SUN, SKY BRIGHTNESS, AND GLOW: MAKING THE MOST OF DAYLIGHT

JEFF GOLDBERG/ESTO, COURTESY CARRIER JOHNSON+CULTURE

LEARNING OBJECTIVES

After reading this article, you should be able to:

- **DISCUSS the benefits and ideal kinds of daylighting illumination desired for such interiors as workplaces, libraries, and museums.**
- **DESCRIBE the types of enclosure technologies and whole-building design approaches for maximizing beneficial daylighting.**
- **LIST techniques for improving daylighting performance.**
- **COMPARE the methods or materials commonly used in daylighting applications.**

The Tidewater Joint-Use Library, Virginia Beach, Va., has an angled "daylight harvester" that runs its length to maximize available sunlight.

To some project teams, "daylighting" means using glass area to admit direct sunlight, period. Yet there are better approaches to illuminating building interiors. Often, the sun's direct rays are the last thing you need for effective daylighting. Sunlight comes with high solar heat gain—measured as solar heat gain coefficient (SHGC) for various types of glazing and translucent materials—and can lead to glare, occupant thermal discomfort, and material degradation caused by ultraviolet (UV) light.

Building occupants and owners want useful, uniform light, not high-contrast or high-heat sources, according to surveys like the seminal study led by the University of Washington (https://tinyurl.com/zhpx7h3). That's why controlled and redirected sunlight almost always provides the best approach, while direct rays may be counted among the least desirable techniques. Building surfaces and enclosures

‘THE BEST APPROACH FOR DAYLIGHTING IS TO DELIVER GENTLE, EVEN ILLUMINATION THROUGHOUT A SPACE. THIS DIFFUSED, COMFORTABLE DAYLIGHT IS THE BEST FOR VISUAL NEEDS AND FOR MINIMIZING ENERGY USE.’

— LAYNG PEW, AIA, WXY ARCHITECTURE + URBAN DESIGN

receiving direct sunlight need solar control systems, including shading devices such as overhangs and fins that may be opaque or translucent, solid or louvered, according to the Best Practices Manual published by the Collaborative for High Performance Schools. Canopies, window films, and insulated glazing units (IGUs) with internal louvers may also be required. Façades and areas facing north, on the other hand, need ways to maximize daylight harvest.

“The best approach for daylighting is to deliver gentle, even illumination throughout a space. This diffused, comfortable daylight is the best for visual needs and for minimizing energy use,” says Layng Pew, AIA, a Principal with WXY Architecture + Urban Design, New York. “Design that maximizes the smart use of daylight has a multitude of benefits. Energy savings and health benefits are both achievable.” Natural light, with the full visible light spectrum, has been shown to increase alertness and productivity, says Pew. Views to the outdoors also improve mood and possibly health. Seminal research by Roger Ulrich at Texas A&M University reported an 8.5% advantage in recovery for patients in rooms with windows.

Daylight is essential to sustainable design ratings as well as health certifications, notably the WELL Building Standard. Light helps “minimize disruption to the body’s circadian rhythm,” says the International Well Building Institute, which spells out requirements for window performance and design, light output and lighting controls, and task-appropriate illumination levels to improve energy, mood, and productivity.

The effectiveness of daylighting strategies should be evaluated on the basis of human usefulness, energy efficiency, and other factors, says Christopher Alt, RA, Principal and Technical Leader with architecture firm Studio Ma, Phoenix. Alt’s team uses daylight simulation in design-phase project modeling in order to assess spatial illuminance qualities, visibility and glare, thermal considerations, and the protection of building contents. “The 3D simulations and analyses are especially important in our many museum and cultural building projects, including some in desert climates, where artifact protection is of paramount concern,” says Alt. Underlying photometrics and daylight modeling are highly effective in the early design phases to assess a range of project goals, including:

- Uniform light distribution
- Low glare
- Reduction of energy costs
- Overall cost effectiveness
- Safety and security issues
- Maintenance requirements

Controlled daylighting is historically elemental to the design of museums, yet recently some cultural institutions have erred on the side of using more artificial illumination, including halogen and LED sources, and less natural light.

To renovate a 1990 commercial building in Boston for Columbia Property Trust, design firm Dyer Brown opened up the northwest-facing lobby with a floor-to-ceiling, point-supported glazing system and high-reflectance, specular wall finishes.

DARRIN HUNTER

SPECIAL CASES FOR DAYLIGHTING

Experts in museum design from Cooper Robertson encourage expanded use of controlled daylight for gallery spaces through careful analysis and the application of novel building tech-

NIC LEHOUX, COURTESY COOPER ROBERTSON

nologies that "preserve safe light levels and environmental conditions for the art," says Scott Newman, FAIA, a Partner. "Daylighting reduces the need for artificial illumination, allows works to be shown in the full light spectrum for which they were conceived, and accentuates the three-dimensionality of sculpture," he adds.

Newman describes the design of the new Whitney Museum of American Art, in Manhattan. For its extensive use of solar illumination, Cooper Robertson and design architect Renzo Piano Building Workshop used fritted glass edges, interior shades activated by photosensors, and insulating glass units with a polyvinyl butyral (PVB) interlayer. The façade designs respond to the building's position or solar orientation. The design also admits light to wash interior walls and illuminate display areas.

At the Florence (S.C.) County Museum, controlled natural light illuminates the second-floor galleries through filtered clerestories and light scoops, says Newman.

Whether for museums or any other use, positioning of openings is critical to the effectiveness of daylighting, according to Gregg D. Ander, FAIA, of Southern California Edison. "The higher the window head height, the deeper into the space the daylight can penetrate," writes Ander in the Whole Building Design Guide.

Openings "should ideally be composed of two discrete components: a daylight window and a view window," Ander writes. In a typical space, the daylight window's sill should be 7½ feet above the finished floor, with a high visible light transmission (VLT) of 50–75%. The windows for occupant view should be located below the daylight openings, with a lower VLT.

For some building types, the view windows often are beside the point. That's one reason Studio Ma Principal Christiana Moss, AIA, often advocates for clerestory windows and other fenestration concepts with high sill heights ideal for lighting museums and libraries. "For both qualitative and quantitative reasons, we keep going back to clerestory in our cultural and institutional designs," says Moss. "For the renovation of the Yuma Heritage Library, we added four double-height structures to serve as light monitors for the one-story Carnegie town library, a daylighting strategy that transformed the scale and quality of the user experience."

Other products and assemblies used to admit tempered, useful solar illumination for daylighting include view windows, high sidelights with light shelves, wall-wash toplighting, central and patterned toplighting, linear toplighting, and tubular skylights.

Skylights, roof windows, and other forms of toplighting are highly effective for internal light propagation, but they raise similar questions about undesirable hotspots, glare, and interior wear, says Kevin Krumdieck, AIA, LEED AP, Principal with Carrier Johnson + Culture. "To prevent unwanted heating or over-illumination, we assess the skylight orientation (north is preferred), the roof slope, and the skylight size and spacing to distribute the daylight well, while controlling heat gain and glare," says Krumdieck. In some projects, the firm uses solar panels integrated with sunshade elements to mitigate heat from high-angle sun.

For office buildings and workplace interiors, north light is a valuable asset, says Brent D. Zeigler, AIA, IIDA, President and Director of Design with Dyer Brown Architects, Boston. "Sunlight coming from the west, and the setting sun, can be tough on open workspaces. It can be hot, with long shadows and too much glare on monitors," he says. "Morning light from the southeast

To daylight the new Whitney Museum of American Art, Cooper Robertson used fritted glass edges, interior shades activated by photosensors, and IGUs with PVB interlayers to illuminate display areas.


BILL TIMMERMAN, COURTESY STUDIO MA

Studio Ma added double-height structures, called "light monitors," to enhance daylighting in the Yuma (Ariz.) Heritage Library.

can have a wonderful visual quality, and in the winter months this low-angled sunlight helps warm spaces."

Building Teams should begin workplace design analysis by quantifying solar availability and comparing it with interior daylight effectiveness and need. For the Boston office interiors of global engineering firm Arup, Dyer Brown determined that it should locate most open workspaces on the north side of the space, so that those areas would receive ample diffused lighting. The design team positioned a key shared space—Arup's new large, collaborative pantry—at the building's eastern perimeter, where it takes advantage of morning light and receives more brightness throughout the day.

TRY ADDING TRANSLUCENCY, ACTIVE GLAZING TO THE MIX

Daylight tuning is also accomplished through the use of varied fenestration materials, including glass, polycarbonate, composites and "sandwich" products, and advanced active glazings.

Active products include electrochromic glazing, although the term "active" may also be used to describe sensor-controlled shades and automatic dimming sensors.

Active approaches tend to make buildings more adaptable to variable sky conditions, seasonal weather changes, and occupant needs, says Josh Battles, Manager of Architectural Solutions with manufacturer SageGlass. "Electrochromic technology means the glass is able to tint in accordance with the sun's position and intensity to control sunlight, heat gain, and glare," he says. "By letting sunlight in on cool days and blocking it on hot days, the technology reduces energy demand, while increasing occupant comfort and well-being."

New applications of electrochromic glazing include glass panels with multiple tint zones, says Battles, to help reduce transmission through lower-height window areas causing glare, or areas closer to the ceiling plane that create excessive brightness during the day. Another tool is called dynamic tinting, an application of smart controls that tracks the sun to allow for customized light-zoning strategies.

The recent addition to Colorado State University's 1964 Morgan Library, in Fort Collins, was conceived to add seating, computing resources, and study space. The school's administrators wanted a modern glass cube to express their safe, open campus while also showcasing sustainability and efficiency. "In Colorado, the western sun is extremely harsh late in the day, making the glare and heat gain on the west façade very hard to mitigate," says Matt Edmonds, Project Manager with the facility's architect, Studiotrope. After considering shades, louvers, and a temperature-based thermochromic glazing, the project team selected electronically tintable dynamic glass that can be darkened either manually or automatically.

The electrochomic active glass covers the Morgan Library addition's two-story western curtain wall, including on operable and egress sections. The system is zoned for the upper and lower floors, allowing for separate control of each area, as well as activation by exterior photosensors, with a manual override.

Other approaches to daylighting glass are also possible. For its Scottsdale Museum of the West, the project team employed a 1.5-inch-thick IGU with spectrally selective, low-emissivity (low-e) coatings and a solar-absorbing polyvinyl butyral interlayer. PVB is an effective solar-control layer for laminated glass that allows high visible light transmission—up to 75%—while also affording structural integrity, sound abatement, and weather protection to the glazing assemblies, says Studio Ma's Alt. It also reduced energy use 38% compared to national averages of energy use index. (EUI is the ratio of energy consumed, in Btu, within a building divided by its total square footage.)

The team for several Connecticut elementary schools selected glass enclosure systems to allow for double-height zones clad in glass for lobbies and libraries, as well as daylight openings to ease navigation and inspire learning.

At the Columbus Family Academy in New Haven, windows at the ends of each hallway allow for easy orientation in the space, according to architect Svigals + Partners. Every classroom

The design for a sanitation garage in Manhattan employed 2,600 custom perforated metal vertical sunshades to mitigate solar heat gain and glare and block vehicle headlights.

has windows to the outside and many have clerestory windows to maximize daylight penetration.

Similar ideas inform the new Sandy Hook School in Newtown, Conn., with its large windows and soaring central lobby of colored glass panels and metal tree shapes. "To make the concept work best, we designed the building and site for optimal daylighting in the fall, winter, and spring," says Julia McFadden, AIA, Project Architect and Associate Principal with Svigals + Partners. The firm specified IGUs and framing designs to minimize thermal bridging and reduce unwanted solar heat gain. Two kinds of glass coatings—one for north-facing windows and another for east, west, and south orientations—provide a neutral appearance and low reflectivity, but with high VLT to increase daylighting efficacy. "For the classroom wings, colorful vertical fins help block direct sun," says McFadden.

For school projects like these, daylighting and outdoor views are central to creating a supportive, inspiring educational experience, says McFadden, helping students become more aware of their connection to nature and their surroundings. "The use of glass helps students connect to the natural beauty of the site, and also allows lots of sunlight and views that help make schools more nurturing and healthy," she says. "Colored daylight splashing across the lobby adds a warm and inspiring touch."

GLOW AND LUMINANCE

Translucency is another critical ally in daylighting applications, one that may be underutilized. It is especially valuable in sunny, hot climates, but can be effective in all climate zones. For example, translucent fenestration made with fiberglass, fiber-reinforced polymer (FRP) or polycarbonate facers, and leading-edge translucent aerogel insulation have measured a U-value of 0.05 and insulating efficacy of up to R-20. As for the daylighting, the illumination is diffused, glare-free, and softened, with VLTs from 5% up to 50%, depending on the insulation selected. In other cases, insulation such as fiberglass batts or an air gap, or both, can be used in place of aerogels.

For an adaptive reuse of a commercial box building into the high-end, natural wood-paneled interiors of 1060 Redwood Office Building in Mill Valley, Calif., the project team led by Studio VARA and Van Acker Construction used natural daylighting and ventilation to enhance its bullpen-style layout and meeting areas. To complement the existing building's industrial aesthetic, large skylights of translucent panels define activity hot spots in the open plan while providing diffused, glare-free daylight, according to the project team. Faced in polycarbonate, the insulated skylights require no shading or other solar protections. On the perimeter, shadow-boxed window openings and black metal panels punctuate its façade of corrugated steel panels raised above a dark stucco base.

The glow of the sky brightness has a powerful effect on the mood and performance of office workers, according to studies such as one by neuroscientists at Northwestern University (https://tinyurl.com/jakunkr).

Regardless of the fenestration systems used, a few factors about daylighting remain constant and essential. First, daylighting calculations depend on the location's sky luminance distribution, which allows for "modeling skies under a wide range of occurrences," from overcast sky (reduced sunlight) to cloudless situations (with sunlight), according to Richard Kittler, a physicist with the Slovak Academy of Sciences. Available daylight in a room is linked closely to sky brightness, which describes how the sky reflects and radiates light, by means of scattering that occurs in direct sunlight but also indirectly, as observed with twilight after sunset. This indirect scattering creates a very bright light even on overcast and cloudy days.

With these variables in mind, the project team led by Dyer Brown and construction

+EDITOR'S NOTE

This completes the reading for this course. To earn 1.0 AIA CES HSW learning units, study the article and take the exam at **www.BDCnetwork.com/DaylightingTech**

manager Shawmut Design and Construction executed a $10 million retrofit of a 1990 commercial building in Boston to open up its northwest-facing lobby with a floor-to-ceiling, point-supported glazing system. Conceived by owner Columbia Property Trust, the renovation also addresses the building's sidewalk arcade and dark original materials to further brighten up the tenant experience. Dyer Brown's design team added light gray pavers under the arcade. In the lobby, they bumped up surface reflectance with the addition of light gray stone and mica-flecked wall plaster. This improved illumination in the entry by bouncing specular daylight and incidental rays deep into the space. "With elements like the frameless glass façade at the entrance, the redesign delivers on the promise of raising the property's prestige and, ultimately, its value," says the firm's Deniz Ferendici.

The use of glass façades and active shading mechanisms can allow for even greater areas of glass with carefully tuned daylight entry.

For a new sanitation garage in New York City, a double-skin façade wraps its acoustical curtain wall with 2,600 custom-perforated metal fins to vertically articulate the massing and mitigate solar heat gain and glare, says WXY's Pew.

Designed by Dattner Architects in association with WXY, the 425,000-sf municipal building also uses the solar control strategy to block views to the mechanical louvers and garbage trucks inside—and to block headlights aiming outside—both critical benefits to neighbors in the trendy downtown district.

They may look like fins, but the 30-inch-wide vertical silver elements are actually powder-coated aluminum shades mounted on the entire curtain wall with a custom bracket system detailed by the architects with manufacturer CS Sun Controls. A benchmark project for the local government's Active Design program, the garage earned LEED Gold certification and a commendation for improving employee wellness.

In order to properly select and apply architectural sun-control strategies, project teams like the one behind a new addition to the Phoenix Art Museum show how daylight modeling again can lead to useful design choices. Studio Ma architects Alt and Moss determined the optimal overhang depth for a community room overlook, a large window in a space otherwise illuminated by clerestories. Using the modeling program Rhinoceros and the daylight tool DIVA, the team studied the room areas with glare and those underlit.

With glare at the overlook window, Studio Ma considered a roof extension or canopy element to protect from over-illumination. The question was: How deep would the overhang need to be to optimally address glare without overly penalizing with loss of daylight?

Using the modeling tools, the team iteratively tested roof extensions of two feet and up to 16 feet. They determined the optimal length to be an eight-foot projection from the wall and window.

The Phoenix Art Museum case offers a basic approach to daylighting analysis for any building. First, identify the sustainable design principles to test. Second, isolate and test specific variables needed assess those principles. Third, record and catalog the test data for analysis by the project team.

Last, for LEED certification, keep in mind the basic requirements for daylighting in the early design phase, says Cooper Robertson's Newman. These include:

- 75% or more of regularly occupied spaces must be "functionally daylit." This means the area must receive 10 to 500 footcandles, as measured on the equinox at 9 am and 3 pm.
- An extra LEED point is available if 95% of regularly occupied spaces are functionally daylit.

For green rating programs, the daylighting analysis points used for an Illumination Engineering Society–based computerized simulation must be located 30 inches above the finished floor—a reminder that natural illumination is needed most at the work plane, on wall areas where paintings hang, and on students' desktops.+