A modern heritage office building looking at energy and users satisfaction

Lighting control and automation system, combined with daylight in the Ministry of Mines and Energy (MME) in Brasilia.

The modern building designed in 1958 by Oscar Niemeyer is an architectural heritage, limiting interventions on facades. The electric lighting control and automation system optimizes light integration and reduces energy use, while improving user satisfaction. The building makes good use of daylight, thanks to the laminar shape; most offices are located in east façade to prevent glare and overheating.

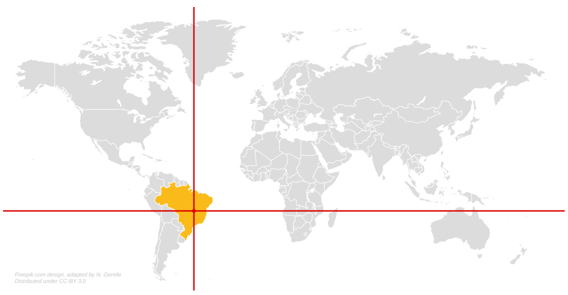
Figure 1. Ministries Esplanade in Brasilia.

The project

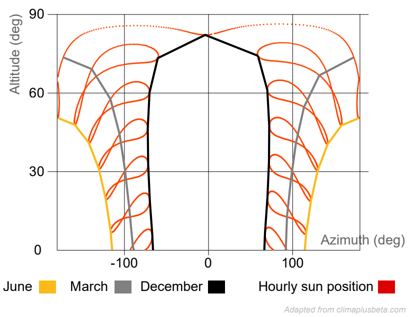
The Ministry of Mines and Energy (MME) is a modern building, designed in 1958 by the architect Oscar Niemeyer and part of the Ministries Esplanade (figure 1), a complex of 17 identical buildings. The complex is a cultural heritage listed by the Brazilian National Historical and Artistic Heritage Institute (IPHAN).

On a construction site of around 5,000 square meters on aThe building has an area of 19 734 m2 distributed in 11 floors (including two underground floors). Its laminar shape (102.5 x 17.4 m) allows daylight penetration. East and west façades are totally glazed, with solar protection (brise soleil) on the west façade and solar control films on east façade. Most offices are facing east, to reduce overheating and glare. Because of the heritage restrictions, the façades cannot be changed, so actions to improve lighting and reduce energy consumption were done by means of a sophisticated artificial lighting control and automation system that optimizes light integration and reduce energy consumption, improving wellbeing and user satisfaction with the light environment.

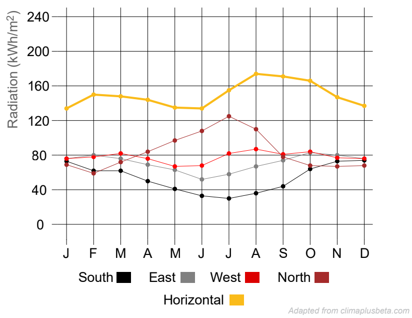
The lighting control system implemented is the EcoSystem© from LUTRON and it was installed during the building retrofit, consisting in five control possibilities: on off, dimming, individual controls on daylit workplaces, central



Location: Brasilia , Brazil
-15.80°, -47.87°



Sun path for
Brasilia, Brazil



Global horizontal and vertical radiation for
Brasilia, Brazil

IEA SHC Task 61 Subtask D

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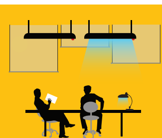

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Figure 2. West and East façades of the building.

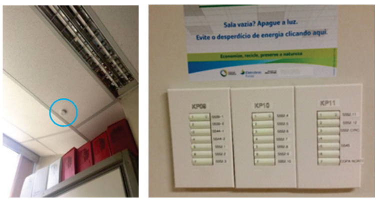


Figure 3. Photosensors close to windows and lighting switch interfaces in corridor.

control for workplaces far from windows. The main innovation is the dimming; in order to integrate day and electric lighting there are photosensors near to the windows (figure 3), and the luminaires in the nearby lamps are dimmed according to the amount of daylight. Users can request changes in light intensity by contacting the responsible for the central system. The system configurations also include the regulation of lamps intensity in 50% of luminous flux e and automatic turn off at 7:30 pm every day. Besides, there are switches in the corridors that control rooms lighting (figure 3), remote controls for dimming in some special rooms and occupancy detection sensors in common areas (corridors and WCs). A monitor placed in the main entrance displays in real time the global energy consumption of the building.

Monitoring

The first field monitoring was performed on 7th October 2019 at night and on 8th October 2019 around 12 pm. The condition was clear sky, with global illuminance values between 39 000 lux and 120 000 lux. The second field monitoring took place on November 10th, 2020 between 12pm and 13pm. The sky condition was overcast and global illuminance values ranged between 23 300 lux and 38 200 lux. All measurements were performed in a representative office room on 6th floor in east façade (figure 4), with 50.32 m2 area and 7.40 m deep (figure 5), same of all other rooms in east façade. The limited depth ensures good daylight penetration. Internal reflectances are as follows: floor 38%, walls 62%, ceiling 80%, partitions 70%. Windows in east façade are composed by a 6 mm glass with solar control film (silver coloured from Intercontrol©), with visible light transmission of 15%. All rooms have internal vertical blinds, but all measurements were done with opened blinds.

Energy

The electric lighting system consists of efficient fluores¬cent T5 recessed luminaires 2x28W (103 lm/W) providing lighting at 4000K -, and a closed-loop daylight harvesting system. Sensors are located in the ceiling next to the window, controlling the row of light fixtures near to the window in the room, which are automatically dimmed according to this sensor. The other light fixtures are centrally controlled,

Figure 4. Plan of 6th Floor, with the monitored room.

Figure 5. Layout and pictures from monitored room.

and workers can ask the central to diminish or enhance luminosity according to their preferences. There is no separate energy meter for lighting, so the calculation of energy consumption for lighting was made based on EN15193-1:2017, and the calculated LENI was 17.23 kWh/m²year.

Measurements of actual savings were also made with the following method: lighting control system was turned off for two days and the global energy use registered and compared with normal consumption (lighting control system on). According to measurements performed, the lighting dimming system can reduce by 9% the global energy savings of the building.

Photometry

The field monitoring was conducted with three different conditions: daylighting, electric lighting and day+electric lighting (Table 1).

Factors such as the distance between buildings allow daylight penetration. Both with clear and overcast sky, average illuminances (E_{avg}) (day+electric light) are above recommended values of 500 lux according to NBR ISO/CIE 8995-1. Regarding lighting uniformity, all values obtained are below the recommended minimum (0.5). Daylight Factor (DF) values measured with overcast conditions for three points in the room also lack in uniformity: 8.0% next to the window, 2.5% in the middle of room and 0.4% in the back of the room. The high DF near the window suggests potential thermal discomfort and glare.

The directionality of daylight was measured via produc-

Table 1. Measured illuminances, uniformity ratio, and directionality.

	E_{avg} (lux)	E_{max} (lux)	E_{min} (lux)	U_0 (E_{min}/E_{avg})	Directionality (E_v/E_s)
Electric light	292	586	95	0.30	-
Clear sky (8/10/2019)					
Daylight	898	3360	127	0.14	-
Day+ Electric	1213	4130	243	0.20	1.39
Overcast sky (10/11/2020)					
Daylight	730	2776	113	0.15	-
Day+ Electric	1002	2540	179	0.27	1.53

Figure 6. HDR photographs for directionality calculation.

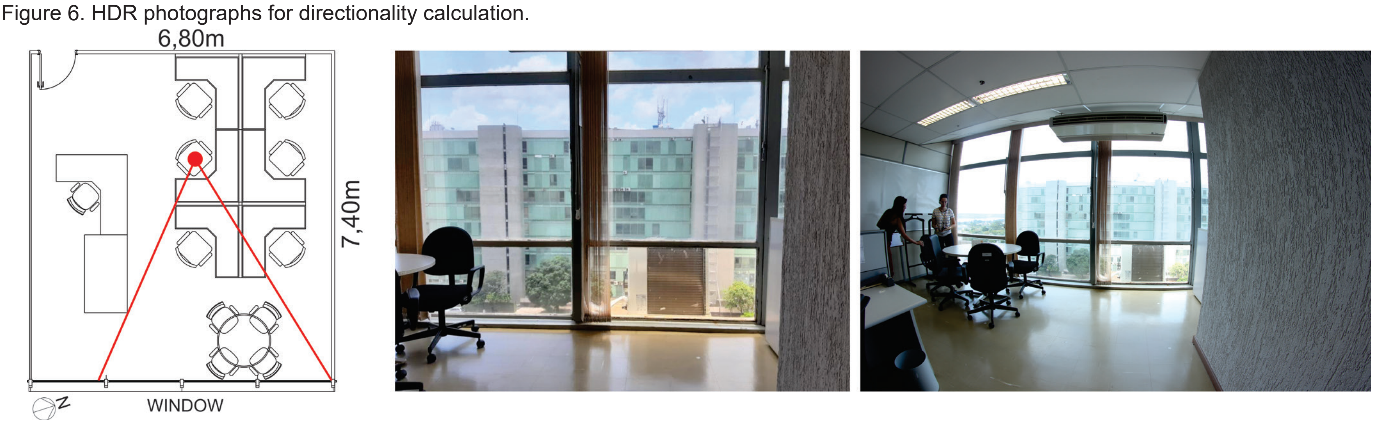


Figure 7. Monitored position in the room and pictures of the view out.

Table 2. Quality of view out for the East room, thresholds as defined by the EN 17037:2018.

	Measured vs threshold	Rate
Horizontal sight angle	100% > 54° /83°	High
Distance of view	> 50m / > 50m	High
Number of layers seen from 75 % of area	3 / 3	High
	General view rate	***High***

tion and manipulation of HDR photographs of a diffusive sphere (Figure 6).The directionality values in both clear and overcast sky (Table 1) are adequate and comfortable for the human eye, according to Cuttle (2003), that recommends values between 1.2 and 1.8. Ambient light produces diffuse shadows, which do not cause visual discomfort. The combination of artificial lighting and natural lighting from the window produces a weak and comfortable shadow for the user's eye.

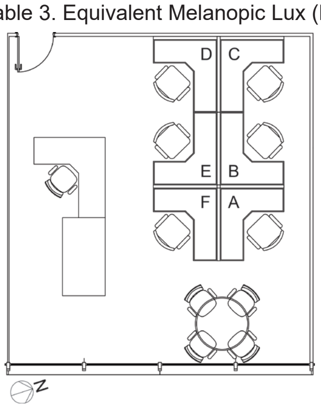
Regarding view out assessment, photographs of the view were taken at a height of 1.2 m from the floor, simulating a seated person (Figure 6). The evaluation (Table 2) shows that view out is rated as High, in all parameters proposed by EN 17037 – Daylight in buildings.

Regarding contrasts, the luminances of the main vertical surfaces were measured, in three different workstations, during the field monitoring in November 2020.

Circadian potential

Equivalent Melanopic Lux (EML) values were calculated via Lucas toolbox and verified against the WELL v2 criteria. The credit requires verification of the EML value re-

Table 3. Equivalent Melanopic Lux (EML) measured via Lucas toolbox with photopic illuminance data



Equivalent Melanopic Lux (EML)			
Workstation	Electric lighting	Daylight + Electric lighting	
		Clear sky (8/10/2019)	Overcast sky (10/11/2020)
A	167.2	283.1	308.5
B	219.4	534.1	705.2
C	41.6	107.9	111.2
D	71.5	148.8	165.3
E	290.9	743.6	716.0
F	219.4	451.3	380.0

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ceived at the eye of the occupant during specific times of occupation, awarding a number of credits. Results are showed in Table 3.

According to the WELL v2 criteria,not all the workstations reach the requirements. Only 66% of the workstations reach 200 EML, when combining day- and electric lighting. Again 66% of the workstations reach the target level of 150 EML from electric lighting alone. However, according to the results from the questionnaire, this does not seem to affect psychological health.

User perspective

The building hosts 850 employees and 87 valid responses from questionnaires were obtained. The survey was limited to rooms in east facade, where the field monitoring was performed. Considering that the luminaire close to windows are dimmed by a photosensor, the respondents were divided into two groups: Group 1 consisting of workstations up to 3.7m from the window, and Group 2 with workstations more than 3.7m from the window (figure 8). Most respondents (70) are from Group 1. Overall, 54.5% of respondents were men and 45.5% women, between 17 and 81 years old, working 5 days a week, from 8 am to 6 pm, using monitors.

Most work environments are shared. This is reflected in the users' perception of lighting control, especially the rate of control over electric lighting. In rooms with up to two employees, the rate of respondents who consider that they have a lot of control over electric lighting on their workstation is 65%. In rooms with five or more users, this rate drops to 39%. It can be inferred that the more users share an environment, the more difficult it is to reconcile personal preferences, which can lead to friction. Overall, only 46% of users consider that they have a lot of control over electric lighting in their workspace, even though there is a central lighting control. 43% consider having little or no control over electric lighting. In conversation with the employees, it became clear that most of them were unaware of the existence of the control system, which can explain these results.

> ***"Controls for electric lighting are not available to us – it´s necessary to make a formal request"***

Regarding daylight control, in Group 1 (near the window), 78% of users consider that they have a lot of control over daylight in their workspace, while in Group 2 only 59% consider that they have a lot of control. Possibly the proximity of the window gives the users more freedom to interact with the shading devices (internal blinds).

The combination of electric and daylighting is the preferred condition for both groups, with the preference of 74.3% of respondents in Group 1 and 82.4% in Group 2. 67.2% of users rarely, if ever, work using only daylight. This can be explained because daylighting illuminance is low for carrying out visual activities, requiring the combination to achieve satisfactory illuminance rates. But daylight is very much appreciated (79% satisfied or very satisfied), as it is the windows size (79,5%) and the view out (80.0%). Discomfort due to reflections with daylight is mentioned by 61% of users, mostly in Group 1, although Group 1 users are generally very satisfied with daylight (80%). Despite the generous glazing, there are few complains at all about discomfort with daylight, with mentions that it occurs only in first hours of the morning.

> ***"With closed blinds, daylight becomes poor and it is difficult to do my task"***

Lessons learned

Daylight dimming helps to save around 9% of global energy of this building, despite the high luminous efficacy of the installed fluorescent lamps, which is comparable to that of many today's commercial LEDs.

The building has a good daylighting design, especially due to the laminar shape and limited room depths. Despite the east/west orientation being not the ideal for solar protection, most offices in east façade did not show particular glare issues. The high quality of view out and the presence of daylight helps to improve visual environment. The addition of more efficient internal solar control elements could help to avoid some reflections mentioned by users in the morning. The combination of electric and daylighting produces a weak and comfortable shadow for the user's eye.

Users opinion shows that they are quite satisfied with daylighting in rooms, and they most prefer to work with the combination of day- and electric lighting. The perceived control over electric lighting is poor, even if the users consider the control system easy to use. Informing and educating users about the functioning of the control system would greatly help.

Further information

D.Silva, I. and Amorim, C.N.D. (2020). *Qualidade da iluminação e impactos no usuário: monitoramento do ritmo circadiano e satisfação do usuário em edifícios de escritório*. Proceedings of the XXVI Congress of Scientific Initiation 2020, University of Brasília, Brazil.

Toledo, G. and Amorim, C.N.D. (2020). *Qualidade da iluminação, vista exterior e direcionalidade: monitoramento em ambientes de edifícios de escritórios*. Proceedings of the XXVI Congress of Scientific Initiation 2020, University of Brasília, Brazil.

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