Windows + Doors

Daylighting, Passive Solar, and Energy Modeling

RENDERING: COURTESY RMJM

Learning Objectives

After reading this article, you should be able to:

- ✔ Discuss how modeling and other design studies can be used to ensure more efficient envelope and fenestration systems.
- ✔ Understand how choices in doors and windows affect such variables as lighting, heating, and occupant experience.
- ✔ List the comparative benefits of specific approaches to daylighting and passive solar design.
- ✔ Explain how architectural technologies contribute to the success of daylighting strategies.

By C.C. Sullivan and Barbara Horwitz-Bennett

Windows are among the most desirable features of most building types, welcoming in natural light, linking to the outdoors, and serving as an attractive aesthetic. Along with doors, however, windows raise concerns with regard to the energy efficiency of the building enclosure.

"The most thermally efficient building would have no fenestration at all, but who would want to live in it?" asks Niklas Vigener, PE, LEED AP, principal of Simpson Gumpertz & Heger (SGH), a Waltham, Mass.-based firm specializing in building enclosures.

That's why successful Building Teams focus on the goal of successfully integrating window and door assemblies into the building envelope by employing a whole-building design approach advocated by experts in enclosure

For the design of the Champalimaud Foundation Research Centre in Lisbon, Portugal, RMJM architects used several different shading techniques, which were all carefully studied and detailed using digital energy and solar modeling to ensure the optimal density of screening, spacing of louvers, and orientation of shading devices.

design and sustainability. This involves simultaneous coordination of the building materials, daylighting, and solar design with the HVAC, lighting, and electrical systems. In order to effectively accomplish this, however, the process must begin early in the project. "It is critical that the project designers and technical leaders establish an approach to set and achieve sustainable goals as early as the conceptual and schematic phases of a project," says Conrad Talley, AIA, a designer with RMJM, Princeton, N.J. "For example, having the mechanical engineer involved in these early discussions is important to establishing the feasibility of the ideas being pursued."

Practically speaking, if the majority of the conceptual design is completed early on, it is then possible to do a thermal load simulation prior to the design of the HVAC and lighting systems, says Russell Leslie, AIA, professor of architecture and associate director of the Rensselaer Polytechnic Institute (RPI) Lighting Research Center, Troy, N.Y. "This way, the Building Team can look at a number of alternatives and make adjustments before the size and shape of the building are completely fixed. This then provides an opportunity, for example, to downsize the required cooling systems," says Leslie.

CAD/BIM modeling. Fortunately, more and more tools, such as parametric building modeling, are becoming available to designers to better facilitate whole building design.

"Whole-building modeling software can help the designer sort out the energy costs, including thermal efficiency and the value of daylighting in reducing electric lighting costs, and of various assemblies so they can be weighed against more qualitative benefits," says Vigener, who is also a lecturer in Johns Hopkins University's Department of Civil Engineering.

Kurt Kalafsky, principal of The Aztec Corporation, an

Integrated Daylighting: A Case Study of a Middle School

During the design of Smith Middle School in Chapel Hill, N.C., the DOE-2 energy simulation program predicted a 64% reduction in lighting energy and a 19% peak cooling load reduction. But it wasn't just a prediction. A follow-up study by Rensselaer Polytechnic Institute's Lighting Research Center (LRC), Troy, N.Y., actually confirmed these numbers with data logger measurements.

Chapel Hill-based Corley Redfoot Zak's architectural design and Raleigh-based Innovative Design's daylighting scheme achieved these savings through: 1) light shelves installed beneath the school building's south windows, 2) optimized window sizing, and 3) generally avoiding east- and west-facing windows for minimized heat gain.

Roof monitors were the primary daylighting element in the school. The south-facing monitors were designed with baffles to help distribute the light uniformly and minimize glare. In addition, a white roofing membrane was selected to reflect additional light into the monitors, which passes easily through clear, double-glazed glass inside the monitors.

To measure the design's daylighting effects, the LRC installed data loggers to record light levels and temperatures for a four-week period (see accompanying illustration). Although estimated additional daylighting design costs were about $158,000, or $1.23/gsf, savings from reduced lighting and cooling costs have achieved a 4.2-year payback.

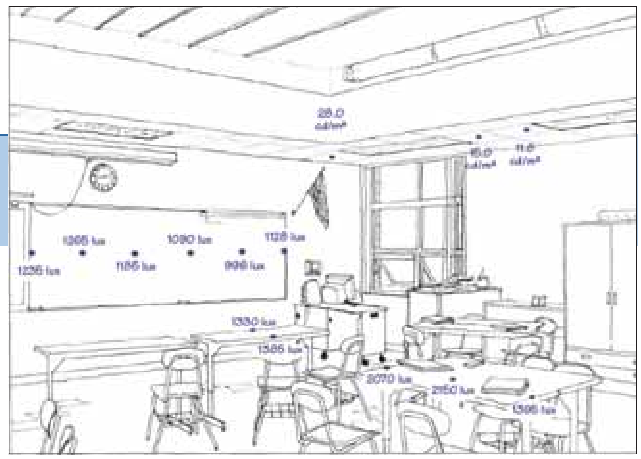

IMAGE: COURTESY LIGHTING RESEARCH CENTER

PHOTO: COURTESY LIGHTING RESEARCH CENTER

This figure shows recorded illuminance measurements in lux (1 lux equal to .09 foot-candles) and luminance measurements in candelas per square meter (cd/m2). Measurements were taken at Smith Middle School, Chapel Hill, N.C., by the Lighting Research Center on a sunny day with all electrical lighting turned off and window shades open.

architecture and planning firm in Iselin, N.J., says, “By creating a three-dimensional model, we can simulate the actual environmental conditions under which the building will be subjected throughout the full range of seasons. This allows us to balance the performance of the glazing system, for instance, with the mechanical heating and cooling systems to create the most efficient building for the intended site.”

Offering even more functionality, one of the latest advances has been the integration of software for building information modeling (BIM) with systems for building performance analysis. As a result, Building Teams can conduct a variety of analyses, such as load calculations, dynamic thermal analysis, and daylighting assessment, or even produce a LEED daylighting credit report.

For the design of the Champalimaud Foundation Centre in Lisbon, Portugal, RMJM utilized such an integrated software package. The designers were able to extract such useful information that they needed no other modeling.

As valuable as they may be, current building modeling tools do have limitations. For example, U-value must be taken into consideration, according to Vigener. (U-value, a measure of the rate of heat loss through a material, describes the insulating value of glass. The lower the U-value, the better. A cost-effective, energy-efficient window will have a U-value of about 0.30 Btu/hr/sf, although U-values of 0.2 are possible.) “The user must acknowledge, understand, and modify U-values for the windows and the walls to deal with thermal interactions between the two, as the tool is blind to what occurs at this interaction.” For example, he explains, condensation may form on the window in colder climates during winter months.

In order to address this, Vigener and his colleague Bradford Carpenter, PE, LEED AP, an SGH senior staff member in building technology, recommend employing “building science”; specifically, 2- and 3-D computer analysis of heat transfer computer analysis. “This is needed to examine these interactions and the resulting changes in U-values seen in these models,” Vigener says. “This then needs to be incorporated into the resulting whole-building energy analysis.”

Energy simulation programs. In addition to modeling software, other energy simulation programs, such as DOE-2 and Hevacomp, can be useful.

“Whole-building energy simula-

Three Components of Daylighting Design

Design elements	Aesthetic	Human	Energy
Integrated design	Low	Medium	High
Orientation/form/footprint/massing	•	•	•
Sidelighting (including WWR* and view)	One or other	One or other	Both
Toplighting (including SFR**)	One or other	One or other	Both
Glazing performance	•	•	•
Building occupancy		•	•
Electric lighting-fixture selection		•	•
Floor-to-ceiling height		•	•
Interior colors/surface reflectances		•	•
External shading		•	•
Interior shading/lightshelves			•
Electric lighting-task/ambient lighting strategy			•
Lighting power density (kW and kWh reduction)			•
Lighting controls (kW and kWh reduction)			•
HVAC sizing (kW and kWh reduction)			•
Climate appropriate design			•

*WWR = Window-to-wall ratio ** SFR = Skylight-to-floor ratio

Source: Energy Center of Wisconsin Daylighting Collaborative

According to Abby Vogen Horn of the Energy Center of Wisconsin Daylighting Collaborative, daylighting that uses diffused light from the sky and is the primary source of illumination will provide aesthetic, human, and energy benefits.

Daylighting Approach Comparison

	Baseline	Better	Best
Lighting (watts/sf)	1.1	0.9	0.9
Envelope	Blinds	Shades	Shades + interior & exterior lightshelf
Glass	Clear	Dark tint	Low-e with light tint
Controls	Manual	Stepped dimming	Continuous dimming
Watts/sf (peak)	8.82	5.19	3.79
kBtu/sf	180	147	112
Glazing factor	78 (pass)	51 (fail)	75 (pass)
Glare	Poor	Excellent	Good
View	Excellent	Good	Good

Source: Energy Center of Wisconsin Daylighting Collaborative

Best practices for daylighting a commercial facility: consider envelope materials and energy efficiency, as well as experience of building occupants and integration of daylight-related systems.

tion programs simulate the energy flows from the solar gain, conduction, air exchange, and interior loads, hour by hour, throughout the year. That way we have some feedback on how the building will perform," explains RPI's Leslie.

Developed in the early 1980s by Lawrence Berkeley National Laboratory in collaboration with James J. Hirsch & Associates, DOE-2 (whose version 2.2 was released in 1995) is considered an industry standard for calculating detailed energy performance and life cycle cost data. Hevacomp, on the other hand, is the most commonly used energy simulation software in the U.K. and can be utilized for things like analyzing heat loss and gain and building area overheating. Recently acquired by Bentley Systems, Exton, Pa., the software can also produce 3-D external shading graphics and internal solar penetration graphics, showing the moving patches of sunlight within rooms.

If passive solar design in the aim, then the National Renewable Energy Laboratory's SUNREL simulation program can be useful. The program offers integrated algorithms for trombé walls, advanced glazings, schedulable window shading, active-charge/passive-discharge thermal storage, and natural ventilation.

Mockups. Enclosure mockups with windows and doors are another approach to high-performance fenestration design.

Restored vs. Replacement Windows: A Mockup Study

In an attempt to evaluate the energy performance, constructability, and appearance of alternate window design options—whether it was more effective to restore windows or replace them—engineers at Simpson Gumpertz & Heger, Waltham, Mass., performed a valuable study in 2006. By mocking up two window alternatives and then monitoring their thermal performance, the team made some interesting discoveries.

The study monitored the surface and air temperatures and other ambient conditions in order to quantify solar heat gain, radiation gains and losses, and conductive gains and losses through the window frame and glazing assembly for a restored built-up metal window with an interior blast-resistant storm sash. This was compared with a replacement blast-resistant window with similar sightlines and overall appearance. Both windows were installed on the job site with an east-facing exposure.

View of the replacement window (left) used for Simpson Gumpertz & Heger's mockup study comparing the thermal performance of a replacement and restored window. (Temperature sensors are indicated by red dots.) An interior view of the restored window mockup (right) with thermal and relative humidity sensors indicated by red dots.

"Our analysis showed significant differences in thermal behavior between the restored window and the replacement window," report Niklas Vigener, PE, LEED AP, a principal of the firm. "We found that the restored window experienced more solar heat gain during morning and early afternoon hours, primarily due to the less efficient single-pane window glazing. In turn, the replacement window experienced more heat loss through the glass and frame during evening and early morning hours due to the increased thermal bridging and exposure of the window frame."

Because solar heat gain can be manipulated—for example, via low-e coatings—while heat loss through the frame cannot, "This indicates that the restoration window provides superior heat-loss performance and significantly greater potential for optimizing glazing and heat-gain performance than the replacement window," concluded the engineers.

The study also found that solar heat gains for both windows tended to more than offset the heat loss. This discovery may not be applicable to north-facing windows, however, and the team recommended further analysis.

"As solar heat gains vary throughout the year, careful consideration of the whole building and mechanical system requirements is needed to balance the gains and losses through the windows—maximizing gains when needed, while minimizing losses throughout the day and the changing seasons," explains Bradford Carpenter, PE, LEED AP, a senior staff member of the firm in building technology.

Further study will include evaluation of other exposures, glazing coating options, and related factors. This analysis can be achieved with additional mockups, careful application of computer simulation, or ideally through a combination of both, Vigener and Carpenter note.

PHOTO: COURTESY SIMPSON GUMPERTZ & HEGER

Flashings and air-barrier transition membranes at the sill, head, and jamb are important to ensure continuity of the enclosure.

"In addition to finding a solution through analysis, a field-constructed mockup is helpful to validate that the appropriate insulation components are installed at these critical interface conditions and to determine if the system is constructible, or if an alternate system is needed," say SGH's Vigener.

RPI'S Leslie agrees that mockups enable designers to try out different designs. He notes, however, that full-scale wall sections can be fairly expensive to produce. As a result, for daylighting evaluation, he prefers smaller physical models, built to scale.

Yet another powerful and cost effective tool is to create "digital mockups" with lighting visualization software, says Tate Walker AIA, LEED AP, senior project manager at the Energy Center of Wisconsin, Madison, Wis. He cautions, however, that "nothing beats the real thing," for assessing interior conditions, and recommends doing an actual mockup, "if you have the means."

SUSTAINABILITY MATTERS

With the AEC industry's strong focus on green buildings, sustainable design is an important factor in window and door selection and design. Whether it's choosing recycled materials, reducing HVAC costs, or achieving certification by the U.S. Green Building Council's LEED rating system, such sustainable strategies have become high priorities. One of the main reasons is to improve the well-being and enjoyment of the building occupants, by maximizing daylighting or improving occupant comfort and productivity.

"The first thing you find out about your project is where the sun goes. That used to be just being a smart designer, and now you get LEED points for it," says Barry Poskanzer, AIA, partner and owner, Poskanzer Skott Architects, Ridgewood, N.J.

LEED factors. In addition to earning points in the "Materials and Resources," "Indoor Environmental Quality," and "Energy & Atmosphere" categories, designers may be able to pick up additional points for LEED certification under "Sustainable Sites" by reducing light pollution and "Innovation and Design Process" via highly energy-efficient window and door systems.

Regarding LEED-NC daylighting criteria for new construction projects, one point can be earned by assuring a minimum of 2% daylight factor over 75% of the floor space. Another point may be awarded for ensuring a direct line of sight to vision glazing from 90% of the occupied floor area.

LEED certification aside, Laura Carlson AIA, LEED AP, a senior associate with RMJM who runs the firm's LEED accreditation training program, names a few important sustainability issues related to the design of windows and doors:

- Effective ventilation. Are windows and doors part of the ventilation strategy for the building? Are there safety factors that would prohibit their use?
- Personal control of environmental comfort. Can windows be operable in spaces such as offices to allow personal control? Should the building management system (BMS) override individual control in very hot or very cold weather?
- Daylighting. Is fenestration providing usable daylight without creating glare?
- Views. Do interior spaces provide views to the outdoors, an amenity shown to be beneficial to occupant well-being?
- Low-VOC materials. Are sealants used on the inside of the building a source of high levels of VOCs?
- Location of specified manufacturers. Can you specify material suppliers close to the project site, reducing the amount of fuel used to transport these building elements?

As for key sustainable benefits, a design guide prepared by LBNL's Building Technologies Program states that comfortable, pleasant daylighted spaces can increase occupant and owner satisfaction. While this may seem obvious, more concrete benefits are documented for a range of building types, including decreased absenteeism, leasing at better-than-market-average rates, lower tenant turnover, and reduced lighting and cooling energy costs. These factors may justify any additional investment in the amount of fenestration or daylighting systems in a project.

Productivity and health studies. Comfortable, glare-free daylighting—combined with outside views—increases the ability of students and employees to concentrate, according to the Massachusetts Technology Collaborative Renewable Energy Trust, Westborough, Mass., in a summary of human workspace performance studies conducted in the last decade or so. There may also be a correlation between healthcare premium costs and absenteeism due to reduced incidence of employee illness,

as evidenced by a 2000 Seattle City Light study of 31 buildings designed with sustainable technologies, which showed absenteeism reductions of 40%.

Documenting human preference for natural light, a 1999 post-occupancy study of 2,340 Danish workers and their office environment revealed a strong preference for having one's workstation close to a window, despite a higher incidence of glare and reflections on the computer screen. In addition, 60% of occupants desire direct sunlight in their offices during at least one season of the year.

Yet another study listed on RPI's Lighting Research Center website in its daylighting resource is a mid-1990s survey measuring the performance of workers to complete clerical tasks on a computer in rooms with and without windows. Although the difference documented in this Italian study was small, researchers found a statistically significant improvement in task performance when windows were present.

DAYLIGHTING DESIGN CONSIDERATIONS

A number of factors must be taken into consideration to achieve optimal daylighting design due to the fact that "enhancing daylighting and reducing heat loads can be a tricky balancing act," according to Aztec's Kalafsky.

"A useful strategy for designers is to kick off the project with some target numbers," recommends the Energy Center of Wisconsin's Walker, who is also vice president of the Wisconsin Green Building Alliance. He recommends the following sources of information on system performance targets:

- The New Building Institute's Core Performance Guide
- ASHRAE's Advanced Energy Design Guides
- For building performance targets, Energy Star's Target Finder

Although general daylighting rules of thumb are useful, Building Teams need to evaluate the climatic and seasonal variables that make every building project a unique design solution. "Each location has a different set of concerns and issues, so the design response is never a stock solution, but responds directly to the climatic influences," explains Jillian Burgess, AIA, LEED AP, a senior associate in RMJM's Philadelphia office, "For example, the southern façade on a classroom building in Libya will warrant a different response than a western-facing office in St. Petersburg, Russia."

Similarly, "We need to know if it's a heating-dominated or cooling-dominated building because that will affect design decisions such as the glazing that we choose and the amount of glass," says RPI's Leslie, who specializes in research related to daylighting and building systems integration.

Site specifics must also be evaluated. For example, when designing a facility in midtown Manhattan, the sun may be blocked by surrounding buildings, says Leslie. "Or a highly reflective building could be bouncing light onto your building."

Leslie, a past director of the Illuminating Engineering Society of North America and former board member of the National Council on Qualifications for the Lighting Professions, prefers windows on the north and south sides, to minimize heat gain and glare. "I also try to avoid having all the light coming through one place. It's better to get light flowing from two sides, as it creates a better balance of light," he adds.

Burt Andrews, AIA, principal architect with Larson and Darby Group, St. Charles, Ill., says, "Don't be afraid of tinted glass, as tinting can save a lot on energy. It also improves the interior quality by evening out light levels between the perimeter and the interior, where you can't get natural light."

Leslie points out that dark tints reduce heat gain and cut out a percentage of the daylight. "The tint does reduce some of the glare, but seldom enough on its own." Consequently, Leslie prefers using mini-blinds, especially if privacy is the aim. However, he adds that blinds should be opened once a day to overcome the problem of people closing the blinds and leaving them closed for long periods of time. Blinds can also be adjusted automatically, he notes.

As for the sizing and placement of windows, LBNL's design guide offers a few valuable pointers:

- The higher the window, the deeper the daylighting zone.
- Strip windows provide more uniform daylight. While punched windows also bring in daylight, the breaks between windows can create contrasts of light and dark areas.
- Large windows require more control.
- Size the windows and select glazing at the same time.
- Introduce more light-colored surfaces for good distribution.
- Use horizontal window shapes for more even distribution.

Southern California Edison's Gregg D. Ander, FAIA, lists other approaches—known collectively as **sidelighting strategies**—in the authoritative Washington, D.C.-based Whole Building Design Guide, an online resource created collaboratively by the U.S. government and private sector experts. Ander, the author of *Daylighting Performance and Design* (John Wiley & Son, 2nd ed., 2001), suggests the following:

- Increase perimeter daylight zones.
- Reflect daylight within spaces to increase room brightness.
- Slope ceilings to direct more light into a space.
- Avoid direct beam daylight on critical visual tasks.
- Filter daylight with vegetation, curtains, louvers, or the like.
- Understand that different building orientations will benefit from different daylighting strategies.

Another technique, much favored by RPI's Leslie, is **toplighting**, which he calls "the most underutilized and excellent opportunity for daylighting in buildings." Toplighting includes such common approaches as skylights and roof windows, as well as related devices, such as roof monitors, which can effectively emit light into the facility. Another benefit of toplighting, says Leslie, is that it does not require blinds or shades if proper baffles or diffusers are incorporated for direct sun control.

Yet another key component to daylighting is its careful integration with electrical lighting systems. "You have to make sure you have enough daylight before cycling off the electrical lights, and in order to do that you need to include a control system that is selected, positioned, and commissioned appropriately," explains Leslie.

The ideal scenario is to utilize photosensors that accurately measure the presence of light and alert ballasted fixtures to increase or decrease their light output. RPI's Leslie warns, however, that certain photosensors are not always accurate enough for lighting controls. For example, he says, "A black coat on a white table could throw the system off if the sensor is angled in a certain way."

To address this issue, RPI's Lighting Research Center recently released a DaySwitch product that more efficiently responds to daylight via self-commissioning. This refers to the system's ability to determine and adjust its own set points. Basically, the product's built-in microcontroller calibrates the DaySwitch, enabling the photosensor to perform more accurately.

DAYLIGHTING TECHNOLOGIES

Specifying architectural elements and technologies for shading and daylighting should come only after evaluating an overall strategy for incorporating natural light. "And these elements must be even more carefully studied and designed, as their impact and application are more precise," cautions RMJM's Burgess.

Kenneth S. MacKay, AIA, an assistant professor at the University at Buffalo, says you must give priority to project architecture, placement, and site over daylighting components and assemblies. "Exterior shading devices, window films, and the like, while important, are best seen as mitigating the consequence of form and orientation," MacKay explains. Building Teams should keep in mind such possibilities as balconies, deep reveals, recessed windows, arcades, and other formal articulations as ways to utilize the structural components of the building to enhance daylighting.

Following this, there are a number of architectural options. Poskanzer, who has been running his own firm for 37 years, points out that "overhangs, shading devices, tints, and window films are the ones most available and commonly considered." Light shelves and fins are a more expensive option, he notes, "but if one can get architectural value out of them as well, it might be possible to convince the building owner" of their value.

The chief function of light shelves is to improve illuminance distribution and reduce glare; when designed to block direct sun, light shelves can also serve as shading devices. Illuminance is defined as the total luminous flux incident on a surface, per unit of area.

Although exterior shelves are more effective than interior ones, according to the LBNL guide, it's best to use both to account for year-round sunlight distribution. As for ideal positioning, light shelves are generally most effective on the south façade, says Leslie: "Light shelves help a little bit on the east and west, but they're not effective at all on the north side."

On the other hand, vertical fins for blocking sunlight are more useful on the east and west windows, blocking early morning and late afternoon sunlight coming from the north side, according to LBNL. Burgess, who heads the sustainability committee for RMJM's Philadelphia office, explains: "A vertical fin will help prevent computer screen glare in a west-facing office, but would not prevent overheating of a south-facing corridor."

Interior shades and standard glass treatments are often more available and affordable than fixed external shading devices, says Poskanzer, adding that exterior treatments generally are much more expensive and require a receptive client. At the same time, the LBNL guide points out that exterior systems are typically more effective in blocking solar heat gain.

A similar tradeoff occurs with fixed and movable shading devices. Whereas fixed shading devices tend to be more affordable, movable shading devices enable more efficient use of daylight and permit occupants to make adjustments. Taking it one step further, movable devices controlled by a sun sensor leverage leading-edge technologies for the greatest energy savings.

One example of effective shading is RMJM's Champalimaud Foundation Centre project in Lisbon. "Energy modeling identified places where the louver design was over-shading, and through a detailed study of louver density and orientation options, the design was optimized to provide ample daylight while preventing glare and overheating," says Burgess.

Rounding off the selection of daylighting technologies is frosted, fritted, and prismatic glass. "Fritting can be decorative and diffuses or partially diffuses the light," explains Leslie. "It's usually driven by an interest in achieving a certain aesthetic." Prismatic glass, which has been used since the late 1800s, redirects and distributes illuminance from both direct and indirect sunlight. Some window and door manufacturers offer prismatic lites as an option.

PASSIVE SOLAR DESIGN

Although daylighting is a universal design strategy, passive solar design can be a very energy-efficient solution in the right setting. "Because they're low risk, simple, and effective, passive strategies don't require extensive commissioning or repair, and they're permanent for the life of a building," says the Energy Center of Wisconsin's Walker.

To getting started on a passive solar design, says Burgess, "The first thing to consider in a new project is building orientation, as proper orientation can drastically impact operability." Similarly, siting plays a key role in using landscaping to advantage. For example, "A tall grove of trees could potentially be used to shade the windows at peak times depending on how the building is oriented on the site," says Aztec's Kalafsky.

SGH's Vigener advises Building Teams to conduct a rigorous review of possible future development in the area: "A new high rise installed to the south of the building, for example, could reduce winter time heat uptake," significantly compromising the passive solar design, he notes.

Climate is also a key consideration in guiding passive solar design. "Shading southern exposures in hot climates in the northern hemisphere, orienting buildings with a long east-west axis in moderate climates, and utilizing natural stack ventilation techniques to create habitable environments without mechanical means are simple passive solar strategies in theory, but they must be applied appropriately depending on the particular climate," explains Burgess.

Other strategies include configuring the building with vertical fins and using deep recesses or other articulation to control excessive thermal loading. Other effective off-the-shelf strategies suggested by Walker include the use of thin floor plates, higher ceilings, and north- and south-facing glass in moderation, as well as adding mass to the building envelope.

However beneficial, passive solar systems are not all that simple to implement. "An emphasis on passive strategies requires a very advanced modeling approach, if they are to be accurately quantified," explains Walker. "Codes and energy models target the active systems in the buildings, but the passive systems are far more complex and variable; therefore, additional time and cost must be allocated for this purpose."

DOORS OPEN TO EFFICIENCY

The proper design and specification of doors is crucial not only for energy efficiency and performance, but also for occupant life safety and egress, says architect Barry Poskanzer. Building codes make this a relatively straightforward exercise, with different requirements based upon building use, occupancy load, and door type. In the International Building Code, for example, key egress requirements include minimum door height and width, panic hardware, door swing direction, illumination, operating force, and signage.

In terms of specifying the most effective product, however, it is important to understand the performance requirements for each individual door, whether it's fire resistance or user durability, says Ken Coupé, senior associate, RMJM, Princeton, N.J.

Coupé draws on his 23 years of architectural experience in creating door schedules for project construction documents that include increasingly more detailed descriptions. Typical characteristics listed include frame type, door type, materials, sizes, finishes, fire-resistance ratings, and door hardware sets. "Detailed and complete submittals from the contractor will help ensure that what was included in the documents will be installed," adds Coupé.

When it comes to larger, more complicated projects, Coupé suggests bringing in a certified hardware consultant to help with proper hardware selection in order to meet code requirements and performance criteria.

Once life safety and security are addressed, it is important to focus on energy performance, as doors frequently throw a wrench into the building's thermal performance, whether via heat loss when opening doors or radiant heat loss through the door itself.

To address this, the Whole Building Design Guide's section on doors, written by Vigener and his former SGH colleague Mark A. Brown, recommends the utilization of:

- Revolving doors to minimize heating and cooling losses from air movement, as well as to minimize the effect of winds.
- Air curtains, often used with sliding doors in colder climates, limit penetration of cold exterior air while the door is open.
- Entrance vestibules with two sets of doors to limit the loss of conditioned air.
- Weatherstripping between the operable sash and the doorframe limit air movement when closed.

DETAILING THE OPENING

Another critical component of preserving thermal performance integrity is the way that the window and door openings are detailed. "As part of the building envelope, window and door openings must be able to resist water penetration under severe weather conditions, limit air penetration, and control heating and cooling loads," says David King, VP at Kaestle Boos Associates, an architectural and planning firm based in New Britain, Conn.

In order to ensure weathertight design, Kalafsky stresses the importance of following the manufacturer's guidelines for flashing and sealing. "Proper field supervision during the installation process is also essential to ensure that the job is being performed as the architect intended it to be," he says. Another useful resource is the American Architectural Manufacturers Association (AAMA) Window Selection Guide, which also addresses condensation resistance.

For optimal thermal performance, Vigener says, "Doors and windows require placement in line with the thermal barrier plane of the surrounding wall assembly." In addition, air barrier, flashing, and thermal barrier continuity near these elements is needed. With regard to the details for the window surround, the SGH engineers explain that flashings and air-barrier transition membranes at the sill, head, and jamb are important to ensure continuity of the enclosure.

Coupé further emphasizes the importance of properly selecting systems to meet performance requirements for cladding wind loads, water penetration, deflection, thermal movement, and sound transmission. Detailing must also address heat loss and gain through the building assembly itself. Because different materials conduct heat at different rates, envelope components such as sills, studs, joists, and connectors will conduct heat across the wall assembly via thermal bridges. Consequently, the DOE advises making wise detailing decisions about, for example, the choice and placement of insulation material.

Finally, air infiltration, once thought to be relatively inconsequential, has come under great scrutiny in recent years. In fact, a National Institute of Standards and Technology (NIST) study estimated air infiltration to account for 15% of total heating energy used and 4% of the total cooling energy used in U.S. office buildings.

The solution: air barriers, concludes another NIST report, "Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use". According to this study, air barrier systems can potentially reduce air leakage by up to 83% in commercial buildings, potentially saving more than 40% in gas costs and greater than 25% in electrical consumption.

OPENINGS FOR PROJECT MANAGERS

While Building Teams may be equipped with knowledge of the latest window and door design strategies and technologies, in order to put them into place a well-oiled project management process is essential. This begins with early involvement of key members of the Building Team, notably the architect, M/E/P engineers, structural engineers, the daylighting team, an energy analyst, and even the door hardware consultant. Others who should be at the table include the construction manager, cost estimator, and, in some cases, a curtain wall consultant and acoustician.

The Building Team's first task is to learn and understand the owner's objectives and make sure everyone is on the same page. "The realization of a successful fenestration project is a collaborative process that starts with the architect's vision, but requires a diverse team of professionals to bring to fruition," says Vigener.

"During the design-development and construction-documents phases, it is important for the design and technical leaders to communicate the standards and goals set by the architectural team," says RMJM's Talley. "During these phases, the workload of the project is distributed to many team members, and having these goals in mind—while researching products, developing technical details, writing specifications, and coordinating requirements with the project consultants—is critical to success."

In some cases, a mockup or sample installation is the next step to help the design team, contractor, and window and door manufacturers better understand how the various products and trades are integrated into the wall assembly, according to Vigener. The mockup is tested by the design team or a testing laboratory to verify that it can withstand wind-driven rain and air infiltration. Mockups can also be instrumented and monitored to check their thermal performance. "The information collected during the mockup phase is important feedback for the designer and builder, who will use lessons learned here to finalize the installation details and sequence of the windows for the remainder of the job," says Vigener.

With the growing complexity and sophistication of fenestration systems, manufacturers are also playing an increasingly important role in the project management process.

"With an increased use of technology for security, integration with electrical and telecommunications trades is also important," notes King, who has worked as a practicing architect for the past 32 years with Kaestle Boos. "We generally require a prefabrication conference with all the related trades to iron out coordination issues, followed by a pre-installation conference after fabrication, when installation is ready to take place."

Moving on to construction, it's important for the design team, with the owner's support, to reinforce the sustainability goals set during the conceptual phase, says Talley. "The construction team, including builders, architects, engineers, and the owner, must work together to ensure that the execution and craft of the construction provide the results desired and quality needed to achieve the established sustainability goals," he says.

Commissioning. As for window installation, SGH's Vigener and Carpenter recommend that a commissioning agent or testing laboratory conduct performance testing of the windows installed in production mode to ensure that they meet the quality standards established by the design and the mockup. Adds Aztec's Kalafsky, "Building commissioning is vital in the process to guarantee the desired result."

Unfortunately, commissioning is often viewed as an extra expense, but Walker points out that "commissioning can provide a second pair of eyes in the design review stage and test assumptions that are difficult to predict in energy models." Most importantly, he says, "It can provide early fault detection in the assemblies, ideally while the work is still under warrantee."

Doing fenestration the right way requires proper building orientation, well-placed and detailed windows, and balancing daylighting with solar heat gain, all under the direction of a tightly collaborative Building Team. It may not be easy to successfully integrate the window and door assemblies with the building envelope, maximize daylighting, and produce an energy-efficient building, but it can be done. BD+C