RESEARCH ON ENERGY SAVING POTENTIAL OF DAYLIGHTING IN TROPICAL CLIMATES: A CASE STUDY OF THE BUILDING IBOPE, BRAZIL

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ABSTRACT
There are many references on the potential energy savings over the use of daylight, mostly from the international experience presented in the national literature as the potential savings for Brazil. This work aims the assessment of impacts of different controls systems of lighting in an office building located in São Paulo, Brazil. It was proposed then, the comparison of two automation systems for the integration of daylight and artificial light: dimming and switching multi-level. The two systems were effective in reducing energy consumption, mainly in the winter months, but during the year the automation system with switching allowed a reduction of 16% of total annual consumption, while the automation system with dimmer generated a 23% reduction.

INTRODUCTION
The daylight is a renewable resource available in abundance in Brazil with no cost, so it can be widely explored in this context, when considered in design. Nevertheless, the daylighting is still underexplored, especially in Brazil.

The global distribution of energy consumption reveals that most of the energy in Brazil is used in commercial, residential and services buildings. Currently, the buildings are the second largest consumer of electricity in the country, consuming 42% of the supply. In these buildings, a considerable part of energy is consumed by air conditioners and lighting (BEN, 2008). Lighting is responsible for approximately 24% of electricity consumption in the residential sector, 44% in the commercial sector and public services and 1% in the industrial sector (Procel Edifica, 2006).

The rates of energy consumption by buildings can be dramatically reduced with decreasing dependence on artificial systems of air conditioning and lighting.

There are many references about the potential energy savings over the use of daylight, although many rates come from international experience cited in national literature. However, it is unknown, in fact, the real potential for energy savings through the use of daylight for the Brazilian case. This occurs because the Brazilian climate, economic conditions and availability of technology are quite distinct from the reference countries. So, these rates needs to be investigated for the Brazilian context.

This work propose a data collection in national and international level about the real energy savings using daylighting. This aims to build a national scenario of the potential energy savings of this source and compare it with the simulations for a case study in São Paulo, Brazil.

A research of the related literature found the following percentages of energy coming from the integration of daylighting and artificial lighting.

According to Caddet apud Ghisi and Lamberts (1997), in spaces properly lit by daylight and with control systems for artificial lighting, can be achieved an energy saving in lighting between 30% and 70%.

In the School of Engineering and Manufacture, the use of occupancy sensors and daylighting generated an estimated savings of 50% to 75% (The European Commission apud Ghis and Lamberts, 1997).

In the study conducted by Opdal and Brekke (1995), the authors investigate the potential savings in direct and indirect use of daylighting within the environment through measurements and simulations of 10 offices for a period of one year in Trondheim, Norway. Measurements showed a potential for energy savings by the use of daylighting integrated with artificial lighting system by control systems, around 30%, while the simulation for the same situation gave values above 40%. The south facades have demonstrated the greatest potential, around 30%, while the north facade showed a potential ranging between 2% and 29%.

Roisin et al (2008) developed a article which they compare the savings potential of energy from lighting in offices using different controls (occupancy sensors and dimmer) for three locations in Europe (Brussels, Stockholm and Athens). It was observed that the use of control systems have a high energy saving, depending strongly on the orientation and location of the environment. Energy savings ranged from 45 to 61%. The best case was a simulated office with south facade in Athens. In this case, there was a saving equivalent to 61% of the annual energy consumption. The worst case was a simulated office with north facade in Stockholm, where the savings potential was close to 45%.

Szerman (1993) develop a lighting energy saving by approximately 77% and 14% in total energy savings, through simulation in a hypothetical office (5.5 x 2.2 m) with a single opening to the front south (northern hemisphere), and the use of control systems of daylighting.
Embretcs and Van Bellegem (1997) found that a dimmer individualized system can offer an energy saving between 20 and 40% depending on the facade.

In the work developed by Li et al (2003), measurements were made in an open plan office, which had control systems lighting with dimming control and automatic on/off in Hong Kong to the north facade. The office is located on the fifth floor with dimensions of 5.88 x 10.29 m. It was estimated an annual saving of 33% for this case.

In similar work, the following results were found:
- Knight (1999) measured gains between 44% to 76% using lighting control systems;
- Galas et al. (2003) found values between 30-40% in south facades and 20-30% in north facades;
- Li et al. (2001) evaluated the performance of dimerization coupled with controls on/off and concluded there was a reduction in energy consumption by 33%.

In the national scene, Ghisi and Lamberts (1997) conducted a survey of the use of daylighting in classrooms of the Technological Center Federal University of Santa Catarina, to evaluate the potential of saving electricity by reducing the use of artificial lighting. Measurements were made in four classrooms in conditions of equivalent dimensions. The system of classrooms, with four lamps perpendicular to the plane of the windows, allowed the shutdown of two rows of lights near the windows or just the row nearest the windows, according to the availability of natural light. By applying this type of on/off control were achieved savings of electricity for lighting by 50% during spring and summer. In the fall and winter period the economy was 18%.

Already the work of Alves et al. (1998) concerns the integration of artificial lighting systems and daylight and applied to the case study of the Central Market in Belo Horizonte. The Central Market occupies an area of 14,400 m² and its building currently consists of two floors: the ground floor where the boxes and warehouses for sale are located and the second floor, which houses parking and administrative sector. The integration of systems in this case was through dimerized conjunction with lighting sensors. In the study, the controller activates the power circuit to the planned level of 33%, 50% or full load. With this system in terms of energy consumption monthly, came to a saving of 64.3% on the first floor and 12.7% in the second floor.

Souza et al. (2002), through simulations, evaluated a model of main orientation North and of fixed width of 6 m with a depth ranging from 4 to 10 m, with three types of openings (unilateral, on adjacent walls and on opposite walls) and three types of windows (one window, double window and will total) on the city of Florianópolis (SC). The authors considered two types of control: dimmer and on/off. In this study was verified that the use of daylight combined with automatic controls of artificial lighting is able to provide a large reduction in energy consumption. The results varied according to the control strategy, the orientation of the main facade and the depth of the room. Environments with unilateral illumination reached a potential energy saving ranging between 7% and 54% and a change of strategy of controlling on / off to a dimmable provided an average increase of 13%. The ambient lighting on adjacent walls reached a potential between 18,5 and 75% and a change of control on/off to a dimmable provided an average increase of 15%. Finally, lighting environments on opposite walls had a potential saving-ranging between 26% and 69%. The control strategy change, represented an average increase of 14% in the potential energy savings.

Through the contemplated literature can be seen that the control system chosen has a strong influence on the potential savings. When dimerization was used, the potential savings ranged between 12.7% and 79%. In the case of on/off control the economy was 18% to 70% and in the automatic control on/off it was 70%. The use of dimming control and automatic on/off led to savings of 33% to 60%. Longer the dimerization coupled to the presence control generated savings of 20% to 76%. And in the case of associating with the dimerization to control individual motion sensor, the savings ranged from 2% to 63%. The system showed that the largest economy was combined with a dimming system and occupancy sensors. However, even between types of control system, there was considerable variation from one case to another, which is probably due to different latitudes and cities where the studies were made, which have different people outside natural light.

It can be observed that the variation of potential energy savings through the use of daylight is related to the type of control system used or characteristics of the environment and it was not observed significant influence of latitude in the values obtained. There is also a need to investigate the influence of climate and its variables, such as the predominant type of sky. It is clear the difference in the ranges of the potential energy savings for Brazil (from 12.7% to 64.3%) and for the international event (between 2% and 77%).

**SIMULATION**

This paper intends to analyze the impact of two types of automation control (switching and dimmer) for integration among daylight and artificial lighting systems in a commercial building, inserted in the context of the Brazilian reality.

This study will be developed through computer simulations and comparison with the current energy consumption of the building.

The following will describe the building.
Model construction

The selected as a case study was Paulo de Tarso Montenegro building, the present headquarters of the Brazilian Institute of Public Opinion and Statistics (IBOPE). This building is characterized by being an open plan office building situated in the center of São Paulo (SP), which latitude is 23 ° 37 'and longitude is 46 ° 39 '. The Figure 1 shows the edification and enables to verify the existence of significant dimensions of the nearby buildings capable of influencing the availability of shading and daylighting in the building under study.

The developed computational model considered the effect of louvers, ceilings, walls and light shelves on the availability of natural light inside the rooms, to create routines representing the integration of systems of daylight and artificial lighting. The building of study, used in addition to these strategies to optimize the use of daylight, automation devices that allow intervention in the artificial lighting system. This is only activated to supplement the light levels provided by daylight when necessary. Through these simulations, systems with dimmers and switching control were compared. The simulation model will be further detailed below.

Solar shading

The building has solar shading in its glass facade, which contribute also to reduce heat gain to the building and for a better distribution of diffused daylight inside the rooms. Such devices are composed of horizontal and vertical plates fixed, both made of reflective materials, in order to reflect the most of daylight for the interior.

The horizontal louvers (10 pieces with 18 cm distance) take place on all facades, and, in the southeast and northwest facades, these were combined with vertical devices. The horizontal plates prevent the incoming of sunlight through the opening, when the sun is at high altitude and the vertical plates, when it is present at low altitudes and focuses laterally. The assembly protects the facade of sunlight during periods with high temperatures and elevated solar radiation gain, especially in the summer months, as seen in Figure 4 Image of the louvers in the model simulation.

Daylight

Aiming to maximize the use of daylight in indoor environments, were considered the use of light shelves, in order to uniformize and improve the distribution of light in internal spaces through the redirection of direct light by reflection to the deeper parts of environments, since the building under study consists of open plan offices. Moreover, the device is designed to shade the part near the opening, avoiding high levels of illumination and glare.

Furthermore, the model has considered a sloping ceiling to help in the reflection of light to the deeper
regions. Along, in the same lines, the surface of the ceiling was painted of white, the interior surfaces prioritized clear colors (absorptances maximum 0.4) and the divisions had the upper glass.

**Artificial lighting system**

Inside the rooms, it was considered fixtures with two bulbs of 28 watts each, with adjustable light intensity. The luminaires are recessed, with body phosphatized sheet steel and painted electrostatically, with parabolic reflector and anodized aluminum fins with 99.85% purity. They have a high efficiency of 78% and avoid glare.

As a reference to preparation of the lighting project, were adopted the illuminance levels recommended by the NBR 5413 - Interior Illuminance (ABNT, 1992), current standard in Brazil. To meet this standard, the system has been designed in the following manner: the offices were adopted 500 lux, while bathrooms, entries and garages had illuminances of 150, 200 and 50 lux respectively. The depreciation factor used was 0.80 and the manufacturer of the luminaries provided the utilization factor.

The luminaries are arranged in parallel systems to glass facades.

**Integration routines**

In order to verify the impact of the energy saving strategies by optimizing of the daylighting, simulations were performed in DAYSIM software used to compute the daylight autonomy and the levels of illuminance. The program Daysim, developed by the National Research Council Canada (NRCC) and the Fraunhofer Institute for Solar Energy Systems in Germany, was developed in order to calculate the illuminance for the period of one year, quickly and independent of the type of sky (Reinhart, 2006). The DAYSIM is a computational simulation tool with the advantage of being able to estimate the annual profile of the environments indoor lighting and daylight autonomy. And besides, it uses the same weather file that DesignBuilder and EnergyPlus, differentiating itself to predict the amount of daylight in an environment during an entire year, due changes in sky condition, unlike the static simulation capable of simulating one condition sky only, thus allowing the simulation closer to the actual condition.

Through the simulation of daylighting in the case study, there was obtained illuminance levels and the potential use of daylight for the integration of lighting systems.

Then simulations were performed in DAYSIM aiming to quantify this levels of daylight autonomy and illuminance levels obtained, once this program is capable of consider solar shading and light shelves by quantifying the levels of daylighting.

Based on the simulation of the daylight autonomy, representative routines of systems integration of daylighting and artificial lighting have been established in the Design Builder. This software is a thermoenergetic simulation program that enables to measure the impacts of such integration on thermal comfort and energy consumption.

To ensure fidelity to the building and validate results for the simulations, the models developed in each of the programs (Daysim and DesignBuilder) maintained the properties and physical construction of the building materials (Table 1, Figure 5 and Figure 6), the geometry and orientation of the type pavement. The work plan adopted was 0.70 m above the ground.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Absorptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>0.80</td>
</tr>
<tr>
<td>Ceiling</td>
<td>0.18</td>
</tr>
<tr>
<td>Walls</td>
<td>0.20</td>
</tr>
<tr>
<td>Louvers</td>
<td>0.10</td>
</tr>
</tbody>
</table>

From the simulations in DAYSIM, it is possible to compare the use of daylight in the type pavement, as seen in Figure 7 and therefore we can fit the routine of lighting fixtures on the Design Builder. Daylight autonomy simulations presented an average of 91% in the use of daylight in the environment.
SYSTEMS were effective in reducing energy consumption for the same building considering three situations: the case of “Reference”, “Case 1” and “Case 2”. The “Reference” is the consumption on the original building. The “Case 1” shows the total consumption of the building considering the replacement of existing devices by the proposed model and the integration between natural and artificial lighting systems through the switching multi level, reducing the percentage of consumption obtained. And the “Case 2” shows the values obtained when considering the use of louvers and the reduction through integration between natural and artificial lighting systems through dimming use.

The monthly consumption of electrical energy, computed by DesignBuilder in different simulated cases is presented in Table 2.

**DISCUSSION OF RESULTS**

On Table 2 is possible to notice that both automation systems were effective in reducing energy consumption. During the year the automation system with dimmer generated a 23% reduction of total energy consumption. Already the automation system with switching allowed a reduction of 16% of total annual consumption. If compared these medians percentages to those previously studied here, it is clear that the economy achieved with the use of these systems is within the range studied in Brazil. When comparing the energy savings obtained through the simulations in this work and the values found in international literature, one can see there is a significant difference between the potential savings, lower values being obtained (around 20%) in the study compared to 70% of the literature.

Over the year simulated, we realize that the greatest reductions in consumption occur in winter months (June, July and August) for both automation systems. This is a result to be in this period that the sun has a lower solar altitude, so there is greater availability of daylight environments.

**CONCLUSION**

Daylight is an interest strategy for reducing energy consumption in buildings, especially for non-residential, which often operates in the period when there is daylighting. The correct adoption of appropriate strategies for their use can not only reduce energy consumption, but promoting an improvement in luminous and thermal comfort of the user. Despite having a climate favorable light, is unknown in Brazil the potential energy savings by integrating the system of daylight and artificial lighting.

To estimates the impacts of the integration between daylight systems and artificial lighting, it was evaluated a commercial building in the center of Sao Paulo. It was adopted the simulation without automation controls and two control types: dimmer and on/off.

Through these simulations, it can be seen that the automation system with dimmers generated an energy savings greater than those systems on/off in studied in Brazil, going against what was reported in the literature review. However, the values found for the integration of lighting systems for the case of Sao Paulo, Brazil, were inferior to the study cases showed in this paper. This may indicate that besides the influence of the type employed, the shape, the construction and construction features can significantly influence the availability of daylighting in the environment and, therefore, power savings through its use.

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