

FAÇADES DESIGN STRATEGIES IN A WARM-HUMID CLIMATE TO REDUCE THERMAL LOADS IN VENEZUELAN BUILDINGS

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ABSTRACT

Contemporary architecture of non-domestic buildings in Venezuela has introduced inappropriate design and technology criteria for the warm-humid climate because of ineffective regulations. As a result these buildings are responsible for high energy use and high costs. These results represent a first exploration for developing a method to evaluate design strategies for commercial buildings. It is based on a comparative study of several techniques in west façades, to evaluate the effect of the selection of opaque and translucent components on the cooling loads of the air conditioning system and electric lighting. The aim is to provide a method to compare diverse strategies in the design of the facade, specifying its advantages and relative defects in relation to the energy efficiency, and also to relate that to environmental impact and the cost of construction and operation. The façade design strategies are supported by the literature and by ad-hoc simulations, for the latitude of Venezuela. In facades, the total translucent surface area and the orientation influence the increase of the cooling loads of the air conditioning system. In west facades, for the same area of windows, a greater increase of cooling load is observed. A decrease in the cooling load, in a warm-humid climate, is a result of using windows or curtain walls with spectrally selective glass of low solar gain. Nevertheless, traditional solutions, such as external shading, balconies and vegetation in windows, have a significant effect in reducing cooling energy; for they are the most energy efficient and economic design strategies.

Keywords: Façade, Sustainable design, Energy efficient, Building envelope, Warm-humid climate, Non-domestic buildings.

ESTRATEGIAS DE DISEÑO DE FACHADAS EN CLIMA CÁLIDO-HÚMEDO PARA REDUCIR LAS CARGAS DE ENFRIAMIENTO DE EDIFICIOS EN VENEZUELA

RESUMEN

La arquitectura contemporánea de edificios no residenciales en Venezuela ha introducido criterios tecnológicos y de diseño, inadecuados para el clima cálido-húmedo, debido a la ineficacia de las regulaciones. Como resultado estos edificios son responsables de elevados consumos de energía y costos económicos. El presente trabajo representa una primera exploración para desarrollar un método para evaluar las estrategias de diseño de la envolvente de edificios de oficina, basado en un estudio comparativo de varias técnicas arquitectónicas en fachada oeste. Esto permite evaluar el efecto de la selección de componentes traslúcidos y opacos sobre el consumo de energía debido al sistema de aire acondicionado y al sistema de iluminación eléctrica. El objetivo es desarrollar un método para comparar diversas estrategias en el diseño de fachadas, especificando sus ventajas y desventaja en relación a la eficiencia energética, y también en relación al impacto ambiental y a los costos de construcción y operación. Las estrategias de diseño en fachada están fundamentadas en la literatura y en simulaciones ad-hoc, para la latitud de Venezuela. En fachadas la superficie total translúcida y la orientación influyen en la carga total de enfriamiento del sistema de aire acondicionado. En la fachada oeste, para la misma área de ventana una mayor carga de enfriamiento es observada en relación a otras orientaciones. Una disminución en la carga de enfriamiento en clima cálido húmedo es resultado de usar ventanas o fachadas de vidrio con cristales espectralmente selectivos de baja ganancia solar. No obstante, las soluciones tradicionales como parasoles, balcones, corredores y jardineras en ventanas tienen un efecto significativo en la reducción de la carga de enfriamiento, pues ellas son las estrategias de diseño que presentan menores consumos de energía y costos económicos.

Palabras clave: Fachadas, Eficiencia Energética, Diseño sustentable, Envolvente, Clima calido húmedo, Edificios de oficina.

INTRODUCTION

Venezuela is located at the north of South America, between 1° and 13° north latitude, with a population of about 25 million people. It is a tropical country, and has four climatic sub-zones, as a result of the topography, the presence of coasts, mountains and forest. In general the climate is classified as warm-humid with the following characteristics:

There are high solar radiations the whole year; there are only 2 seasons; rainy and dry, high relative humidity (around 75%), moderate average annual temperature and small temperature difference day/night (approximately 7° C). The coldest months are December, January and February. The hottest months are July and August.

Caracas, the capital of Venezuela is located in a valley between 870 and 1000 metres above sea level. The climate is pleasant all year round; the maximum temperature is 29° C. Maracaibo, the second most important city, is located on the coast and has the hottest conditions of any major city in Venezuela, with maximum temperatures averaging 34° C.

The appropriate design criteria for the Venezuelan climate must be based in sharing heat gains by high radiation all year and to stimulate the natural ventilation to control internal temperature. It is convenient to use natural lighting but taking care of reducing heat loads through the radiation. The typical elements of tropical architecture in Venezuela are: great openings with shading, lattice windows, eaves and awnings, pergolas, balconies, internal courtyards, ventilation blocks, openings in ceiling, skylights, clear colours on walls and roofs, and gardens on roofs and balconies.

In effect, the indigenous architecture of Venezuela uses permeable shades to mitigate heat loads. These are made from materials like cane or palm trees that allow natural illumination and ventilation. The colonial architecture (1500-1800), known as «oil architecture», which was introduced by the oil companies when they came to Venezuela (1920-1940), and the tropical modern architecture (1940-1970), all maintained the basic design criteria for warm-humid climates, but adapted new materials and new building technologies.

During the 1970s, inappropriate design and technology criteria for climate conditions were imposed by Venezuela contemporary architecture. It was during this time that glass façade technology was incorporated in an indiscriminate form and a great number of buildings were constructed with their whole facades in glass without shading. There were no differences in the façade design used; being favourable or unfavourable with respect to the sun (north-south or east-west).

This work is based on a comparative study of several techniques used in façade design in warm-humid climates, with an emphasis on the west façades, and to evaluate the effect of the selection of the constructive components of walls and windows on the air conditioning system and artificial lighting cooling loads. Moreover it shows the advantages and relative defects in relation to the energy efficiency and more global concepts including environmental impact over the construction costs, operations and maintenance for Venezuela.

NON-DOMESTIC BUILDING AND ENERGY CONSUMPTION

The biggest percentage of energy consumption in a commercial building takes place through the air conditioning systems and artificial illumination. «A survey of over 1000 public and commercial buildings in Greece (Santamouris 1992) has shown that the typical annual energy consumption for non-air-conditioned buildings is 140kWh/m², while that for air-conditioned buildings is in the range 226 – 250 kWh/m²» (Bowman 1997:191).

In office buildings in Venezuela energy consumption by air conditioning systems is 46% and for artificial illumination it is 33% (CAVEINEL 2000)(Figure 1).

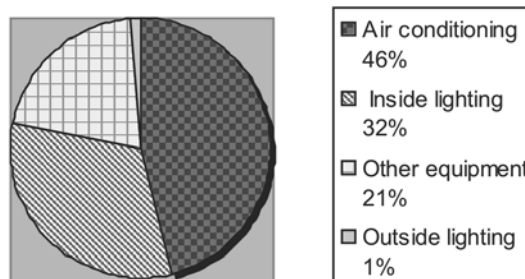


Figure 1. Office buildings in Venezuela: Energy consumption by system.

Several causes of the constant increase of electric energy use have been identified in Venezuela: 1) The population's poor energy consumption habits. These have been stimulated by the very low cost of energy in a country producing petroleum, hydroelectric energy and thermoelectric energy. 2) Contemporary architecture is incompatible with the climatic variables due to the indiscriminate incorporation of design criteria adapted from other latitudes. These disregard the domestic climatic, cultural, technological and economic requirements. 3) Inefficient regulations in the construction sector: standards of construction do not regulate thermal and light quality of buildings and the rationality in the use of energy. This

circumstance favours non-implementation of design orientations adapted to the warm-humid climate (Siem 2001).

The Thermal Quality of Constructions in the Maracaibo Municipality (2006) is the first standard of its type and of the 336 existing municipalities in Venezuela. The objective of this legal instrument is to regulate heat transmission through the surrounding mass of the buildings. As an evaluation parameter the Decree establishes the Value of Thermal Transfer Global (VTTG), in which it limits maximum heat transference with regard to the surrounding mass of the building. It is 25 W/m² for walls and 60 W/m² for the roof (ENELVEN 2005).

The efficiency of use of the air conditioning systems in Venezuela is generally expressed in m²/ton, which is equivalent to the area of construction per ton of air conditioning installed. Commercial buildings commonly work with ratios of 20m²/ton. In developed countries, which have appropriate criteria of building design and energy standards, these ratios are established around 40m²/ton (Nedianni 2000).

This fact highlights the necessity of establishing criteria of building design that match the climate, and that they make a rational use of energy. The residential and commercial sectors represent 60% of the consumption of the electrical energy in Venezuela, for the economic sectors. It is necessary to guide the attention toward these two sectors.

DESIGN OF FAÇADES: QUANTITATIVE AND QUALITATIVE APPROACHES

The building envelope acts as a filter to the penetration of the solar radiation, wind, humidity and the rain, modulating the exchange of heat between inside and outside. The appropriate solutions therefore should consider the climatic, geophysical and urban conditions to achieve the comfort of the occupants, for «The design of a building envelope has a significant impact on performance in terms of lighting, heating and cooling energy use, occupant comfort, and aesthetics» (CBE. Berkeley 2006: Web page).

«The best opportunities for improving a building's energy performance occur early in the design process» (Goulding 1998:3). In effect, the initial approaches of the facade design of a commercial building will define its future behaviour in relation to energy demand. The potentiality of establishing this behaviour is greater at the beginning of the design process, it diminishes as the process advances and it becomes almost nil when concluding the construction and the installation of equipment. In this last case, the measures to save energy will be mainly oriented to act on the application of use and maintenance of equipment and

services.

Several quantitative and qualitative approaches to the study of façades have been carried out, especially concerning non-domestic buildings. They are essential references for this study and some authors have based their studies on simulations of the thermal behaviour of façade components (Ansari 2005, Lam 2005). Several tools have been studied, such as LTV TROPICAL tool development and testing for warm climate (Hyde and Pedrini, 1999). Other authors also include such aspects as the comfort of the occupants and/or the environmental impact with an integral focus of sustainability in the design (Kolokotroni 2004, CBE. Berkeley 2006, Euleb 2006).

This paper has carried out a comparative study of diverse technical strategies in facades, with emphasis on the west facade for warm-humid climates. It has evaluated the effect of the design decisions and selection of opaque and translucent materials in the cooling loads of the air conditioning system and of electric lighting. This paper uses a reference model whereby a window of simple clear glass is exposed in the sun without shade. Different types of glass are then evaluated within this model, showing good relationships between wall and translucent components and the impact of different techniques of shading walls and windows.

The objective is to provide a method of understanding to compare diverse strategies in the design of the facade, specifying its advantages and relative defects in relation to the energy efficiency and more global concepts including environmental impact and the construction, operation or maintenance costs.

Each one of the strategies of the design is endorsed by the literature and by its own simulations. The approaches and related indicators and criteria are explained next.

A. Energy efficiency: The energy efficiency is evaluated from two aspects: Cooling Energy and Lighting Energy.

Cooling Energy: If the architectural solution of a building has disregarded the climatic aspect as fundamental criteria of design, the thermal quality of the spaces is affected. The most expeditious solution to this problem, which is considered later on, constitutes the installation of high capacity air conditioning systems. An important criterion to consider is the energy consumption required for the air conditioning system, because it represents increase in energy use and economical costs of the building throughout its lifecycle. The indicators proposed to evaluate the strategies in facades are: Percentage of reduction of solar

heat gain and percentage of reduction of cooling load.

Lighting Energy: The architectural response should be dedicated to taking advantage of the potential of natural lighting to illuminate the interior spaces and to diminish the necessity to illuminate by means of electric lighting. For each kW saved in the electric lighting system there is a decrease by approximately 0.28 tons of refrigeration in the capacity of the air conditioning system. The proposed indicators are: Solar Heat Gain Coefficient (SGHC) and Visible Light Transmission Coefficient (VLTC).

Table 1. Energy efficiency indicators.

ENERGY EFFICIENCY		
Cooling Energy		Lighting Energy
% Reduction of inside solar heat gain	% Reduction of Cooling Load	Coefficients Solar Gain SHGC vs. Coefficient Visible Light VLTC

B. Construction Costs: A building can represent an important investment during the project and the construction, but those are not the only elements to consider in the global cost. A general approach of global vision also takes the costs of construction, operations and maintenance along the lifecycle of the building. A more energy efficient design does not necessarily have to be more expensive. The proposed indicators are: Construction, Operations and Maintenance Costs.

Table 2. Construction, operations and maintenance costs indicators.

CONSTRUCTION COSTS		
Typical	High	
Traditional design strategies or simple technology with typical cost	Less traditional design strategies with more construction or technological costs	
OPERATIONS AND MAINTENANCE COSTS		
Low	Medium	High
Low costs for operation, maintenance or renovation of parts	Averages costs for operation, maintenance or renovation of parts	Elevated costs for operation, maintenance or renovation of parts

C. Environmental Impact: The summations of the Rio Summit (1992), the Kyoto Protocol (1997) and the Johannesburg Summit (2002) identified the necessity to adjust energy use in the world, and to reduce the emissions of gases into the atmosphere. Buildings are responsible for the consumption of around 40% of energy in cities. As a result, disciplines such as Architecture and Engineering will be required to work more harmoniously with the environment and as a consequence reduce the consumption of energy. The indicators to consider are direct impact on the microclimate, namely the energy included in the production component.

Table 3. Environmental impact indicators construction, operations and maintenance costs indicators.

CONSTRUCTION COSTS	
Typical	High
Low direct impact on the microclimate or average energy for production of the materials and/or average energy for transport (National product)	Direct impact on the microclimate or high energy for production of the materials and/or high energy for transport (Import product)

STRATEGIES OF DESIGN OF FAÇADES

The façades are exposed at high levels of solar radiation, with more influence in the case of buildings of great height. Facades oriented west can have heat loads of up to 3000 W/m²/day, when perceiving in perpendicular form the solar rays during a long part of the day for the whole year, in the case of tropical climates.

The strategies to control heat gain through facades in commercial buildings in warm-humid climates, should give priority to orientation, thermal properties of walls and windows, area of windows and solar shading. These elements must be conceived in a coherent form to guarantee an appropriate thermal quality of the space and a rational use of the energy from the air conditioning systems.

Windows and other translucent surfaces in façades

Windows, curtain walls and other translucent surfaces offer a view to the exterior and they allow natural lighting and possibly natural ventilation. In opposition, the solar light with direct entrance through these surfaces can represent a high gain of heat toward the interior of the spaces. In tropical climates, this can mean more than half of the loads of cooling energy in buildings with air conditioning.

The simple clear glass transmits to the interior more than 80% of the incident radiation. The external solar shading is the most effective method to reduce the heat load through translucent surfaces and windows and this reduction can be considered up to 80% in the case of windows compared with simple clear glass. A comparative study applying different strategies to a fixed window of simple clear glass of 1/4" exposed in the sun, demonstrates the percentage of reduction of the loads of internal heat (ASHRAE: 1998):

Table 4. Percentage comparison of the reduction of the solar gain of a window of simple clear glass when applying solar shades and technology glass.

Strategies	Reduction of the solar gain vs. window of simple clear glass of 1/4"
External solar shade	80%
Paper or reflective layer in glass	37 - 68%
Spectrally selective glass	37 - 58%
Glass of bronze or grey tint	26 - 37%
Interior blind of clear colour	30%
Interior blind of medium colour	22%
Curtain inside translucent	54%
Curtain inside white colour	59%
Curtain inside dark colour	15%

Source: Data taken of ASHRAE Handbook of Fundamentals, 1998.

One typical and economical strategy of appropriate solar shading in a warm-humid climate is the placement of vegetation or external gardens embedded along the windows with simple glass. This element called bioshader (Lam 2005) allows the solar heat loads to diminish and it improves the quality of the circulating air around the facades. Also, it can valorise the aesthetic factors. Another strategy of tropical architecture in Venezuela is shading windows with external corridors or balconies. They help to reduce the heat gain inside, by using a buffer effect.

The use of spectrally selective glass is another strategy to reduce the quantity of heat transmitted through windows or curtain walls, and also it allows the penetration of high levels of visible light. This way it can decrease the energy necessary for the cooling load and electric lighting. A curtain wall facade reduces the electric energy demand by 48% in comparison to windows without shading (Kolokoteroni 2004).

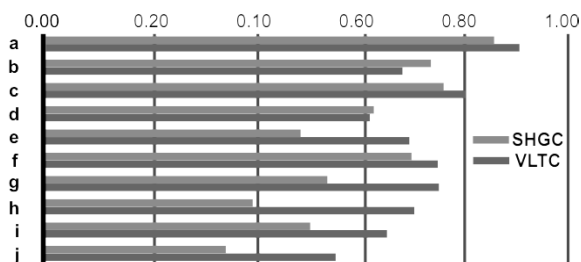
Several types of spectrally selective and low emittance (Low-e) glass have been developed, but not all of them are adapted

for warm-humid climates. Some glass systems have been designed for temperate climates and they work by maintaining the warm spaces in winter, but in warm-humid climates the glass should be of low solar gain properties.

Next some indicators are presented to select the glass with thermal properties adapted for warm-humid climates such as that of Venezuela:

- A low value of Coefficients Solar Gain SHGC is the most important property in warm climates. Select windows and translucent surfaces with a SHGC 0.40 or less.
- Select windows with a high value of Coefficient Visible Light VLTC 0.7 or more, to maximize the natural light inside the space.
- The rate of flow of heat through the unit of area of the glass (W/m^2 grade C) is another property that should be considered. A low Factor U is useful when it is important to maintain the heat outside, but it is less important than the SGHC in warm climates. Select windows and skylights with a Factor U less than 4.00.

Table 5. Comparison of the thermal and light behaviour for different types of glass in window.

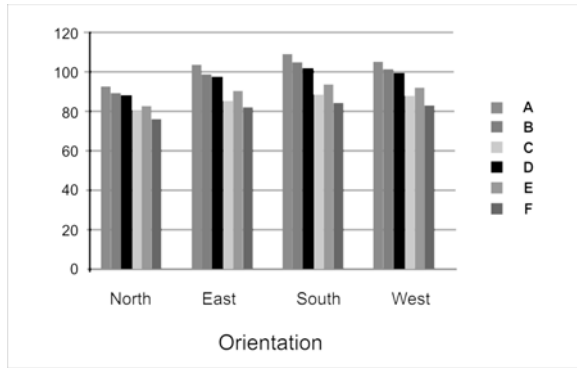


CODE	WINDOW WITH GLASS	Coefficients		
		SHGC	VLTC	Factor U
a	Simple clear	0.86	0.90	6.59
b	Simple bronze or grey tint	0.73	0.68	2.09
c	Double simple clear	0.76	0.81	4.48
d	Double bronze or grey tint	0.62	0.62	3.41
e	Double high technology Low-e	0.48	0.69	2.04
f	Double high solar gain Low-e	0.71	0.75	1.82
g	Double medium solar gain Low-e	0.53	0.75	
h	Double low solar gain Low-e	0.39	0.70	
i	Triple low solar gain Low-e	0.50	0.65	
j	Triple medium solar gain Low-e	0.33	0.56	

Source: (Data Visible Light Transmission Coefficient (VLTC) and Solar Heat Gain SHGC (SHGC) taken from www.efficientwindows.org/glazing_double.html).

Simulations done for the latitude of Venezuela demonstrated the effect in the demand of the cooling loads of air conditioning for different types of window glass and for different orientations. The results were obtained with the simulation software APACHE™ IES (Integral Environmental Solutions) with climate data corresponding to March (2003). This software was validated previously with experimental results corresponding to an existing building.

Table 6. Impact of different types of window glass and orientations in the cooling load (kW/h) for Venezuela.



	Window F	Window E	Window D	Window C	Window B	Window A
Glass	Simple clear	Simple bronze or grey tint	Double simple clear	Double medium solar gain Low-e	Double high solar gain Low-e	Double low solar gain Low-e

Source: Sosa and Siem 2004

These results reflect:

- The influences of window orientation in the cooling loads of the air conditioning system. In the west facade for the same area of window the highest cooling loads were observed. It is important to underline the high results for the south facade, because they correspond to the month of March when the sun is inclined towards the south in the north hemisphere (the latitude of Venezuela is 10 degrees north).
- The lowest cooling loads are obtained with high-technology glass of low solar gain.
- The highest cooling loads are obtained with simple clear and bronze or grey tint glass. Bronze and grey tint are not high-technology glass and they do not reflect the infrared radiation; on the contrary, they absorb it. Some dark tints admit more heat than visible light. For example, a simple glass with bronze or grey tint presents a high SHGC 0.73 and a low VLTC 0.30. Additionally, the colour of the glass can produce darker interior spaces resulting in more energy use for artificial lighting.

In warm-humid climates with high radiation for the whole year, the west facades should be opaque with small area of

windows. A big ratio between window and wall, results in a high solar gain (Hyde). The curtain wall has the largest cooling demand because of higher glazing (Kolostroni 2004).

Simulations done for the latitude of Venezuela demonstrated the impact of the area of windows in the thermal load for the HVAC system for west facades. It are shown in Table 7.

Table 7. Impact of the ratio windows/wall in the thermal load for the HVAC system in west facades.

RATIO WINDOWS / WALL Facade West	ENERGY EFFICIENCY HVAC	
	Thermal Loads HVAC kWh/years (for 400 m ²)	Thermal Loads HVAC kWh. m ²
CITY: Maracaibo Latitud 10.6 N - Longitud 71.7 - Altitud 40 m		
0% Windows - 100% Wall	21197.18	52.99
25% Windows Simple Clear Glass 6mm - 75% Wall	24238.94	60.60
50% Windows Simple Clear Glass 6mm - 50% Wall	27383.74	68.46
75% Windows Simple Clear Glass 6mm - 25% Wall	30502.56	76.26
100% Windows Simple Clear Glass 6mm (curtain Wall) - 0% Wall	34061.86	85.15

Source: Simulation and data done by self elaboration with the software ECOTECT™ for office building with a square-shaped floor and with de climate data of Maracaibo.

Also, the simulations demonstrated the impact of the area of windows and types of glass in the annual costs of electric consumption. The results obtained for a ratio of 15% and 30% of the windows area in relation to the area (m²) of the floor area are shown in Table 8. Venezuelan standards demand a minimum ratio of 15% between windows and floor.

Table 8. Percentage increase of annual electricity consumption when increase the ratio between windows' area.

	Glass Type		
	Simple clear	Simple bronze or grey tint	Double Low-e low solar gain
Percentage growth of annual electricity consumption which increases with the enlargement of the window area from 15% to 30%	50%	40%	33%

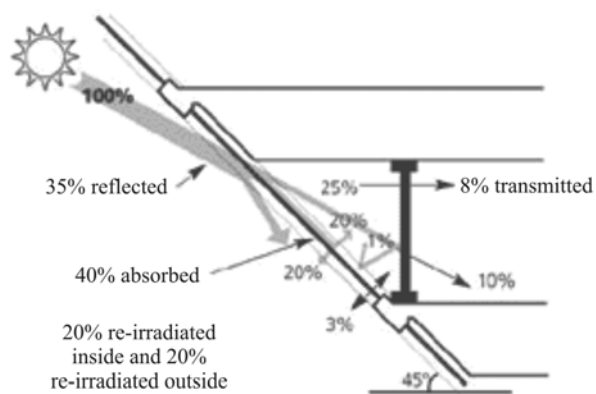
Source: Sosa and Siem 2004

These results reflect:

- The windows with clear simple glass or bronze or grey tints present a significant increase in the cooling load when

the area of glass is duplicated. The analysis indicates that the increment of the area of windows increases the energy use but it is lower when windows are used with spectrally selective glass (example: double glass with low solar gain Low-e).

In warm-humid climates, another important factor to consider is the constructive technique for windows in west facades. Surfaces of glass inclined toward the inside, as shown in Figure 2, attenuate the solar irradiations transmitted by the glass significantly. With a vertical inclination of 15°, a 14% reduction of solar penetration is obtained for windows in north facade, 28% for orientation east-west and 32% for glass to the south (Nedianni, 1998). For attenuations of 50% in the most critical facades (west or east), glass façades could be designed with angles of 35° regarding the vertical one (135° for the horizontal one).



Fotografía: Siem-Sosa

Source: (Sosa and Siem 2004)

Figure 2. Strategic constructive technique in window's façades for reduction of solar penetration.

On the next page, a table summary is presented (Table 9), to compare diverse strategies in the design of the west façade with windows in warm-humid climates, specifying its advantages and relative defects in relation to the energy efficiency and more global concepts including environmental impact and the construction costs, operation or maintenance, based on the outlined indicators

CONCLUSIONS

Contemporary architecture of non-domestic buildings in Venezuela has introduced inappropriate design criteria and technology for the warm-humid climate because of ineffective regulations. As a result these buildings are responsible for high energy use, high costs and environmental impact.

These results represent a first exploration for the development of a method to evaluate the typical strategies for the building envelope of commercial buildings for warm-humid climates, north latitude such as that of Venezuela. This will allow a comparison of the design strategies, with an integral vision in relation to the energy efficiency and other global concepts including environmental impact and the construction, operation or maintenance costs.

It has evaluated the effect of the design decisions and selection of opaque and translucent materials in the loads of cooling of the air conditioning system and of electric lighting. This paper uses a reference model whereby a window of simple clear glass is exposed in the sun without shade. Different types of glass are then evaluated within this model, showing good relationships between wall and translucent components and the impact of different techniques of shading. Each one of the strategies of the design is endorsed by the literature and by its own simulations for the latitude of Venezuela. These results reflect:

In façades, the total translucent surface and the orientation has an influence on the increase of the cooling loads of the air conditioning system. In the west façade for the same area of window a greater increase of the cooling load is observed. In west facades, the best solution is to offer walls limiting the areas with windows.

A decrease in the cooling load is a result of using windows with spectrally selective glass of low solar gain, in a warm-humid climate. A low value of Coefficients Solar Gain SHGC (0.40 or less) is the most important property in warm-humid climates. The curtain wall with high-technology glass is more appropriate than windows without solar protectors. However, the technologies of spectrally selective glass are of high cost in Venezuela, especially if it is compared with the price and the efficiency of simple glass with solar shading. Additionally reflective glass can have an environmental impact when increasing the temperature of the microclimate, and they can produce damage in the immediate urban context because of the glare.

The application of shading to the façades has a significant

Table 9. Comparison of diverse west façade design strategies for Venezuelan warm-humid climates.

STRATEGIES	INDICATORS					
	Energy efficiency			Environmental Impact	Construction, Operations and Maintenance costs	
	Lighting Energy	Cooling Energy		Microclimate's impact, Energy Efficiency	Construction costs	Operating and maintenance costs
SHGC vs. VLTC	Reduction gain of solar heat	Reduction cooling load				
Solar shading						
Windows with simple glass and external solar shading (louvre).	SHGC=0.86 VLTC=090	80%	18.25%	Typical	Typical	Low
Windows with simple glass and external bioshade (vegetation)	SHGC=0.78 VLTC= 0.81	Dynamic shading coefficient, maximum value of 0.55. \ (LAM 2005)		Typical	Typical	Low
Windows with simple glass with interior solar shading (curtain or blind).	SHGC=0.78 VLTC= 0.81	15 - 30%		Typical	Low	Low
Windows with simple glass and external corridors or balconies.	SHGC=0.78 VLTC= 0.81	Buffer Effect". It controls the loads of heat to the interior of the space		Typical	Typical	Low
Technology glass						
Spectrally selective glass Low -e	SHGC=0.38 VLTC= 0.71	37 - 58%	48%	High	High	High
Bronze Glass	SHGC=0.72 VLTC= 0.67	26 - 28%		Typical	Medium	Medium
Double simple clear glass	SHGC=0.78 VLTC=0.81		8.8 %	Typical	Low	Low
Ratio between windows and walls						
Increase of the window area from 15% to 30%, with simple clear glass	SHGC=0.86 VLTC=090	50% Percentage increase of annual electricity consumption		Typical	Low	Low
Increase of the window area from 15% to 30%, with simple bronze glass	SHGC=0.72 VLTC= 0.67	40% Percentage increase of annual electricity consumption		Typical	Medium	Medium
Increase of the window area from 15% to 30% with double Low e, Low gain solar	SHGC=0.38 VLTC= 0.71	33% Percentage increase of annual electricity consumption		Typical	High	High
Constructive technique						
Windows with glass placed with angles of inclination of 115° (toward inside).	SHGC=0.86 VLTC= 0.90	28 % in west facade		Typical	Medium	Medium
Windows with glass placed with angles of inclination of 135° (toward inside).	SHGC=0.86 VLTC= 0.90	50% in west facade		Typical	Medium	Medium

effect on the reduction of cooling energy. The traditional tropical shading solutions in windows, in particular external solar shading, corridors, balconies and vegetation, are the most energy efficient and economical design strategy.

The present study will be continued, with further fine-tuning of the evaluation approaches. Also, it will include a deepened analysis of other design strategies as these influence the loads of cooling of the air conditioning system and the electrical energy consumption. This study also attempts to evaluate strategies of design that involve intelligent or more novel technologies such as self regulated shade, double ventilated façades, solar collectors, determining the relationship benefit, costs and environmental impact in a climatic, technological context, such as that of Venezuela.

GLOSARY

Coefficients Solar Gain SHGC or Solar Heat Gain Coefficient of glazing:

«This is the fraction of incident solar radiation entering the building through the windows. The lower the number, the better the window is at preventing solar gain - critical at reducing cooling costs». Source: Building Singapur Regulations http://www.nccc.gov.sg/building/bldg_facade.shtm

Coefficient Visible Light VLTC or Visible Light Transmission of glazing:

This is the fraction of visible light transmission entering the building through the windows.

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