Enhancing workplace quality in existing buildings with dual-zone shades

SOLAR HEATING & COOLING PROGRAMME
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Indoor shades with an upper daylight zone and lower view zone in a pilot office demonstration in California

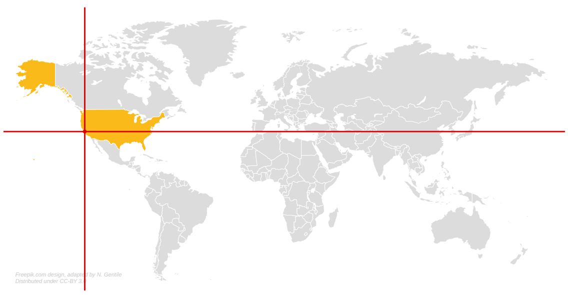
A novel, operable shade left a positive impression on office workers by opening up views to the outdoors and increasing daylight and comfort compared to conventional shades. 80% of occupants were satisfied with the dual-zone shades. Cooling and lighting energy consumption were reduced by 20%.

The project

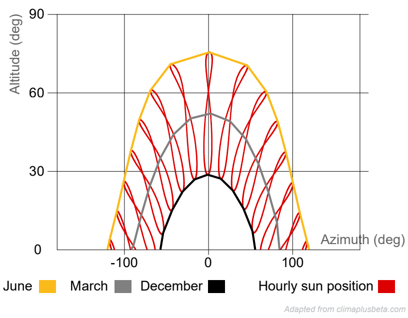
Windows in existing commercial buildings pose a variety of challenges given today's demands for energy efficiency, comfort, and indoor quality in the workplace. Natural daylight fails to penetrate more than a meter or two from the window because blinds or shades are lowered to reduce discomfort, particularly for those sitting next to the window. When shades are lowered, views are obstructed. Novel shading and daylighting attachments can address these challenges by separating the shading attachment into functional zones. In this study, the concept behind a dual-zone, solar control (DZSC) indoor shade is to bring in more daylight through the upper zone and allow unobstructed views through the lower zone. The upper zone consists of inverted, curved, horizontal louvers that are manually or automatically controlled to reflect sunlight up to the ceiling and further from the window. The lower zone consists of a roller shade made of a transparent tinted or metallized reflective film (for additional solar control) that can be raised or lowered manually.

Figure 1. Exterior facade of the monitored commercial office building.

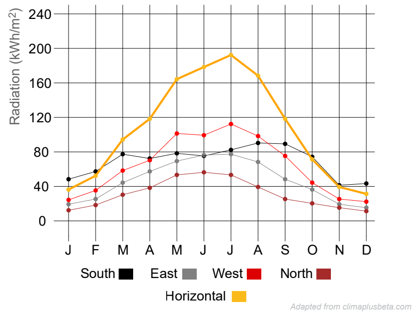
DZSC shades were installed on the seventh floor of a 99.87 km² commercial office building (vintage 1992) in Oakland, California (Fig. 1). The building has single-pane, tinted windows with non-thermally broken, aluminum frames, vertical fabric blinds, and pendant T8 fluorescent dimmable lighting. The workspace consists of 1.68 m high cubicles and a few private offices at the window. The climate is moderate and sunny and there are spectacular, sweeping views of the San Francisco Bay and low surrounding hills.



Location: Oakland, California, USA
37.80° N, 122.27° W



Sun path for
Oakland, California, USA



Global horizontal and vertical radiation for
Oakland, California, USA

IEA SHC Task 61 Subtask D

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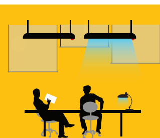

Figure 2. Indoor view of upper and lower zones of the DZSC shade.

Figure 3. Indoor view of the DZSC shade in the open plan work area.

Monitoring

A six-month, on-site evaluation of the dual-zone shades included surveys of occupant comfort and satisfaction and recording the position of the existing and new shades every two weeks (Fig. 2-3). Several different configurations of the DZSC shade were evaluated: manual ("man") or automated ("auto") control of the white upper blind and manual control of the grey-grey (GG) tinted or grey-silver (GS) reflective lower shade.

A separate six-month, monitored evaluation (November 21 to June 19) was conducted in the Advanced Windows Testbed at the Lawrence Berkeley National Laboratory (LBNL), Berkeley, California. This facility consists of three side-by-side, 3.05 m wide by 4.57 m deep, private, unoccupied office test rooms with large-area, south-facing, dual-pane, low-emittance windows. Two types of reference shades were installed: a light grey fabric roller shade (3% openness factor; lowered to 0.64 m above the floor) or a fully-lowered, white Venetian blind with slat angles set to block direct sun. The DZSC shades had the same configurations as at the Oakland site. The fluorescent dimming level (20-100% power output, standby power of 30 W) was determined by the light level at 3.8 m from the window from 8 AM to 6 PM with a setpoint of 300 lx. Cooling loads were measured directly and converted to cooling energy use with a coefficient of performance of 3.0. Measurements of the three rooms were made simultaneously under the same weather conditions.

Energy

When compared to the reference roller shade in the LBNL testbed (Fig. 4), the auto-GG shade reduced daily cooling and lighting energy use in the south-facing perimeter office zone by 20% (number of test days, n=10). Manual control for the tinted man-GG (n=5) and reflective man-GS cases (n=4) provided savings of 8% and 14%, respectively. Savings are given for the summer period with the DZSC shades fully lowered. When compared to the Venetian blind, cooling and lighting energy use was significantly higher with the DZSC shade. The white blind was able to

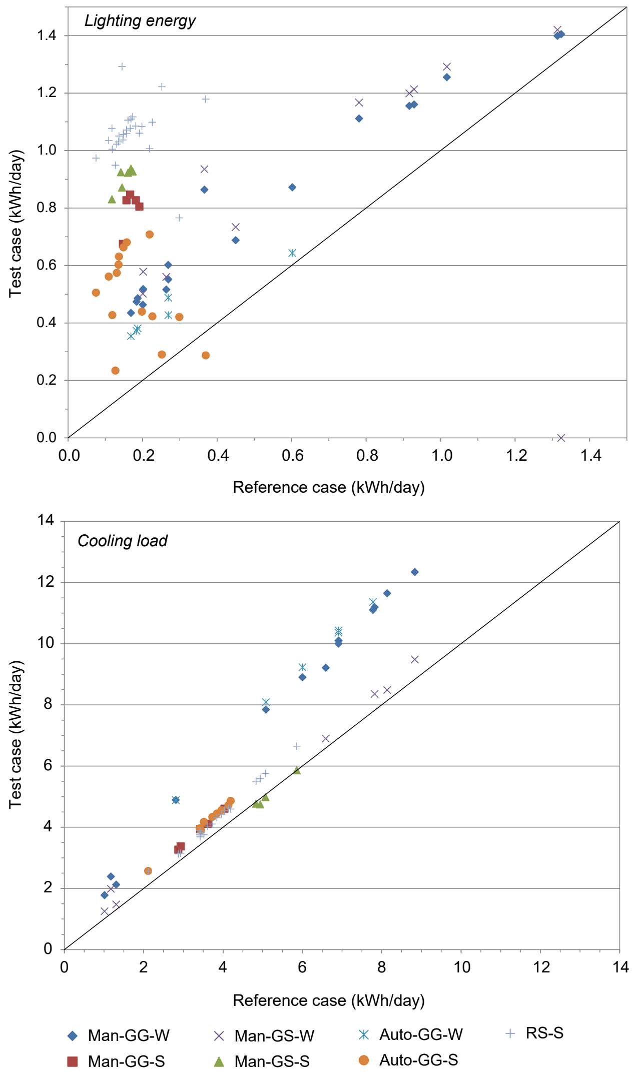

Figure 4. Daily lighting energy use (above) and cooling load (below) due to the window and shading system (kWh/day) for the reference Venetian blind (x-axis) and test shade (y-axis) conditions. W=winter, S=summer data, Man=manual, auto=automated, GG=tinted, GS=reflective, RS=roller shade.

admit more daylight and was more effective at reflecting sunlight back to the outdoors.

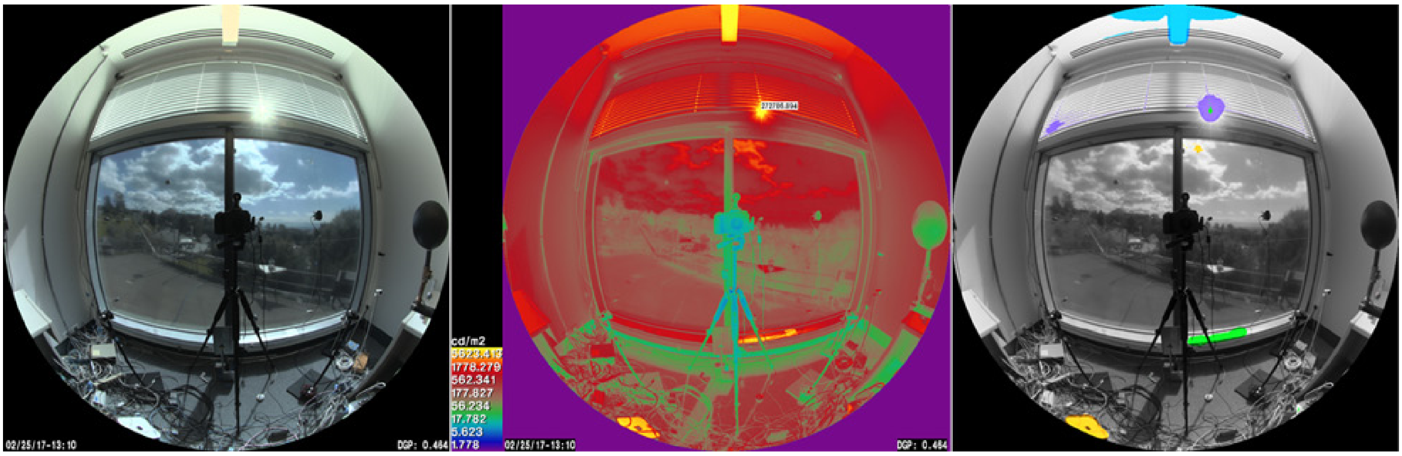

Figure 5. Left to right: Photograph, HDR image, glare sources for sunny winter day at the LBNL testbed. Glare was rated as "intolerable" due to sunlight through the man-GG upper blind when facing the window. Automated slat adjustments can prevent this from occurring.

Figure 6. Outdoor view of the roller shade, auto-GG shade, and Venetian blind (from left to right) in the LBNL Advanced Windows Testbed, Berkeley, California.

Photometry

High dynamic range imaging was used in the LBNL testbed (Fig. 5-6) to measure discomfort glare during winter and summer periods. For seated view positions parallel to the window, the DZSC and roller shades kept discomfort glare below "noticeable" levels (Class A) for 95% of the day while for the Venetian blind, discomfort glare exceeded "perceptible" to "disturbing" levels for most days (Class B-D). For view positions where the sun orb is in the field of view, glare levels are estimated to be "disturbing" to "intolerable" for both the grey-grey and grey-silver films (visible transmittance, Tvis, of 0.07 and 0.02, respectively).

During the winter on sunny days, the DZSC shade and Venetian blind provided adequate daylight for 85-98% of the day while on cloudy days, it was 55-100% of the day (for auto-GG, the upper blind was raised on cloudy days). During the summer, the DZSC shade and Venetian blind provided adequate daylight for 93-100% of the day while the roller shade provided daylight for 55-85% of the day under both cloudy and sunny conditions. Adequate daylight was assessed by computing the percentage of time from 8 AM to 6 PM when workplane illuminance levels were within a range of 100-2000 lx at a distance of 2.29 m from the window.

Circadian potential

Bright light levels with the proper spectral distribution can support alertness in the workplace. Based on photopic daylight illuminance levels measured in the LBNL testbed, equivalent melanopic lux (EML) levels were likely reached for the majority of the day in the case of the Venetian blind, perhaps for the DZSC shade, but is unlikely for the densely woven, lowered roller shade. EML levels were not evaluated in this study.

User perspective

Survey responses at the Oakland site indicated that the DZSC shades provided a more comfortable and higher quality visual environment (i.e., less glare, more view) compared to the existing vertical blinds.

Eighty percent of survey respondents indicated that they preferred the DZSC shade over the existing shade and thought that the new shade somewhat enhanced their ability to get their job done.

More occupants indicated that they liked their view somewhat or very much after installation of the DZSC shade (8 before the DZSC installation, 12 after, out of 21 total responses). Sixteen of the survey respondents sat next to the window with the remaining respondents seated further from the window with partial or fully blocked views to the windows (cubicles had both opaque and transparent walls). When standing in the open plan area, the upper DZSC blinds blocked views to the sky while the walls of the cubicles blocked lower outdoor views.

Glare discomfort was reduced from just below "uncomfortable" to "acceptable" levels. However, occupants commented on glare from daylight coming through the slats of the DZSC upper blind, from the window sill when sunlight was reflected onto the sill from the GS shade, and from reflected glare on computer screens. When partially lowered, reflected or transmitted sunlight and brightness contrasts between shaded and unshaded portions of the window caused glare for some occupants. Manual over-

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Figure 7. Indoor view of the DZSC GG tinted shade when fully lowered.

ride was provided with automation of the upper blind, but control of the blinds was grouped to lower the cost of installation, so comfort control per individual preferences was constrained even in the private offices.

Light levels were judged to be the same as before, so daylight quality (i.e., perceived room cavity brightness, absence of gloom) was not perceived to have been improved with the upper daylight system of the DZSC shade in the open plan or private office areas. This may in part have to do with the lack of sunlight redirection provided by the slats, since matte white slats (as opposed to the silvered reflective slats) provide soft diffusion of reflected sunlight towards the ceiling (Fig. 7). The dimmed output from the indirect-direct, pendant, fluorescent lighting system, which was not monitored in this study, also affects perceived room cavity brightness. Some open plan offices with the DZSC shades were also immediately adjacent to open plan areas with the existing shades, confounding assessments.

Rating of temperature conditions during warm or hot weather was improved. The surveys were issued May 30th (three months after installation) prior to the hot period, which occurs from summer through late autumn. In offices where the existing vertical blind had an opaque backing added to the fabric slats to reduce discomfort due to intense solar gains, occupants commented that the room was more comfortable with the existing blinds compared to the GS or GG films. Other occupants commented that thermal comfort was better but conditions were still too hot when the weather was warm. Heat could be felt

Figure 8. Outdoor view of the upper blinds (dark grey) and lower reflective shades (white) with the lefthand lower shade partially raised.

coming out of the bottom and sides of the DZSC shades. During cool or cold weather, temperature conditions were deemed "just right".

Some objected to the non-uniform, shiny, outdoor appearance of the reflective GS film (Fig. 8). Aesthetics will need to be judged on a case-by-case basis. Five out of the 21 survey respondents (and 51 total occupants) expressed dissatisfaction with automated control. This may be due in part because manual override of the shade was not on a personal level as mentioned above or because of occasional erroneous control.

Lessons learned

The DZSC shade was satisfactory to 80% of survey respondents despite a number of comments concerning visual and thermal discomfort. The lower view zone provided unobstructed views to the outdoors, which was positively received, but discomfort occurred during sunny periods for some seated next to the window. The upper daylighting zone did its job brightening the ceiling near the window but did not increase perceived light levels deeper in the open plan area. As a retrofit measure for existing buildings with inefficient windows (i.e., single pane, tinted windows with no low-emittance coatings), the DZSC shade offers a user-acceptable solution that balances difficult trade-offs between glare and solar control versus daylight and views. The shade would be most applicable to south-, east-, and west-facing windows, in rooms with light-colored walls and ceilings, and work areas where the workspace views are parallel to the window.

Further information

Lee, E.S. et al. *Dual-Zone Solar Control Indoor Shade: Demonstration at the Ronald V. Dellums Federal Building and U.S. Courthouse and the Lawrence Berkeley National Laboratory Advanced Windows Testbed*, Berkeley, California, Green Proving Ground Report, January 2018. https://eta-publications.lbl.gov/sites/default/files/lbnl_dual-zone_shades_lbnl2001196.pdf

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