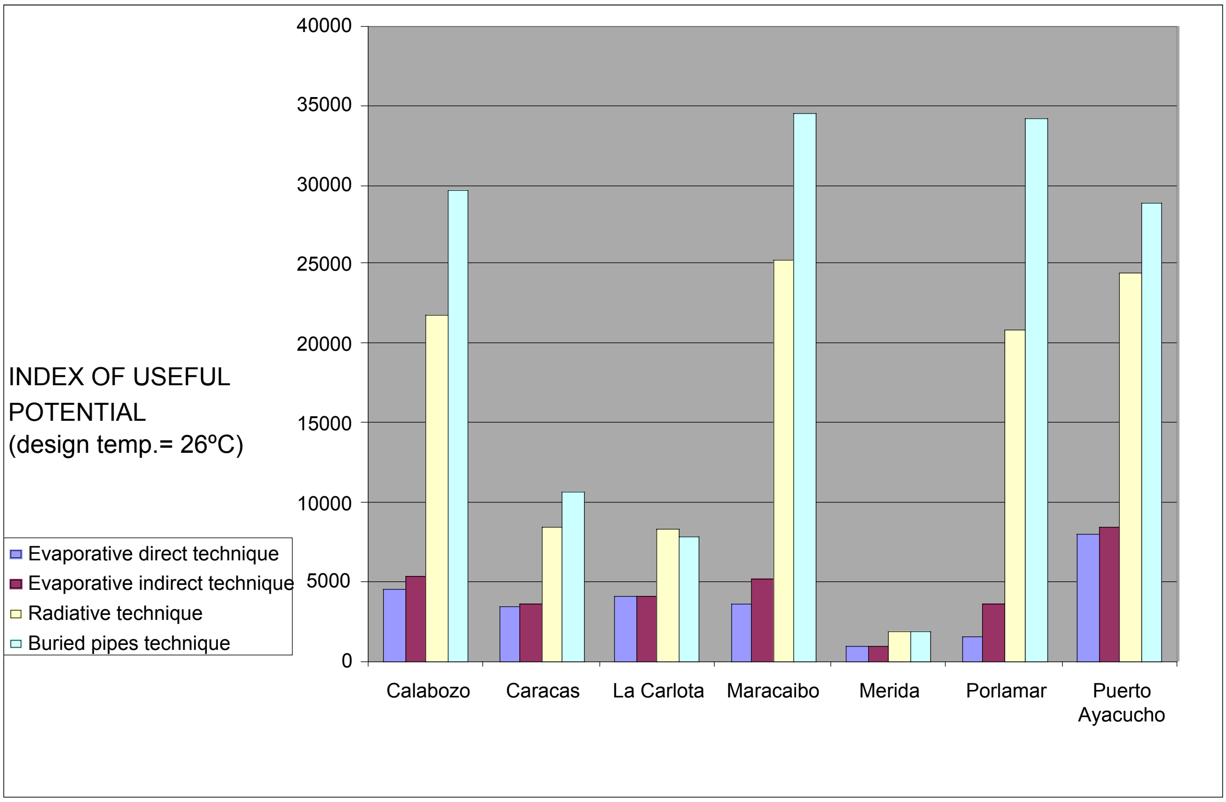

Figure 3: Index of useful potential for a design temperature of 26ºC

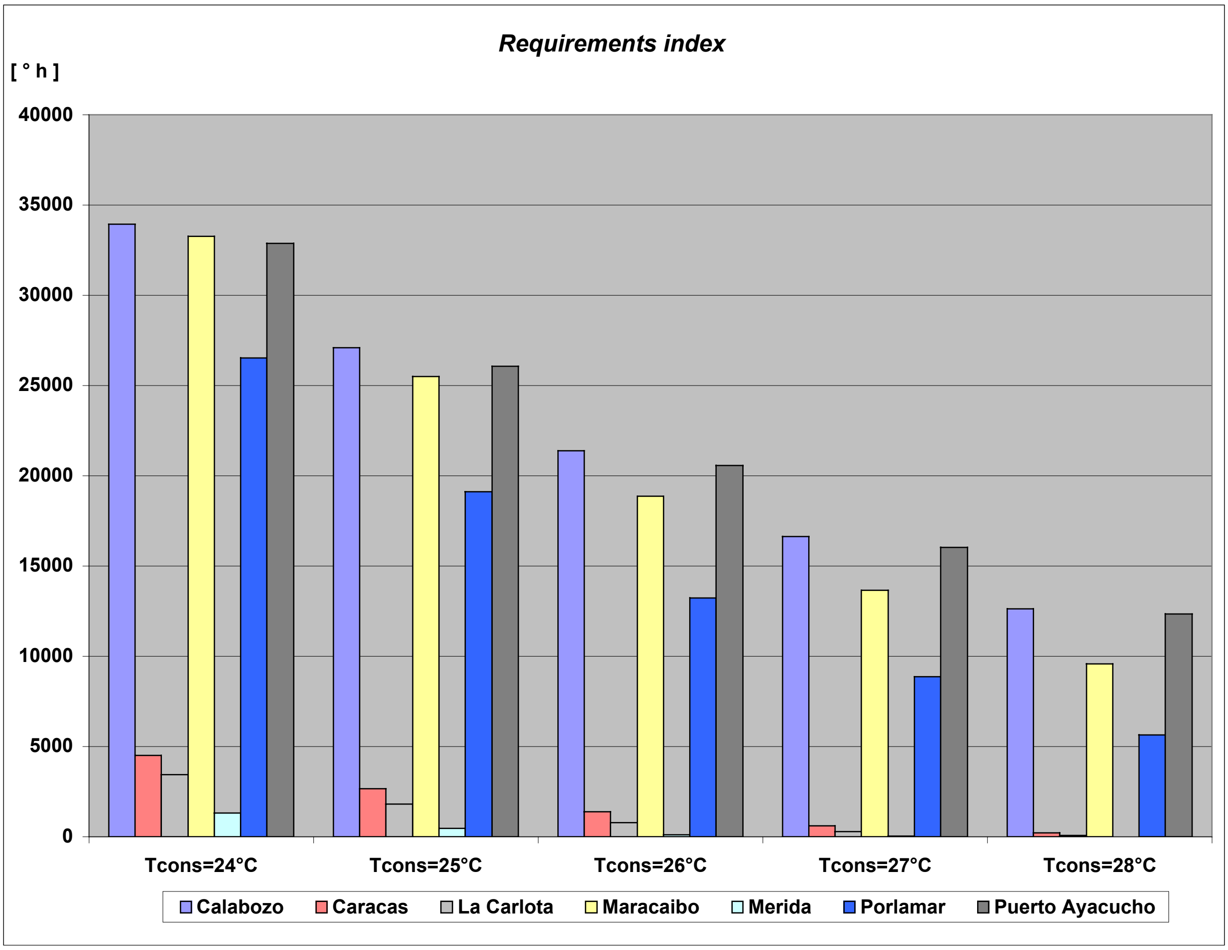

Figure 4: Requirements index for design temperatures going from 24 to 28ºC

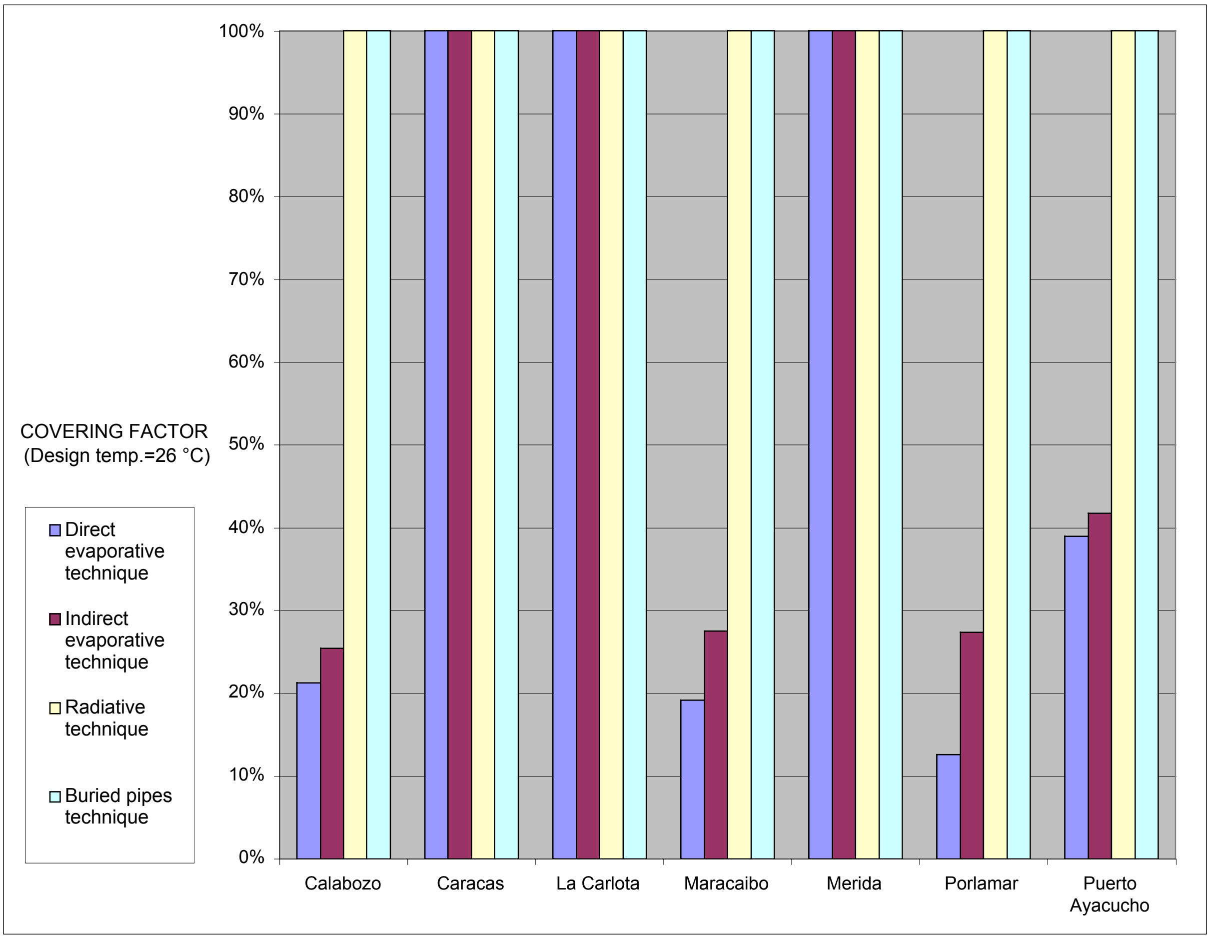

Figure 5: Covering factor for a design temperature of 26ºC

References

Alvarez, S. et al. (1997). Final Report of ALTENER/SINK Project. European Comission DGVII for Science, Research and Development. Brussels, Belgium.

Belarbi, R. (1998). *Développement d´outils méthodologiques d´évaluation et d´intégration des systèmes evaporatifs pour le rafraîchissement passif des bâtiments*. Thèse pour obtenir le grade de Docteur. Université de La Rochelle, F17042, France.

Florenza, R., Roura, H. (1995). *Arquitectura y energía natural*. POLITEX. Área de Arquitectura y Urbanismo. Ed. UPC. Universidad Politécnica de Cataluña, España.

Santamouris, M. et al. (1995). Final Report of PASCOOL Project. European Comission DGVII for Science, Research and Development. Brussels, Belgium.

Sosa, M.E. et al (2002) Final Report of AGENDA CIUDAD Project. *Técnicas de reducción del gasto energético en edificaciones*. CONICIT Nº98003396. IDEC-FAU-UCV. Caracas.