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# Analysis of variables that influence electric energy consumption in commercial buildings in Brazil

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ABSTRACT

Air conditioning systems in commercial buildings in Brazil are responsible for about 70% share of their energy consumption. According to BEN 2009 (The Brazilian Energy Balance), energy consumption in the residential, commercial and public sectors, where most buildings are found, represents 9.3% of the final energy consumption in Brazil. This paper aims to examine design factors that could contribute to greater reductions of electric energy consumption in commercial buildings, with emphasis on air conditioning. Simulations were carried out using shades and different types of glass, walls, flooring and roofing. The VisualDOE 2.61 was used as a simulation tool for calculating energy consumption of the analyzed building. This paper shows that the energy performance of the building is considerably influenced by the façade protection and shows, through tables, the impact that decisions related to the top-level and façades have on the energy consumption of the building. The authors concluded that the results confirm the importance of taking energy use into account in the very first design stages of the project, since appropriate choices of types of glass, external shading and envelope materials have a significant impact on energy consumption.



**Contents**



## 1. Introduction

Meeting man's growing needs, while taking into consideration environmental, economic and social factors, is the main motivation behind the search for energy solutions, which stimulates investments in energy efficiency [1]. This paper shows some evidence that energy efficiency is directly related to the reduction of unnecessary expenses and polluting emissions, making architecture less aggressive to the environment. This study aimed to examine design factors that could contribute to greater reductions of energy consumption and $CO_2$ emissions. The building sector represents a large percentage of global consumption in Brazil because it is a principal factor in many energy sectors such as: commercial, industrial, residential and public activities, and nearly

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all buildings have some similarities among themselves [2]. According to BEN 2009 (The Brazilian Energy Balance), energy consumption in the residential, commercial and public sectors, where most buildings are found, represents 9.3% of the final energy consumption in Brazil [2].

Considering this new international architectonical model for office buildings, fully glazed façade, that was also adopted by Brazil the most office buildings use continuously operating mechanical air conditioning [3]. Air conditioning systems in commercial buildings in Brazil are responsible for about 70% of their energy consumption [4]. Considering also the lighting systems this percentage can reaches 86% in banks and offices [5]. Given this fact and in order to minimize increased temperatures from solar gain, it is important to adopt project strategies and decisions taking into account the climate and its integration with the architecture, from the very beginning of the first programming phase of the building project [6].

A model of an existing office building was developed using the VisualDOE 2.61 software. Using this model in simulations, its energy performance can be diagnosed and evaluated as the model is subjected to hypothetical alterations of building materials and building insulation. This allows a dynamic overview associated to local climate conditions in order to obtain large gains in energy efficiency. Computer simulation makes it possible to test a broad range of architectural possibilities, based on the energy performance of the building, providing technical support for project decisions [7]. This investigation is performed for an existing office building named here as base case.

This paper seeks to depict the main envelope materials widely used in office buildings in Brazil. Literature review shows several papers on these materials and their relation to the building's energy efficiency, but none of them have this focus [8–9]. The authors compare the impacts (presenting the results in tables) caused by each decision related to façade and roofing on the air conditioning and on the total energy consumption of the building.

The objective of this paper is to provide technical information that can be used to support decision making processes for architects, engineers and experts that deal with commercial office building project, mainly during the initial phase of the architectural project. Design options, such as orientation changes and some bioclimatic solutions, may no longer be adopted after building construction is finished. Additionally, as the simulation methodology used allows evaluation of the energy performance of the building, it also becomes quite useful in other phases of the project, as well as in retrofits.

## 2. Methodology

The need for energy conservation and sustainable design in buildings was the mainly reasons for the development of this paper. The commercial sector posted the highest economic growth rate and it accounts for a large share of energy consumption in Brazil. The commercial building analyzed in this paper was selected for its architectural style (fully glazed façade) and because it is fully air-conditioned. These two features are widely used in office buildings in Brazil. Although the glass façade can provide advantages beyond its good aesthetics, it may be not the best solution for preventing high cooling loads caused by solar radiation.

VisualDOE 2.61 was used to fully integrate the various aforementioned factors (see considerations on the program [10]), to determine hourly building energy loads and specific loads for end uses, such as external lights and others. This made it possible to simulate many variations of the architectural design, with the aim of obtaining better solutions for the project within the analyzed context [11]. VisualDOE 2.61 is a computer simulation program used to explore the electrical energy consumption pattern of a typical office building, simulating its dynamic thermal performance.

At first, several technical visits, followed by surveys and interviews, were carried out to collect information about the existing office building. The following items were taken into consideration:

- Built volume with internal partitions and outside openings, described in terms of materials as well as its thermal characteristics, use (office, toilet, etc.) and dimensions.
- Installed power densities for lighting and equipment.
- Geographic orientation of the construction and the existing external shading elements – trees, other constructions, brise soleil, etc.
- Timetable of working hours, usage intensity of equipment and lighting facilities, air conditioning system data, and others.
- Hourly meteorological data for Rio de Janeiro.

Through the use of simulation software, a building model was created; based on this model, architectonical modifications were simulated. This building energy-use simulation software uses its own climate data file. The annual hourly climate data used in this paper is in Test Reference Year format [12].

The consumption portion relative to air conditioning facilities is emphasized in this paper, since it's highly representative and offers a high potential of adequacy, from a viewpoint of equipment efficiency, and as a result of local thermal load factors. The methodology used to study the building consisted in checking the effects of altering certain parameters in the architectural design when comparing them to the base case. After this initial analysis with the purpose of evaluate the building sensitivity as to the changes in the envelope, which are, in this case, specifically related to façade and top-level floor.

After this analysis, different situations were simulated, such as glass exchange, use of external protections, replacement of glass curtain by masonry in the windows, etc. At this stage, the building energy behavior is evaluated, which is the purpose of this paper. Tree scenarios were developed for this study:

Scenario 1 – existing building model, do-nothing (calibration of the existing building model).
Scenario 2 – roofing alterations in the existing building.
Scenario 3 – façade alterations in the existing building.

The main benefits are reducing cooling loads and reducing solar gains. The results of these alterations were shown in tables that provided input for a critical analysis of these parameters.

## 3. Data description

The analysis focuses on an office building, located in a commercial condominium called Città America, Barra da Tijuca, West Zone of the city of Rio de Janeiro, latitude 22°49′S and longitude 43°15′, and temperatures varying from 21.1° to 27.3 °C on average. The building is in an urban area, with medium density occupation. The orientation of its frontal façade is 5° east of North. Construction of the modern-design office building ended in 1999. The building has a fully glazed façade system using reflective green glass, with some external protection provided by the shadows of trees. The plan of a typical floor, section and an outside view of the building are shown in Figs. 1 and 2. Within each block is an open courtyard. There is a garden on the way to this patio which is used to provide a relaxing area and improve the quality of life. The center of the floor plan consists of a closed stairwell and three elevators shafts.

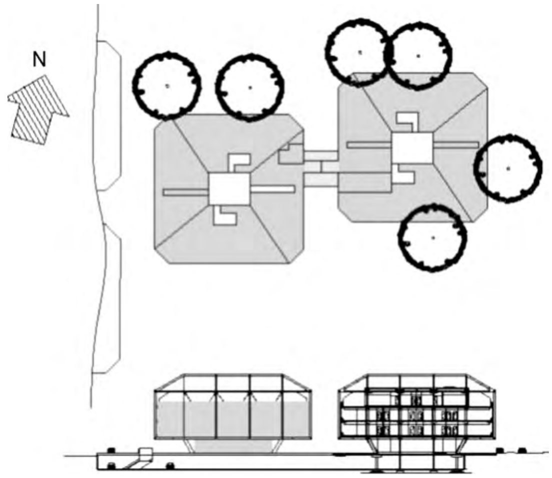


**Fig. 1.** Section and plan of a typical floor with zone layout and existing shading provided by trees and surrounding building.

**Fig. 2.** External view of the façades.

The medium-sized building has five stories, with about height of 15 m, being the height from level to level of 2.90 m and total built area of 6.627 m$^2$. Most of it consists of flexible layout offices. The office building is fully air-conditioned and the main air conditioning system uses fan coils that are fed by a central water chiller. As the central chiller does not operate 24 h a day and the CPD,[1] which operates uninterruptedly, requires cool air, one additional air conditioning self-contained unit's used. Another two split-type systems are available as reinforcements for the ground floor. Fig. 1 represents the layout with the air-conditioning zoning; each of the shaded zones have fan coil air conditioning systems, the others areas are not conditioned. For a brief analysis of the sun's behavior on the façade, the Light of Sun 1,1 [13] software was used. After using it, we could verify the impacts of solar spots and their intensity on the building surfaces. The orientation of 5° east of North (practically north) adopted for the largest façade of the building was the correct one for the climate because it receives less solar radiation and at a low incident angle. The east and west façades are smaller than the others and are also more exposed to solar radiation.

[1] CPD: data processing center.

## 4. Case study – results and discussions

A number of simulations were performed with the purpose of identify the building sensitivity under study as to alterations in the façade and roofing. Input parameters for the model and material specifications are shown in Tables 1 and 2.

### 4.1. Scenario 1 – existing building model, do-nothing

The air conditioning system is responsible for a significant share of the total energy consumption of the building, approximately 63% (Fig. 3). Figs. 4 and 5 show the office building's total annual electric energy consumption in kWh/m$^2$. Fig. 4 shows the results of the simulation in kWh/m$^2$/month and the Fig. 5 shows electrical end-use separated by use categories of the basic model, in near real conditions. The top-level floor terrace is exposed to direct solar radiation and is composed of:

- 30 mm subfloor covered with non-slip ceramic floor tiles;
- 100 mm thick concrete slab;
- plaster ceiling with plenum for the air conditioning return painted with light color.

On the roof, the existing cover was made of aluminum tiles internally filled with expanded polyurethane.

### 4.2. Scenario 2 – roofing alterations in the existing building

The parameters examined were, concrete pergolas in the top-level terrace, and two simulations were performed replacing the top-level floor: one of the modifications proposes to add, in the composition, a styrofoam plate, one on the top and another below the slab, with 2 cm of cement mortar in both sides. The other one was the replacement of the floor by a green roof (turfing). On the roof, the option was to replace the existing cover by a green roof. Table 3 shows the results of these simulations in scenario 2.

The 5th floor terrace is open and totally exposed to direct solar radiation. This terrace extends throughout the top floor, with two widths: 5.40 m and 6.00 m.

Simulation was carried out using concrete pergolas covered with perennial vegetation. The distance between two vertical posts was 0.50 m. Simulations were carried out with depths of 4.00 m and 2.50 m.

In the simulation, the terrace floor material was replaced by a more efficient one, as the terrace is strongly affected by solar radiation and there is no protection. The proposed modification adds 20 mm thick polystyrene layers above and below the concrete, with 20 mm cement grout on both sides.

According to Ekaterini and Dimitris [14], the total solar radiation absorbed by planted covering splits as follows: 27% is reflected, 60% is absorbed by the plants and the soil through evaporation, and 13% is transmitted into the soil. The absorbed value of solar radiation for a vegetated covering is about 0.3 [14].

Plants can protect the roof from the thermal loads of solar radiation in three main ways: their reflective properties, the convection of energy absorbed by the plants, and the evaporation from the plants and soil [14]. To simulate the planted roof covering, the following data were used [15]:

Vegetate absorbance was defined by 40% and the roughness, 1;

For the moisturized land: Specific mass (kg/m$^3$) = 1800, Conductivity (W/m/°C) = 0.580, Specific heat (J/kg/°C) = 1460.

### 4.3. Scenario 3 – façade alterations in the existing building

The parameters examined in scenario 3 were the effects on energy consumption of external shadow of the envelope

**Table 1**
Indicates the conditions used in the simulated base case after calibration.

*Building description*
Type: office building, fully air-conditioned.
Number of floors: 5.
Floor type: width × depth × height: 78 m × 46 m × 15.30 m; height from floor to floor: 2.90 m. Percentage of glazed area in the front façades: 100%.
Courtyard space: width × depth × height: 8.20 m × 10.20 m × 15.30 m.
Total constructed area: 6,627 $m^2$.

*Building characteristics and finishing materials*
External floor: predominantly white sandstone.
Internal floor: glazed porcelain stoneware tiles in a light beige color and details in beige granite (ground floor); dark gray carpet (floors); light ceramic tiles (5th floor terrace). External walls: fully glazed façade system with green reflective glass.
Internal walls: masonry; concrete block; single colorless glass 4mm; PVC board. All internal walls are painted in light color. Ceiling: white plaster, 3 mm thick.
Window glass: reflective green glass 6 mm (single clear SS08); U = 4.90 W/$m^2$; CS = 0.23; LT = 0.08.
Roof: aluminum roofing tiles sandwich filled with expanded polyurethane. Concrete slab cover with polystyrene and asphaltic paint.

| | |
|---|---|
| *Space use conditions* | |
| Avg. Occupation density: | 8.73 $m^2$/person (1.11 persons/$m^2$) |
| Work hours: | 8:00–17:00 hs and 24 hs (CPD, security and reception) |
| Work schedule: | 100% during working hours, 50% half hour before and after Weekends, 25% Saturday and 5% Sunday |
| Lighting use intensity (W/$m^2$): | 7.82 |
| Lighting hours: | 7:30–17:30 hs |
| Equipment use intensity (W/$m^2$): | 17.18 |
| Equipment operating schedule: | 7:30–2:00hs and 12:35–7:15hs |
| Air infiltration: | 0.20 air change/h |
| *Air conditioning – systems and controlss* | |
| System types: | Fan coil (TPFC) with chilled water pump type: fixed – speed, chilled water temperature 6.7 °C, chiller type average efficiency with water-cooled condenser, cooling tower efficiency (KW/(Cap. KW)) = .0027; split (SZRH); self-contained (PSZ); and not conditioned (FPH – heat). |
| Temp. to switch on heating:: | −4 °C |
| Heating period: | Year round, workdays 7:00–18:00 hs |
| Cooling temperature: | 24 °C |
| Cooling period: | Year round, workdays, 7:00–8:00 hs and 24 s (CPD) |
| Schedule of mechanical ventilation: | 7:00 to 18:00 hs On during working hours |
| Air renewal rate/person: | 27 $m^3$/h/person or 7.5 l/s |

*Common equipment*
Elevator power: 1.13 Kw.
Elevator schedule: 8:00–17:00 hs.

*Note*: energy consumption for heating water was calculated in equipment, as it is based on electrical resistance.

**Table 2**
Indicates the technical data of glass supplied for the VisDOE.

| Technical data for glass simulated | Emissivity | | Thickness (mm) | Gap thickness | SC[a] | LT[b] | U-factor |
|---|---|---|---|---|---|---|---|
| | Front | Back | | | | | |
| Single clear SS08 (base case) | 0.84 | 0.4 | 6 | – | 0.23 | 0.08 | 4.90 |
| Double clear SS08 | 0.84 | 0.84 | 6/6 | 12.7 | 0.15 | 0.073 | 2.26 |
| Double clear SS08 Argon | 0.84 | 0.84 | 6/6 | 12.7 | 0.14 | 0.073 | 2.02 |
| Double Low-e (e2 = 0.04) clear IG | 0.84 | 0.4 | 3/6 | 6.3 | 0.48 | 0.682 | 1.66 |
| Single colorless 6 mm glass | 0.84 | 0.84 | 3/3 | – | 0.95 | 0.881 | 6.17 |

[a] SC: shading coefficient.
[b] LT: light transmission.

provided by trees, shading devices (brise soleil) were used with solar factor of 0.14 in all façades and only in the Northwest and Northeast façades, different types of double and single glazed façades and standard external walls with double and single

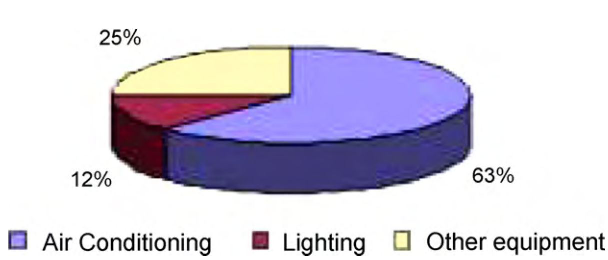


**Fig. 3.** Energy consumption per end-use.

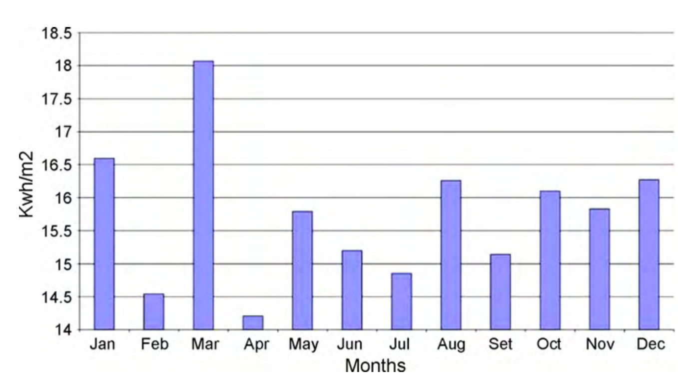


**Fig. 4.** Monthly Electrical Usage in kWh/$m^2$.

**Table 3**
Results of the top-level floor alternatives simulated in the building energy-use simulation software.

| Top-level alternatives | Reduction/Increase | |
|---|---|---|
| | % Air cond. | % Total |
| Inclusion of two Styrofoam plates in the top-level floor slab | −0.87% | −0.54% |
| Replacement of the top-level floor by a green cover | −0.83% | −0.51% |
| Placement of pergola (2.5 m) in the top-level terrace | −4.27% | −2.65% |
| Placement of pergola (4 m) in the top-level terrace | −6.40% | −3.98% |
| Replacement of roof tiles at the top-level by nature cover | −0.01% | 0.00% |

**Table 4**
Indicates the façades alternatives simulated in the building energy-use simulation software as well as its results.

| Façades alternatives | Reduction/increase | |
|---|---|---|
| | % Air cond. | % Total |
| Protection of the façades northeast and the northwest for trees | −2.97 | −1.85 |
| Use of sun break in all the façades | −6.35 | −3.93 |
| Use of sun break in the sunniest façades (NW and NE) | −3.92 | −2.42 |
| Substitution of the existing glass by double clear SS08 | −2.24 | −1.55 |
| Substitution of the existing glass by double clear SS08 Argon | −2.72 | −1.87 |
| Substitution of the existing glass by double low-e (e2 = .04) clear IG | 5.66 | 3.18 |
| Substitution of the existing glass by 6 mm transparent plated glass | 18.79 | 11.79 |
| Standard wall with colorless 6 mm single glazed window | 3.41 | 2.03 |
| Standard wall covered with polystyrene in its internal face with colorless 6 mm single glazed window | 4.71 | 2.57 |
| Standard wall with SS08 double glazed window | −4.95 | −3.10 |
| Standard wall covered with polystyrene in its internal face with SS08 double glazed window | −4.95 | −3.31 |
| Standard wall covered with polystyrene in the external face with colorless 6 mm single glazed window | 4.15 | 2.21 |
| Standard wall with colorless 6 mm single glazed window and a 0.4 air change/h infiltration | 3.35 | 1.99 |

glazed windows. Table 4 shows the results of these simulations in scenario 3. Since the building is low, with a height of around 15 m, the sheltering effects of trees were included in the simulation. This option is interesting because the tree canopies can shade the building, preventing those surfaces from receiving direct solar radiation.

Different types of double and single glazing were used in this simulation. Double glazing was filled with either air or argon to compare the energy saved through these modifications. The types of glass used were: single clear SS08 (base case), double clear SS08, double clear SS08 Argon, double low-e (e2 = 0.04) clear IG and single colorless 6 mm glass. The technical characteristics of all these glass types are described in Table 2.

It was decided to perform simulations with two types of building envelopes. The first one, the base case, had a fully glazed façade system. The second one was a standard external wall, 60% built with bricks, painted in a light color, and the remaining 40% with windows. Both buildings are fully air-conditioned and have low air infiltration,[2] with a 0.2 air change/h, except for one situation that had a 0.4 air change/h. Six options were tested on the second type of building envelope. They are as follows:

- Standard wall with colorless 6 mm single glazed window.
- Standard wall covered with polystyrene in its internal face with colorless 6 mm single glazed window.
- Standard wall with SS08 double glazed window.
- Standard wall covered with polystyrene in its internal face with SS08 double glazed window.
- Standard wall covered with polystyrene in the external face with colorless 6 mm single glazed window.
- Standard wall with colorless 6 mm single glazed window and a 0.4 air change/h infiltration.

[2] Air infiltration is the passage of air into a structure through joints, pores, cracks and other openings.

### *4.4. Results and discussions*

From Tables 3 and 4 its possible to say that the building consumption suffers more influence from the façade alterations. Solutions for the top-level floor (Table 3):

When the simulation includes styrofoam plates in the top-level floor or the replacement of the floor by slabs with vegetated cover, the reduction is only of 0.54% and 0.51%, respectively, in the consumption of electric energy, overall in the building. Such situation takes place because the floor is light colored (low absorption, 40%) and it is somewhat shaded by the roof itself. This reduces the heat that reaches the floor surface. Additionally, the conditioned environment below has a plaster ceiling, i.e. it already has a low thermal transmittance. Therefore, the solutions that propose reduced thermal transmittance in this place tend not to show high performance gains.

However, shading solutions exhibit better performances than addition of insulating materials. Simulations using pergolas in the top-level terrace exhibited reductions of 2.65% and 3.98% in the building overall electric energy consumption, for pergolas of 2.5 m and 4 m, respectively. The results achieved are more remarkable as in these cases there is a reduction of the direct solar radiation that

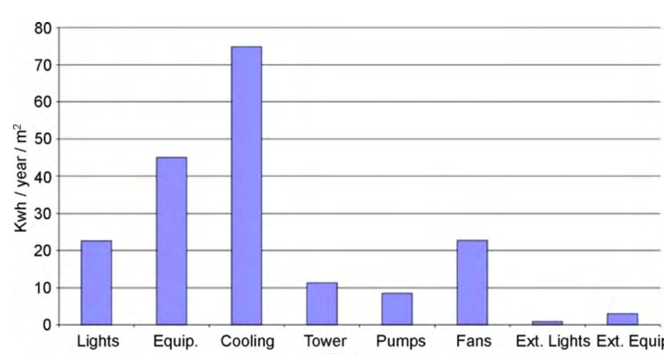


**Fig. 5.** Electrical end-uses in kWh/year/m$^2$.

reaches the top-level floor terrace. Its noteworthy that preventing the radiation to reach the closure (opaque or transparent) is much more efficient, for the following reason: initially, the external surface received the heat by convection and radiation, when the increase in the surface temperature occurs. In a second stage, through conduction, the heat flow starts; only at this moment the thermal resistance increase of the closure reduces the entrance of heat inside the building. The thermal resistance increase may not be effective at this point, since the building envelope has already absorbed the heat.

Another alternative tested was the replacement of the top-level tiles by vegetated covering, and the reduction was negligible. This may be explained by the fact that the existing aluminum tiles filled with expanded polyurethane supply good insulation. Therefore a good solution, such as the vegetated cover, had nearly the same result.

Of course, beyond the thermal capacity, the green roof shows several other positive features associated to is fabrication and use, being noteworthy: improvement in the building aesthetics; acoustic problems reduction; improvement of the local micro climate; it does not require energy intensive materials in its manufacturing.

By simulating trees giving major shading on the NE and NW facades, there was a reduction of 1.85% in the building overall electric energy consumption, once again evidencing the importance of the envelope external shading. Its observed that this solution is a feasible solution once the building is not higher than 15 m.

Now, the inclusion of shading devices is feasible in lower as well as taller buildings. In the building under survey, shading devices with solar factor of 0.14 (only 14% of the direct solar radiation that impacts the device crosses it and reaches the closure) allow for a reduction of 3.93% and 2.42% of the building overall electric energy consumption when used in all façades and only in the Northwest and Northeast façades, respectively. This sun baffle may be horizontal or vertical, however dimensioned to comply with the specific solar factor.

A simulation set was performed in order to evaluate the impact caused by the type of glass and also by a larger or smaller glassy area. At first, the glass panel was kept and the existing glass was replaced by other types of glass. The results interpretation is based on the glasses thermal characteristics, exhibited in Table 2.

The adopted single clear SS08 glass is suitable for the local climate. Simulations demonstrated that some double glazed façades increased electricity consumption, the worse case occurring with colorless 6 mm single glass and the best one was the clear SS08 Argon double glass, as shown in Table 4. If clear SS08 Argon double glass were used in the façades, the building would remain with the same aesthetic appearance and electricity consumption would fall in relation to the base case. It was also observed that when using argon, the energy performance was better than when using air in the intermediate layer.

The internal heat increase originating from the use of glass can be diminished by using openings with low solar factor[3] or low shading coefficient. However, since glazing panels respond differently in each region of the spectrum when receiving the solar radiation, the luminous and thermal efficiency of the glass should be taken into account. The chosen glass must have high luminous transmission, low infrared heat transmission and extremely low ultraviolet transmission [16].

In relation a smaller glassy area in all cases where colorless 6 mm single glazed windows were used, the energy used increased. The increase was greater when using polystyrene in the internal face and lower when infiltration rate was higher, as shown in Table 4. When the standard wall was used with SS08 double glazed windows, the energy consumption decreased. When using standard wall covered with polystyrene in the internal face with SS08 double glazed windows, the energy consumption decreased even more. In the last two cases, the decrease in energy consumption was, however, less than three percent. This fact can be explained by the greenhouse effect. Moreover, the colorless 6 mm single glass has higher conduction.

All the radiation transmitted to the interior of the environment is absorbed and/or reflected by the existing objects. The absorbed energy heats the objects and is re-emitted to the internal environment of the building in the form of infrared radiation. This radiation will remain in the internal environment of the building because the glass is opaque and, therefore, wavelengths greater than 4 mm cannot go through the glass. Thus, solar radiation can easily penetrate the interior environment through the glass, but it cannot cross the glass to the exterior.

Two factors have strong influence on the thermal performance of external surfaces. First, the absorptance ($\alpha$) related to the color of the wall and the angle of solar incidence and second, the porosity ($\rho$) of the construction material used in the surfaces. These two factors are directly related to the solar radiation incident on the envelope. Part of the total radiation is absorbed and another part is reflected and then dissipated into the atmosphere at the surface. Dissipation on surfaces of building envelopes consists of three components: convection, long-wave radiation and solar absorption. The intensity of the flow is a function of the thermal conductivity ($\lambda$) and the thickness of the envelope material.

Polystyrene is usually considered a thermal insulation material due to its low density and high porosity. To test this idea, several simulations were carried out showing that when polystyrene was used on external standard walls, the thermal performance was better than in the case where polystyrene was only used in the internal face of the wall. This can be explained by the fact that a polystyrene cover placed on exterior walls delays the entrance of heat into the internal environment.

In the building project studied, the architect employed several energy efficiency measures such as:

- efficient air conditioning system;
- low infiltration rates;
- efficient glass;
- rooftop with insulating treatment;
- efficient light bulbs and ballasts.

Nevertheless, simulations proved that energy savings could be even greater. So the energy efficiency could be improved even further without modifying the office design. The present case study shows that the best options were for the initial phase, when the architectural project is defined.

## 5. Conclusions

It was confirmed that solar radiation is the main source of heat gain in the building. The results show the importance of shading, to prevent direct solar radiation from reaching the building envelope. Therefore, solutions were developed to minimize this effect. Among them we can cite the use of: thermal efficient glass; external shading of the building; external light colors; construction materials with low U-factors and an adequated geographic orientation.

The use of external solar protection is very important in Brazil. It blocks direct radiation before it can penetrate the glass. As the building façades are totally glazed without openings and it has a large terrace, external solar protections are resources of great importance for reducing thermal heat gains. The fact that the

[3] Solar factor is the ratio of incoming flow to the incident flow.

building is not tall, makes the planting of perennial trees outside the building the most convenient solution for providing external shading. All the measures that used external shading produced good results. They proved to be better than solutions that used materials with low thermal conductivity.

It is very important to select an adequate glass, specially in buildings that have glass panels, where the glass area is large, as the impact in the electric energy consumption is actually strong. The greenhouse effect has to be avoided and, whenever possible, the direct solar radiation must be blocked before it penetrates the glass. Comparing the use of a double clear SS08 Argon glass – which is the most efficient glass tested – with the single 6 mm colorless glass, it was noticed that the energy efficiency improved by around 12%. Therefore, choosing the right glass is a very important measure, when weather is taken into consideration. This is specially true in Brazil, where there is no great annual thermal variation. Efficient glass has the advantage of relatively fast thermal response and low thermal inertia. It can also reduce the lighting energy consumption by making full use of daylight and provide a large external view, increasing comfort sensation.

It is important to remind that the best results are certainly in the project initial stage, when the architecture solution is being defined, once at this time, the shading elements may be inserted in the building in a harmonious and energy efficient way.

## Acknowledgments

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