Saving energy with integrated lighting design: the headquarter of IDOM

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Skylight, daylight harvesting and microperforated façade in a southern European landscape office in Madrid.

A range of daylight and lighting design strategies has been applied in the IDOM office building. The design is focused on the performance and well being of the workers as well as reduction of the electric lighting. Simultaneously the prevention of solar gains with blinds and a double skin façade has been successfully implemented.

The project

The new headquarter of IDOM is nature-inspired multistorey building. The entrance floor stands out for its biophilic design; surrounded by gardens and fountains, outdoors and indoors limits disappear. The façades have different designs: fully glazed on the north, and a distinctive double skin with microperforated sheet and landscape windows on the other sides. Offices, which are found in the upper floors, are at the focus of this monitoring. Common spaces are located facing south, the landscape offices are located north (Fig 2), while private offices are found in the core area. The latter is illuminated by skylights, bringing a sense of spaciousness to the interior. The materials in the indoor are basic: wood slats for the ceiling, visible bricks or white stucco for the walls, and dark vinyl flooring.

In the landscape office we found a daylight harvesting system, cleverly divided in several control groups, depending on the distance from the façade. Solar protection is guaranteed by internal roller shades.

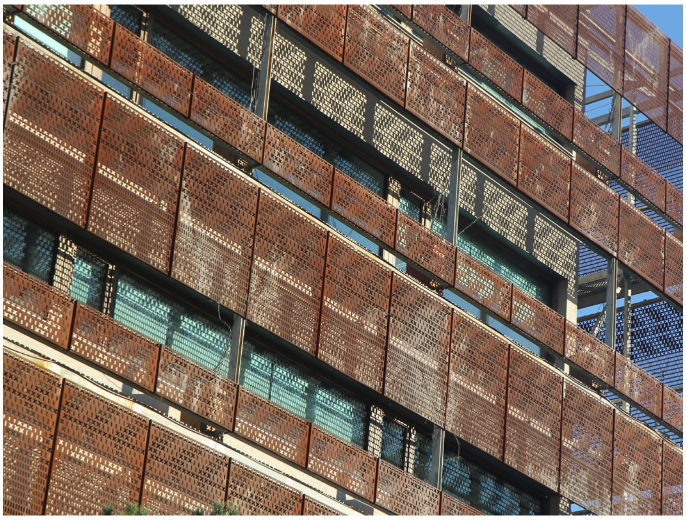
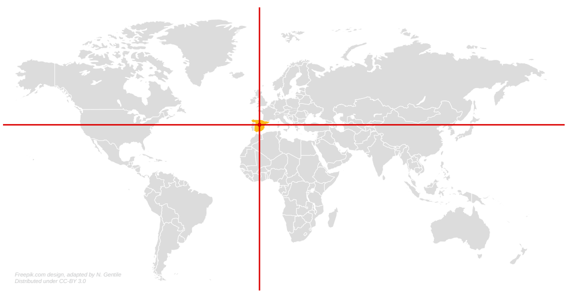


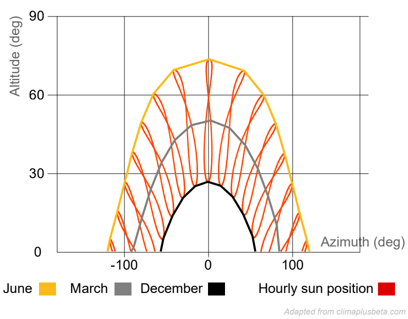
Figure 1. South view of the double skin micropeforated façade of IDOM Headquarter in Madrid. This façade is perhaps its most distinctive sign. The façade, which was designed to reduce overheating, provides also some glare protection if combined with roller shades.

Monitoring

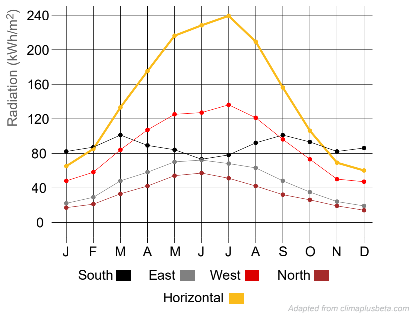
The building was visited for the first time in February 2020 and accessed for daily point-in-time measurements, surveys and pictures until March 15th, when the global Cov-



Location: Madrid, Spain
40.50°, -3.71°



Sun path for
Madrid, Spain



Global horizontal and vertical radiation for
Madrid, Spain

IEA SHC Task 61 Subtask D
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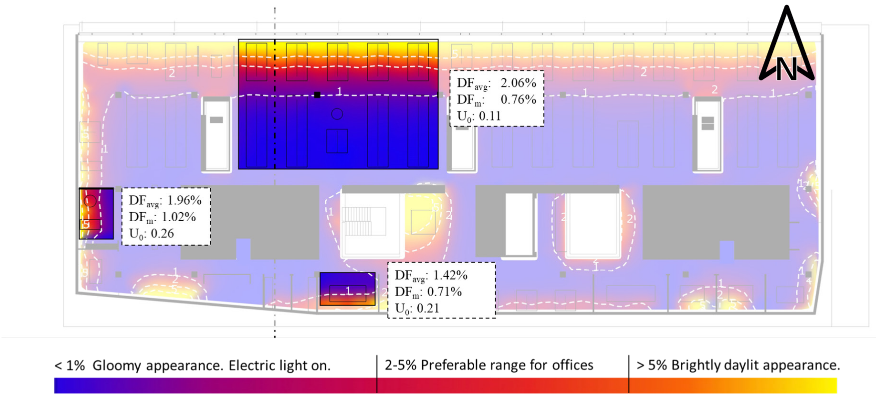

Figure 2. Average and median Daylight Factor(s), and daylight uniformity ratio under overcast conditions for the three monitored spaces: landscape office, west facing and south facing private offices.

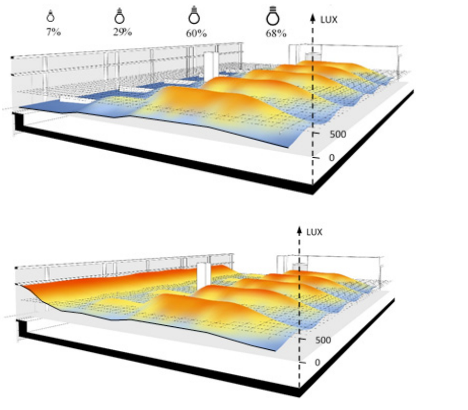

Figure 3. Illuminance profiles for the open plan office: daytime profile for electric lighting only (top), daytime profile for both daylight and electric lighting (bottom).

id-19 pandemic stopped the field monitoring. Nevertheless, the field measurements provided data to characterize the lighting system, to simulate daylight performance, to evaluate the circadian potential in particular conditions, and to draw some valuable conclusions. The model was created in Rhinoceros 3D and the simulations were run in Grasshopper by using Radiance and Daysim via Honeybee/Ladybug interface. The circadian potential was instead assessed with the Lark plugin for Grasshopper. The monitoring focuses on the landscape office, while glare assessments are provided for the private offices, in particular those facing the microperforated facade (Figure 2).

Energy

The electric lighting system consists of efficient fluorescent T5 pendants 2x28W (104 lm/W) combined with compact CFL 2x26W - both providing lighting at 4000 K -, and an open-loop daylight harvesting system. A single sensor located on the roof controls all the light fixtures in the open plan office, which are manually switched on-off. The light fixtures are grouped in four groups, which are calibrated in groups according to this sensor. There is no separate energy meter for lighting, so the system had to be simulated with Daysim. Daysim works with an ideal open-loop control, so this tool was quite appropriate to simulate this specific electric lighting system. For the simulation, the open office area was divided in four different control groups regarding the distance from the façade based on the Daylight Autonomy simulations (Figure 3). The simulation used standard occupancy schedule.

Despite the 15m depth of the office, even the areas close to the building core could slightly benefit from daylight, possibly thanks to the extra contribution of core skylight. This exploited the potential of the daylight harvesting system, resulting in very low energy use for lighting (Table 1). Although the results were obtained with computer simulations, site observations suggest that the open-loop daylight harvesting system was working as for design. It should be noted also that the luminous efficacy of the fluorescent lamps is comparable to that of many today's commercial LEDs.

Table 1. LENI the open plan office simulated for an ideal open loop daylight harvesting system. Benchmark Tab M1 EN15193-1:2017.

	LENI DHS kWh/m^2	LENI Benchmark kWh/m^2	Savings %
Open plan office	4.90	23.23	**78.91**

Photometry

The headquarter is designed such that daylight is maximized and solar heat gains reduced; yet room for improvement exists. The daylight factor, which was both measured and simulated, showed that the workplaces close to the core lacked of daylight (DF < 1%) despite the contribution of the skylight, while some places closer to the façade were potentially at glare risk (DF > 5%). This also resulted in low illuminance uniformity (Figure 2). Not only the layout, but also the materials were responsible of the low daylight penetration; the ceiling, for example, is characterized by very low reflectance (35-50%). As a comparison, the EN12464-1:2011 recommends 70-90% reflectance for ceilings.

Another interesting is the dynamism of daylight for the west and south offices, where skylights and microperforated façade provide an ever-changing appearance to the space. This, however, makes also daylight much harder to control (Figure 4).

Indeed, daylight glare (DGP) simulations shows that the

Figure 4. Rendering for the west facing offices with clear sky conditions on June, 21st 18:00.

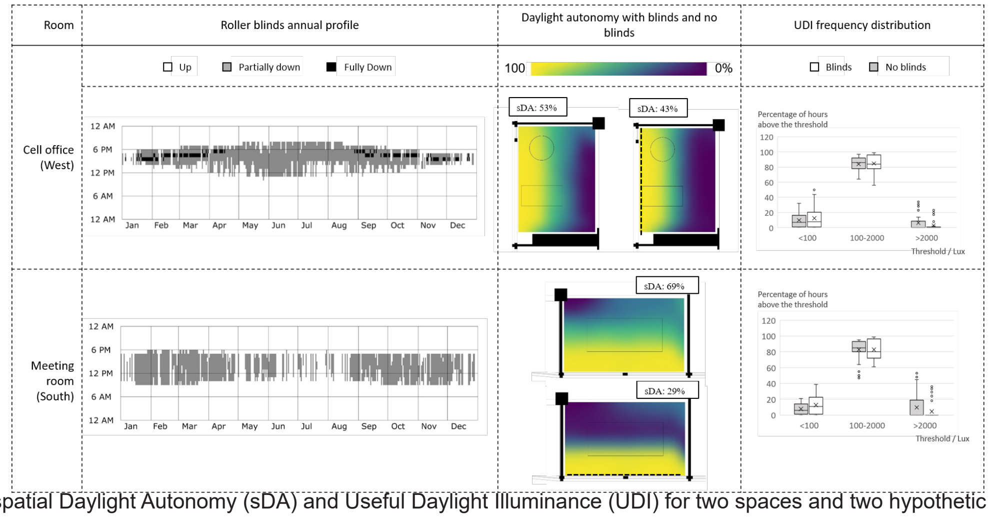

Figure 5. Simulated spatial Daylight Autonomy (sDA) and Useful Daylight Illuminance (UDI) for two spaces and two hypothetic scenarios: 1) no roller blinds in use, and 2) manually operated roller blinds with annual use profile as in figure.

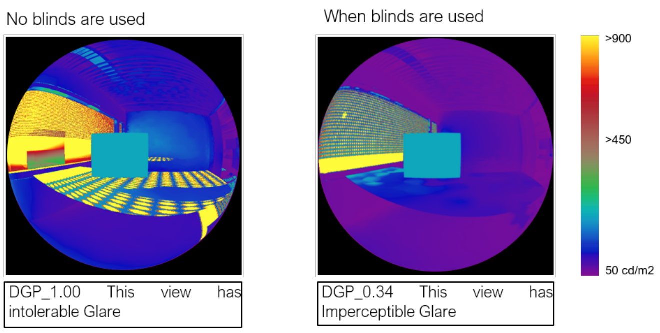

Figure 6. DGP analysis with and without roller blinds for the west facing office. Analysis performed for June 24th at 19:00.

perforated façade alone do not prevent glare, but it needs support by the roller blinds (Figure 6).

On the other hand, roller blinds may reduce the daylight penetration. For example, in the south meeting room, the spatial daylight autonomy (sDA) drops from 69% to 29% when occupant controlled blinds are included. The drop is less pronounced (53% to 43%) on the west façade for this south location, since that façade receives less hours of direct sunlight (Figure 5).

Circadian potential

Workers at the office spend on average about 8 to 9 hours per day seated in a fix position. This has a great impact in their well being and productivity, hence the importance of daylight also as a regulator for their circadian rhythms.

For the IDOM case study, some simple simulations for daylight conditions and for the workers sitting in the north-facing landscape office are shown (Figure 7).

The Melanopic over Photopic (M/P) ratio ranges between 0.7-0.9 even for workstations closer to the building core. These ratios suggest a blue-enriched light supporting alertness. The simulations were run only for March, 21st 12:00 and clear sky. More sun positions and weather conditions should be tested, but this is certainly a good news for a location like Madrid, which enjoys a prevalence of clear sky conditions throughout the year.

User perspective

Fifteen employees replied to a custom made questionnaire with few closed-ended questions dealing with the satisfaction about different aspects of the integrated lighting design. Their sitting positions were spread in the landscape office, with some employees sitting in the core of the building and others next to the windows. Therefore the survey provides an overarching picture of the space, albeit not detailed. The employees and the building managers shared additional thoughts during informal chats, including the interesting observations, which can be read in the quote boxes.

The results of the questionnaire, which are shown in Figure 8, inspires a first general deduction: daylight and view out are essential for the quality of a space. Indeed, the preference for light source is strongly oriented towards

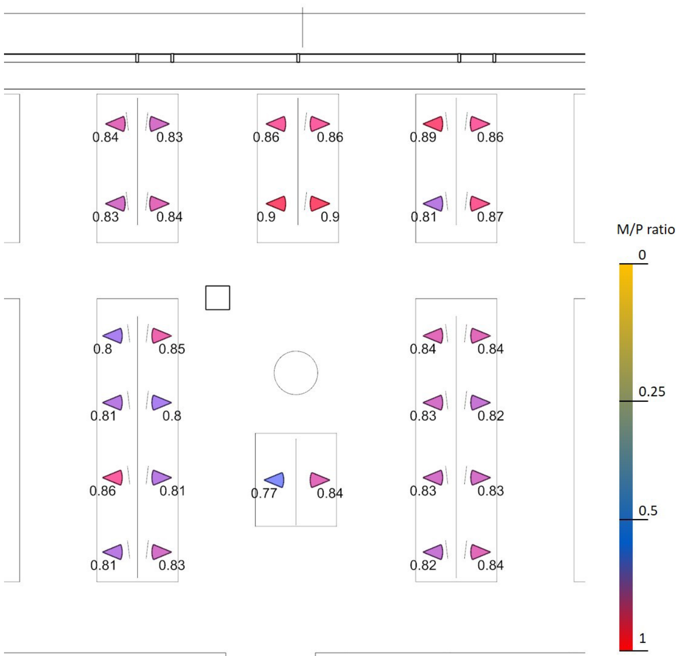

Figure 7. Lark M/P ratio simulation for one view direction of thirthy employees in the landscape office, March 21st 12:00, clear sky.

Integrated lighting design in Madrid: the headquarter of IDOM

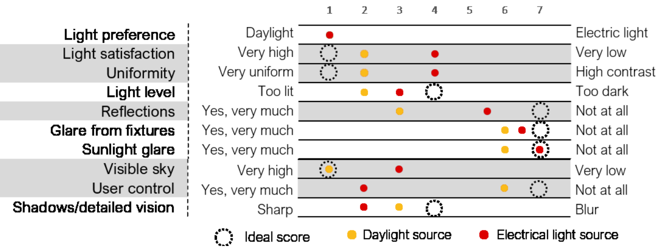

Figure 8. Results from the questionnaire submitted to fifteen employes. Results are filtered for sitting positions: "Daylighting" and "electric lighting" indicate sitting position with prevalence of daylighting or electric lighting respectively. Median values are shown.

daylight, while the possibility of viewing the sky – somewhat connected to the more general concept of view out, is also highly valued. Despite the generous glazing, there are no complains at all about daylight glare, possibly because the landscape office is oriented towards north.

The self-reported evaluation of light uniformity and light satisfaction has identical median values. A further analysis showed a strong correlation between uniformity and light satisfaction (Figure 9), despite the small number of subjects. In integrated design, one could speculate that choosing materials with higher reflectance materials in the darkest areas of the room can increase uniformity and possibly satisfaction.

For electric lighting, is interesting to see that employees wish more personal control over lighting, see quote box, which is in line with many other post-occupancy evaluations. The 4000 K for electric lighting seems also to be bit too high correlated colour temperature for this office space.

Lessons learned

The potential for energy savings from daylight harvesting systems have been claimed for years, but these systems have received much less market attention than what predicted. In part, lack of experts' knowledge for installation and calibration, little maintenance, and lighting designs caring little of users' desires, can be blamed for that. At IDOM Madrid we rather witness daylight harvesting as it supposed to be. A system that is designed to control fixtures per daylit area, which adopts efficient light sources, and which makes use of generous daylight provision on façade which is unlikely to receive direct sunlight. Most important, a system that seems to be correctly calibrated and installed. Although the numbers here reported are generated by computer simulations, there are no apparent reasons to believe that they deviate much from the actual ones, according to observation during the site visits. Even in a conservative perspective, and in respect to standard lighting installation, the IDOM solution is most likely to generate those 60% energy savings which are generally claimed for daylight harvesting systems.

"We need more control over electrical light or task lights, sometimes it feels too bright and cold"

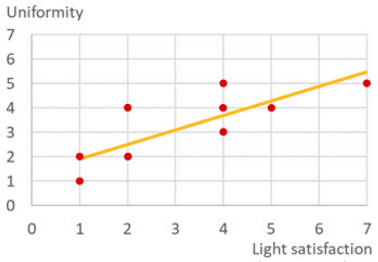

Figure 9. Correlation between perception of light uniformity and light satisfaction, Spearman's Rank Correlation $R_s = 0.79$, $p < 0.1$

While the open-loop daylight harvesting system on the north-facing façade was justified by abundant and more predictable daylight provision, daylight on the west and south façade is more difficult to control. The microperforated façade may prevent overheating, but it does not suffice for glare protection. The use of roller shades was fundamental in this perspective, but we have also seen that they may reduce dramatically daylight penetration throughout the year. The shading schedules provided here were determined by the software, but it is clear that the impact of user behaviour in the daylight performance is remarkable. This leads to two main observations with direct backlash on the final energy use for lighting. First, integrated design is a must; we cannot pretend anymore to design facades and electric lighting independently, and expect high performing lighting projects. Second, the integrated design should account for user behaviour to the highest level of detail, if the energy goals are to be achieved. Learning from post-occupancy evaluations may be very useful in this sense.

"It is important for the people health and well being to see or feel daylight and the movement of the sun and not only the skylight coming from the north"

The survey proposed at IDOM was limited to the general satisfaction of some aspects of the integrated design. Yet it showed a clear inclination towards daylighting. Daylighting benefitted energy, appreciation, and, not last, circadian potential. The electric lighting, which consisted of efficient light sources and established, simple automated controls, complemented a well-designed energy-efficient integrated lighting project.

Further information

Fernandez Amodia, J. (2020). *IDOM's high performance office building lighting audit: a case study.* Master thesis in Energy-efficient and Environmental Buildings, Faculty of Engineering, Lund University, Sweden.

Acknowledgements

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