Design opportunities with high performance glass products

There's more freedom and opportunity to achieve reduced building costs and ongoing operating savings through energy conservation

By Susan Reilly

Over the past 50 years, there has been a constant evolution of glass products and technology. We have seen the development of tinted glass, insulating glass, heat-treated and safety glass, reflective and low-emissivity coated glasses, and spectrally-selective glazings.

This wide array of products has provided design professionals with countless aesthetic possibilities and significant opportunities to achieve increased energy efficiency and occupant comfort.

This trend is not unique to North America. In other parts of the world, glass components are utilized, and often showcased, as part of the building envelope. European glass and window systems frequently involve double-wall glazing. Operating windows, which allow natural ventilation to reduce or eliminate mechanical ventilation, are commonly used. The German energy code even limits the area in the core of a building to ensure that offices have access to natural light coming through glazing systems.

Regardless of the specific climatic condition, today's glazing products afford architects and engineers more design freedom and greater opportunity to achieve reduced building costs and ongoing operating savings through energy conservation.

High Performance Products

Glass products are a complex part of a building's envelope and play a key role in the energy efficiency of the building. While current glazing systems cannot achieve the same insulating performance or direct solar heat gain reduction as materials like masonry or metal panels, neither can these opaque components allow the free use of natural daylighting like glass products. Modern design, therefore, is premised on a recognition of the trade-offs among alternatives and the integration of these to achieve desired aesthetics, and, more importantly, optimum first costs and long-term energy conservation.

A high performance glass product has three principal performance criteria: insulating performance or U-factor, solar control or solar heat

High performance glass products allow structures to include large expanses of glass so that they can take advantage of daylighting opportunities while keeping energy costs at a minimum.

Sampling of High Performance Insulating Glass Units

Product*	Manufacturer	Solar Heat Gain Coefficient	Visible Light Transmittance	U-Factor Btu/hr-ft²-F
Sun-Guard LE-40 on Clear	Guardian	0.31	40%	0.33
NP-61 on Green	Guardian	0.29	51%	0.31
EverGreen	Pilkington	0.39	59%	0.49
EverGreen/Energy Advantage Low-E	Pilkington	0.34	55%	0.33
Solarban 60 on Clear	PPG	0.37	69%	0.29
Solarban 80 on Clear	PPG	0.23	47%	0.29

*All of these are 1-inch insulating glass units comprised of 6 mm glass and a 1/2-inch air gap between the glass. Center of glass values given for solar heat gain coefficient, visible light transmittance, and U-factor.

Table 1

gain coefficient (SHGC), and visible light transmittance (Tv). The key is to assess the interaction of all three and their total impact on a building's energy consumption and to select products that meet the most efficient performance specification. *Table 1* lists several glass products currently available from different manufacturers and illustrates the range of performance achievable. It must be emphasized that this is a small sampling of the hundreds of products available today.

Glazing functions as an enclosure, and has a key role in the heat gain/loss balance of a building. Higher performance products are better insulators than their predecessors and typically achieve a U-factor of 0.35 Btu/hr-ft^2-F or less. In cold climates, where wintertime space heating is significant and reduction of heat loss is important, a lower U-factor results in less heat loss, and improves interior comfort. In hot climates, the U-factor is less important; solar heat gain control and reduced air conditioning are key elements of design, making a lower solar heat gain coefficient the most important criteria.

In office buildings, artificial lighting accounts for 40 to 50 percent of the energy used, and a good daylighting design can minimize lighting energy use. Because of the potential benefits of daylighting, high performance glazing is often defined as having a visible light transmittance greater than the solar heat gain coefficient. However, high performance glazing is not limited to this definition. In buildings without actively controlled daylighting, managing solar loads and heat loss may be the most important selection criteria. Another important consideration is minimizing glare, which may require a low visible light transmittance.

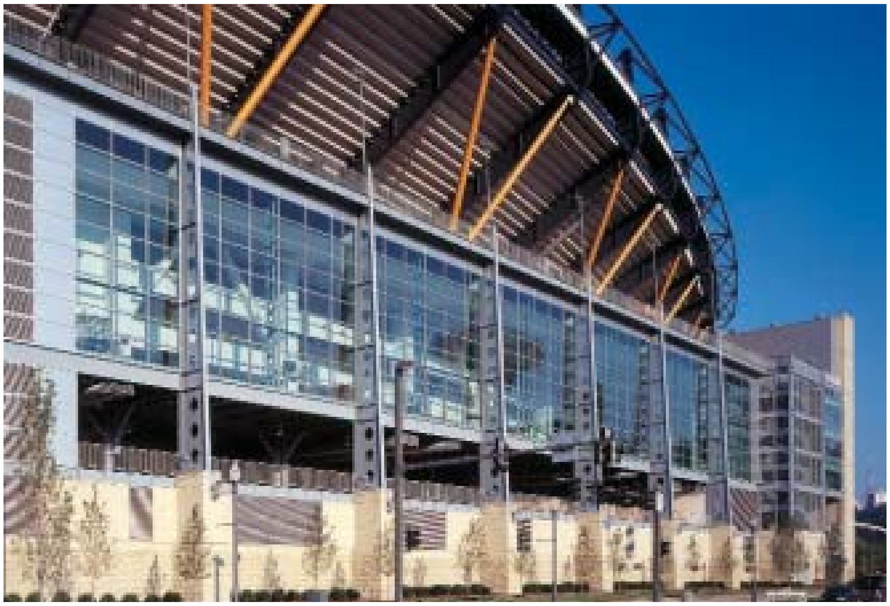
As design professionals establish specific glass product performance criteria for a project, typical considerations include aesthetics, relative first costs, impact on HVAC, and interior lighting. As a base line, they also must consider applicable local building codes. In the few areas without codes, it is common to refer to ASHRAE/IES Energy Code for Commercial and High-Rise Residential Buildings (ASHRAE/IES 90.1). It is the most widely used standard and contains prescriptive requirements for glazing U-factors and solar heat gain coefficients for locations throughout North America.

Energy Use and the Building Codes

Glazing systems are specifically addressed in the energy codes because of the significant impact they can have on energy use. The most widely recognized commercial building code for energy efficiency is ASHRAE/IES 90.1. This standard was developed by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society of North America (IES). Currently, there are two versions of the ASHRAE/IES 90.1 standard in use: the 1989 version and the 1999 version. As of June 2001, 26 states had adopted ASHRAE/IES 90.1-1989 and six states had adopted the most recent version of the standard, ASHRAE/IES 90.1-1999, or its equivalent. Many of the states that adopted ASHRAE/IES 90.1-1989 automatically did so through adoption of the 2000 International Energy Conservation Code (IECC).

The glazing system performance requirements in ASHRAE 90.1 are based on a detailed cost analysis. The cost analysis uses actual products and real costs to establish the cost effectiveness of glazing options in different climates. The analysis shows that high performance products are cost effective in almost all climates.

California updated Title 24, its energy code, in 2001, and it is very similar to ASHRAE/IES 90.1-1999. In comparing the current Title 24 with the old version, the new SHGC requirements are lower than the old. The lower SHGC requirements are the result of applying the same



High performance glass products have allowed designers to expand glass in innovative applications for sports facilities, such as the glass curtainwall on Heinz Field in Pittsburgh, Pa.

cost effectiveness analysis that ASHRAE used in developing the latest version of ASHRAE/IES 90.1.

An important prerequisite of ASHRAE 90.1-1999, IECC 2000, and California Title 24 is that glazing must have National Fenestration Rating Council (NFRC) ratings for U-factor and SHGC. NFRC, a nonprofit public/private organization created by the window, door, and skylight industry, has recently adopted a site-built procedure for rating commercial windows. These ratings verify that the fenestration products installed in a building meet performance specifications.

Designing with the Energy Codes

As mentioned earlier, the energy codes can help define the most appropriate glazing for a project. Because ASHRAE/IES 90.1 is based on an extensive cost-effectiveness analysis, the prescriptive requirements in the code, especially the 1999 version, provide a solid starting point. In addition to the prescriptive building envelope option, the code includes two other compliance methods, which are particularly instructive when using an integrated design approach.

The other compliance methods in ASHRAE/IES 90.1 are the building envelope trade-off option and the energy cost budget method.

Basically, the energy code sets an energy budget for a building. The prescriptive method gives you one way to meet the budget without any flexibility. The building envelope trade-off option and energy cost budget method allow for many different designs to meet the energy budget.

The trade-off option allows trade-offs between envelope components, such as glazing systems and wall insulation. The energy cost budget method allows trade-offs between all the building components and systems. For example, glazing with a lower SHGC than the prescriptive requirement can offset a less efficient lighting design. Any building with more than 50 percent glazing area must use the energy cost budget method to demonstrate compliance.

Two software tools have been developed to help show compliance with ASHRAE/IES 90.1 using the trade-off option, and could easily be applied during the design process to identify the best glazing system for a project. They are ENVSTD, which was developed through ASHRAE, and COMcheck-EZ, which was developed by the Department of Energy. Both programs can be downloaded free from the Web. For COMcheck-EZ, go to www. eren.doe.gov/buildings/codes_standards/buildings/commercial_codes_ products.html. For ENVSTD 4, go to www.ashrae.org. (Go to ASHRAE Site Map, Publications Update.)

COMcheck-EZ is more flexible than ENVSTD. It has a simple, two-screen display to input the envelope and determine compliance for the envelope. There are just four steps to using COMcheck-EZ to show envelope compliance *(Fig. 1)*.

1. Click on the Project tab and enter the building location and type of building.

2. Click on the Envelope tab and begin to enter the envelope components by selecting the component from the list running across the screen.

• For walls, enter the gross area, which includes opaque wall area and window area.

• For windows, enter the U-factor,

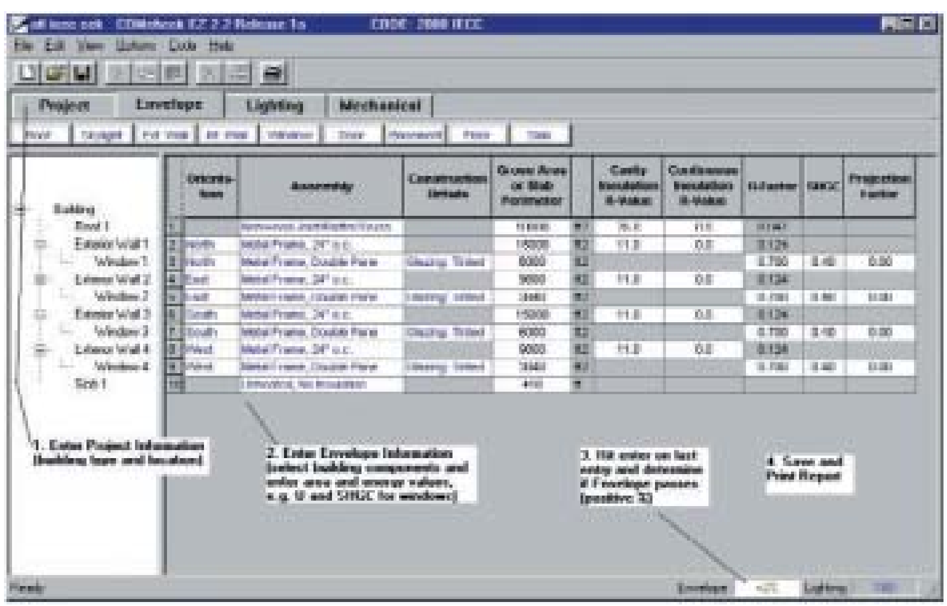


Fig. 1

solar heat gain coefficient (SHGC), and projection factor (PF). The projection factor characterizes external shading, such as overhangs; use Help for a description on how to calculate it.

• Daylighting also is handled by specifying visible light transmittance and the daylighting control factors (DLCF). To engage this feature, the user must select Daylight Control Factor under Options and specify the orientation of each wall. Otherwise, the wall and window orientation does not need to be specified.

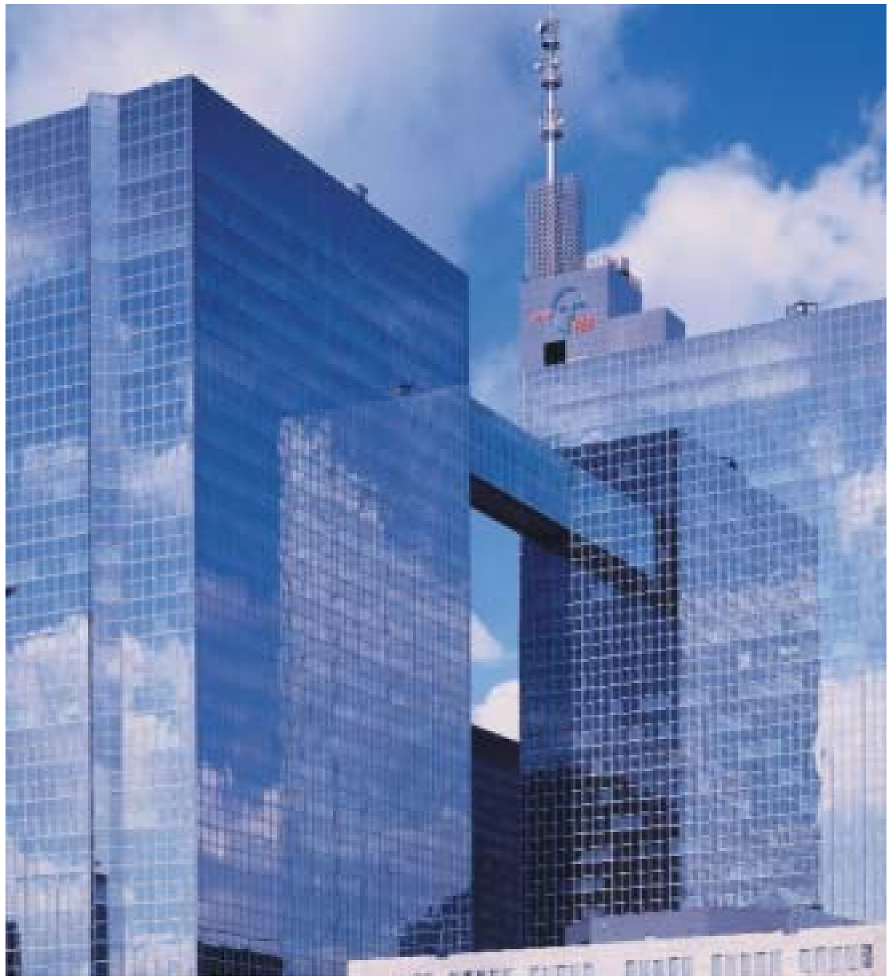
• Hit Enter after the last entry, and review whether or not the envelope complies. A positive percentage means the envelope complies.

3. Save and print the report.

Now, let's take a look at how COMcheck-EZ could be used in the design process. Consider a 10-story, 100,000-square-foot office building with 12-foot floor-to-floor heights located in Atlanta, Ga. (IECC climate zone 7A). Each floor has an 80 by 125-foot floor plate with the long axis oriented east-west, i.e. facing south, and there is 30 percent window area on each elevation. In Atlanta, the IECC 2000 prescriptive tables (Chapter 8) require that the windows have a U-factor of 0.70 and an SHGC of 0.40. After inputting the wall, roof, foundation, and window prescriptive requirements, COMcheck-EZ reports that the design is 14 percent better than the minimum code requirements. Increasing the window area to 40 percent shows the design is still 2 percent better than the IECC 2000 prescriptive requirements.

Windows with metal frames and insulating glazing (two lites with a 1/2-inch air space) meet the 0.70 U-factor, but the same windows with clear, uncoated glass will not achieve the 0.40 SHGC. For the most part, glazing systems that incorporate tinted glass, low-emittance (low-E) coatings, reflective coatings, or spectrally-selective tints will meet the 0.40 SHGC requirement.

Consider a high performance window with a metal frame and low-E glazing with a U-factor of 0.60 Btu/hr-ft^2-F and an SHGC of 0.30 or less. The lower window U-factor improves the energy efficiency of the building by 1 percent over the example above, while the lower window SHGC increases the energy efficiency by another 8 percent. Daylighting controls with the high performance glazing increase the efficiency by an additional 5 percent. In fact, this building could have 50 percent window area with the high performance windows and still outperform the code by 5 percent.



Europe has always been a leader in the use of glass for innovative, attractive design. The Tours Belgacom building in Brussels, Belgium, makes extensive use of the product.

As the glazing system area increases, the SHGC code requirement stays the same or decreases. In Atlanta, a building with no more than 25 percent window area needs an SHGC of 0.50; with 25.1 percent to 40 percent window area, an SHGC of 0.40 is required; and with more than 40 percent window area, an SHGC of 0.30 is required to meet the prescriptive requirements in the code. There are many glazing products that can meet the 0.30 SHGC, although most of the tinted options alone will not get there. Most of the reflective coatings have lower SHGC values, and tints combined with low-E coated products also can achieve the low SHGC value. The high performance glazing available today has made it much easier to comply with the energy codes, regardless of glazing area.

In colder climates where heating is important, insulation plays a much more important role than it does in hot climates. This makes the building envelope trade-off option even more attractive because trade-offs between the roof, walls, floors, and glazing systems are more substantial. With the same building and the IECC prescriptive criteria for Chicago, Ill., consider substituting better glazing for the code-compliant U=0.50 and SHGC =0.40 windows. Glazing systems with a U-factor of 0.45 and an SHGC of 0.30 improve the energy performance of the building beyond code requirements and, thereby, allow the designer to consider other design options that could improve the first costs of the project.

To identify the best glazing for a project, the energy cost budget method or the use of an hourly, whole building energy simulation program is the most helpful. Whole building simulations predict the interactions between all building systems in terms of peak and annual energy use. The most common tools are DOE-2, Blast, and Energy10. Employing such a tool is more time intensive and costly, but if used by the design team from the beginning has the potential to pay for itself and more. Also recall that ASHRAE 90.1-1999 requires compliance via the energy cost budget method when the glazing area is more than 50 percent of the exterior wall area.

Many projects today have established a goal of complying with certification programs such as the LEED Green Building Certification Program. It promotes a more sustainable and environmentally-benign approach to the design and construction of a building. A prerequisite of LEED is compliance with ASHRAE/IES 90.1-1999, and additional credits can be earned by achieving greater energy efficiency than required by the standard. The improved efficiency levels must be demonstrated using the energy cost budget method, meaning that hourly, whole building energy simulations must be run. The buildings earning these credits typically have high performance glazing systems, daylighting controls coupled with an efficient lighting design, and high efficiency chillers.

Other Benefits

While only a small sampling of high performance products has been mentioned in this article, it is important to remember that there are many more energy-efficient products that can result in a much more comfortable space. The challenge is taking advantage of all the benefits high performance glazing offers within the design of a project. This can be accomplished through an integrated design approach that recognizes the synergistic relationship between building systems.

For example, the default assumption for glazing is that it has a shading coefficient of 0.50. This is equivalent to a solar heat gain coefficient of 0.43. In many locations, the energy code requires that the glazing system have a solar heat gain coefficient of less than 0.35. If the SHGC of the glazing system is less than the default, the cooling loads will be significantly reduced. Reduced cooling loads lead to lower air flows, smaller ducts, smaller pumps, smaller chillers, etc. This translates into substantial first cost savings.

Few buildings have active daylighting controls to dim electric lights or turn them off when the natural light coming through the glazing is sufficient to light an area. The operating cost savings from such controls are tremendous, both in energy savings and lower replacement costs. Recent studies have shown increased productivity levels in daylighted spaces, particularly in schools (Heshong Mahone Group 1999). The controls typically have paybacks of two to five years. A few showcase buildings have even taken into account that the electric lights will be off during peak cooling periods with daylighting. This has lowered their cooling loads, and the cost savings on the cooling side have paid for the daylighting controls.

On the heating side, high performance glazing systems significantly improve thermal comfort and can eliminate the need for supplemental baseboard heating. An HVAC design handbook states that baseboard heating is generally specified when the heat loss through the exterior wall is greater than 450 Btu/hr-lineal feet of wall. Therefore, if there is a 9-foot tall glazed wall with low-E insulating glazing (U-factor of 0.40 Btu/hr-ft^2-F), baseboard heating is only needed when it's colder than –55˚F. There are comfort issues that counter this, although in climates with winter design temperatures in the 0˚F range, low-E insulating glazing can eliminate the need for baseboard heating.

High performance glazing systems have greatly expanded design opportunities for a project. Advances in coating technology and tinted glass have made a broader range of products available, many of which have a solar heat gain coefficient of less than 0.40.

The current energy codes can be used to identify the most suitable product and show that glass-enclosed buildings can meet the energy code with the use of high performance glazing. High performance glazing also improves comfort conditions and has the potential to reduce first costs as well as operating costs. g

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Definitions

Low-E Glazing. Glass with a nearly invisible, metallic coating. The coating has a low emittance, meaning it absorbs and emits a small percentage (typically less than 20 percent) of the thermal radiation incident on it. Uncoated glass absorbs and emits more than 80 percent of the thermal radiation incident on it.

Solar Heat Gain Coefficient. The fraction of solar heat admitted through a glazing product, including direct and indirect transmission.

Spectrally-selective Glazing. Glazing designed to have a high visible light transmittance and a low solar heat gain coefficient.

U-factor. The coefficient of heat transmission (air to air) through a building envelope component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h –ft^2 °F).