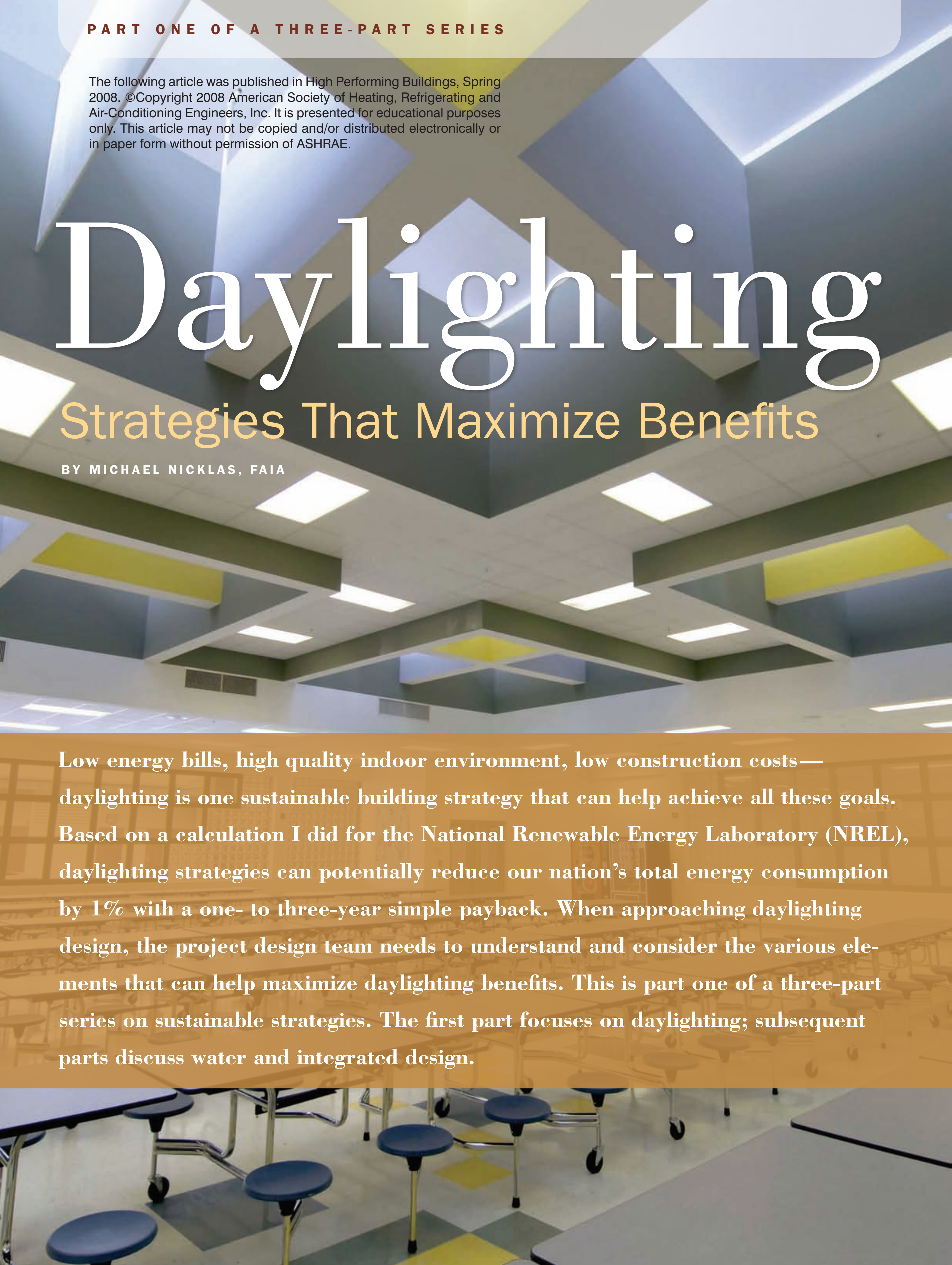


Daylighting

Strategies That Maximize Benefits

BY MICHAEL NICKLAS, FAIA

Low energy bills, high quality indoor environment, low construction costs—daylighting is one sustainable building strategy that can help achieve all these goals. Based on a calculation I did for the National Renewable Energy Laboratory (NREL), daylighting strategies can potentially reduce our nation's total energy consumption by 1% with a one- to three-year simple payback. When approaching daylighting design, the project design team needs to understand and consider the various elements that can help maximize daylighting benefits. This is part one of a three-part series on sustainable strategies. The first part focuses on daylighting; subsequent parts discuss water and integrated design.

For Chattanooga Convention Center, south-facing roof monitors provide natural lighting into the 100,000 ft^2 main exhibit area. The daylighting strategy and color selection reduced the load by 40 tons in just this one space.

Site Maximization

The most obvious site consideration is orientation. Elongating the building on an east-west axis and locating high priority spaces on the north and south exposures can enhance cost-effective daylighting. Account for shading from adjacent buildings and trees and consider the reflectance of the materials in front of glazing areas.

Integrated Design

The most cost-effective, energy-efficient daylighting strategies are integrated into the overall design and take into account all impacts, not just lighting. They consider the structural, mechanical and electrical systems, as well as the landscaping and architectural design. To fully integrate daylighting strategies, they cannot be regarded as alternative strategies.

Roof Monitors and Lightshelves

Roof monitors or side lighting with south-facing lightshelves or high, north transoms can reduce lighting and cooling loads.

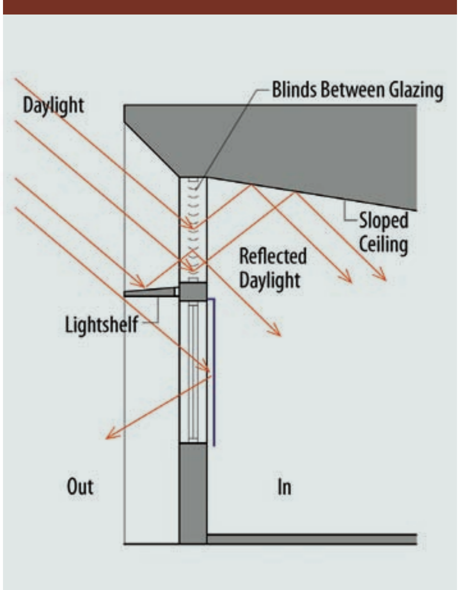
South-Facing Roof Monitors

Roof monitors with vertical south glazing, interior baffles and properly sized overhangs can create uniform lighting having less contrast, provide daylight in spaces far from the perimeter of the building, provide passive heating benefits, and effectively diffuse and filter lighting. Unfortunately, roof monitors can only be used in single-story designs or on the top floor of multistory designs.

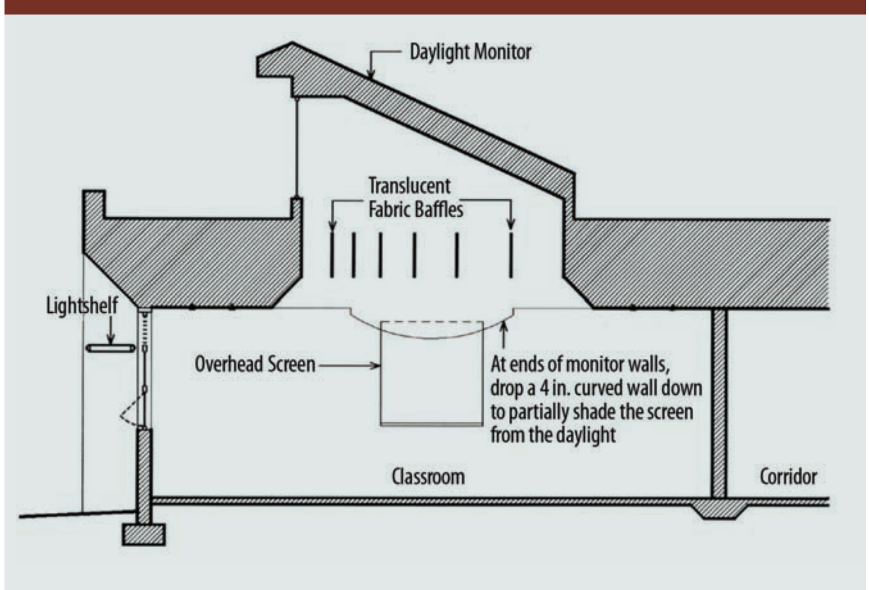
With south-facing roof monitors:

- Use light-colored roofing material to reflect sunlight into the glazing. When placed in front and to the sides of the south-facing roof monitors, the glazing area in the monitors can be reduced by up to 30%, according to a study of my projects by North Carolina State University graduate students.

The lightshelf reflects daylight deep into the space and shades the lower view window.

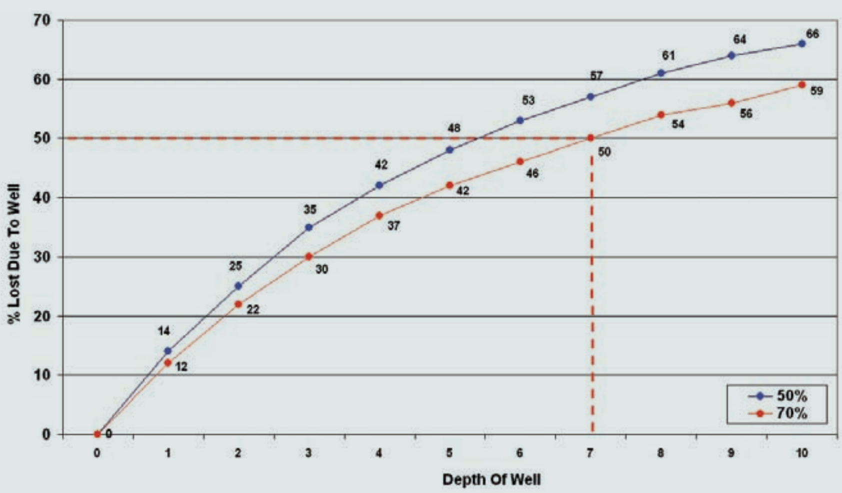


The south-facing roof monitor with baffles blocks direct beams.



Smith Middle School was constructed at $750,000 under budget. The Lighting Research Center at Rensselaer Polytechnic Institute analyzed the daylighting performance and found that electric lighting was reduced by 64% and 78 tons of cooling were saved. The facility is 128,000 ft^2 and the area daylit is 63,000 ft^2.

IMPACT OF CEILING CAVITY



Light lost when depth of ceiling cavity increases.

- Use fire-retardant and ultraviolet-resistant baffles to diffuse light. Space white baffles, hanging parallel to the glass, to block direct beams from entering the space.
- Design the south-facing monitor to capture passive heating in the winter months. This helps to replace the heat usually provided by electric lights.
- Minimize contrast at the intersection of the well and ceiling. At the bottom of the light well, contrast is greatly lessened if there is a transition between the vertical and horizontal plane surfaces. A 45-degree angled plane is good, but a curved transition is better.
- Make sure the colors used within the monitor well are very light with high reflectance. If acoustical ceiling material is used, ensure that the total assembly's reflectance and acoustical properties are high.
- Rely on stratification of heat within the monitor itself to help reduce cooling loads. Do not place supply and return grilles in this area; instead, let the heat stratify.
- Minimize the depth of the ceiling cavity. The depth of the well is important. The deeper the well, the harder it is for light to reflect down into the space. Figure at left shows the theoretical decrease in efficiency resulting from deep wells. According to an IESNA workshop, a 7 ft deep, square sky well with 70% reflectance loses 50% effectiveness because of well depth.

North-Facing Roof Monitors

North-facing monitors, although effective in providing natural light, typically require at least 25% more glazing than south-facing monitors to achieve the same annual daylighting contribution. Because of the additional glazing needed and the lack of passive heat benefits in winter, they are not as cost-effective as south-facing monitors.

In many spaces, baffles can be eliminated when using north-facing roof monitors because direct beam

Lightshelves can shade lower view glass.

light enters early or late in the day during the summer. If baffles are needed, consider vertically suspended baffles, such as banners, that can intercept the light during these key times.

South-Facing Lightshelves

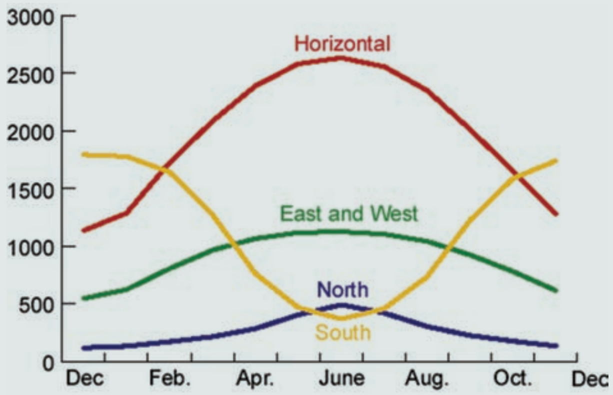
Lightshelves are typically the system of choice for multistory buildings because they can bounce sunlight deep into moderately sized rooms through high glazing areas on the south side of buildings. Typically, lightshelves cost less than monitors. The downside of this approach is that the light comes from one side of the room, making it harder to achieve uniform lighting. Also, contrast between the brighter glazed wall and the opposite side of the room must be addressed.

When optimizing lightshelf design:

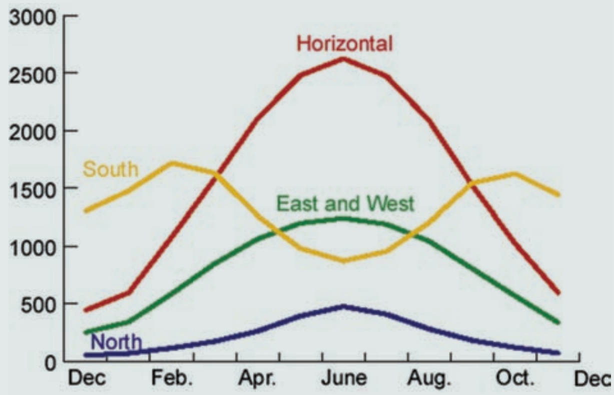
- Recognize the limitations of side daylighting. In typical windows, light levels drop considerably moving away from low view windows. It is common for the light level to

Baffles inside south-facing monitor.

THERMAL GAINS BY WINDOW ORIENTATION



Btu/ft^2 of unprotected glass/day at 35°N Latitude.



Btu/ft^2 of unprotected glass/day at 48°N Latitude.

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Architectural detail intentionally darkens the projection screen while still allowing daylight to the rest of the classroom.

be 120 footcandles at a low window and 20 footcandles at a distance 8 ft away. However, with lightshelves, this is an effective multistory daylighting strategy in rooms with 10 ft ceilings and no more than 15 to 20 ft deep from the window. The deeper the room, the higher the ceiling must be. The daylighting windows should be placed as close to the ceiling as possible.

GLASS-TO-FLOOR AREA GUIDELINES

	Small to Midsize Spaces (Classrooms)	Large Volume Spaces (Gymnasium)
South-Facing Roof Monitor	8% to 11%	5% to 8%
South Lightshelf		8% to 11%
South Lightshelf With Blinds Between Glazing	10% to 18%	
North-Facing Roof Monitor	12% to 15%	7% to 10%
High North-Facing Transom Glazing	15% to 20%	

Until detailed daylighting analysis is conducted, these guidelines, developed based on my experience, can be useful in estimating daylighting glazing amounts for particular approaches.

- Select durable but reflective lightshelf material. Aluminum is a good option.
- Shade low view glass. The exterior lightshelves can shade the windows below. If using window treatments, do not install one continuous blind that covers the top lightshelf glass and the low view glass.
- Stop direct beam light with blinds between the glass. An interior lightshelf usually cannot stop direct beam light from entering the top section of glazing when the sun has a low altitude. One option is to incorporate an extended interior lightshelf, but this requires a

deep shelf. Another option is to incorporate blinds between the glass to intercept this problematic light and reflect it up to the ceiling. When sizing the amount of glazing required, account for the loss in transmission due to blinds between the glass. Most blinds between the glass can be closed if desired. However, if the space does not need this option, the blinds' position can be permanently set to angle up to the ceiling.

- Increase the performance of the lightshelf by implementing a sloped ceiling from the top of the lightshelf glass downward to the back, north wall. In my experience, this improves reflectance and can reduce glazing up to 10%. By sloping the ceiling from the outside wall to the back of the space, it is often possible to encroach into the ceiling cavity above the window area and gain needed space for mechanical systems on the north side without increasing floor-to-floor dimensions. The benefits of the sloped ceiling are apparent when comparing a room with a flat, 10 ft ceiling to one with a ceiling that is 11 ft 4 in. at the lightshelf and 9 ft at the back of the space.

North-Facing Transom Glazing

In spaces located on the north side of the building, high transom glazing can be an effective strategy, specifically in narrow rooms or large spaces, when used in combination with south-side lightshelves or roof monitors. High north-facing transom glazing can provide good daylighting in spaces that are not too deep without the problem of direct beam

ENERGY RAMIFICATIONS

A daylighting strategy that is not typically superior to electric lighting will create a negative energy situation. Insufficient daylight results in the lights being turned on, meaning heat is produced from the lights as well as from the sunlight. If designed correctly, a daylighting strategy can reduce electricity for lighting and peak electrical demand, cooling energy and peak cooling loads, maintenance costs associated with lamp replacement, and electrical service to the building.

Maximize south glazing and minimize east- and west-facing glass. The accompanying charts indicate the amount of thermal gain on different flat surfaces without a south overhang. To maximize winter heat gain and minimize summer heat gain, use south-facing apertures. It is easy to add glazing and achieve a high daylighting contribution. The key is implementing glazing that provides superior daylighting for 60% to 70% of the time without increasing cooling loads during peak. The best design can be determined by simulating the varying glazing amounts and overhang lengths during peak cooling times. Because of the sun's low azimuthal angles that hit the east and west elevations, it is difficult and can be expensive to produce a controlled daylighting solution using east- and west-facing glazing.

Avoid uncontrolled horizontal skylights. Skylights provide the least daylighting benefits from an energy perspective. More than twice the heat will enter into a building through a flat skylight in the summer than in the winter, just the opposite of what is desired. If the size of a flat skylight is optimized to reduce heat during the summer, it will not provide the necessary daylight during the rest of the year and can become problematic from a direct beam standpoint. Although skylights can be designed with internal tracking louvers and produce good quality daylighting, it is difficult to justify their use when considering cooling peak loads. Only in a few areas of the country, where the climate is mild and sky conditions are optimal, should skylights be considered a better energy choice than roof monitors or lightshelves.

Reduce cooling loads. In the warmer months, cooling loads can be reduced by providing just the right amount of daylight to meet the footcandle objective. When the electric lights are off, the cooling load is less because daylight can produce the same lumens as fluorescent fixtures but with only half the heat. To achieve these cooling reductions, use south- and north-facing strategies with automated dimming.

Consider passive solar gain to offset winter heat previously provided by lights. Good daylighting strategies result in the lights being out the majority of the time year-round. This means that the winter heat typically produced by lights is significantly less. South-facing, vertically placed daylighting strategies naturally increase heat entering into the space during the winter months and can compensate for the heat that was provided by lights.

Select the right glazing. It is important to minimize the size and maximize the visible light transmission of daylighting apertures. Windows should be made of high-quality construction, incorporate thermal breaks, and include the appropriate glazing for the application. Make a clear distinction between glazing for views and/or ventilation and glazing for daylighting. For daylighting windows, clear glass typically has an advantage over glazing with a low-e coating. Because a 10% to 40% reduction in visible light transmission characteristics of most low-e coatings exists, 10% to 40% more glass is required to attain the same daylighting benefit. When comparing the thermal benefits of low-e coatings to the benefits of visible light transmission, consider the cost of lightshelf or roof monitor components that would be added if more glazing is required. However, wherever low view glass windows are incorporated, low-e coating should be used to improve comfort and save energy.

light. However, like north-facing roof monitors, it is necessary to increase the glass area to achieve the same contribution as south-facing lightshelves.

When optimizing north-facing transom glazing:

- Don't use lightshelves. Because of the lack of direct beam light on the north side, lightshelves do not provide any benefit and should not be used.
- Use high, sloped ceilings. Place the glazing high in the room, with the ceiling plane starting at the window head and sloping to the opposite wall, to enhance performance.
- Use high glass instead of view windows. High, horizontally placed glass is, from a daylighting perspective, superior to low view windows.
- Provide proper glass-to-floor area ratios.

Human Factors

Understanding human nature is essential to designing good daylighting solutions. Quality, energy-efficient daylighting cannot be accomplished by installing many uncontrolled windows. For example, if direct beam light enters a space, it quickly will irritate occupants, leading them to block the light, negating the daylighting strategy.

- Eliminate direct beam light. A key component of good daylighting, which essentially eliminates commonly used view windows, is the elimination of uncontrolled, direct beam light. In all spaces where light quality is critical, the

Eliminate direct beam light by bouncing, redirecting and filtering sunlight.

The south-facing monitors with baffles provide daylight to the gymnasium.

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GLAZING FOR DIFFERENT APPLICATIONS

Application	Exposure	Glazing Type
Non-Daylighting		
View Windows	South	Clear Double (or Tinted), Low-e
View Windows	North	Clear Double, Low-e
View Windows	East or West, Unshaded	Tinted Double, Low-e
View Windows	East or West, Shaded	Clear Double, Low-e
Daylighting Apertures		
Glass Above Lightshelves	South	Clear Double
High Glass Above View Windows	North	Clear Double
Roof Monitor Glass	South or North	Clear Double
Blinds Between the Glass	South	Clear Double

This chart does not apply to the coldest climates, which may require triple glazing.

strategies used should bounce, redirect or filter the sunlight so that direct beam light does not enter.

- Develop daylighting strategies to provide superior lighting for two-thirds of the daylit hours. Daylighting must be superior to electrical lighting the majority of the time the space is occupied. If not, the habit of walking into a space and turning on the lights will never be broken.

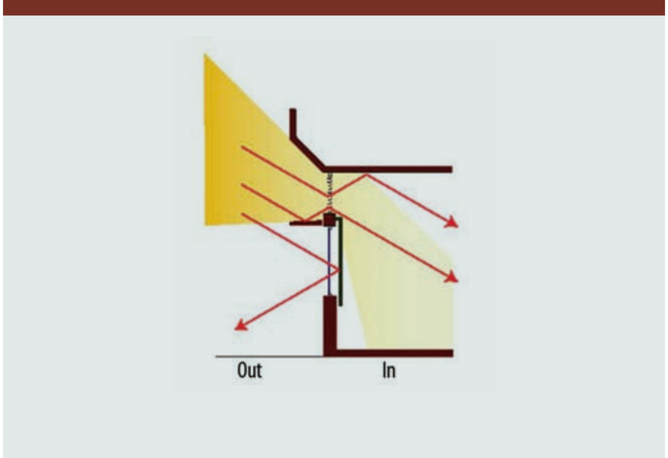
- Consider the need to darken individual spaces. The success of daylighting strategies is greatly influenced by how the occupants interact with the components of the strategy, especially blinds or shades. If periodic darkening of a space is not required, do not install shades or blinds. Using blinds results in decreased performance, increased first costs, and greater long-term maintenance expenses. Try designing the space so that areas that need to be dark, such as a projection screen, television monitor and computer monitor, are in a shaded area, while the majority of the space remains lit. Televisions can be located in a corner, not adjacent to a window, to avoid glare.

General Recommendations

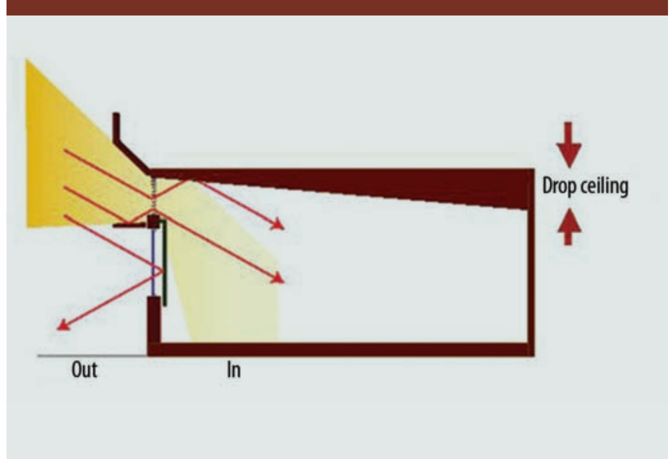
- Minimize contrast between bright surfaces and dark surfaces. Avoid bright, visually exposed windows.

- Select light colors for interior finishes. The color of the ceiling, walls, floor, and furniture has a major impact on the effectiveness of a daylighting strategy. Finishes should be white or light colored with good reflectance. Color is not the only factor to consider. Account for fissures or holes within acoustical tiles that will absorb light.

A south-facing lightshelf with blinds between the glass can reflect problematic light to the ceiling and back into the space.



Sloping the ceiling downward from the head of the window to the back of the room improves reflectance.



• Use dimming controls. To enhance the economic benefits and provide for a smoother transition between light conditions, use dimmable or multistepped lighting controlled by photosensors. There should be compatibility between ballast, lamps and controls. Mount the photosensors in a location that closely simulates the light level (or can be set by being proportional to the light level) at the work plane.

Durant Road Middle School was constructed under budget. The first year savings attributed to the daylighting and roof assembly were over $0.50/ft^2. The additional cost for the 150,000 ft^2 facility was $115,000, and the simple payback was less than two years.

• Select compatible electric light fixtures. Use indirect lighting fixtures that more closely represent daylight.

• Consider the furniture and space layout. Notice the light direction and the potential for glare. This is particularly important when deciding the location of computers.

Subsequent articles by the author, discussing water and integrated design, will be published in future issues. ●

ABOUT THE AUTHOR

Michael Nicklas, FAIA, is president, cofounder and design principal at Innovative Design, Inc., in Raleigh, N.C. He is past president of the International Solar Energy Society. Recently, he served on the project committee of ASHRAE's publication, *Advanced Energy Design Guide for K–12 School Buildings: Achieving 30% Energy Savings Toward a Net Zero Energy Building*.