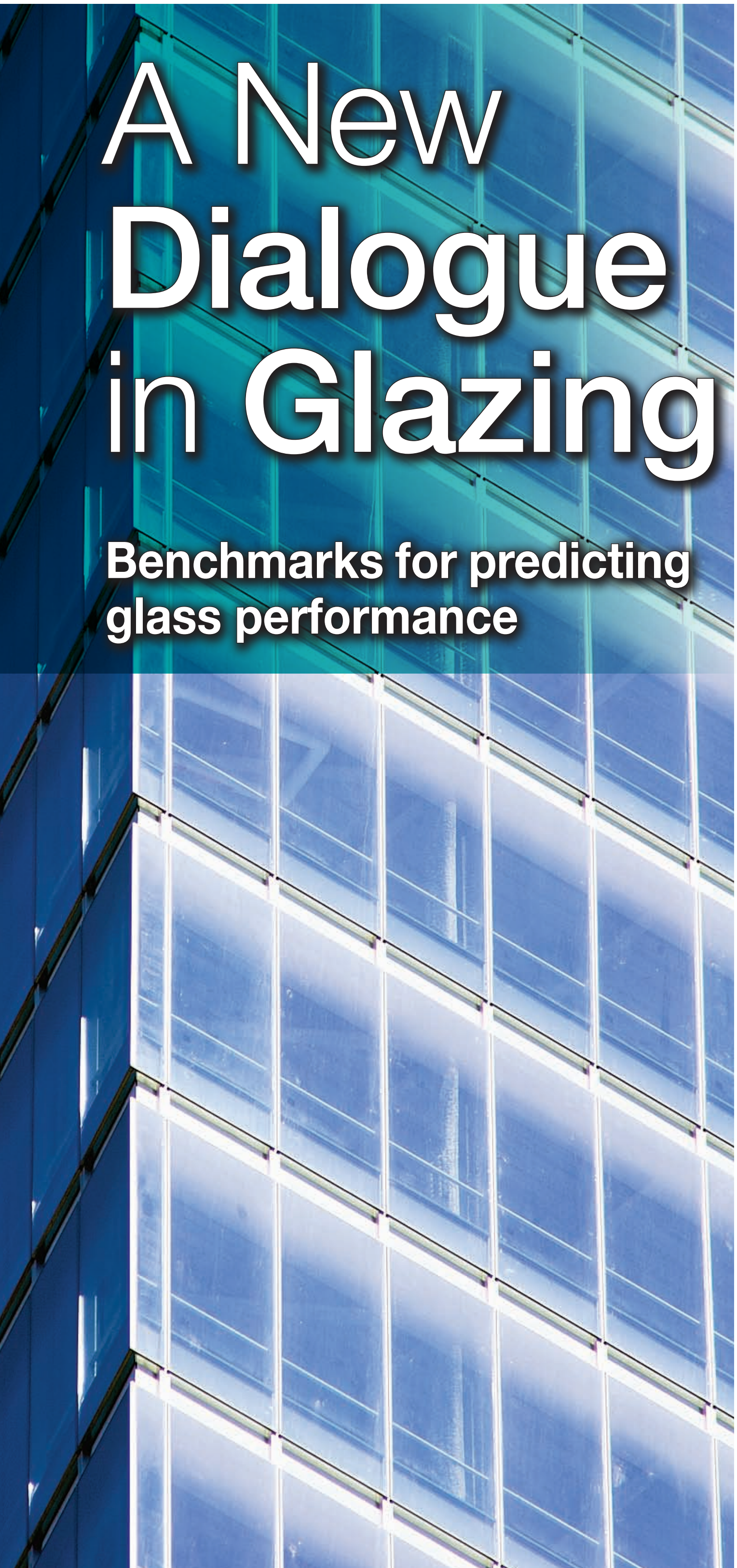
the construction specifier

solutions for the construction industry | april 2011

A New Dialogue in Glazing

Benchmarks for predicting glass performance



by Paul LaBerge, LEED AP, and Don McCann, AIA Allied

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WHEN IT COMES TO DESIGNING ENERGY-EFFICIENT GLAZING SYSTEMS FOR A BUILDING, THE INTRICATE BALANCE BETWEEN BEING COST-EFFECTIVE AND MEETING NEEDS FOR HUMAN COMFORT HAS CREATED NEW CHALLENGES.

Since the 1990s, glass technology has improved exponentially, offering an almost bewildering array of high-performance choices. In addition to sustainability, designers must consider how glass affects the building lifecycle, moisture control, daylighting, structural qualities, acoustics, security, and a host of other criteria in their glass choices. Even the terminology of glass is complex and changing.

Metrics such as U-value, solar heat gain coefficient (SHGC), and visible light transmittance (VLT) are now commonly used to discuss and specify glazing. However, while the terms have provided a useful way to compare glass products, it is often difficult to discern exactly what they mean for the daily functioning of a building.

Traditional glass values are based on static evaluation conditions that have little relation to the real, practical window design situation. What does it mean to occupant comfort to have a U-value of 0.88? How much might a building owner lower energy bills by selecting a glass with a lower SHGC? How much glare will occupants experience?

Most professionals in the design and building industries have rough rules of thumb that give these values meaning. However, it has been hard to quantify exactly what it means to actual building performance. A fundamental lack of user-friendly tools and information for designers—particularly at the early stages of a project—has historically resulted in many buildings with large central cores with few windows on the perimeters.

For example, many school, government, and office buildings constructed during the 1970s and ’80s have large floor plates with smaller windows around the perimeter and many interior rooms or cubicles lit solely with artificial light. Even buildings with curtain walls were often constructed largely of opaque glass, resulting in very low window-to-wall ratios (WWRs).

As both sustainability and occupant comfort become increasingly important in today’s building design, a new set of design values is emerging to help architects and owners evaluate more precisely how a certain glass type will impact building performance, occupant comfort, and overall building costs.

[Research is demonstrating optimal energy use and occupant comfort is achieved by doing exactly what designers previously avoided.]

In a dramatic departure from traditional glass values, these new performance measurements represent an entirely new way of thinking and talking about glass—one more in line with the current green movement. The values predict how glass will perform, taking into account factors such as local climate, building orientation, and percentage of window-to-wall. Further, new tools are making it easy for architects to quickly calculate and compare these numbers for their own projects. The result can be optimal building performance.

New performance measurements

While traditional glass performance numbers give people an easy comparison between glass types, it was often difficult to translate this into the 'real' glazing's function in a building. The newer measurements that are discussed in this article offer insight into how glass will actually impact energy use and occupant comfort.

Annual energy

Annual energy use is a measure of how glazing will impact a building's yearly energy consumption, including lighting, heating, and cooling. Data is usually given as kBtu per square foot per year, with lower numbers being better. Having local weather data for the proposed building site is critical to successful calculation of this value.

This metric gives architects and building owners an idea of how much money they could spend or save with different glazing choices by increasing or reducing ongoing energy costs per square foot of glass.

Peak demand

Peak demand is the greatest amount of electricity required at one point in time during the year. Measured in Watts per square foot (W/sf) of floor area, the value includes all electrical end uses such as lighting, cooling, fans, and plug loads. A higher peak demand reflects both the likelihood of higher utility demand charges as well as the need for larger mechanical equipment.

As a general rule, one ton of cooling costs about $1000. If selecting a better-performing glass could reduce an HVAC system from 100 to 60 tons, the building could save about $40,000 in up-front equipment costs, in addition to lowering the annual energy cost.

The expense of upgrading to better-performing glass tends to be minimal—often a two to four percent increase in the cost of the entire glazed assembly. In most cases, the return on investment (ROI) period for upgraded glazing is within a few years, based on the specific type and location of the building.

Carbon emissions

There is no doubt 'carbon footprint' has become a hot topic in building and design. Glass can have a tremendous impact on a building's carbon emissions by directly influencing energy use.[1] To calculate this value, the electric or gas CO_2 factor (as established by the U.S. Department of Energy [DOE]) is multiplied by energy consumption to calculate the pounds per kilowatt hour (kWh) or pounds per kBtu emitted due to building energy use.

An interesting calculation here is to estimate the carbon savings per square foot of glass—how much less carbon will be emitted due to enhanced glass options. For clients who are interested in pursuing true sustainability goals, this could be a significant figure.

Daylight

The window design and glazing choice can dramatically affect the quantity and quality of daylight in a space and how it is experienced. Average annual daylight illuminance is calculated in footcandles. Most office visual tasks require from 30 to 70 footcandles of light. Larger windows with low-transmission glass can have the same average daylight illuminance as small windows with high-transmission glass. However, daylighting design is more complex than this simple formula.

More daylight does not always mean better lighting conditions; it must be carefully balanced with glare control. Uniform distribution of daylight into the space also has to be considered. Ultimately, the tasks performed in the building must guide the daylight selection. For example, glare is a concern for office workers at computer screens while children in classrooms may benefit from increased natural light.

A second measure of daylight is effective aperture—the light-admitting potential of a glazing system. It is determined by multiplying the window-to-wall ratio with the visible light transmittance. This can be useful when evaluating the cost-effectiveness and daylighting potential of a glazing system.

There is a common misconception that there is a conflict between obtaining optimal daylighting and energy efficiency. In fact, simply controlling the light coming through a window does not deal with the entire range of lighting a building will experience. Understanding the orientation of the windows, and their location with respect to the sun, can help architects and specifiers select glass that will allow daylighting while curbing energy consumption.

Glare

Glare can vary considerably depending on the orientation, the presence of shading devices, and other window properties and design conditions. Similar to daylighting, the average annual glare index does not reveal severe glare problems that may occur infrequently over the course of a year. As an annual average may be misleading, a weighted glare index was developed to emphasize the fairly infrequent periods of perceptible or uncomfortable glare that occur.[2]

This index is based on a subjective response to brightness within one's field of view. It provides a rating between zero and

25; lower is better, but anything below 22 is considered to be acceptable:
• imperceptible glare: below 7;
• just-perceptible glare: 7–10;
• just-acceptable glare: 10–16;
• glare becoming uncomfortable: 16–22; and
• always uncomfortable: more than 22.

Thermal comfort
Thermal comfort is measured as the predicted percentage dissatisfied (PPD) within a particular environment. Lower is better, with an acceptable range typically lying between zero and 20 PPD. This attribute is determined by:
• air temperature;
• relative humidity (RH);
• air movement;
• mean radiant temperature;
• presence of direct solar radiation (*i.e.* insolation); and
• occupants' clothing and activity levels.
The thermal comfort of a space is calculated by a complex formula that takes into account the Department of Energy's DOE-2.1E program (which generates an hourly mean radiant and room air temperatures) and the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Thermal Comfort tool that was developed in 1994 by M. Fountain and C. Huizenga.

Windows affect human comfort in several ways. During cold periods, the exterior temperatures drive interior glass surface temperatures down below the room air temperature; how low the glass temperature drops depends on the window's insulating quality. If people are exposed to the effects of a cold surface, they can experience significant radiant heat loss to that cold surface. This may cause them to feel uncomfortable, even if the room air temperature would normally be fine.

Site-specific versus static material attributes

The benefit in the new values discussed in this article lies in the fact they are site- and building-specific. While U-value and SHGC are calculated using just the attributes of the component, the six values in the preceding section are devised using simulation software that can take into account the project's local climate, orientation, WWR percentage, and other factors.

Created by DOE, EnergyPlus is energy simulation software that models heating, cooling, lighting, ventilating, and other energy flow in buildings. A powerful tool, it requires a fairly high level of engineering sophistication to use, according to Stephen Selkowitz of the Lawrence Berkeley National Laboratory (LBNL), which helped create the simulator.

"It is used on many large commercial projects, but is typically run by engineers later in the building process," he explained. "However, we found most major decisions are made early in the process by architects, consultants, and owners that do not possess the detailed engineering knowledge to run EnergyPlus."

To help architects and owners make glazing decisions earlier in the design process, LBNL created COMFEN. This software allows users to systematically evaluate alternative fenestration systems for project-specific commercial building applications.

This building, owned by the Arkansas Department of Environmental Quality (ADEQ), benefits from natural daylight provided by ample glazing. However, when not carefully specified and designed, too much glass can lead to issues with heat loss or gain.

Photo © Wes Thompson Photographer

It employs EnergyPlus, but offers a more user-friendly interface. With COMFEN, users can identify the effects of key glazing fenestration variables on energy consumption, peak energy demand, daylighting, and thermal and visual comfort.

COMFEN has a generic library of glazing options. If users are considering glazing from a certain manufacturer, they need to create a custom entry, which requires additional time and user knowledge. However, while COMFEN is significantly easier to use than EnergyPlus, it was still often outside the expertise and comfort level for many architects and building owners. Thus, some proprietary tools have been developed to make it even easier to quickly calculate the same site-specific simulation data as COMFEN.

At least one of these new programs—found free and online—also gives building owners square foot dollar comparisons to help them evaluate which type of glazing would have the highest energy payback.

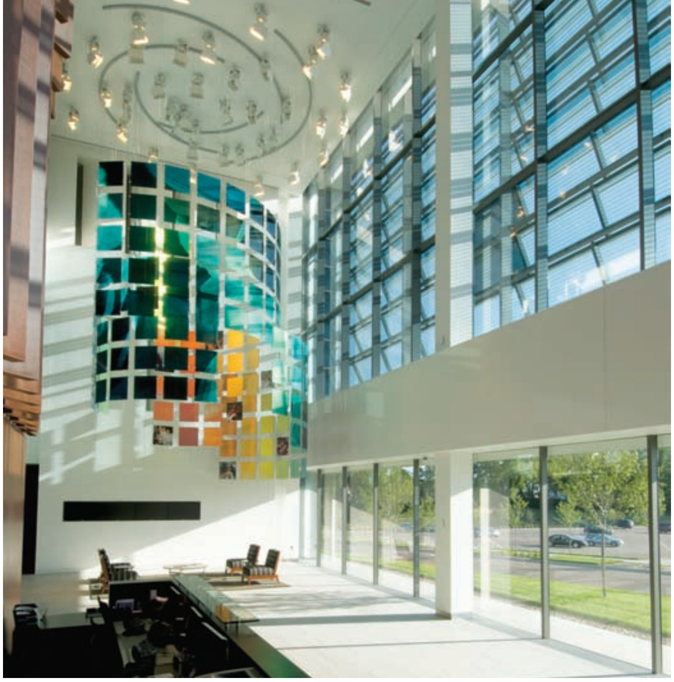
Large firms and projects may use such resources as a starting point before bringing in a mechanical engineering team for full building calculations. However, the new tool will also help small and medium-sized buildings achieve optimal energy performance and cost-savings without any additional expense.

Moving beyond rules of thumb

Before simulation tools, architecture was often partially guided by unwritten rules: "To save energy, don't orient a building to the east or west." "Don't use expanses of glass to avoid glare." However, today's high-performance glass is now showing those rules no longer always apply. In fact, research in areas such as daylighting and energy control is demonstrating optimal energy use and occupant comfort is achieved by doing exactly what designers previously avoided, provided the appropriate glass is specified.

In recent years, the simulation tools developed by scientists and engineers have offered new, project-specific means of evaluating and predicting glass performance in buildings. However, these tools and calculations have been beyond the reach of typical architects and building owners.

The advent of user-friendly tools is enabling architects and building owners to make more informed glass decisions early in the design process. DOE research has shown up to 50 percent of commercial buildings in the United States have no high-



Software can help project teams consider important new metrics when designing large expanses of glass.

Photo © Bistram Photography. Photo courtesy St. Jude Medical.

performance coatings on the glass, making those structures extremely inefficient and a major contributor to greenhouse gas (GHG).[3]

The new tools are changing the vocabulary used to discuss glass performance and giving even small building owners a chance to calculate long-term cost savings and payback periods for specific projects. They may also help usher in a new era of sustainability. **CS**

Notes

[1] Information on calculating the energy use of a building can be found at apps1.eere.energy.gov/buildings/energyplus. For information about national source energy numbers for comparing building energy use across the country, visit www.energystar.gov/ia/business/evaluate_performance/site_source.pdf.

[2] The weighted glare index is calculated by DOE-2, the Department of Energy modeling software, and based on the Hopkinson Cornell-BRS formula. It is weighted to provide a useful gauge of glare in a perimeter office.

[3] Information on calculating the carbon emissions from electricity generation can be found at tonto.eia.doe.gov/ask/environment_faqs.asp.

ADDITIONAL **INFORMATION**

Authors

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Abstract

As both sustainability and occupant comfort become increasingly important in today's building design, a new set of design values is emerging that can help architects and owners evaluate more precisely how a certain glass type will impact building performance, occupant comfort, and overall building costs. In a dramatic departure from traditional glass values, these measurements represent an entirely new way of thinking and talking about glass—one much more in line with the current green movement.

MasterFormat No.

04 21 13–Brick Masonry
08 40 00–Entrances, Storefronts, and Curtain Walls
08 50 00–Windows

UniFormat No.

B2020–Exterior Windows
B2010.40–Fabricated Exterior Wall Assemblies

Key Words

Divisions 04, 08
Daylighting
DOE
Energy efficiency
Glare
Thermal comfort