# **Energy Consumption in Office Buildings**

## Analysis of the influence of Architectural and Occupational Parameters

### LEANDRA BEGGIATO PORTO DO NASCIMENTO<sup>1</sup>, MIRIAM JERONIMO BARBOSA<sup>1</sup>

<sup>1</sup>State University of Londrina, Londrina, Brazil

ABSTRACT: This study analyses the influence of architectural and occupational parameters in the energy consumption of offices buildings in Brazil. Using the software Energy Plus 2.2.0, the simulations defined which group of parameters has more responsibility in the energy consumption of offices buildings and the percentage of responsibility among them. The architectural parameters considered were: floor plan proportion, transmittance, absorptance of external walls, window to wall ratio (WWR), shading of the windows and orientation. And the occupational parameters were: internal load density, occupancy schedules, equipment and lightning. The results of the 84 simulations determinate that the occupational parameters influence the energy consumption of office building in almost 30% for equipments, whilst the architectural parameters have a maximum influence of 10% for window wall ratio.

Keywords: Energy efficiency, Energy Plus, energy consumption, thermal and energy simulation, office buildings.

#### **INTRODUCTION**

Edification is considered more efficient than another in terms of energy use when it is capable of assuring the same environmental comfort conditions, through lower energy consumption [6]. Nevertheless, the evaluation of energy efficiency in edification is a complex process because the concept of efficiency involves many different factors [3]. It's important to conduct studies to evaluate the energy efficiency in office buildings because of their great energy consumption. There are three main groups of parameters that influence the energy consumption in edifications: weather. architecture and internal loads density [3].

Studies have analyzed different parameters and the relations among them. However there's still a lack of knowledge regarding the influence of architectural and occupational parameters in the energy consumption of office buildings in Brazil. The main purpose of this study is to define which one of these two groups of parameters influences the most energy consumption in office buildings considering the Brazilian weather and understand the responsibility of each parameter.

To achieve these objectives, the research method used is a case study. The intention is to study the thermal and energy performance of an office changing architectural and construction properties and internal load density, but not the weather. This case study was developed for an office model that presents all the characteristics of a typical office space in Londrina such as size, height, materials, window to wall ratio (WWR). During the development of the simulations of this study a problem in Londrina's weather file was discovered, demanding a change in the methodology. Instead of Londrina, the model was simulated using São Paulo's weather file which presents a similar weather.

#### **RESEARCH METHODOLOGY**

This typical office building was defined by a survey that analyzed every office building in the city. The sampling considered commercial buildings used by private companies that presented more than 5 floors.

These buildings were classified by date of construction, area, number of floors and type of occupation of the offices. And the most common activities in theses buildings is small lawyer firms. After careful selection two buildings were elected as representatives, presenting the following characteristics:

- Decade of construction: 1980
- Square footage: 50m<sup>2</sup>
- Number of floors: 9
- Number of offices per floor: 4



Figure 1: Picture of a typical building of Londrina..

An office was chosen from one of these two buildings to be used as a model for the simulation. The model selected presents  $47.10m^2$  per office,  $283.43m^2$  per floor and total area of  $4,082.90m^2$ .



Figure 2: Sketch of the office layout.

After defining the typical building of Londrina and choosing an office used by a law firm, it was necessary to obtain information about the office space, such as constructive properties, equipments and occupational schedules. During visits to the office and interviewing occupants and the engineer responsible for the construction, it was possible to create a virtual office space, with the same occupancy schedule using the software Energy Plus 2.2.0. The information considered was:

- Weather data: TRY file indicating temperature, wind, humidity;
- Project information: dimensions of the office and windows, materials of walls and floor, internal and external color, type and color of the glass, layout;
- Occupancy schedule and internal load density: people, equipment and lightning.



Figure 3: Sketch of the office model.

It was created one model for each solar orientation and an air conditioning system was inserted to inform the annual energy consumption of each model.

The initial intent of this study was to use the weather file from Londrina. However, during the simulations we verified that it had problems considering solar radiation. In order to correct this problem we decided to use the weather file of São Paulo. São Paulo has a weather similar to Londrina, presenting close temperatures during the year. They belong to the same climate zone and demand the same constructive techniques, according to Brazilian rules.



Figure 4: 3D Sketch of the office model.

After the simulation of the models, we started simulating the alterations of the architectural parameters, considering minimum and maximum values, according to city reality (Table 1).

Table 1: Architectural parameters of the model and values for the simulations of the alteration.

Parameters	Model	Minimum	Maximum
Floor plan (m)	10,60x4,90	7,20x7,20	-
Transmittance	2 W/m <sup>2</sup> .K	1 W/m².K	5 W/m <sup>2</sup> .K
WWR	15%	10% - 20%	40%
Absorptance (a)	0,5	0,2	0,8
Shading	-	-	Shading

During this part, each alteration of parameters was simulated for each orientation. The annual energy consumption was defined and gathered in one table. In the third part of the research simulations considered parameters related to occupation of the space such as: internal load density, occupancy schedules, equipment and lightning (Table 2).

Table 2: Occupants parameters of the model and values for the simulations of the alteration.

Parameters	Model	Minimum	Maximum
Occupants	3	1	10
Lighting	735W	210W	1050W
Equipments	505W	145W	2370W

During the simulation process all reports emitted presented the annual energy consumption, divided in: air conditioning (fan, heating and cooling), equipment and lighting. The analyzed reports defined the responsibility of each architectural and occupational parameter in the annual energy consumption of the building.

#### **RESULTS OF THE SIMULATIONS**

The first objective of this study was to define a typical office building in Londrina to be used as a model. The initial survey determined the building and the activity to be considered (advocacy).

An office was chosen based on the survey considering constructive properties, equipments and occupational schedules. A virtual model was created using the software Energy Plus 2.2.0 and the model was simulated. The software provides after each simulation a file that contains every input and output of the model. Each model was simulated using the same weather data of São Paulo.

The most important information provided by the simulation is the table of the annual energy consumption based on to the use of the air conditioning system. According to the thermal exchanges between the internal and external environments along the day, the air conditioning system is activated for heating or cooling the internal space to keep the temperature in a comfort zone (from 18° to 29° Celsius).

The total energy consumption of the office is divided by air conditioning system (fan, heating and cooling), lightning and equipments. Table 3 presents the results of each initial model according to the solar orientation. Each one of the four models has the same air conditioning system, architectural and occupational parameters, maintaining the same consumption.

Table 3: Results of the four initial models, separated by solar orientation.

Solar Orientation	Annual Energy Consumption
Southwest	5601 KWh
Southeast	5769 KWh
Northeast	6058 KWh
Northwest	5955 KWh

It's possible to notice the energy consumption values of each solar orientation are close figures, presenting a maximum variation of 457 KWh along the year. The average consumption is 5843.25 kWh. The model with the northeast orientation presented the highest energy consumption, followed by northwest, southeast and southwest. The energy consumption was almost 10 times higher for cooling than for heating.

The simulation of the alteration of occupational parameters offered more significant results than the architectural parameters. The three evaluated parameters were: people, lightning and equipments. When the number of occupants was switched from 3 to 10, the energy consumption increased more than 10%.



Figure 5: Graph indicating the energy consumption of the model, architectural and occupational parameters.



*Figure 6: Graph indicating the percentage of energy consumption of architectural and occupational parameters.* 

Changing the lightning loads from 735W to 1050W, the energy consumption increased nearly 20%. And by modifying the internal loads of electric equipments from 505W to 2370W the increase was 30%. The alterations of architectural parameters were always smaller, presenting a 7% increase when considered reflective glass and 13% when the window wall ratio was more than 40%.

	Parameters	Energy Consumption (kWh)	%
	Model	5843.25	
Architectural Parameters	Form (Square)	5812.50	-0.53%
	Absorptance (0.2)	5570.25	-4.67%
	Absorptance (0.8)	6075.25	3.97%
	Transmittance (1)	5972.00	2.20%
	Transmittance (5)	6092.00	4.26%
	WWR 10%	5609.50	-4.00%
	WWR 20%	5988.00	2.48%
	WWR 40%	6642.00	13.23%
	Grey Glass 3mm	5746.00	-1.66%
	Reflective Glass 6mm	5423.50	-7.18%
	Window shading	5689.25	-2.64%
Occupational Parameters	Occupants (1)	5674.25	-2.89%
	Occupants (10)	6456.25	10.49%
	Lighting (210)	3996.75	-31.60%
	Lighting (1050)	6966.50	19.22%
	Equipments (145)	4077.50	-30.22%
	Equipments (2370)	7523.25	28.75%

Table 4: Table of the Energy Consumption of each parameter and the percentage of influence for the simulations of the alteration.

The first alteration done was in the shape of the floor plan. The initial model had a rectangular floor plan, measuring 10.6m by 4.90m and internal area of 51.94m<sup>2</sup>. The new model presented almost the same area but different proportion, measuring 7.20m by 7.20m. When the floor plan of the office space was altered from a rectangular to a square shape, keeping the same internal area, the energy consumption was reduced in 0.53%.

The second alteration referred to absorptance values. The absorptance initially considered was 0.5, based on the grey color of the building. This value was changed for 0.2 (light grey) and 0.8 (dark grey). In this case, the annual energy consumption decreased 4.67% in the first case and increased 3.97% in the second case. These values illustrate that in this kind of construction, using this weather data, the color of the façade can influence in almost 9% the annual energy consumption of the office building.

The third analysis was related to the transmittance of external walls values. The original model was created considering transmittance value of 2 W/m<sup>2</sup>.K. The first simulation changed this value to 1 W/m<sup>2</sup>.K and it provided an energy consumption increase of 2.2%, and the second one to 5 W/m<sup>2</sup>.K, increasing the consumption of energy in over 4%.

The initial model was elaborated with a WWR of 15% and in the fourth part of the simulation this percentage was changed to 10%, 20% and 40%. When the window wall ratio was reduce to 10%, the energy consumption decreased 4% and when the WWR was altered to 20%, it increased 2.489%. For more significant values, such as 40%, the annul energy consumption also raised significantly to 13.67%.

The fifth parameter altered was the type of glass of the windows. The previous model had regular glass 3mm thick. Using grey glasses 3mm thick only reduced 1.66%, but with the reflective glass of 6mm, the reduction was over 7.18%. These results illustrate the benefit of using reflective glasses in office buildings, due to the considerable energy consumption reduction.

The sixth alteration was a creation of shading to protect the windows from the sun. The shadings were designed with length of 50cm and applied to every window of the building, vertical and horizontally. The energy consumption reduction notice was about 2.64%.

#### CONCLUSION

The simulations allowed to answer the proposed question elaborated with the study's methodology. The main objective of this paper was to verify how much some architectural an occupational parameters influence the annual energy consumption of office buildings in Brazil.

To achieve this purpose it was necessary to determinate a typical building to serve as a model. The study was divided in three parts: definition of a typical office building, simulation of the model and simulation of alterations of architectural and occupational parameters. The first part of the study was a survey that analyzed every office building in Londrina and classified them according to main constructive characteristics. The typical building was defined and its properties obtained. In the second part, a virtual model was created using the software Energy Plus 2.2.0, allowing simulating real conditions with the weather data of Londrina. In this part of the study a problem with the weather file of Londrina was discovered and it was necessary to change it to a city with a similar weather. The model was calibrated as close to reality as possible. The third part of the study used the same initial model and simulated five architectural parameters and three occupational parameters, considering higher and lowers values. Every simulation produced a table containing the annual energy consumption. These tables were analyzed providing enough information to answer the research question. The results demonstrated that occupational parameters have greater influence in the energy consumption in office buildings. The consumption of energy increased from 10% to 30% with the alterations whilst the architectural parameters went from 0.57% to 13.23%.

These results show that a typical office building in Brazil has its annual energy consumption more influenced by the occupational parameters, such as number of occupants, lightning and equipments internal loads, than by its architecture (architectural characteristics like façade material and color, WWR, type of glass, solar orientation and shading). Although the study showed a smaller influence of these architectural parameters, they are not null, being able to increase in over 13% consume of energy. It's expected that this study will be able to help architects and engineers work and make their decisions based on reviewed facts to create more efficient buildings

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