



WINDOWS TO THE WORLD: Going Big with Operable Glass Walls

Examining the varied applications of multi-slide and multi-fold glass walls allows for new directions in more effective, sustainable, and valuable buildings.

BY C.C. SULLIVAN, CONTRIBUTING EDITOR

Today's commercial and institutional buildings increasingly take advantage of large openings, including fenestration systems with multiple connected sliding or folding sections. These windows and doors can integrate with the building enclosure and each other, presenting a unique and even unexpected architectural element. Regardless of their design or stylistic function, the systems called multi-slide/fold operable glass walls provide a range of configurations and attendant performance features that lend appealing flexibility and openness to a variety of facility applications. Properly specified and integrated, they also deliver essential protective functions for the building envelope.

To this end, building teams interested in glass wall systems must review in the planning phase their engineering and installation criteria, as well as long-term performance attributes, including operations and maintenance impacts. This applies to glazing, framing, and hardware components, as well as optimal multi-slide/fold location and orientation. When properly specified, fabricated, and installed well, these systems complement sustainable and high-performance building projects. Successful integration for green buildings hinges on highly weather-resistant and energy-efficient construction assemblies. At the same time, these windows and doors dramatically open up interior spaces to the outdoors, creating memorable and inviting spaces as well as increasing the available daylight and outdoor views that contribute to LEED certification and healthy building properties.

To review the potential solutions in this fenestration category, savvy building teams are examining its growing popularity and appeal across a broad range of facility types, including multi-family residential structures, hospitality settings, institutional buildings, and even healthcare, education, and civic projects.

In addition, the use of multi-slide/fold glass walls is coming indoors to address transparent wall applications and other operable partitioning needs inside buildings. The interior uses add considerable flexibility as well as basic acoustic controls while also allowing for transparency, improved communication, and visual connection.

Whether for indoor or exterior uses, architects and engineers must compare multi-slide/fold system types on the market today in the light of core technical considerations for their specification, installation, and operations. Key criteria include airtightness and moisture resistance, pressures and loading, and energy efficiency. For the latter, today's glazing specifications include dual-paned insulated panels with low-emissivity (low-E) glass that reflects heat but admits high levels of visible light. Where needed for envelope moisture resistance, the doors and windows may require water barrier sills, although some applications can use minimalist flush sill designs. Other

LEARNING OBJECTIVES

At the end of this program, participants will be able to:

- + **DESCRIBE** general principles of designing with multi-slide/fold glass openings and the system types available.
- + **LIST** the benefits of using multi-slide/fold openings, including sustainability and ROI considerations.
- + **DISCUSS** the basic technical issues as well as ratings and applicable codes that govern the use of multi-slide/fold fenestration systems.
- + **EXPLAIN** how certain features and options in these fenestration systems, such as hardware and glass type, help address facility life cycle and maintenance concerns.



ALL PHOTOS BY WESTERN WINDOW SYSTEMS

options include matching screens for sliders as well as a range of metal and wood finishes.

Criteria for durability as well as air, water, and structural integrity include ANSI standards and performance certifications published by the National Fenestration Rating Council (NFRC) and the American Architectural Manufacturers Association (AAMA). In addition, teams are cataloging facility best practices for design, operations, and maintenance against a backdrop of evolving building codes and standards, related regulations, and even voluntary certifications that can be met with these large glass window-door systems.

MARKET APPEAL AND NEW POSSIBILITIES

The main engines behind the relatively fast growth of this product category reflect some dynamic market factors, says Ty Cranford, a manufacturing company executive and expert in multi-slide/fold systems. “Some building teams have demonstrated an underlying business case for the use of these operable glass walls, such as enhancing sales and leasing values or boosting facility operating revenues, or both,” he explains. “These economic benefits add to the backdrop of several macro-trends in architecture today, including owners who want to encourage more indoor-outdoor spaces, the prerogatives of sustainable design, and the appeal of operable façade systems.”

Other experts have noted that multi-slide/fold systems simply add a “cool factor” and even an “ego boost” for owners and occupants. The ability to have very large glass openings and large-scale indoor-outdoor experiences are a relatively new and promising area of architectural design. Facility aesthetics have also evolved with the possibilities of these large operable glass walls. “It wouldn’t do these products justice to simply call

them windows or glass doors. Rather, these are glass walls capable of opening up, or in some scenarios, nearly disappearing altogether,” according to the Washington-based architecture firm BUILD LLC. “In the Pacific Northwest, operable glass walls make a significant lifestyle difference.”

Other architecture firms and commercial developers share this view. Increased glazing area, sometimes with floor-to-ceiling glazing, is an appealing strategy for more natural light in regions with low-angle sun and short winter days. This can also reduce reliance on electrical lighting as it maximizes daylight. It is equally appealing to program more indoor-outdoor uses and exterior access in areas with temperate climates or with seasonal preferences for indoor-outdoor activities. In all these cases, “designing transparent walls that can easily fold or slide open creates a strong relationship between inside and outside, allows for exterior spaces to become outdoor rooms, and provides excellent natural cooling for the interiors,” according to the Seattle firm.

The business case made for these precision-engineered premium fenestration systems covers a large segment of the building market and some unlikely applications. Cranford notes that some residential, hospitality, and multifamily/mixed-use facilities have applied multi-slide/fold systems in settings where the glass walls may be opened only a few times per year. The use in educational facilities is growing, including interior applications for K-12 “flex classrooms” as well as exterior uses in university dining halls or for libraries with patios or outdoor study areas. For retail applications, some owners report incremental revenue or increased sales associated with the indoor-outdoor appeal.

At hotels such as the Marina Del Rey Hotel in California (above), sliding glass doors to amenities, such as balconies with expansive scenic views, are key. This is particularly true for hotels and resorts in desirable climates, where guests can utilize them year-round.



Indoor-outdoor lounge seating at restaurants and hotels is a big draw for customers, and the latest trends in fenestration systems, such as folding doors and window walls, can easily accommodate. The doors at this sushi restaurant in Phoenix leave little distinction between the dining and patio areas.

(See “Typical Uses, Benefits and ROI” on page 28.) Another equally fast-growing application is for hospitality environments, including hotels, resorts, casinos, restaurants, and lounges.

In all of these applications, the operable glass enclosures add daylight and views, increase access to the outdoors, and maximize view corridors. There also is a fourth top-level benefit, though it is largely psychological: The multi-slide/fold glass assemblies can transform and expand a small space, literally creating more square footage outdoors but also seeming to create larger interiors, too. This appeal, say experts like Cranford, are largely about owner-occupant perceptions as well as the integrated nature of glass window and door elements.

EVOLUTION OF SYSTEM CONFIGURATIONS

Because the market for multi-sliding and folding glass openings has matured over the last decade, it is valuable for building teams to bone up on the varied “off-the-shelf” product systems available from fabricators and manufacturers. Commercial and institutional uses tend to gravitate toward aluminum framing as well as aluminum-clad wood frame options, often paired with performance-specified glazing. Hardware designs vary widely, from value-oriented models to others with rugged, high-quality operable hardware requiring minimal maintenance. While many

custom and proprietary variations add to the list of possible specifications, the basic product types include:

Multi-Slide Door Systems. These are moving walls of glass that stack or slide into pockets for very wide openings. The frames are generally aluminum or aluminum-clad wood, though other materials may be employed, and many frames combine painted or anodized aluminum exterior surfaces with an interior side of exposed wood with a stained or painted finish. Typical frame thicknesses are around 2 inches, worked into various modern or traditional profiles such as a beveled glazing leg or, in some cases, with simulated divided lites, as needed to match or contrast with other project fenestration.

Folding Door Systems. This product type comprises arrays of paired bi-fold doors and represents an increasingly common amenity for multifamily projects. It is also seen in hospitality, retail, and other commercial applications. Bi-fold doors can open completely to the outdoors, with the arrays stacking and folding typically against side or end walls, sometimes creating openings that span an entire room’s width. In some settings with frequent or daily use as an entry, the arrays include single- or double-swing doors matched to the folding arrays. Critical to effective specification is robust, smooth-operating hardware such as sealed stainless steel ball bearing rollers. Thermally broken frame members, especially for aluminum-framed products, help boost energy performance and reduce thermal variations in interior spaces. Adding dual-pane low-E glass enhances energy efficiency further.

Sliding Door Systems. A more basic architectural opening, sliding systems typically employ a single-track sliding system for use with two, three, or four stackable panels. Able to span a wide variety of size openings, these door systems have evolved to include narrow-profile frames for a simple and clean contemporary look. As with multi-slide products, use of thermal breaks and low-E glass improves their energy performance.

Window Walls. To add an even larger glass expanse, some teams incorporate window walls with operable sections, including swinging and sliding doors, multi-slide/fold arrays, and casement, hopper, and other ventilating window styles.

Windows and Doors. In other building designs, multi-slide/fold fenestration is matched with other doors and windows in the building, including multi-slide and folding type systems set at typical window heights. In addition to the multi-slide and folding arrays, which potentially create very large, wide openings, matched windows with hinged, sliding, and single-hung hardware can be incorporated into the façade.

GENERAL PRINCIPLES OF APPLICATION

There are a few basic considerations for designing with operable multi-slide/fold glass wall systems. First, the building’s orientation will dramatically affect daylight harvesting and the prevention and control of unwanted heat and glare. Second,

the project's team must determine the ideal opening area: Beyond pure aesthetics, the glass area or window-to-wall ratio (WWR) "is an important variable affecting energy performance in a building," according to the Efficient Windows Collaborative, adding that it impacts the "building's heating, cooling, and lighting, as well as relating it to the natural environment in terms of access to daylight, ventilation, and views." Because they use high-performance glazing, some façades have allowable fenestration areas that exceed prescriptive maximums given by the International Energy Conservation Code (IECC) and the energy-efficiency standard ASHRAE 90.1. Other regional energy codes, such as California's Title 24 and the Massachusetts state energy code, may require additional computations and reporting to verify compliance.

Third, teams must take into account how glazing and shading strategies can reduce undesirable heat gain while still admitting plenty of daylight. High-performance fenestration products include such features as insulating glass to block heat transfer; tight and durable seals (weatherstripping) to minimize air leakage; and thermally broken frame designs that provide an insulating barrier within metal or aluminum members, for example. NFRC's ratings and its product database provide immediate guidance for key performance variables, listing their solar heat-gain coefficient (SHGC), visible transmittance (VT), and also the U-factor (sometimes called U-value) quantifying the overall heat-transfer capacity of the building component. Most multi-slide/fold products are made in conformance with the standard NFRC 100 for determining U-factor and NFRC 200 for assessing SHGC values.

These ratings help teams calculate overall data on the products and façade assemblies, which can be used for performance method compliance for many energy codes, an option that can offer flexibility and other advantages over the prescriptive paths. "In some cases, building teams should consider the performance path," according to codes consultant Stephen Mogowski of Desert Skies Code Compliance, because it allows a view of the final project as a whole, and what certain trade-offs in architectural design can achieve, such as increasing WWR or adding extra insulation in opaque façade sections.

Glass and frame type tend to be the primary variables affecting energy performance, daylighting levels, and occupant comfort. Other product characteristics of multi-slide/fold glass wall systems that impact sustainability goals may include:

- **Certified Wood.** Some wood-frame panels are made with timber reviewed by groups including the Forest Stewardship Council (FSC) to verify that materials originate from sustainably managed forests.

THREE KEYS TO SUCCESS: HARDWARE, HARDWARE, HARDWARE

The performance and the life cycle cost of a multi-slide/fold door or window opening will hinge—almost literally—on the judicious selection of hardware. The hardware must be suitable for the desired opening sizes and jamb depths, as well as for the ratio of glazed area to frame area. Examples of some key hardware choices include:

- **Sill Tracks and Hardware:** Multi-slide/fold door and window systems can be applied with bottom-load or top-hung sill tracks. For strength and durability, stainless steel hardware is a common specification. Some stainless steel head load carriers and hinges carry panel weights of around 260 to 265 pounds, while some bottom-load carriers and hinges can accommodate door panels weighing up to 175 pounds. Sealed stainless steel ball bearing rollers offer a durable and easy-to-operate solution even for heavier panels. Interior doorstops may be specified in wood, metal, or rubber.

- **Floor Tracks and Sills:** For multi-sliding door systems, a water-barrier sill, such as one designed with a higher interior leg and weep holes, can help reduce or eliminate bulk water intrusion. In some designs, the back leg of each sliding panel penetrates the track to help keep out dust and debris, providing added protection. Contrast this with a flush sill, which is ideal when ease of entry is more important than performance against water ingress. These align with the interior finished floor height and still may have weep holes and back legs that protect against debris. In addition, a narrow concealed sill can be used to provide the look of a seamless continuation of flooring from the inside to the outdoors. These can be assembled with staggered tracks to expose a slim channel on which the panels roll, with the finished floor installed between them.

- **Top-Hung Tracks:** For multi-slide and fold systems that can be hung from the header, these include hardware for a water-barrier sill with a longer interior leg to accommodate the weight concentrated in the heads. A flush sill is also possible. Also, for top-hung bi-fold doors intended for interior use only, a U-shaped track can provide a flush transition element.

- **Heavy Duty Hardware:** For strength and durability, some door and window systems should be specified with heavy-duty hardware of stainless steel or comparable, although other materials are available on the market. One benefit of stainless steel rolling hardware is that the materials help resist corrosion and the assemblies tend to require low levels of maintenance. Standard-size rollers are nominally 2 inches in diameter, while the rollers for large, heavy operable wall panels may be about 3 inches in diameter.

- **Security and Locking:** Many multi-slide/fold fenestration assemblies require locking and security features. Options available on the market include concealed multi-point lock mechanisms that secure large sliding panels for additional strength under high wind loads, for example, as well as security against intrusion. Keyed cylinders may be desired for some applications.

- Recycled Materials. Examples include aluminum, a highly recyclable material, as well as some vinyl and even cardboard and paper used for shipping.

- Regional or Domestic Manufacture. There are various benefits to a “made in the U.S.” label, including reduced energy needed for transport as well as all code-mandated air, water, and structural testing with verifications by the NFRC, AAMA, and other authoritative groups.

In terms of specifications, multi-slide/fold door products range up to 12 feet in opening height and can span an entire wall, multiple column bays or more. For this reason, structural testing is essential.

All the systems must meet basic fenestration standards for performance class, which assure general compliance with building codes and key ratings. The primary specification for windows, doors, and skylights is the North American Fenestration Standard AAMA/WDMA/CSA 101/1.S.2/A440, a performance-based and material-neutral designation for minimum design pressures that range from 15 psf for detached dwellings, to 25 or 30 psf for low- and mid-rise multifamily and other commercial applications, and up to 40 psf for architectural applications including mid- and high-rise structures expecting higher loads. The design pressure is listed as PG (for performance grade) followed by the psf value; PG25, for example, is typical for a multi-slide door assembly. For a multiple bi-fold assembly, a common specification is PG20.

When specifying multi-slide/fold doors, teams also may call out product material and construction options to ensure proper performance under expected operating conditions and weather. For example, component parts of aluminum alloy, plated steel, stainless steel, and nonmetallic materials help resist deterioration and corrosion. Details such as extended legs on the bottom rails of operating sliding door panels penetrating a weather-stripped channel in the threshold will help prevent the panels from becoming disengaged from the sill under wind loads. Specs may call for an interlock system on door stiles for bi-fold door arrays, a feature that ensures proper engagement with rails, secured with a tie-rod assembly for a permanent rigid connection at the panels’ top and bottom corners.

For robust and solid operation, multi-slide/fold assemblies are similar to other medium- and large-scale fenestration systems. Framing assemblies should be neatly fitted and mechanically joined at the corners with stainless steel screws, for example, ideally with all horizontal members doweled and glued. Pocket-type doors should include post-interlock frame members at the interior and exterior of pocket openings—as well as integral J-channel trims for finish application inside and out—to assure proper detailing and operation.

Considering the needs of facility management in the design phase also helps assure proper product specification.

Removable glazed panels facilitate maintenance and any needed reglazing. Insulating glass used for multi-slide/fold panels should conform to ASTM C1036 (a standard specification for flat glass) and ASTM E774 (standard for sealed insulating glass). Typical details include a dual seal with a thermoplastic spacer and silicone, holding fast panels of 3/16-inch-thick glass for glazed areas up to 40 square feet. For greater areas, quarter-inch-thick glass is employed. Weatherstripping may include combinations of polyurethane foam, polyethylene film, and inserts of glass fiber thread or polypropylene. Per code, door glass should be fully tempered.

TYPICAL USES, BENEFITS, AND ROI

Fortunately, multi-slide/fold systems on the market today are available with increasingly robust features in order to suit an expanding range of application types. Evaluations of ROI help explain the current growth. So while operable glass walls are associated most frequently with the luxury residential market, including custom homes and market-rate multifamily projects, a confluence of facility trends is increasing their use in other project types.

These applications share some key attributes: For many of them, the primary driver is an indoor-to-outdoor experience; a secondary benefit is flexibility, which applies to both exterior wall installations as well as use as interior glass partitions. Other benefits include conformance with green ratings and healthy building guidelines, which tend to call for more natural light, outdoor views, and outdoor ventilation. Adding to the list are:

Market Differentiation. Whether for a university dining hall in San Diego or a premier big-box retailer in Kansas City, the use of an operable wall system allows for year-round or seasonal access to outdoor recreation, displays, and amenities. If the competition doesn’t offer the same experience, say some owners, more students and customers may be retained.

Sustainability and Wellness. Several trends in making facilities more environmentally responsive and sensitive are being addressed with operable glass walls. Some of these, such as increased outdoor views, natural daylighting, and fresh outdoor air levels, are also considered in standards for human health and wellness. The WELL Building Standard, evidence-based healthcare design, and even some active-design proponents see operable glass walls as adding some social and health benefits to new and renovated buildings.

Adaptable Layouts. Multi-slide and multi-folding glass assemblies also are increasingly selected for high-value interior locations, primarily to make adjoining spaces more flexible and useful. Classic examples in this regard range from the use of interior operable glass walls for conference areas and automobile showrooms, to the use of both fixed, swing, and multi-slide/fold products in university academic building interiors and even inside some new elementary schools.

Incremental Revenue. Project developer-owners have found opportunities for enhancing property values as well as resale values by increasing aperture sizes of fenestration schemes. In other cases, facility operators and tenants have reported improved per-visitor sales or satisfaction (or both) in facilities with large operable glass walls versus others built without.

This bottom-line benefit merits further exploration. For example, experts on retail and hospitality markets have studied the impact of “outdoor customer experience” in a variety of commercial settings, according to groups like the International Council of Shopping Centers (ICSC). One of those, restaurant consultant Peter Breslow, has described the curb appeal of outdoor dining as something akin to watching a live television commercial about the clientele and their experience. In urban settings, passersby experience “all of the sights and smells” of the current customers. In addition, if the patio seating is full or the outdoor shopping is busy, more prospects are converted to actual customers, all things equal.

Adding outdoor floor space can also boost revenue. *Philadelphia Business Journal* reported that by adding 20 outdoor seats, a typical restaurateur could increase revenues by as much as a fifth. Another economic case relates to the incremental sales associated with outdoor seating, which can also increase gross profits—and provide a rationale for the ROI of adding multi-slide/fold glass walls to a new or reconstructed facility. If the proprietor sees faster “table turns” and/or a likely additional sale of one premium coffee or appetizer for every five to 10 tables per shift, monthly revenues could increase by several hundred dollars up to several thousand, depending on the size of the enterprise. For many retailers and restaurants, the incremental improvements estimated in business scenarios like these suggest ROI levels that may rationalize financing the retrofit of operable glass walls or door arrays.

There’s one last factor, of course: climate and weather. For much of the year it’s too humid in Houston and too chilly in Philly for indoor-outdoor retailing, right? In some cases, this is true, yet some six-month revenue projections are rosy enough to have large, high-quality glass doors year-round. Many facilities are also being built with MEP systems designed to extend the outdoor season, according to the ICSC: water misters and fans in Phoenix, and radiant lamps and fire pits in Colorado Springs, for example.

And for such image-driven industries, it’s important to add a hard value for the “ego boost and cool factor” of dining al fresco or shopping under the stars, as Cranford calls it. According to shopping center owner-manager PREIT, in



Whereas retail storefronts in the past were less concerned about open access and wide aperture sizes, many of today’s building designs, such as that for Joyride Taco House in Phoenix, take advantage of surrounding natural environments to appeal to customers.

some contexts the aperture size—a storefront’s transparent opening area—is an indicator or visual cue of a store’s status or a restaurant’s rank, so the group codified the ideas in its recent tenant design guidelines. According to PREIT, historically this has been an inverse relationship, so small aperture sizes (such as at a jeweler) suggest a higher price point. Yet in recent years, openness and transparency have become a hallmark of premium retailers—think Apple stores and others like Tesla, Lego, AT&T, and Disney stores. Better access, views of the product and customer traffic, and other factors have led to bigger apertures.

Over the life of a building, users and occupants will determine its success. The use of bold, innovative techniques to blend the indoors with the outside, such as multi-slide/fold systems, do more than just create dramatic spaces. They offer ways to change the space around the user, beautifully and efficiently, for years to come. +

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