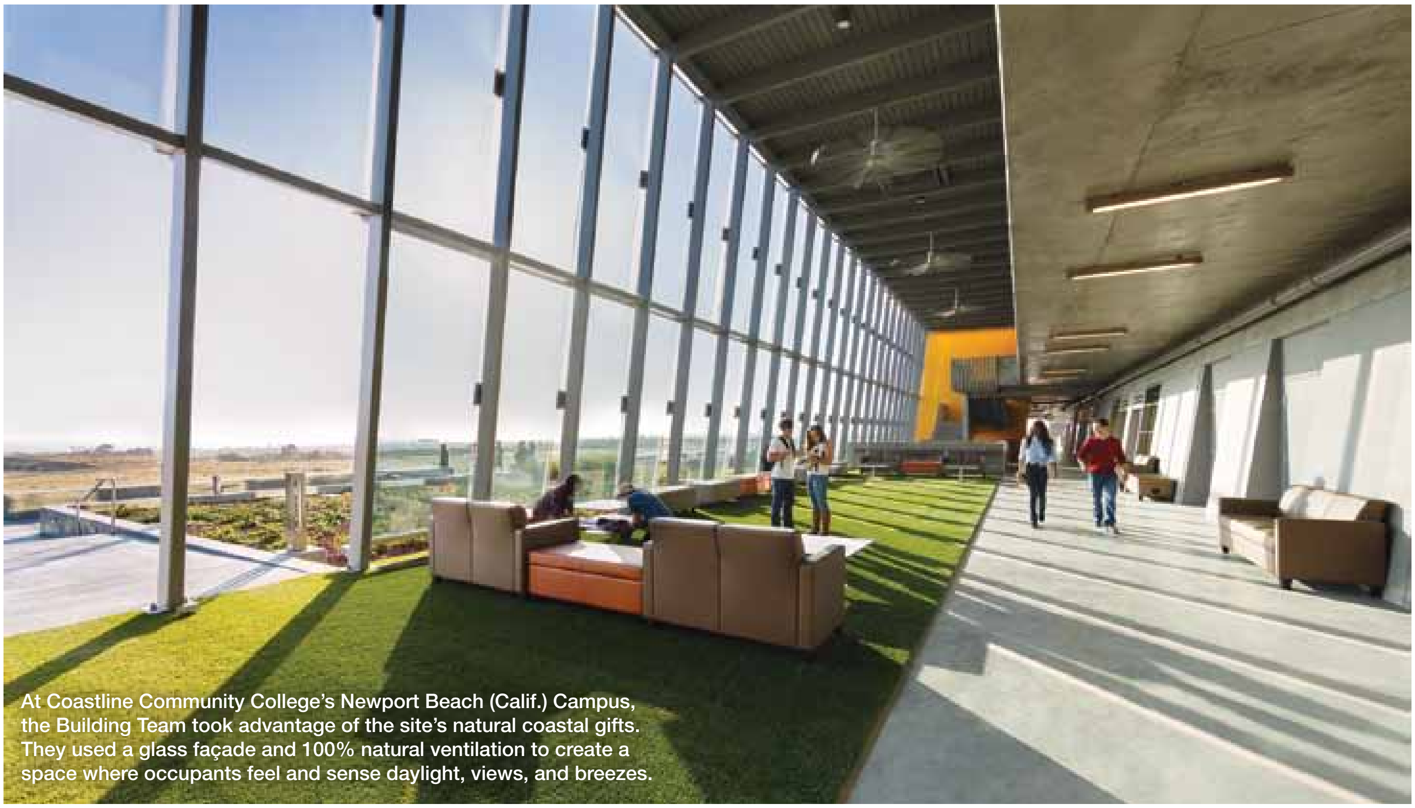
enhancing interior comfort

WHILE IMPROVING OVERALL BUILDING EFFICACY



COURTESY LPA INC.

At Coastline Community College's Newport Beach (Calif.) Campus, the Building Team took advantage of the site's natural coastal gifts. They used a glass façade and 100% natural ventilation to create a space where occupants feel and sense daylight, views, and breezes.

LEARNING OBJECTIVES

After reading this article, you should be able to:

+ EXPLAIN how environmental effects of building interiors can impact human comfort, productivity, workplace satisfaction, and mood.
+ DESCRIBE various approaches to daylighting and how each approach optimizes building interiors and benefits building performance.
+ DISCUSS shading systems, their applications, and how they can have a positive effect on occupant comfort.
+ LIST the benefits of lighting controls and underfloor air distribution toward improving the interior environment while reducing energy use.

BY C.C. SULLIVAN AND BARBARA HORWITZ-BENNETT,
CONTRIBUTING EDITORS

Providing more comfortable conditions to building occupants has become a top priority in today's interior designs. "Today, owners have a better understanding of the impact of thermal comfort on the productivity of building occupants," says Amarpreet Sethi, CEM, HBDP, BEMP, LEED AP, a Sustainability Expert in the Building Optimization Studio of DLR Group, Seattle (www.dlrgroup.com). "They are increasingly seeking design firms that understand how to maximize comfort through design and the selection of systems."

Corporate management is beginning to recognize that human comfort has a direct effect on employee productivity, workplace satisfaction, worker fatigue, and performance. "Owners and developers that prioritize human comfort in building design attract and retain high-quality employees, producing higher-quality work," states Star Davis, Senior Lighting Consultant in the New York City office of engineering firm Arup (www.arup.com). "This value can be difficult to quantify, but the most visionary owners understand that good environmental design will improve the bottom line on many levels for years to come."

Research conducted over the past decade has attempted to quantify the health and comfort benefits of interior design, particularly with regard to occupant performance and productivity. Even without such studies, building occupants themselves are acutely aware of how their immediate environment affects them. "We spend, on average, over 90% of our day inside, so our expectations are greater in terms of how the space performs," says Steven South, IIDA, LEED AP, Senior Interior Project Designer and Senior Associate in Perkins+Will's New York office (www.perkinswill.com).


TIM GRIFFITH / COURTESY HGA

Clerestory windows, skylights, and exterior fins balance daylighting and solar heat gain at the Los Angeles Harbor College Sciences Complex. HGA led the Building Team.

The line between home and workplace also has become blurred, as the prevalence of mobile devices and social media creates a situation where workers and students are constantly multi-tasking, says Linda Rodts, IIDA, LEEP AP, Lead Interior Designer, EYP Architecture & Engineering, Boston. All that technology impinges on people's downtime. "Employees and students need to find ways to relax and unplug, so building designers need to ensure that they provide this capability through the use of materials, color and pattern, selection of furniture types, and lighting design," says Rodts.

Building rating systems also play a role in encouraging designs that enhance indoor comfort. LEED and Green Globes typically evaluate or grade a building on its thermal comfort criteria, or whether the system designs meet ASHRAE 55 standards for thermal comfort.

DAYLIGHTING, DONE RIGHT

Arguably the first thing that comes to mind when envisioning an uplifting, comfortable interior is good quality daylighting. But introducing natural light into a space in a controlled, uniform manner is easier said than done. "One must find a balance between enhancing productivity, maximizing views, reducing energy consumption, and creating a high-quality environmental experience, while dealing with the negative aspects of heat gain, solar glare, and loss of privacy," says Rodts.

This is complicated by the desire to maximize daylighting with the need to increase the building envelope area, which adds to the cost of the envelope and raises the building's energy use intensity. Sethi, who specializes in energy modeling, recommends incorporating windows on more than one façade to allow for more uniform daylighting while maintaining a smaller envelope area and footprint.

The rule of thumb: locate windows primarily on the north and south elevations while limiting extensive east- and west-facing glazing in order to reduce glare and solar heat gain, says Erik Ring, PE, LEED Fellow, Design Director of MEP Engineering, LPA Inc., Irvine, Calif. (www.lpainc.com). To optimize daylighting, designers should carefully select glazing levels, evenly distribute windows and skylights, and consider using architectural shading devices and light-colored interior ceiling and wall finishes to prevent bright and dark areas that create glaring visual conditions, says Ring, who serves on the U.S. Green Building Council's LEED Indoor Environmental Quality Technical Advisory Group.

DLR's Sethi recommends the following daylighting strategies:

- Employ an integrated design approach to strategically limit space depth. This allows you to bring in daylight from more than one direction.
- Optimize orientation with an appropriate external shading device.
- Maximize clerestory window area while keeping the total glazing to roughly 30% of the wall area.
- Maximize visible transmittance with a low solar heat gain coefficient.
- Provide different internal shading solutions for the view window vs. the upper daylight portion of the window.

The key, says Sethi, is to maximize foot-candles while keeping the ratio between the daylight at the perimeter and farthest from the room at less than 1:5. This is a critical ratio and can be an effective guideline for minimizing glare.

Davis, an Adjunct Professor of Lighting and Daylighting at Parsons The New School for Design, says the best daylighting design begins with a careful determination of the building's solar access. Building massing, glazing, and a program layout based on light follow from that first determination. "This is an incredibly strong organizing principle which supports architecture and the people in the building," says Davis.

Her firm, Arup, designed the entire hub for the Metropolitan Transportation Authority's new Fulton Center in downtown Manhattan around a central oculus that collects sunlight and reorients and directs it deep underground to the station platforms and gathering spaces below. This design approach provides natural wayfinding and organization to the space, while creating a dynamic, daylit environment.

CLIMATE'S ROLE IN THE CREATION OF DAYLIGHTING STRATEGIES

Climate also dictates daylighting design, says Sethi. In the Pacific Northwest, movable external shading louvers are an effective way to reflect light into the space during sunny conditions and can be adjusted when the sky is overcast. In the sunny Southwest, the devices can be fixed to save on cost.

An understanding of how the sun moves through the space at different times of the year in different climates can also inform daylighting design—for example, by positioning workstations to avoid glare on computer screens.

Davis points out that our increasing reliance on digital screens—laptops, monitors, tablets, or smartphones—poses a new threat to daylighting design. These displays have limited brightness relative to luminance levels in the natural environment. "For this reason, much of good daylighting design is about limiting the brightness ratios in a room so that it supports the task activity," says Davis. "This means bringing the amount of daylight allowed in a space way down—to 0.1% to 5% of what's available outdoors."

Preferences for go-to daylighting solutions vary among designers. Jon Wiener, AIA, Principal, SRG Partnership, Portland, Ore. (www.srgpartnership.com), is a fan of *top lighting*, which he says is easy to control and distribute evenly across a space. Sethi says she prefers to stick with high-performance glazing, skylights, and clerestory windows, which are a particularly effective in moving light deep into a space. "These provide simple solutions with minimal maintenance or moving parts and can improve the uniformity and balance of daylight in a space," she says.

South-facing shading devices also can double as light shelves and reduce solar heat gain and glare, improving the uniformity of daylight from the perimeter to the core of the space. For renovations where the exterior is not being altered, shading systems and *window films* can be highly effective solutions with a significant impact on the comfort of building occupants, says P+W's South, Past President of the International Interior Design Association (IIDA) New York Chapter.

Tubular skylight systems, particularly for high-volume spaces and classrooms, are another option. "We find that tubular skylights provide even, consistent, and controllable daylighting compared to other daylight approaches such as expansive vertical glazing or larger rectangular skylights," reports LPA's Ring.

The key to getting daylighting right: "Design studies, design studies, and more design studies," says SRG's Wiener, who has more than 30 years of architectural experience under his belt. Every individual case requires its own tailored solution. "We always build physical models and test countless design options in a heliodome," says Wiener. "We create digital models as well, and do countless daylight simulations to confirm that the light is evenly distributed throughout each room type."

THE PROPER USE OF SHADING DEVICES

Another way to control lighting levels, glare, and solar heat gain is shading devices. *Interior shading systems* are less expensive and easier to maintain than exterior shades but only address solar irradiation that has already entered the building. *Exterior shading systems* intercept the heat gain outside and keep the heat load out of the building. A shading system can reduce the building's cooling load, which can sometimes mean that a smaller, less costly cooling system can be specified.

Both vertical and horizontal systems can successfully screen the sun during the harshest times of the day. Horizontal louvers or fins can also serve as light shelves to bounce light deeper into the interior space, when desired. Such devices can be positioned below a rank of clerestory windows to direct the natural light deep into the core of the building.

COURTESY LPA INC.

A well-coordinated daylighting design has turned Malibu (Calif.) Library from a dark, dated, inefficient space to a light, bright, sustainable environment.

Perkins+Will's South says he prefers exterior shading systems for new construction as they can be integrated into the architecture and thereby add to the aesthetic. Davis points out, however, that dynamic sun and sky conditions can limit the effectiveness of such devices to a couple hours a day, usually during one season of the year. In such cases, says Davis, *operable systems* should be considered. Be aware, though, that operable systems can come with maintenance and control problems, and they cost more than static systems.

Fixed systems have their place and can work quite well with proper massing and orientation. Arup oriented Duke University's new Nicholas School of the Environment, in Durham, N.C., with long northern and southern exposures. "Horizontal shading on the south façade shades directs sunlight in the summer, spring, and fall, while allowing lower-angle sun to penetrate during the cold winter months," says Davis. Sunlight coming from the south is relatively easy to control, so a singular fixed solution can work for the entire year. On the north façade, vertical fins divert early morning sun penetrating at low, oblique angles.

Interior shades, blinds, or louvers work well in climates with predominately cloudy sky conditions. Davis points out that exterior shading systems can block usable light, thereby working against daylight penetration. "In these environments, an operable interior system will provide a solution for controlling direct sunlight and glare" when it occurs, she says.

Davis says building massing also has a lot to do with sunlight control. East- and west-facing façades may receive several hours of direct sunlight, which is nearly perpendicular to the window, followed by no solar exposure for the remainder of the day. "An operable interior system can be the right solution based on the orientation and solar exposure of a particular façade," says Davis.

Energy codes requiring more daylighting and lighting control are another factor. Setting up these systems typically includes the installation of several sensors to monitor daylight conditions throughout the day. Sethi recommends that the sensors be programmed with a delay so as to avoid having the shades continually reacting to minute changes such as passing clouds. occupant override controls may be called for in some cases, particularly in settings such as high-end restaurants or video conference rooms, where room darkening would be desirable.

The risk with an override is users pulling down the shades and then forgetting to reactivate the system. Sethi advises setting up the occupant override as a temporary option which reverts back to the automated shading system control after a preset period.

"Typically, we use automated shading systems when it is part of a whole daylighting strategy and the client is on board from the beginning," says Perkins+Will's South. "It's best to use these in conjunction with a building management system so that the client can see the benefit of automated shading and to ensure that the system is working as designed."

ADVANCED LIGHTING CONTROLS: NO NEED TO HIT THE SWITCH

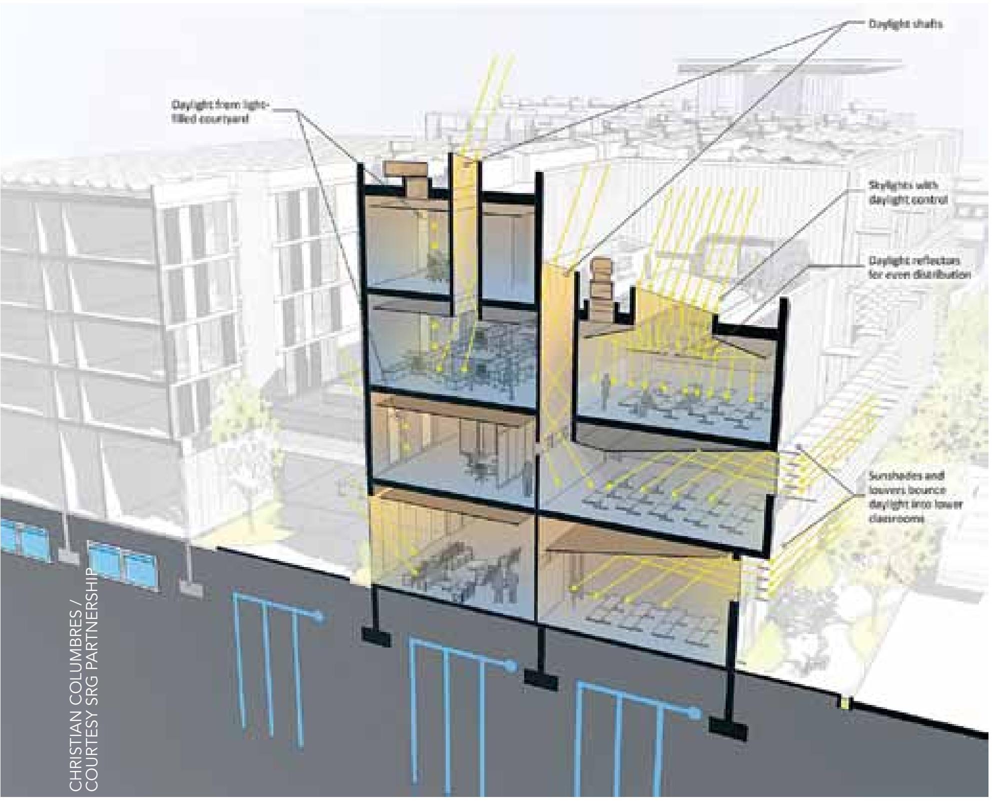
Lighting controls have been around for some time. What is changing is the sophistication and cost-effectiveness of these systems, not to mention stricter code requirements that are pushing designers to specify them more frequently. The International Energy Conservation Code has mandated requirements for such features as automatic lighting shutoff and interior light reduction for the past decade, while manual controls have been permitted in some daylight zone controls. However, lighting designers anticipate that this will soon change as the codes begin to require automated control of artificial illumination in spaces with ample daylight.

California's stringent Title 24, known as "T24," is already raising the bar. "In the past specifying lighting controls in our projects took the form of simple two-level switching and occupancy sensors," says James Montross, PE, CEM, LEED AP BD+C, Managing Director of MEP Engineering at LPA Inc. (www.lpainc.com). "On larger projects, we controlled the lighting over larger areas with lighting control panels." But with T24, he says, "The controls provide continuous dimming in response to occupant needs or available daylight."

Traditional lighting controls systems consisted of occupancy sensors, vacancy sensors, and lighting control relay panels. The latest systems offer more advanced capabilities, such as *self-adapting intelligent sensors* that "learn" about their spaces and adjust their sensitivity to modulate light levels based upon room use. "This reduces the occupant's frustration when a sensor doesn't turn on as

BILYANA DIMITROVA / COURTESY ARUP

Arup engineers equipped Skanska's new headquarters in the Empire State Building with an electric light-dimming system that calibrates so effectively with daylighting levels that it is hard to perceive electric light output changes. Occupants are generally prevented from overriding the automated daylighting controls.



CHRISTIAN COLUMBRES / COURTESY SRG PARTNERSHIP

Daylighting shafts, skylights, reflectors, sun shades, louvers, and a courtyard were all part of design firm SRG Partnership's daylighting strategy for this academic building at Lane Community College's Downtown Center in Eugene, Ore.

the person enters the room," says Sethi.

Control systems can be programmed for shorter time delays for different periods of the day. At night, for example, when the cleaning staff is emptying trash containers, the lights can turn off after five minutes instead of the typical 15 to 20 minutes.

Digitization is making these controls cheaper and easier to install and program. Designed as plug-and-play systems, the latest controls quickly snap together with a Cat5 wire, according to Montross, and additional controls, such as multiple occupancy sensors and photocells, can easily be plugged in. These controls can also interface with the HVAC system, receptacle control (a new T24 requirement), and daylight dimming control. "If needed, the lighting can be programmed with user level software and provide the demand response power reduction of 15%, which is a new code requirement," says Montross.

Occupant override can be a problem with lighting control systems, just as they can be with automated shade systems. When DPR Construction built its first net-zero office in San Diego, dimming control systems were not part of the design. This meant that, early in the morning, someone had to remember to shut off the electric lights once the daylight level came up with the sun.

For their net-zero Phoenix office, DPR made sure to install robust lighting controls with multiple lighting zones. In this setting, daylight sensors gradually dim the lights as the sun rises; the process is so subtle that people usually don't even notice it. At night, the lights shut off every half an hour: DPR employees have to get up and turn the lights back on in their zone.

Light fixtures can now be programmed not to exceed a maximum level. This prevents occupants from pushing illumination levels beyond optimal energy efficiency. "By providing individual lighting, such as desk or task lighting, you can manage energy usage while giving occupants control over their individual lighting needs," says Alyssa Scholz, IIDA, Principal and Director of Interior Design in HGA's Los Angeles office (https://hga.com).

Arup's Davis points out that occupants can be discouraged from overriding automated lighting controls if the design can camouflage the controls system in action. Arup put this into practice with the design of a largely indirect lighting system for the new Skanska headquarters in New York's Empire State Building. Inside the offices, the dimmed lights are overwhelmed by daylight in the space so that it is difficult or impossible to perceive the changes in electric light output, says Davis.

"Old habits die hard, so the natural reaction for many people is to turn on electric lights even if they are not needed," says Wiener. SRG Partnership has been setting up occupancy sensors so that the electrical light fixtures don't go on when someone enters the room. Instead, skylight louvers are triggered to open up so that the room immediately brightens upon entry.

SRG Partnership implemented such a strategy in the design of a Lane Community College academic building in Eugene, Ore. Inside the four-story building, occupancy sensor-controlled louvers were installed below the skylights so that when people enter the space, they are greeted with daylight, which then evens out incrementally until it reaches its target level.

"We also design the hallways and corridors with lower light levels so that the rooms appear brighter when people enter them," says Wiener. "The goal is reduce the use of artificial light, which avoids the heat generated from the lighting as well as the energy it consumes."

NEW UNDERFLOOR AIR DISTRIBUTION AND RADIANT WATER SYSTEMS

Another trend for improving interior comfort is the use of enhanced HVAC system designs, including underfloor air distribution (UFAD) systems. Rather than running ducts overhead and pushing air with fan power, underfloor systems typically use a plenum and the natural effect of warm air rising to introduce conditioned supply air, known as displacement air distribution.

Jeff Harris, PE, Director of Mechanical Engineering for HGA's lead office in Minneapolis, says UFAD's value is two-fold. "One, you get the cleanest air in the breathing zone because it does not mix with the existing air as much as an overhead system does." In other words, having the warmer air rising to the ceiling reduces contaminants at the occupant level, thereby enhancing indoor air quality.

"Two, occupants can adjust the vents themselves, giving each one control of airflow through the floor diffuser."

The supply air is typically delivered at a warmer temperature, which usually results in fewer temperature-related complaints among users. The higher set points also enable MEP designers and facility managers to take advantage of more 100% economizer hours. Tapping into passive ventilation a greater percentage of the time translates into energy savings and enhanced IAQ.

DLR's Sethi notes that one key aspect of these systems is that they deliver higher supply air temperatures at a low velocity. In addition to delivering cooling air masses directly into occupied zones, this approach minimizes drafts and helps eliminate some interior heat gain at its source.

Furthermore, underfloor air systems can allow for a 20% reduction of outside air to meet minimum ventilation requirements, a point that is recognized in LEED credits for ventilation efficiency and in the ASHRAE energy codes. Displacement ventilation is listed in ASHRAE Standard 62.1 with an air distribution effectiveness of 1.2, as compared to 1.0 for typical overhead systems. The ratings mean that displacement ventilation requires 20% less fresh air than the overhead cooling system; it also means that 20% of the 30% increased ventilation needed to qualify for a LEED credit is achieved simply by using a displacement ventilation system.

The latest versions of these products are trimming their total energy usage by utilizing perimeter HVAC systems that don't require fan power. One of these, the linear trough system, can deliver convective heating to the perimeter with little or no airflow, much like baseboard heating. This means that during the cooling season, a low plenum pressure could provide sufficient airflow through the troughs to meet perimeter zone cooling needs for most of the buildings in North America.

To optimize the design of these systems, it's important to carefully manage supply air temperatures, as they tend to rise along the perimeter of the building and can lead to increased airflow requirements for cooling. David Atwood, General Manager of Integrated Interiors in Boston, cites ASHRAE's UFAD Design Guide, which recommends keeping duct outlet velocities in the 1,500–3,000 fpm range and directed toward the building perimeter. This approach may also enable you to reduce the length of ductwork required for the system.

The design process should determine the supply air temperatures, the warmup heating sequence, and the ASHRAE 62 calculation (including ventilation effectiveness, diffuser selection, and air velocity) to ensure that the anticipated energy savings will be realized. This may require the use of *computational fluid dynamics*, says Sethi. "For larger spaces, like performing arts centers, a CFD analysis may be recommended to ensure the airflow requirement is met throughout the space and appropriate mixing of air is achieved by the diffuser quantity and location," she says.

Your team must also set up the supply air distribution system to avoid *thermal decay,* which is caused by unequal zone air temperatures. "For instance, if supply air has to travel too far under the floor, it will warm up too much," explains Scholtz. "You also need to pay attention to the return air path to avoid mixing return air with the supply air."

COURTESY HAWORTH INC.

New raised-floor systems include modular electrical infrastructures for plug-and-play power from the closet to the desktop, including both three- and four-circuit solutions for workspace applications and freestanding or systems furniture. Some can be extended to moveable walls and ceiling systems.

Finally, Building Teams must have a clear understanding of how occupants will use the space. This requires engaging and educating users about how to optimally support system operation. "Gaining this buy-in can determine key locations for diffusers so they will not be perceived as causing drafts and subsequently be covered up by users, which then alters system balance and occupant comfort," says Sethi.

One alternative to underfloor air distribution, especially in high-performance buildings, is a radiant system. "Water-based radiant piping distribution systems are either embedded in the concrete floor slabs or in ceiling panels," says Wiener. "We have found this approach to be very comfortable and more energy efficient than air-based heating and cooling systems."

In order to enhance comfort and efficiencies, Wiener's designs typically utilize the inherent thermal mass of the building structure to moderate temperature swings. But in order to do this, the mass must be exposed to the air and to the people–not covered with insulated assemblies or air pockets such as with a raised floor, which would work against this moderating effect.

> EDITOR'S NOTE

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