Understanding Window and Door Performance for Custom Residential

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INTRODUCTION

In many ways, windows and doors help make a home a home. They let in natural light and fresh air, frame views, block noise, and buffer occupants from extreme heat, cold, and moisture. Windows and doors contribute to a home's beauty, durability, and longevity.

Today's custom homes are distinguished by "big glass"—multiple sliding door assemblies, large, glazed panels, and window walls that blur the boundary between inside and outside. These assemblies allow for expansive views and ample natural light, but they also come with special considerations. They must meet structural requirements, including wind loads, while achieving the desired energy performance.

Glazing methods, low-e coatings, glass spacers, framing materials and finishes, and even operating style, along with the overall quality of manufacture and installation, all influence a window or door unit's performance. It's possible to design homes with stunning window walls without sacrificing energy efficiency,

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comfort, durability, or safety—if the right products are specified.

ASPECTS OF PERFORMANCE

Whether a single window or door unit or a mulled assembly, there are several aspects to performance. These include how well the unit or assembly controls heat loss and gain, the movement of air and moisture, and noise.

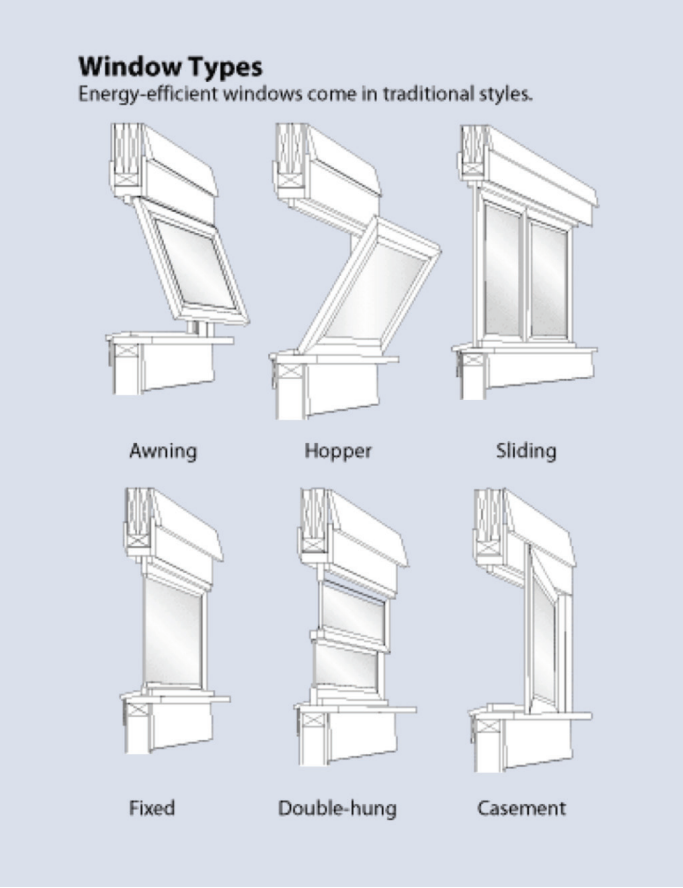
Energy Performance

Energy performance is determined by how well a unit controls heat gain and/or loss through one of three pathways: conduction, convection, and radiant heat transfer. Glazing type, coatings, framing materials, spacers, and the quality of manufacturing and installation all affect energy performance.

SHGC (solar heat gain coefficient) measures the fraction of solar radiation transmitted or absorbed through a window, door, or skylight and released as heat inside. The lower the value, the less solar heat the window transmits.

U-factor measures the rate of heat flow through a window, door, or skylight. Lower U-factors indicate better insulation, meaning less heat loss and greater energy efficiency.

Air leakage measures the rate of air movement around



a window, door, or skylight in the presence of a pressure differential. Typically, building codes limit the rate of leakage to 0.3 cfm for windows, skylights, and sliding doors.

Moisture Control and Condensation

Condensation can occur when the temperature of the unit's inside surface is colder than the dew point inside the house. Left unchecked, condensation can promote mold growth and compromise indoor air quality. This problem is more likely to occur in cold climates. Selecting energy-efficient double- or triple-pane windows with a low U-factor can minimize this issue.

Sound Mitigation

Windows and doors play a key role in mitigating unwanted noise from outside the home. Fortunately, many of the same features that make these units energy efficient also help them effectively mitigate sound. For example, air leakage can significantly drive up heating or cooling demand and compromise a window or door's ability to mitigate noise. Windows and doors that effectively control heat transfer, air movement, moisture, and sound contribute greatly to a home's comfort and indoor air quality.

Operating Types and Energy Performance

Although quality manufacturing and installation are the most important factors, a window's operating type does impact its energy performance. Mulled assemblies often include more than one operating type—for example, a fixed window flanked by two casements is a popular configuration.

Fixed direct-glazed picture windows are more efficient than operable window types, since there are few, if any, places for air to escape.

Awning windows hinge at the top and swing outward, while casements swing out from one side. For both, the sash closes by pressing against the frame, and framing is minimized to the outside of the window. Both generally have lower air leakage than windows that slide open.

Single- and double-hung windows are a popular and traditional window style featuring two stacked sashes: to operate, one sash slides vertically past the other.

Sliding windows allow one sash to slide horizontally past the other. They allow for a clean aesthetic and unobstructed views without projecting to the exterior. Sliding windows and single- and double-hung windows typically leak more air than other window types.

As with windows, the doors' method of operation, whether inswing or outswing, sliding or swinging, opening or a stationary sidelight, can all affect performance.

Glazing Technologies

The selection of glazing is arguably the most important factor affecting the energy performance of the unit. The home's climate zone and specific site will largely determine the type of glazing you choose; large, mulled assemblies may also require some type of safety glass.

Plain "float glass," also called annealed glass, is made by heating the raw materials above 600˚ F, then cooling it a slow and controlled rate. Floating molten glass on a bed of liquid tin process results in all but perfectly flat surfaces on both sides.

Factory processes can enhance certain properties of float glass. These are especially relevant for producing the different types of safety glass, which building codes require in certain locations and applications. Other factory processes can enhance certain properties of float glass.

Safety glass is required in locations where occupants are more likely to fall and collide with a window—near showers and tubs, for example. Windows in coastal locations and high wind hazard areas must include impact-resistant glass. All glass doors and large windows with panes greater than nine square feet also require either tempered or laminated safety glass.

Tempered glass is a type of safety glass that is up to four times stronger than standard glass. It is heated to over 1,100˚ F, then cooled quickly. This process puts the outside of the glass under compression, while the core of the glass remains under tension. When tempered glass breaks, it shatters into tiny pieces, making it less likely to injure someone.

Laminated glass is safety glass that is manufactured by sandwiching a thin film of plastic between two panes of glass and bonding them together under extreme heat and pressure. When laminated glass is broken, the plastic holds the many shards together. The plastic interlayer blocks almost all UV light. Laminated glass is very strong and good at dampening sound.

Impact-resistant glass is required in many coastal zones, as it must withstand the strong winds and flying debris from storms and hurricanes. To achieve impact ratings, thicker laminated panes of glass are required. This increase in the overall insulated glass thickness can require a wider glazing shelf, therefore a thicker window or door sash or frame. Some impact-resisting glass units are assembled using both laminated and tempered glass.

Insulated glazing: A window with insulated glazing consists of two or more panes of glass that are spaced apart from each other and sealed. The insulating air space between the panes helps to reduce heat transfer, thus improving the window's U-factor. Virtually all windows and doors produced today include insulated glazing. Though two panes of glass are typical, triple-

pane and even quadruple-pane units are available.

Replacing the air between panes in an insulating glass unit with an inert, odorless gas, usually argon or krypton, enhances the window's performance, as these gases are denser than air and have lower thermal conductivity. Krypton performs better than argon, but it is rarer—and thus more expensive.

Windows validated by ASTM E2188/E2190, Standard Specification for Insulating Glass Unit Performance and Evaluation, should not lose more than 10 percent of the insulating gas over 10 years.

Low-emissivity coatings consist of extremely thin layers of special metallic coatings that are deposited directly on the surface of one or more panes of glass during the manufacturing

process. They work by blocking some wavelengths of light while allowing others. The industry has developed a range of low-e coatings tailored to different needs and climate zones. Some are spectrally selective and block most of the solar heat while allowing in the full spectrum of daylight. These coatings may reduce energy loss by up to 50 percent.

Low-e coatings have a noticeable color; therefore, the specification of windows with different coatings should be avoided if they are in proximity to one another or at the same elevation on a house.

Tinting: Glazing can be tinted (usually bronze or gray) to reduce solar heat gain. Tinted glass controls glare and solar heat gain well, but it comes at the expense of light transmission, or VLT. It's important to consider whether a low-e coating is a better choice, especially in residential projects.

Materials

Framing materials, spacers, seals, and workmanship are all components of a high-quality window, door, or mulled assembly.

Framing materials contribute not only to a window or door's aesthetic, but to durability, performance, and overall energy efficiency. Here again, the material is only as good as the quality of construction in the factory and proper installation in the field.

Wood is a classic and versatile framing material that can be milled into virtually any shape. Commonly made with species such as pine, oak, mahogany, and Douglas fir, wood frames are beautiful, renewable, naturally insulating, and durable. They must be properly maintained to ward against moisture, mold, rot, and insect damage.

Vinyl, or polyvinyl chloride, is a petroleum-based material used in many building products. Vinyl windows tend to be less expensive, and they are low maintenance and impervious to rot; however, vinyl frames can become brittle over time, especially after prolonged exposure to UV light or cold temperatures. Vinyl is also not a good choice for hot climates or dark colors, as heat can cause the material to warp.

Fiberglass, made from a combination of spun glass fibers and resin, is extremely durable and resists heat transfer. Like vinyl, it is low maintenance and will not rot. However, fiberglass is much stronger than vinyl and resists warping and cracking, even when exposed to extreme temperatures. Fiberglass window frames have limited profile options. Hybrid designs with wood on the inside and fiberglass on the outside allow for beautiful, high-performance products.

Aluminum has many stellar properties: it is durable, low maintenance, and resistant to rot, insects, and weathering. However, aluminum can corrode, and the metal is a very high conductor as well and is prone to condensation in colder climates. For this reason, many aluminum windows are manufactured with a thermal break in the frames.

Exterior Finishes

Exterior finish also impacts a window or door product's durability. Dark-colored finishes warrant special consideration, as they absorb more light and heat energy, including UV, and may be prone to fading and cracking over time.

Factory-applied powder-coated finishes can withstand even he harshest coastal environments. For fiberglass windows, look for finishes that meet the standards of AAMA 624; for aluminum windows, AAMA 2605 is the gold standard.

Spacers and Sealants

Spacers and sealants keep the panes of a window in an insulating glass unit a precise distance apart, typically a half inch or less. They allow for thermal expansion and pressure differences while forming a tight seal that minimizes the leakage of gas from between the panes. Spacers can significantly reduce heat loss, condensation, and water damage. There are several types.

Aluminum spacers are strong, but they transfer heat easily, increasing the risk of condensation.

Stainless steel spacers are durable and strong, and conduct heat less readily.

Warm-edge spacers, made from non-conductive materials like foam or a hybrid of plastic and metal, reduce heat transfer and condensation at the edge of the window. High-quality warm-edge spacers expand and contract with the window, protecting the seal from cracks.

Hybrid spacers, made from a combination of metal and composite materials, offer the best of both worlds.

Mulling Approaches and Structural Integration

The large window walls and sliding door assemblies in modern custom homes are possible because of a process called mulling, where two or more units are joined by their frames. The structural members used to join them together are called mullions.

Mulling enables higher glass-to-wall ratios compared to installing a series of individually framed windows or a single large window. The design options are nearly limitless, and many window types may be used in mulled assemblies. A popular configuration is to flank a picture window with casements on either side. Single- or double-hung windows may be stacked in a series or in rows. Awnings are often used as a transom above or below another window type.

Mulling can take place in the factory or on the project site. In the factory, individual units are fastened into finished assemblies. For larger installations, two or more subassemblies are created in the factory and then joined together in the field.

Factory mulling has many advantages. Factory mulling provides a certified, rated, and warrantied assembly. Each window unit is precisely joined with the next, ensuring consistent sizing and alignment. This consistency is critical for preventing air leaks, water infiltration, and other issues. Quality control protocols ensure each window unit meets its specifications before it is shipped. Factory mulling also provides greater warranty protection since the manufacturer is responsible for the entire window assembly, including the mullion joint. This cannot be achieved with field-mulled assemblies, where liability shifts to the installing contractor. Finally, factory mulling can save time and labor costs since the window units are already pre-assembled and ready to install.

In general, field mulling can be less precise and uniform than factory mulling; the project site presents unpredictable weather conditions, and space for assembly may be limited.

However, because shipping and transportation restrictions typically limit the size of the subassembly to a maximum of 8 x 8 feet, there may be times when field mulling is necessary. Highly customized assemblies may also warrant field mulling.

Some companies offer options for quick on-site assembly by delivering large factory-mulled sub-assemblies with all necessary components and instructions included. Such an assembly prep kit includes all of the necessary fasteners, clips, caps, and other parts, speeding up field assembly while ensuring an AAMA-450-certified window assembly.

The mulling method not only affects how the assembly looks, but also how it performs. A standard mull uses a mull pin to connect the frames and strengthen the system. The frames are joined tightly together, with no reinforcement or space between them. A reinforced mull uses a full-depth reinforcement mull pin to add strength to the mulled system (see image below). The method used will vary depending on the product, project type, and required performance ratings. In general, an integrated design approach, including early coordination with the window manufacturer and the project's structural engineer, will ensure the design succeeds.

How Mulling Affects Performance

Mulling significantly affects the structural and environmental performance of multi-unit window configurations; thus, it's critical to consider how the design can potentially impact water management, air infiltration, structural stability, sound transmission, and code compliance. For example, building codes—in particular, header requirements—may limit the maximum size of the window wall.

Factors to consider include the size and spacing of the windows, glazing type, and the quality of the sealants used. In many