Lighting in shared spaces to support a sustainable and collaborative workforce

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

AECOM Brisbane promotes sustainable and collaborative work practices using practical lighting solutions

A POE assessment was carried out in a Green Star commercial office building in Brisbane Australia. Lighting strategies were evaluated which included observations of user behaviour and surveys. The combination of occupancy sensors, side-lighting and manual blind shades delivered a pragmatic solution for indoor lighting in shared environment, with room to improve energy efficiency and comfort.

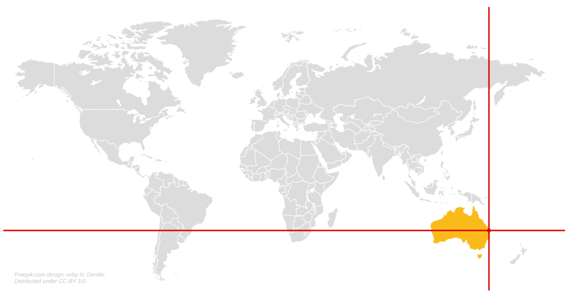
Figure 1. AECOM Brisbane's open plan office located in Brisbane, Australia.

The project

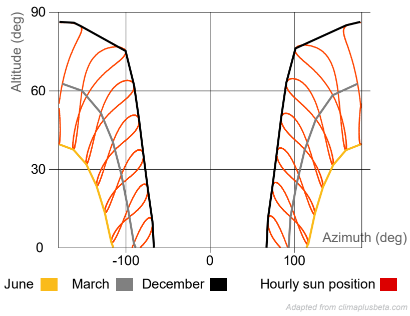
AECOM Brisbane is an awarded Green Star building designed to support sustainable work environments for office workers (Fig. 1 and Fig. 2). Designed by BVN Architects, the 11-storey commercial office building optimizes ambient lighting in a both formal and informal workspaces to promote well-being, productivity, and cross collaboration. Consistent with their core values to find sustainable opportunities, large voids are used to deliver as much daylighting through multiple levels of the open plan office, which can house up to 150 occupants per floor. Timber features recycled from the native Australian Blackbutt tree are highlighted by natural side-lighting, providing a touch of warmth and ambience in the office. Conscious of energy efficiency, occupancy sensors are placed across the office perimeter to maximise electrical lighting savings via vertical glazing. Office workers are able to enjoy the urban city views anywhere within the building with individual control to adjust their local daylighting levels using manual solar blinds shades.

Monitoring

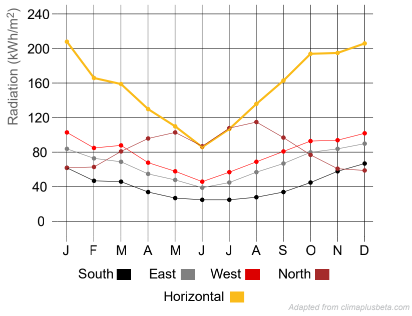
An initial site investigation was conducted on the 22nd of January 2019 and proceeded data collection between the 29th of January 2019 until the 15th of March 2019 (between



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

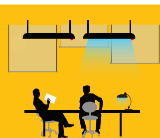


Sun path for
Brisbane, Queensland, Australia



Global horizontal and vertical radiation for
Brisbane, Queensland, Australia

IEA SHC Task 61 Subtask D
Monitored by **Kieu Pham and Veronica Garcia-Hansen**
More info **Prof Veronica Garcia-Hansen,** Queensland University of Technology,
v.garciahansen@qut.edu.au



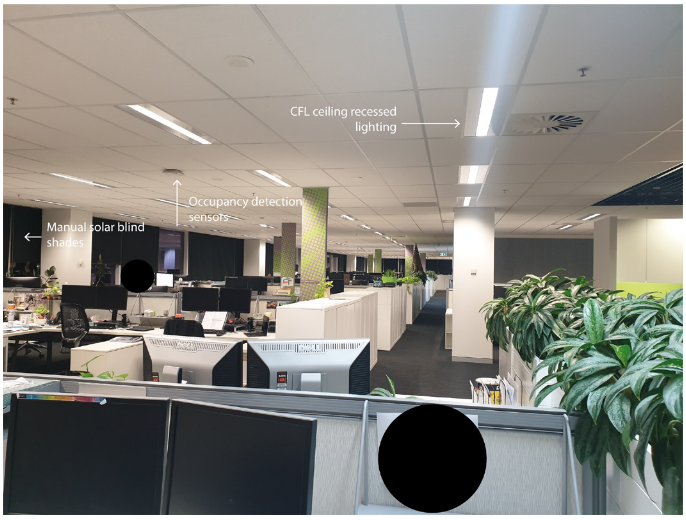


Figure 2. Photo inside AECOM Brisbane showing a portion of the open plan office where occupancy sensors, CFL lighting and manual blind shades are used as part of their lighting system.

Fig. 4. Assessment of the luminous environment and glare sources using a mobile device and micro fish-eye lens.

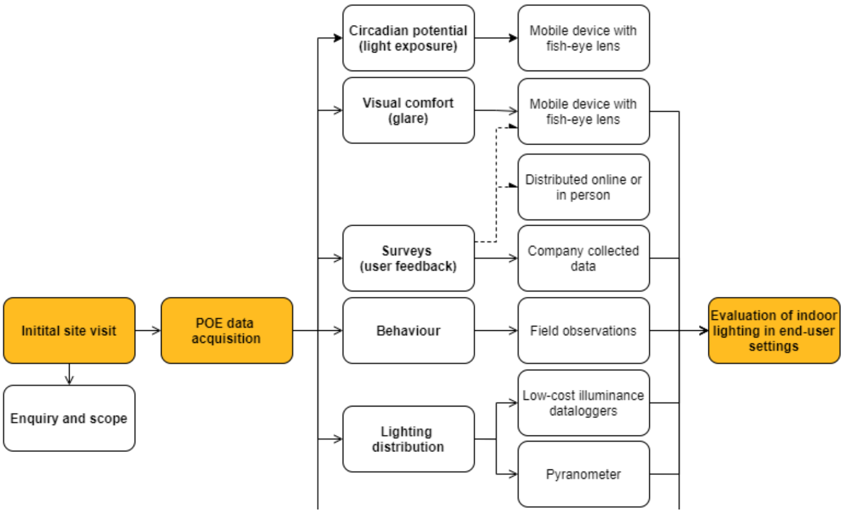


Figure 3. Post-occupancy (POE) framework to collect objective and subjective measures of the indoor lighting environment specific to occupied end-user settings in large open plan office environments.

summer solstice and autumn equinox). Data collection was carried out on a typical floor using a POE framework that 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.

Energy

The electrical lighting system consisted of 28W T5 linear fluorescent luminaires fitted to recessed troffers (LOR > 80% and efficacy of ~60 to 80 lm/W) and occupancy sensors. This was a conscious decision to provide an economic and energy efficient solution based on the available luminaire options at the time. Direct metering was not a target focus during data collection. However, we were informed that future solutions will be to integrate daylight sensing and dimming technologies to reduce the electrical lighting energy consumption.

Photometry

Open plan offices with vertical glazing façades are prone to glare issues, especially in sunny climates. HDR photographs were taken along the perimeter areas of the office where potential glare sources would occur. An android mobile device with a micro fisheye lens mounted on a custom MDF stand was given to occupants to capture their typical viewing position from their workstations.

Open plan offices with vertical glazing façades are prone to glare issues, especially in sunny climates. Glare assessments were carried out at perimeter workstations to identify potential glare sources using an android mobile device with a micro fisheye lens mounted on a custom MDF stand (Fig. 4.). Participants were asked to capture HDR images in their field-of-view facing their typical viewing position at the workstations. Unexpectantly, the DGP and DGI results did not detect glare sources, even though participants reported glare at the time the assessment was made (Fig. 5.). A subsequent survey also showed that 54% of occupants frequently or very frequently experienced glare that can last as briefly as 2 minutes or more than 2 hours (Fig. 6). Evidently, the HDR images were not taken at the right time when glare sources would be present. Considering the limitations to conduct follow-up assessments at the time for this study, asking occupants if they experience

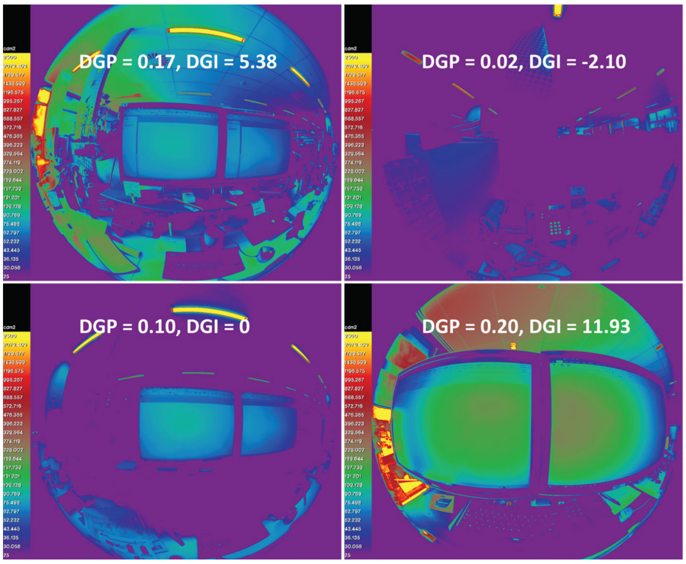


Fig. 5. HDR results of the participants who reported glare using an android mobile device with a fish-eye lens. Unexpectantly, DGP and DGI values were very low, indicating that photographs were taken at the time when glare sources were not present.

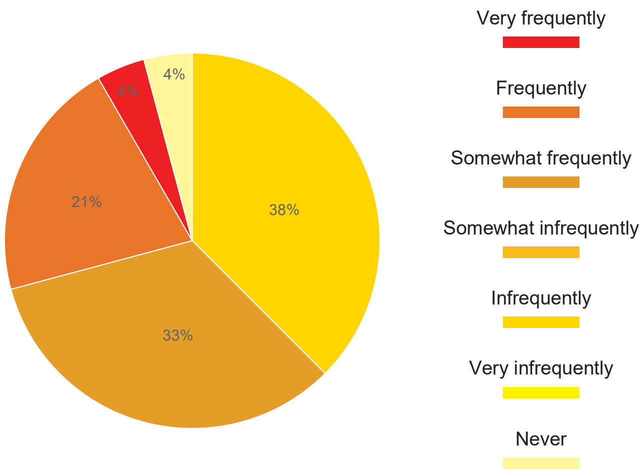


Figure 6. The percentage of occupants reporting glare, showing almost all have had experienced sensations of glare with 54% frequently or very frequently.

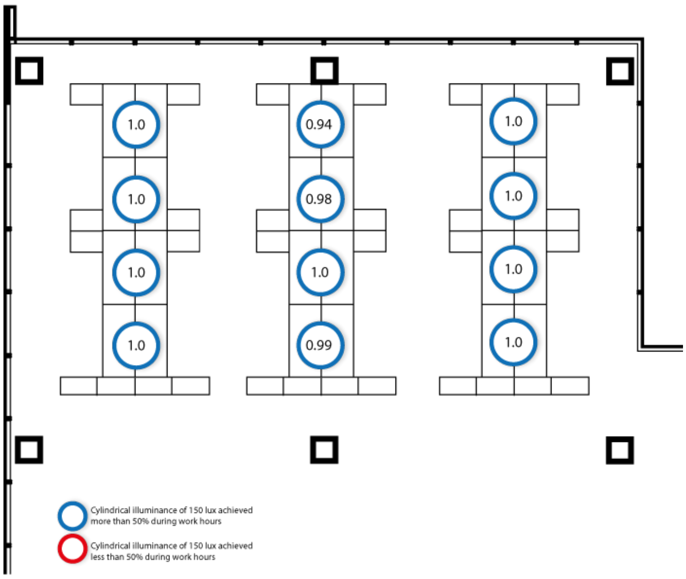


Figure 7. Cylindrical illuminance measured at occupant workstations across a one-day period, showing that sufficient lighting above 150 lux was provided well over 50% of the working period.

glare can still verify visual discomfort issues and warrant follow-up visits to capture additional images at times when occupants would expect glare sources to be present.

However, it is also important to provide sufficient illumination for colour rendering and illumination of faces and objects for communication and face-to-face collaboration. The cylindrical illuminance measures the quantity of illumination of objects. This was measured with low-cost sensors that were mounted at occupant workstations (as close to eye height level – 1.7 m from the finish floor). Continuous measurements of the horizontal and vertical illuminance (from four planar orientations) were recorded across a one-day period between typical work hours (07:00 AM – 05:00 PM). Spectral corrections were applied to minimise measurement error (error uncertainty between 10-25%). A cylindrical illuminance above 150 lux was achieved at all workstations for more than 50% of working hours (Fig. 7).

Circadian potential

Light exposure for circadian stimulation was not a deliberate control strategy. Nevertheless, for sunny climates where daylighting is abundant, this would not be difficult to achieve. Measurements were carried out at workstations facing north-east in the office using a handheld spectrometer. Measurements were recorded in five locations in four vertical directions at 1.2 m from the floor. Two scenarios were considered: melanopic light intensity under daylighting conditions only and the melanopic light intensity under electrical lighting only. Measurements were recorded around 12 noon for daylighting conditions under a semi-cloudy day and at night for electrical lighting. A melanopic/photopic ratio above > 0.9 is considered sufficient and ideal for circadian stimulation which was achieved largely from the vertical side-lighting, where a significant amount of daylighting was provided (Fig. 8).

User perspective

A total of 23 occupants completed a survey about the indoor lighting environment. These questions were focused on their satisfaction with the overall visual environment, colour appearance, views, window size, lighting controls, uniformity, lighting levels and the provision of electrical and natural lighting. A little over half of the occupants were satisfied or very satisfied with the overall visual environment (60.08%), colour appearance (52.17%), outside view (65.22%), light uniformity (60.87%), light levels (60.86%), light uniformity (60.86%) electrical lighting (56.52%) and natural lighting (52.17%). Just less than half were satisfied with the lighting controls (47.83%), whilst well over half were satisfied with the window size (78.26%) (Fig. 9).

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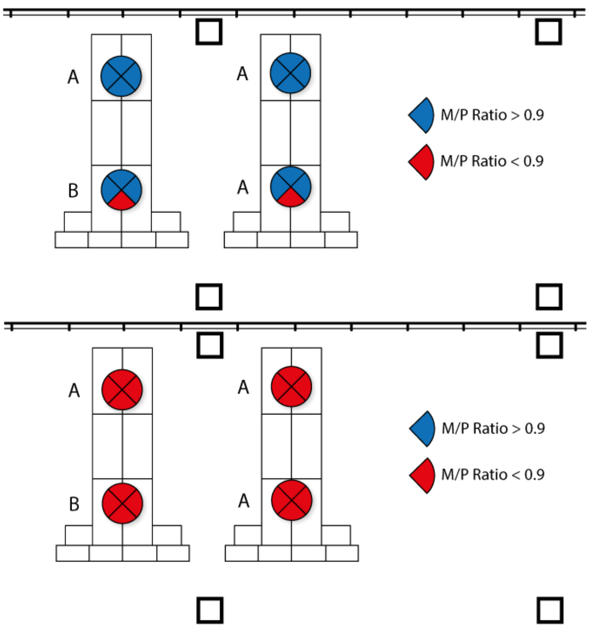

Figure 8. Melanopic/Photopic (M/P) ratios under daylighting conditions (top) and electrical lighting conditions (bottom) for workstations facing north east, showing daylighting via side-lighting provided sufficient circadian stimulation.

Providing user control in open plan office settings can be especially difficult to achieve when occupants are working in shared environments. It is important to provide this since their preferences and comfort levels vary. One way to do this, is to provide manual blind shades to allow occupants to shade blinds closest to their workstations when it best suits them. In Fig. 10, patterns of blind usage in different areas of the office are shown. Whilst there were strong patterns of blind use in the morning and afternoon, the time in which they use it still varied and consistent with the varying patterns of glare occurrences in Fig. 11.

Lessons learned

Open plan offices are shared environments that require thoughtful integrated approaches to achieve multiple objectives: energy efficiency, visual comfort and, occupant satisfaction. There is room to improve the energy efficiency by replacing fluorescent lighting in favour of energy efficient LEDs. Whilst the provision of manual blinds (VLT < 10%) provided individual control of daylighting levels, there are indications to improve lighting controllability and glare.

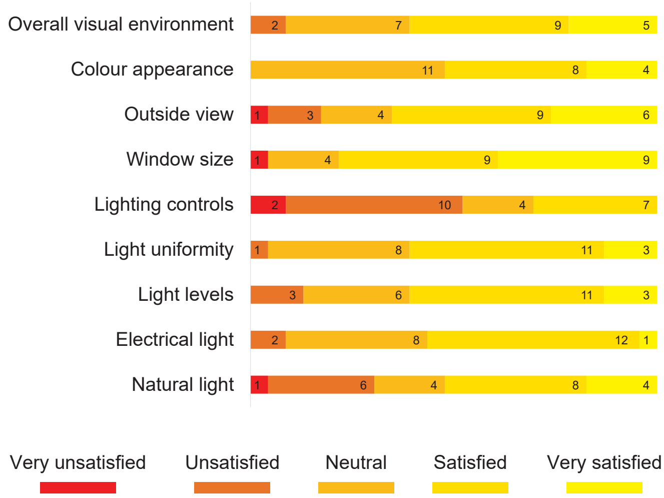

Figure 9. Survey response from 23 occupants about their satisfaction with the indoor lighting environment.

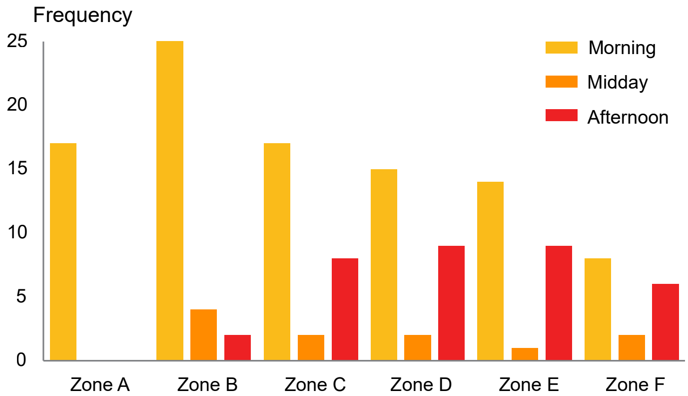

Figure 10. Frequency chart showing occupants having individual preferences to adjust blinds at different times of the day across various zones.

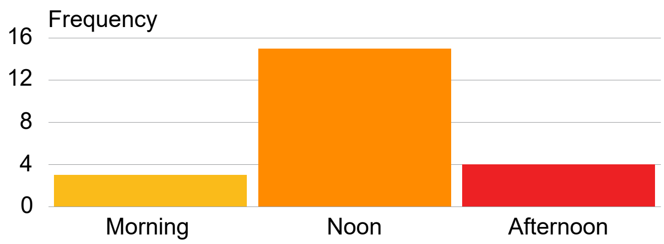

Figure 11. Reports on the occurrence of glare at different times of the day, showing a significant amount occurring in the afternoon.

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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