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4.2.1 Windows and Glazing Systems

Windows, and glazing systems in general, can provide daylighting, passive solar heat gain, natural ventilation, and views. Glazings can be vertical or sloped, wall-mounted or roof-mounted. While a vitally important building component, glazing systems can also be the weakest point in the building envelope—relative to heat loss, unwanted heat gain, moisture problems, and noise transmission. Through proper design, careful analysis, and proper installation, glazing systems allow buildings to work with the climate to reduce energy use as well as enhance human comfort and productivity.

Opportunities

Opportunities to ensure that glazing systems will be effective and climate-responsive are greatest very early in the planning and design process both for new buildings and for existing buildings undergoing renovation. Renovations afford opportunities for replacing older, single-glazed, and either clear or darkly tinted windows. Window and glazing modifications can be considered independently of other building changes, but changes will be most cost-effective when carried out as part of a broader upgrade of the whole building. Improving the energy performance of windows without replacing the window units themselves may be feasible by adding shading devices on the exterior, an extra glazing layer (storm panel) on the interior or exterior, or window treatments (such as shades, drapes, shutters, or window films) on the interior.

Technical Information

Windows and glazings are specified by solar heat gain coefficient (SHGC), U-factor (thermal transfer rate), air-leakage rate, visible light transmittance, and materials of construction. The glazing configuration, frame materials, and quality of construction will determine the environmental impact, maintenance, durability, and potential for disassembly for reuse or recycling at the end of its life.

Issues to be considered in the selection of windows and glazings include the glazing system (see below), framing materials and design, finishes used on framing components, window operation (for operable units), and how windows or glazing units are sealed at the time of installation to ensure a weather-tight envelope.

Windows and glazings allow heat movement via conduction across the glazing and the frame, via air leakage at the frame gaps and between the frame and wall, and via the transmission of solar and heat radiation through the glazing. Window thermal performance should be compared by using the whole-window U-factors, as specified by the National Fenestration Rating Council (NFRC). These unit values account for the glazing, frame, and glazing spacers in insulated-glass units. The lower the U-factor ($Btu/ft^2 \cdot °F \cdot hr$), the better the performance. U-factor is the inverse of R-value (U=1/R). The U-factor of double clear glazing is about 0.5 (R-value about 2).

Types of glazing include clear, tinted, reflective, low-emissivity (low-e), and spectrally selective. Some low-e coatings are on suspended plastic films (Heat Mirror®). There are also some advanced high-tech glazing systems available or under development, including electrochromic (tinted by applied voltage), photochromic (tinted by light intensity), thermochromic (tinted by heat), photovoltaic (power-generating), and transparent insulating.

Low-e coatings have revolutionized glazing design in the past twenty years, dramatically boosting energy performance. These very thin coatings of metal (typically silver or tin oxide) allow short-wavelength sunlight through but block the escape of longer-wavelength heat radiation. There are two types of low-e coatings: soft-coat (vacuum-deposited) coatings that have to be protected within a sealed insulated glass unit; and hard-coat (pyrolytic) coatings that are applied when the glass is still molten and are durable enough to be used on single-pane glazings. Soft-coat low-e coatings generally block heat loss better, but they also block more of the solar heat gain and thus aren't as good for south-facing glazing on passive solar buildings.

Spectrally selective glazings are a special type of glazing used mostly in commercial buildings. These should be specified in climates where solar gain in the summer creates large cooling loads and where daylight also is desired. The coatings allow visible portions of the solar energy spectrum to be transmitted, but they block infrared and ultraviolet portions of the spectrum that introduce heat primarily.

The gap between multiple panes of glass also influences heat flow. The space may be filled with air or a high-conductivity gas such as argon or krypton. Because these gases have lower thermal conductivity than air, they result in lower U-values. While krypton is significantly better than argon, it is also a lot more expensive and therefore rarely used. Low-conductivity gas fills are particularly important when low-e coatings are used on the glass, because the coatings result in a higher difference in temperature across the interpane space.

In renovations—particularly of historic buildings—aluminum, metal, and vinyl panning and receptor systems provide a weathertight, finished covering for

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Photo: Warren Gretz

NREL's Solar Energy Research Facility is designed to use natural lighting. South-, east-, and west-facing windows are specially coated with six different, graduated glazings to mitigate unwanted heat or glare from the sun. Windows facing east and west are also outfitted with "smart," motorized window shades. Each shade has a photovoltaic sensor to detect the sun's intensity and automatically raise or lower the shade to prevent glare and heat gain.

placement over existing wood frames. This simplifies installation of new units and eliminates the removal of old frames. Separate interior or exterior glazing panels can also often be added to single-pane windows in historic buildings to boost energy performance without significantly altering the building's appearance.

> Wood frames may be a better material from an environmental standpoint (if the wood is from a certified well-managed forest), but they may have greater life-cycle costs because of their shorter life, and higher maintenance costs compared with metal, vinyl (PVC), and fiberglass windows. When selecting frame materials, weight heavily the thermal performance and maintenance—not just the initial environmental impacts of the material.

To select windows for the best overall energy performance, first conduct an analysis that accounts for inward and outward energy flows throughout the year. Various computer software tools can be used for this analysis, including *DOE-2* and *Energy-10*.

Sound-control (acoustical) performance of windows can be improved by ensuring that windows are airtight, increasing the thickness of the glass, adding additional glazing layers, and specifying *laminated* glass with a plastic interlayer.

The choice of either fixed glazing units or operable units should be based on site-specific and climate-specific opportunities and constraints. Casement, pivoting, and awning windows offer the greatest opening area for natural ventilation and utilize compression seals that provide the best method of sealing the joint between sash and frame. Fixed windows provide the best thermal performance because of fixed seals; these can be designed to satisfy acoustical and security concerns as well.

> Glazings that insulate poorly and frames that are highly conductive will have a cold interior surface during winter months, and condensation may occur on the inside of the glass and frames. This can damage window frames, sills, wallboard, paint, and wall coverings. A more thermally efficient window and a nonconductive frame with thermal breaks are less likely to result in condensation. Avoid metal frames that lack thermal breaks.

References

Carmody, John, Steve Selkowitz, and Lisa Heschong, *Residential Windows*, W. W. Norton & Company, New York, NY, 1996.

Franta, Greg, et al., *Glazing Design Handbook,* The American Institute of Architects, Washington, DC, 1996.

Certified Products Directory: Energy Performance Ratings for Windows, Doors, Skylights, 9th Edition, National Fenestration Rating Council, Washington, DC, December 1999.

Contacts

The FEMP Help Desk, (800) DOE-EREC (363-3732) can provide window evaluation software developed by Lawrence Berkeley National Laboratory.

The National Fenestration Rating Council (NFRC), 1300 Spring Street, Suite 500, Silver Spring, MD 20910; (301) 589-6372; www.nfrc.org. (Both printed and online versions of *NFRC Certified Product Directory* are available.)