Advanced daylighting

Over the last decade building designers have been returning to the centuries-old practice of lighting indoor spaces using natural daylight. Natural light improves occupant morale and reduces electricity use. While building energy codes now require basic daylighting controls on lights adjacent to windows, designers can utilize more advanced approaches to fully daylight buildings. Advanced daylighting strategies begin with the basics: glazing placement, size, and properties. Glare could be controlled using shades and overhangs to ensure occupants don't get too much direct light. To ensure energy savings and occupant comfort, complete a daylight analysis early in the design while changes can be made to the building architecture.

Once a building is naturally lit, controls can be connected to electric lighting to drastically reduce lighting energy. Good lighting control design is more than simply selecting a photosensor. It should include: setting a target light level, deciding between continuous or stepped dimming, and creating zones of light fixtures to control. Commissioning a daylighting system is an important final step that will often nearly double the savings achieved.

ADVANCED DAYLIGHTING AT 749 UNIVERSITY ROW

The building at 749 University Row is a highly energy efficient, multi-tenant office building constructed in Madison, Wisconsin in 2013. Maximizing use of natural daylight was a key design consideration and included naturally-lit common areas and tenant spaces with daylighting controls. The tall windows along the perimeter of the building have a high visible transmittance of 54 percent while maintaining low solar heat gain of 28 percent. The windows are designed to meet a relatively low window to wall ratio of 38 percent, which puts greater importance on window placement. The height to the top of the window is the primary driver of the depth that daylight will penetrate, so window sill height and total height were kept as high as possible while not obstructing employees' view out the windows. Although it may seem like more glazing will help maximize use of natural daylight, it oftentimes just adds more glare. To control glare tenants pull their shades resulting is less daylight and views and more heating and cooling loads.

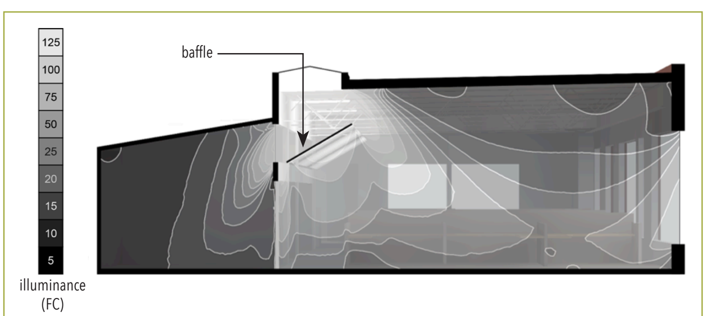

Figure 1: Daylight analysis of Seventhwave space showing increased light distribution

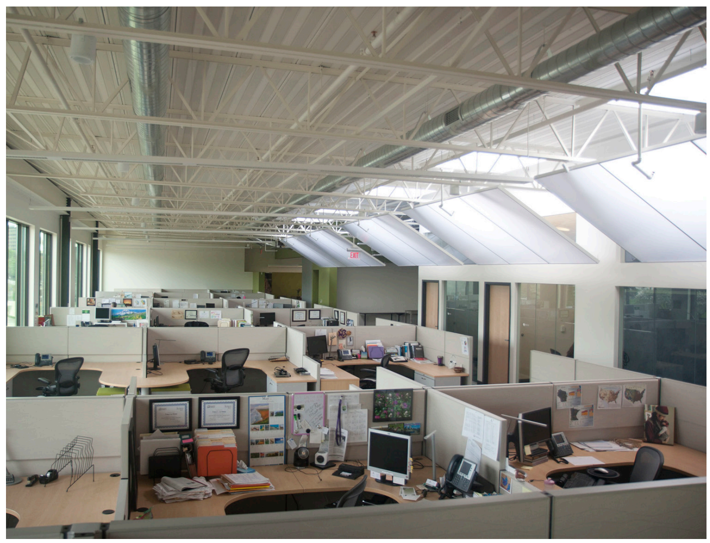
Figure 2: Seventhwave's skylight and baffle design

Seventhwave, one of the tenants, implemented several advanced daylighting strategies in order to bring natural light deep into its office space. Strategies that bring natural light further into the space include: an open ceiling (with 13 feet to the structural deck), low walls (42 inches high) between office cubicles, and skylights and baffles. The design and placement of the skylights and baffles seen on the top right side of Figure 2 was analyzed using DIVA, a daylight analysis software, to optimize the amount of natural light brought into the third row of cubicles and to bounce daylight into the conference rooms. The baffles

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ENERGY SAVINGS FROM DAYLIGHTING IN SEVENTHWAVE'S SPACE			
Lighting power reduction from installed	Annual lighting energy saving	Annual energy cost saving	Daylighting incentive for 749 University Row building
88%	17,000 kWh	$1,500	$2,000

have a visible transmittance of only 25 percent, making them highly reflective, bouncing more light into the conference rooms. The baffles both increase the light distribution of the skylights and eliminate hot spots under the skylights (see Figure 1). The skylights also reduce the contrast ratio from the northeast windows, reducing glare.

Reducing glare was also necessary on the southeast and southwest façade where it would be a problem the majority of mid-afternoons in summer and mid-mornings in winter. To reduce glare, the design team could have selected glass with a lower visible transmittance, but this would also decreased the amount and quality of natural daylight that entered the space. For this reason, the design team selected glass with a high visible transmittance and chose to control glare using other methods. Window overhangs were installed over these windows on the exterior of the building and roller shades that occupants could adjust were installed on the interior windows. Since occupants often leave roller shades down even when glare isn't a problem, it was important to choose a shade that wasn't opaque. Seventhwave chose shades that were both light colored and had a 5 percent open weave that allows significant diffuse daylight into the space when the shades are pulled.

LIGHTING POWER DENSITY REDUCTIONS

1 W/sf
IECC 2009 code required lighting power density

0.72 W/sf
Installed lighting power density

0.52 W/sf
Tuned lighting power density

0.08 W/sf
Operating lighting power density

Because its space has a lot of natural light, Seventhwave chose aggressive parameters to control the electric lighting. When enough daylight is available, the continuous dimming electric light fixtures are completely off.

Seventhwave was particularly aggressive with photosensor-controlled target light levels. Based on occupant feedback, it selected a target light level of 17 foot-candles in the open office, 20 foot-candles in the private offices, and 30 foot-candles in conference rooms (below IES target levels for an office).

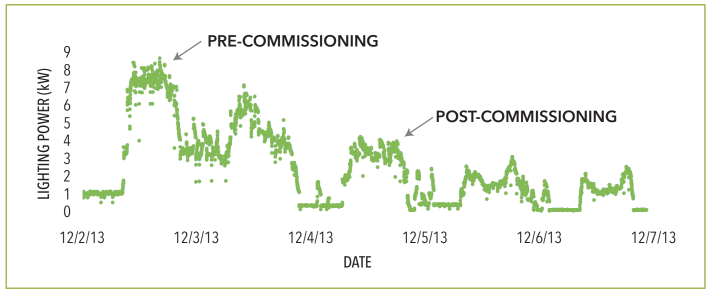

Figure 3: Monitored data showing lighting power before and after commissioning

Commissioning the daylighting controls is critical to achieving the full potential of any daylighting strategy. Figure 3 shows measured lighting power in Seventhwave's space before and after commissioning the daylight controls. Commissioning the controls cut the lighting power in half. Seventhwave chose a wireless daylight sensor that could be moved around to make commissioning easier. The lights were also digitally addressable, so during commissioning the sensor to light relationships could be fully customized. Since the commissioning was completed, the average operating lighting power density is 0.08 W/sf, an 88 percent reduction over installed lighting power density. Seventhwave also has occupancy sensors throughout the space, so not all the lighting power reduction is a result of daylighting.

COST OF DAYLIGHTING EQUIPMENT FOR SEVENTHWAVE'S SPACE		
DAYLIGHTING EQUIPMENT	COST	ADDITIONAL COMMENTS
Skylights	$27,000	~$270/sf of skylight
Daylight controls	$13,000	~$1.30/sf daylit space
Addressable ballasts with dimming capability	$67/ballast	Lutron's suggested retail price
Daylight commissioning	$0	Commissioning was included in cost of system, but typical cost is ~$0.10/sf daylit space
Light shades with a 5% open weave	$2,000	Same price as darker shades with a smaller open weave

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MAKING DAYLIGHTING WORK

- Perform daylight analysis in conjunction with window placement and sizing.
- Orient light fixtures parallel to windows.
- Install automatic instead of manual daylighting controls for more savings because occupants may feel uncomfortable turning lights off if they are unsure how their colleagues will react.
- Use continuous dimming instead of stepped dimming for higher occupant comfort since light level will remain more constant. If stepped dimming is used, deadband should be several minutes to improve occupant comfort.
- Use open loop daylighting for a simpler and cheaper daylighting option in spaces like corridors where light level is not as critical. This involves using one outside photosensor to control lights in a space, and can offset some of the cost of advanced daylighting controls in more critical spaces.
- Use light, reflective (40 percent) colors and finishes in daylit areas
- Set target light levels in the space using: design specifications, the IES handbook, or occupant or facility manager feedback. Tune to design light level plus lumen depreciation.
- Control ambient lights within a distance of 1.5 times the window head height from windows using a photosensor.
- Place photosensors over a workplace to see reflective, representative spaces. Photosensors should not see direct sunlight, as that will cause abrupt changes in electric light levels.
- Calibrate the daylight system after furniture and occupants are in the space. If photosensors were placed before furniture placement was determined, placement should be reconsidered.

OTHER RESOURCES

[1] P. Boyce, Daylight Dividends Program, Lighting Research Center, 2004.

[2] Hackel, S., & Schuetter, S. (2013). Commissioning for optimal savings from daylight controls. www.seventhwave.org/mndaylighting

[3] Daylighting guidance. (2015). www.seventhwave.org/daylighting

[4] Rob Guglielmetti, Shanti Pless, and Paul Torcellini. Fourth National Conference of IBPSA-USA, 2010, pp. 301-309

[5] Hackel, S., & Schuetter, S. (2013). Best Practices for Commissioning Automatic Daylighting Controls, ASHRAE Journal.