Evidence-based management to monitor and improve indoor lighting

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Queensland's first WELL platinum certified open plan office building with daylight responsive controls and active management team

Daylight responsive lighting controls, electrical lighting, user responses and the luminous conditions were evaluated in a Green Star and WELL platinum certified office building in Brisbane Australia. Combining smart technologies with POE surveys delivered practical solutions to mitigate issues of glare and improve individual control.

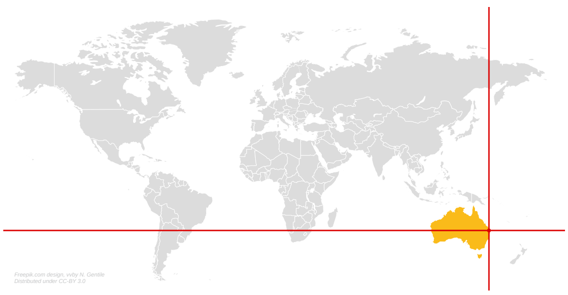
The project

Aurecon Brisbane is the largest and tallest 9-storey engineered timber building in Australia (Fig. 1). It is a 6-Star accredited Green and WELL platinum certified commercial office building designed by Aurecon, Bates Smart and Woods Bagot. The open plan office adopts a unique nomadic work style for occupants to choose and change where they work in the office to enhance multi-disciplinary collaboration and company culture. As the anchor tenant, Aurecon monitors the indoor lighting environment using Post-Occupancy Evaluations (POEs) to fine-tune lighting energy efficiency, visual comfort, and occupant satisfaction. Using an integrated approach, daylight responsive ceiling mounted occupancy sensors and photosensors detect optimal daylighting levels, to offset linear LED luminaires via automated dimming control (Fig 2). Manually adjustable blind shades are used for glare control and to allow occupants individual controllability of daylighting levels.

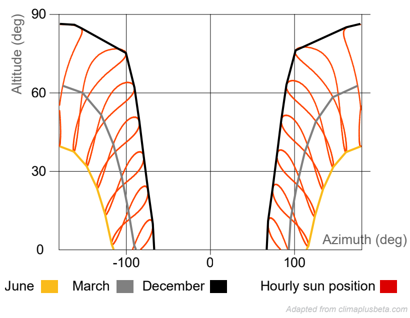
Figure 1. Aurecon's open plan office located in Brisbane, Australia. Image sourced from: https://www.archdaily.com/906495/the-tallest-timber-tower-in-australia-opens-in-brisbane

Monitoring

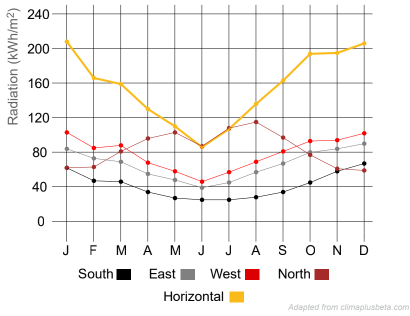
An initial site investigation was conducted in April 2019 and proceeded with a four-week period of data collection in May 2019 and subsequently in May 2021 across a 2-day period (approaching winter solstice). Data collection was carried out on levels 2 and 4. A POE framework



Location: Brisbane, Queensland, Australia
27° 27' 7.884" S, 153° 2' 1.95" E



Sun path for
Brisbane, Queensland, Australia



Global horizontal and vertical radiation for
Brisbane, Queensland, Australia

IEA SHC Task 61 Subtask D

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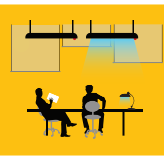

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Figure 2. (Left) Inside the open plan office at Aurecon Brisbane. (Right) Hand-held remote presence sensor controller (Servodan 41-926) to override automated dimming or turn luminaires on-off.

was developed to collect objective and subjective measures about the indoor lighting environment (Fig. 3) Part of the framework was to develop methods and instruments specific to occupied end-user settings in large open plan office environments. In particular, HDR images were collected using an android mobile device and a micro fisheye lens and the indoor illuminance was measured using low-cost lux sensors. Surveys collected where carried out by Aurecon, as part of their evidence-based approach to fine-tuning lighting systems.

Energy

The electrical lighting system consists of 20W Linear LED luminaires fitted to suspended parabolic Beta louvres with DALI ballasts. Obtaining direct metering of the true energy usage was not possible during data collection. It was mentioned during our site investigation that the installation is still being fine-tuned to work in-line with daylight-linked systems (photosensors, occupancy sensors and manual blinds). This was to try to find the best balance between delivering energy efficient lighting and visually comfortable lighting to building occupants.

Photometry

Glazing facades in subtropical climates can become a source of glare for occupants. Glare assessments were carried out to evaluate potential glare sources from using a calibrated android mobile device with a micro fish-eye lens (see Fig.4.). Occupants working along the office perimeter were asked to evaluate their subjective lighting environment by using the device to capture HDR images of their field-of-view (typical viewing position facing their computer monitor screens) and to report whether they experienced glare in a short survey on the phone. Fig. 5 shows the glare results of four occupants reporting glare. The DGP values were well below the imperceptible range (0.35), however the DGI indicated noticeable to acceptable glare (range within 18-22 for the DGI). Whilst the HDR images were captured at a point-in-time, it is likely that the DGI values would exceed towards intolerable glare.

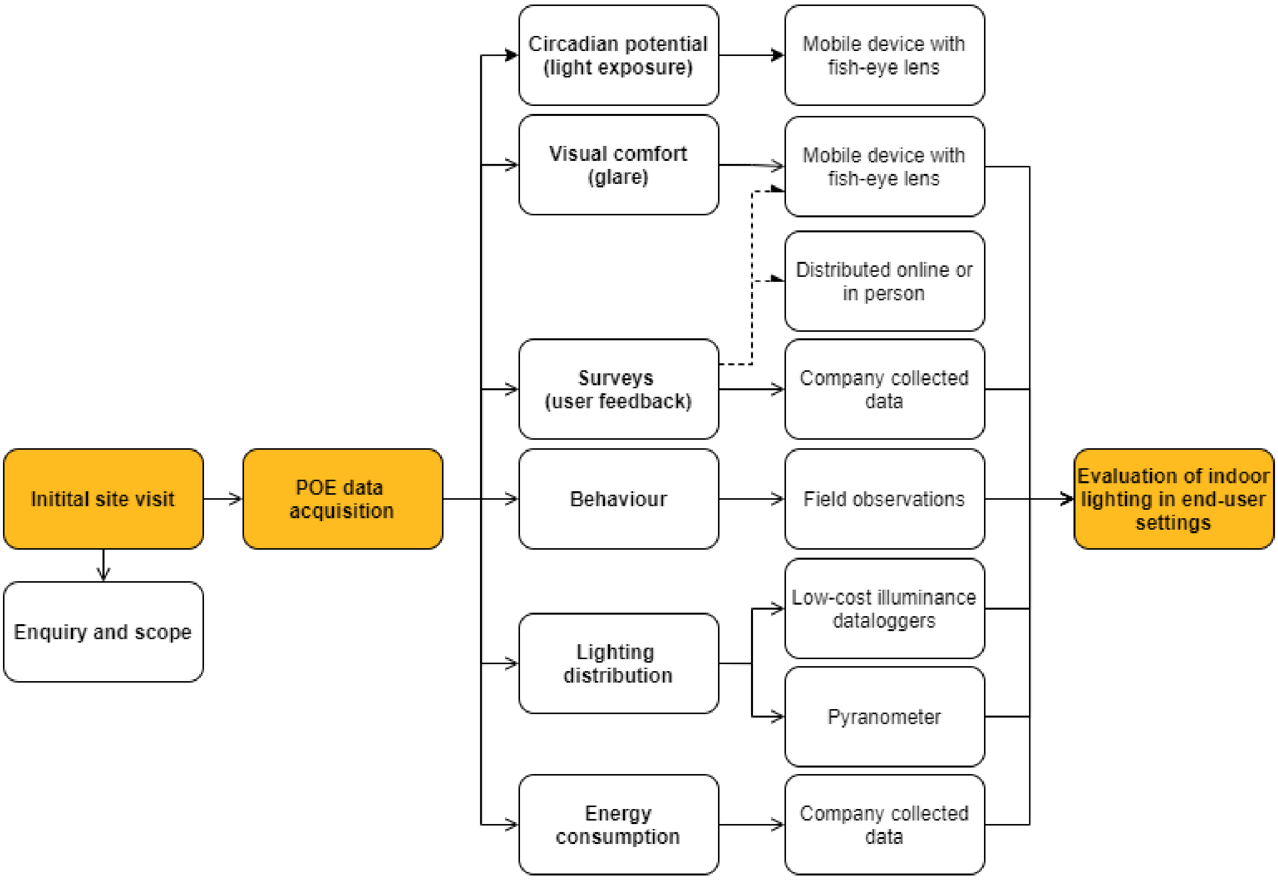

Figure 3. Post-occupancy (POE) framework to collect objective and subjective measures of the indoor lighting environment specific to occupied end-user settings in large open plan office environments.

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Fig. 4. Calibrated mobile phone device with a micro fish-eye lens to capture HDR images at occupant workstations.

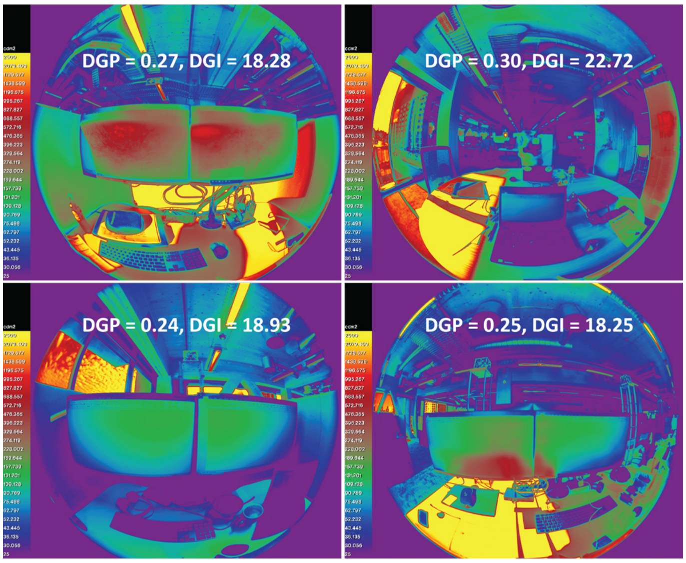

Fig. 5. Assessment of the luminous environment and glare sources using a mobile device and micro fish-eye lens, showing that the DGI detecting noticeable to just acceptable glare for occupants the four occupants reporting glare.

Sufficient colour rendering and illumination of occupant faces and objects are important in offices where communication and face-to-face collaboration are carried out throughout the day. The cylindrical illuminance was estimated in a selected area of the office, to evaluate colour rendering and illumination of objects (occupants' faces) (Fig.6). Low-cost sensors were mounted at occupant workstations (as close to eye height level - 1.7 m from the finish floor) to continuously record the horizontal and vertical illuminance (from four planer orientations) during typical work hours (07:00 AM – 05:00 PM). Spectral corrections were applied to minimise measurement error (error uncertainty of between 10-20%). A cylindrical illuminance above 150 lux was achieved at all workstations for more than 50% of working hours. Part of this result was from allowing manual control of blinds to enable occupants to adjust just enough for visual comfort but still allow for daylight permeation. As demonstrable in Fig. 7, occupants had individual preferences in terms of the fraction of shading that would meet their visual comfort needs.

Circadian potential

Aurecon's approach to deliver circadian lighting was to use daylighting and electrical lighting to achieve an Equiv-

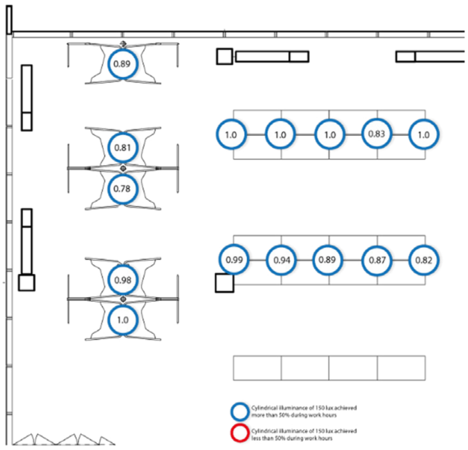

Figure 6. The measured cylindrical illuminance at multiple occupant workstations in a selected zone, showing that workstations receiving illumination above 150 lux for more than 50% of the time.

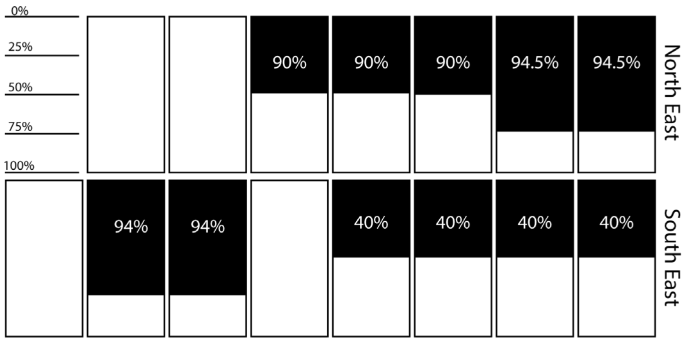

Figure 7. Blind profile showing the percentage of time blinds were closed when the cylindrical illuminance was above 150 lux for more than 50% of working hours.

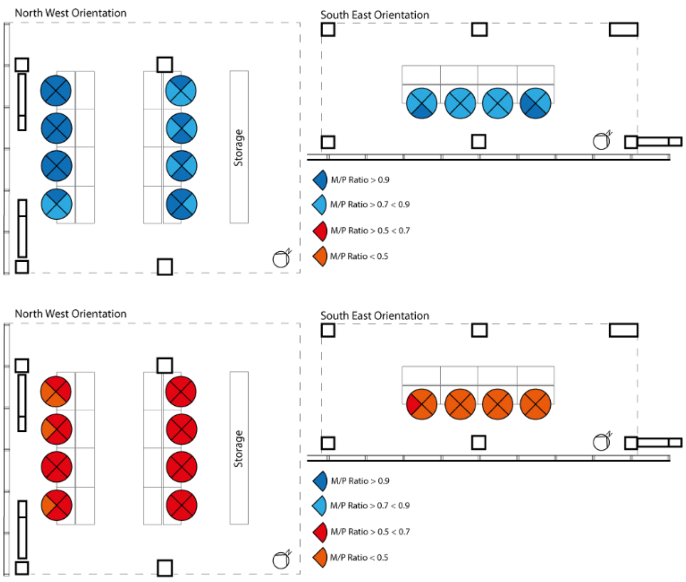

Figure 8. SPD measurements at 12 locations in two different orientations: north-west and south-east. (Top) The M/P ratio under daylight conditions only, showing most locations achieved an M/P > 0.9, however for locations facing south-east, the M/P was largely between >0.7 and <0.9. (Bottom) M/P ratio well below 0.7 indicating that the circadian potential would be from daylighting.

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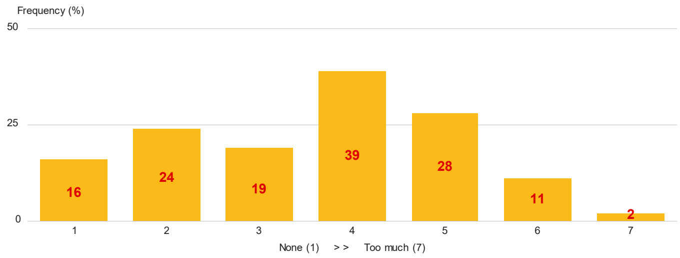

Figure 9. Perceived glare from windows.

Figure 10. A copy of the POE results conducted by Aurecon, showing close to half believed in the importance of personal control over lighting.

alent Melanopic Lux (EML) of 200 lux or more, for at least 75% of workstations (Feature 54 1a). This included on-site verification pre-occupancy. In this case study, the circadian potential was also measured under similar conditions: daylight only (cloudy sky between 11:30 AM to 12:30 PM) and electrical lighting only. Measurements were taken at eye height level (at seating position) at twelve workstations in two areas: one facing north-west and the other south-east. The results indicate that even without electrical lighting, circadian stimulation can be achieved with daylighting under clear to somewhat cloudy conditions for perimeter workstations predominately oriented North, East and/or West (Fig. 8). Workstations oriented south-east typically had a M/P ratio between 0.7 and 0.9 – congruent with solar conditions being less available and having some daylight obstruction from an adjacent building. However, due to sky conditions, the M/P ratio would most likely be higher under clear sky. The M/P ratio under electrical lighting conditions were well below 0.7, which was consistent with the results from their on-site verification. However, this criteria would not be critical since passive lighting is already abundant during typical office hours and is a more energy efficient strategy.

> *"User feedback for fine tuning"*

User perspective

User feedback was collected by Aurecon as part of their POE program using the Building Use Studies (BUS) methodology involving standardised questions about the indoor environment quality (IEQ). This was also carried out in their former office building and was one of the reasons why manual blinds were installed in their new office building. Lighting questions were focused on user satisfaction and comfort towards the perceived brightness from electrical lighting, daylighting from windows and glare. Results

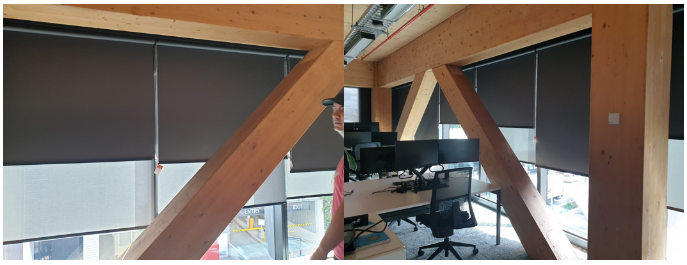

Figure 11. Real outcomes from conducting a POE survey, where glare was reported by a significant number of occupants. Additional blinds were installed with lower VLT (<10%), to deliver a double roller strategy for increase control of daylighting.

showed 70% of occupants were overall satisfied with the indoor lighting conditions, 64% with electrical lighting and, 59% with natural lighting. Significantly, 89% reported glare from windows, with 12% suggesting a high degree of discomfort (Fig. 9 and 46% believing in the importance of personal control over lighting (Fig. 10) These results provided evidence to install additional blinds with lower visible transmittance (VLT < 10%) to allow occupants to completely block off unwanted glare, but still use the existing blinds with higher VLT (>40%) when more daylighting is desired (Fig. 11).

> *"Balance between individual control and energy efficiency"*

Lessons learned

Open plan offices are by far the more challenging environments to conceive energy efficient and visually comfortable indoor lighting. Whilst technologies (occupant sensors and photosensors) can provide better management of both daylighting and electrical lighting systems, and are important components in integrated lighting for energy efficiency, it is difficult to achieve occupant comfort without occupant feedback. Daylight responsive controls provided sufficient daylight illumination and circadian stimulation for workstations located along the perimeter, however, there was a significant number of occupants reporting glare. In sunny climates, issues of glare are prevalent but can be controlled with blind shades. However, direct glare from windows was still visible even when blinds were closed because the VLT was high. The key takeaway is in Aurecon's approach to identify the issues using POE questionnaires and installing additional blinds with lower VLT as a solution for better glare control.

Further information

Wagdy, A., Garcia-Hansen, V., Isoardi, G., & Pham, K. (2019). A parametric method for remapping and calibrating fisheye images for glare analysis. Buildings, 9(10), 219.

Pham, K., Garcia-Hansen, V., Isoardi, G., & Allan, A. (submitted 2021). Open-source hardware and software for in-situ measurements in real contexts: a use case scenario of its usability for lighting research. Energy and Buildings.

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