CODES & STANDARDS: Recognizing the Benefits of Daylighting

Demand for higher levels of energy efficiency will continue to push the envelope

By John Hogan, City of Seattle

June 2007

Consideration of daylighting is gaining momentum within energy codes. That was the theme of a column written by Julie Ruth in the March issue of *Window & Door*, and it is true. This article is designed to serve as a counterpoint, however, to her assertion that “according to the two predominant codes for energy efficient construction currently used in the United States, the ideal energy-efficient building would be a large cave—well insulated by earth—with as small an opening to the outside world as possible.”

From the window and door industry’s perspective, Ruth explains, both ASHRAE 90.1-04 and the 2006 edition of the International Energy Conservation Code treat any openings in the exterior building envelope as a negative influence on the overall energy efficiency of the building. From an outsider’s perspective, however, it’s clear that key code and standard-setting organizations in the development of energy codes and standards have considered daylighting for many years.

The California Energy Commission published a report in the 1980s—more than two decades ago—evaluating the effects of daylighting through vertical fenestration in offices in terms of its potential to offset electrical lighting energy when used in conjunction with automatic controls. The evaluation included the impacts on overall building energy consumption, including space heating and space cooling. That report contained a parametric study showing the impact of various vertical fenestration areas as a percentage of the gross wall area.

As would be expected, the initial increment of adding vertical fenestration to an opaque wall provided the most benefit for daylighting to offset electric lighting. The benefit then tapers off as the space reaches daylight saturation for light needed on the work surfaces. Meanwhile the increased vertical fenestration area also brings increased cooling load during the daytime due to solar gains and increased heat loss during unoccupied hours that must be compensated for during morning warm-up.

The CEC study contained a graph showing that the knee of the curve for daylighting benefits was a vertical fenestration area that was approximately 30 percent of the gross wall area. Yes, additional daylight comes into the space as the fenestration area increases beyond 30 percent of the gross wall area, but the extra electric lighting energy savings is now less than the increased space heating and space heating energy consumption. Recent studies focusing on “big box” retail stores in mild climates have shown an optimum skylight area for specific building types to be 3 percent to 5 percent of the gross roof area.

HIGHER EFFICIENCY ACROSS THE BOARD

But aren’t there better daylighting products now? As it turns out, while there have been significant advances in glass coating technology since that time, there have also been comparable improvements in electric lighting technology. Yes, it is now possible to find glass products with high-performance coatings that have a ratio of visible light transmittance to solar heat gain that exceeds 2.0, compared to older-technology bronze glass, where the ratio is less than one. Therefore, beneficial daylight can now pass through the glass with only half the previous solar gain penalty.

However, the electric lighting system has also made similar strides. Lamps have evolved from T-12 (11¼2 inch diameter) to T-8 (1 inch diameter). Further than that, T-8 lamps are now in their third generation with light output having increased from initially yielding 75 lumens/Watt, then to 85 lumens/Watt, and now to 95 lumens/Watt. T-5 lamps with even greater efficiency are on the market. Ballasts have migrated from magnetic, to energy-efficient magnetic, to electronic. Each step improved efficiency and reduced waste heat loss. As a result, the installed lighting wattages for office space are 1.0 W/ft2 now, only half the 2.0 W/ft2 of the 1980s. This means that the waste heat from the interior lighting that enters the space, which the cooling system has to handle, is only half what it used to be. Consequently, the technology improvements for glass coatings and electric lighting have been roughly equal and offset each other.

NO PENALTIES AT PRESENT

Standard 90.1-04, developed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers and the Illuminating Engineering Society of North America, has included the benefits of daylighting in setting the building envelope criteria since the 1980s. If the supporting evaluation had been limited to the effects of heating and cooling alone, 90.1 would have long ago required glazing with reflective mirror coatings (e.g., stainless steel coatings) with an overall product SHGC below 0.15 for virtually all climates within the continental United States. However, the methodology used for developing the building envelope requirements in the standard assumes that the electric lighting system has a continuous dimming control that reduces electric lighting in response to daylighting. The resultant building envelope criteria is based on fenestration products with high-performance coatings that have a good VT:SHGC ratio, rather than reflective coatings that have a VT:SHGC ratio of approximately 0.5 and poor daylighting performance.

All of which leads back to the issue of whether the 2006 IECC or ASHRAE/IESNA 90.1 “treat any openings as a negative influence on the overall energy efficiency of the building”. The answer is a categorical “no.” Both documents contain prescriptive compliance options that allow for good daylighting design. The vertical fenestration area is allowed to be up to 40 percent of the gross wall area in the prescriptive compliance options in both the 2006 IECC and 90.1. Skylights may account for up to 3 percent of the gross roof area in the prescriptive compliance option in the 2006 IECC and up to 5 percent in 90.1.

Both standards also provide a performance option that can be used for compliance—and neither of these treats openings as a negative by giving credit for reducing vertical fenestration area. Section 506.4.5 of the 2006 IECC states that “the window area of the standard design shall be the same as the proposed design, or 35 percent of the above-grade wall area, whichever is less." Section C3.3 of the 90.1-2004 in Section C3.3 (the basis for the trade-off option) states that "the vertical fenestration area…in the base envelope design shall be the same as the proposed building or 40 percent of the gross wall area, whichever is less."

Yes, both documents do have an upper cap on the amount of vertical fenestration area in the standard design. However, that cap is set in the range where the additional vertical fenestration area is yielding diminishing daylighting returns while the corresponding daytime solar gains continue to drive up space cooling energy consumption (and make it less comfortable to sit near the window) and the corresponding nighttime heat losses continue to drive up space heating energy consumption.

INCREASED RECOGNITION

How is daylighting gaining momentum within the energy code? One of the ways is through a proposal for control of electric lighting within a daylight zone under skylights. This is a confirmation that skylights provide enough daylight to allow a reduction in electric lighting. Is it "punitive" for the energy code to require controls for electric lighting within the daylighting zone? No, it is common sense. If daylighting is to be an energy-efficiency measure, then it must save energy. The way that daylighting saves energy is through reduction in energy consumption for electric lighting and secondarily through reduction in the cooling energy needed to handle the waste heat from the lighting.

This approach parallels that which energy codes have taken for mechanical systems for many years. Energy codes require many controls to ensure that the mechanical system operates and consumes energy only when it needs to. One of these requirements is that cooling systems provide controls enabling "economizer" operation—the use of outside air for cooling in lieu of mechanical refrigeration when the outdoor temperatures are appropriate. This is analogous to daylighting controls turning off electric lighting at times when there is adequate daylighting available.

A second, more-ambitious way that daylighting is gaining momentum in the energy code is through a proposed requirement for skylights in certain types of spaces (big-box retail, warehouses, grocery stores). The codes already allow designers to do good daylighting with a typical design. This proposal takes the next step to make daylighting by skylights a standard practice in these types of spaces.

What does the future hold for energy efficiency in buildings? In response to growing concerns about climate change, the American Institute of Architects, ASHRAE, the U.S. Green Building Council and the National Conference of Mayors (to name a few) have endorsed the 2030 Challenge. The goal of this initiative is to achieve net-zero energy buildings by the year 2030. The near-term goal—the 2010 Imperative—is a 50 percent reduction in fossil fuel energy consumption in new buildings compared to the average existing building. Achieving this goal will require designers to minimize building energy loads and then to serve the remaining loads with renewable energy sources. Fenestration will play a key role in three ways.

First, part of the solution here will be continuing improvements in the building envelope U-factor and SHGC. As a very broad generalization, nonresidential buildings have a bi-modal operation. Cooling takes place during the day when the building is occupied, lights and equipment are on, and solar heat gain is coming through the fenestration. Heating primarily takes place during unoccupied hours at night and especially during morning warm-up (5 a.m. to 7 a.m.), as tenants expect the room temperature to be 70° when they arrive.

Consequently, additional steps will need to be taken both to reduce space-cooling loads and to reduce space-heating loads. For space cooling, this will mean installing fenestration products with lower SHGC, but also using exterior shading systems, and taking more care with orienting fenestration to reduce peak loads. (ASHRAE has published Advanced Energy Design Guides that provide criteria.) These strategies do not need to conflict with daylighting. Indeed, well-designed shading systems (e.g., light shelves) can both reduce the amount of sun that strikes the fenestration while also bouncing daylight further into the building. Similarly, additional steps will need to be taken to reduce space-heating loads. This will mean more insulation for opaque assemblies and lower U-factors for fenestration (better frames, better glazing, better spacers, better gas fill). ASHRAE has addenda to Standard 90.1 for improvements for both U-factor and SHGC. ASHRAE/USGBC/IESNA Standard 189P—the high-performance green building standard now under development—goes another step further.

SOME CAUTION

Second, there needs to be better utilization of daylighting to reduce energy consumption for electric lighting. While there are some nonresidential building types where daylighting is not desired (like multiplex theaters and refrigerated warehouses), in most cases daylighting has the potential for providing improvements in energy efficiency when done correctly. Toplighting—daylighting by skylights, clerestories, and roof monitors—is starting to move into energy codes. Sidelighting—daylighting through vertical fenestration—will follow. However, the code specifications must be carefully written to achieve actual energy savings.

At the recent 2007 AIA convention, many presentations and discussions of daylighting ran the gamut from design to post-occupancy evaluations. The design recommendations were that the mid-wall view fenestration should have low SHGC and be shaded by an overhang to minimize glare for workstations next to the window. Any high-wall fenestration should have a light shelf or "daylight redirecting" glazing to send the daylight further into the space. Low-wall fenestration—located less than 30 inches above the floor—provides little if any daylighting contribution on the work plane surface (while increasing the heating and cooling loads).

However, the post-occupancy evaluation reports show that there needs to be some effort for progress made on a regular basis. Buildings with large fenestration areas require thoughtful design and very careful analysis. Simply throwing glass at a building does not make it sustainable, green or high performance. A National Research Council of Canada study indicated that many occupants sitting next to windows had either closed their blinds or otherwise blocked their windows. Regardless of whether due to glare or discomfort, the result was no daylighting benefit to offset the increased space cooling and space heating energy consumption. Another post-occupancy evaluation report addressed a building with workstations next to a large glass wall. Slides taken during the day with a clear view out of the windows showed that all the workstations next to the windows had task lights with the lights on. The researcher explained that the eye quickly adapts to greater light levels, but more slowly re-adapts to lower light levels. Thus, when people near the window looked up from their work, the light levels were very bright due to the large glass wall. However, when these same people then looked back to their work, they perceived their work surface as being darker—even though it had high light levels—and so they felt the need to add task lights to compensate for their relatively "dark" work surface. Consequently, in this case, the large fenestration area resulted in increased lighting energy consumption, increased cooling energy consumption, and increased heating energy consumption. While energy codes cannot guarantee good design, their configuration needs to limit bad design to the furthest extent possible.

The 189P green building standard under development contains a first step for a requirement for daylighting by sidelighting. The prescriptive requirements specify a minimum effective aperture (VT multiplied by fenestration area as a percent of the gross wall area), coupled with a maximum SHGC that varies by climate, and a maximum fenestration area that is 40 percent of the gross wall area.

Third, fenestration and glass have roles in on-site renewable energy power systems for building projects. Photovoltaic panels are usually covered with glass. These can be installed either on top of buildings or as building integrated photovoltaics. The next generation of photovoltaics mentioned at the recent AIA convention was "electric glass," where the PV components are actually built-in to the glass rather than being mounted in a separate panel. In this case, the PV components contribute to the SHGC of the fenestration assembly. These electric-glass panels can be installed as the vertical fenestration system, and can be employed for shading over windows, weather protection over sidewalks and other walkways, and shading canopies over parking areas in hot climates. ASHRAE/USGBC/IESNA Standard 189P specifies that buildings have on-site renewable energy power systems with a peak electrical generating capacity of not less than 1 percent of the electrical service load.

In conclusion, daylighting is gaining momentum in energy codes and standards and it will continue to do so. Fenestration will play an important role in the next steps in future building energy efficiency.

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"A Long Uphill Battle Before Us"

Hogan's article was written in response to the Code Arena column written by Julie Ruth in the March issue of Window & Door. Ruth, who serves as a code consultant for the American Architectural Manufacturers Association, offers, in turn, a number of comments on Hogan's article.

First, she notes, while the benefits of daylighting may have been a factor in determining certain requirements in the IECC and ASHRAE 90.1, there is nothing in these codes at present that encourages or requires the use of daylighting in buildings to reduce the lighting load. From a window manufacturer's viewpoint, it appears that all the requirements of the codes for their products are punitive. She stands by her statement in her original column, that the codes right now "treat any openings in the exterior building envelope as a negative influence on the overall energy efficiency of the building."

At the present time, Ruth reports, the California Energy Code is the only one she is aware of that actually requires the use of skylights to provide daylighting in certain occupancies. Most of the other efforts to bring recognition of the benefits of daylighting into the energy codes that are mentioned in Hogan's article, she adds, have been spearheaded by the fenestration industry. "We realize we have a long, uphill battle before us," Ruth states. "We are taking it one step at a time and trying to make some degree of progress with each step we take."

Ruth agrees with Hogan "wholeheartedly" that taking advantage of daylighting requires good design. "We don't yet necessarily know how to do that in the most efficient and effective manner possible, or even in a consistently efficient and effective manner," she says. "I do think more attention needs to be paid to this than has been in the past. I don't think it will be possible to reach the 2030 goals that have been set by AIA, ASHRAE and others without it."

Finally, Ruth notes, she hopes the industry will be able to work with Hogan and other energy code officials. "We can look forward to your future input and assistance as we struggle to revise the energy codes in such a manner that they encourage the use of daylighting to reduce lighting load and improve the overall energy efficiency of buildings."