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distinctive solutions for renovating building façades



Window Replacement Unrealized Benefits to Building Owners and Occupants







Building Retrofit Strategy
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New Windows Provide a Better Work Environment and Create Building Value

Building owners, property managers and occupants can enjoy extensive benefits of window renovation and upgrades, such as:

- Improving the appearance of the building
- Expanding useable floor space
- Optimizing daylight and views
- Minimizing unwanted exterior noise
- Saving energy by as much as 40%¹
- Downsizing HVAC loading and lighting capacity
- Reducing maintenance
- Protecting property and occupants
- Improving interior comfort for occupants
- Lowering vacancy rates
- Increasing lease rates
- Enhancing the value of the building

Window systems and components have evolved significantly since the 1980s. About half of all U.S. commercial and institutional buildings were constructed prior to this period, which presents a significant opportunity for owners and occupants to benefit from façade improvements and window replacement.

Many aging buildings' existing windows are leaky, single-glazed units with conductive framing systems. These buildings may be difficult – or even dangerous – to operate. They can promote unhealthy condensation, mold or mildew formation. Occupants may prefer to keep their distance from exterior walls due to glare, solar heat gain, drafts and noise.

In addition to the benefits in the appearance and marketability of commercial spaces, nearly every occupant desires window views and natural light. Tall, triple-hung windows, clerestory and skylight glazing, and courtyard areas characterize turn-of-the-century buildings. These features maximize natural daylight by necessity, as available artificial lighting and climate control were unavailable or

insufficient. As electric-powered lighting and HVAC systems became standard, natural light and ventilation were no longer seen as essential. Today, they are making a comeback as the cost of wasted energy, and the benefits of daylighting and views, are emphasized.

Re-cladding and renovating building exteriors with high-performance window systems can have a significant affect on the building's energy efficiency. When window replacement is timed in conjunction with an HVAC system upgrade, significant reductions in peak load can yield further savings in equipment costs. For building owners seeking enhancements in security, design criteria for façade renovation also can include blast hazard mitigation, hurricane impact resistance, electronic eavesdropping protection and forced entry deterrence.

Most buildings currently in use will continue to be in use until 2050 and, eventually, will require renovation. Establishing clear goals and expectations for building envelope maintenance and renovation will significantly contribute to future success.



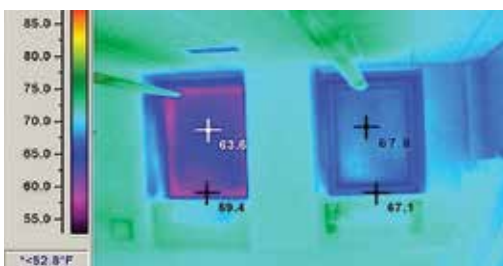


Prudential Plaza, Prudential I Tower, Chicago

Originally built in 1955, Jones Lang LaSalle (JLL) invested \$100 million to update Prudential Plaza, one of the most recognizable landmarks in Chicago's East Loop. Renovating the 41-story façade of this Class A, high-rise office tower included improving exterior aesthetics, tenant comfort and leasing success.

As part of the overall project, the renovation team replaced more than 1,200 bays of existing, single-pane windows with high-performance windows featuring low-e glass. Using proprietary energy modeling tools, the team reviewed annual energy use, peak demand, carbon emissions, daylight, glare, condensation predictions and cost savings to optimize product selection. The modern windows meet the high design pressures needed due to proximity to Lake Michigan, meet acoustic performance for improved occupant comfort, contribute to operational savings through energy efficiency, and achieve JLL's objectives for enhanced appearance and long-term value.

Infrared thermographic (IRT) imaging can identify areas where there is air or water infiltration, as well as where thermal performance can be improved. These images for Prudential I Tower show window frame surface temperature differences of nearly 8°F between the old unit on the left and the new unit on the right. The exterior temperature was 33°F. The interior temperature was 71°F.



“Our new tenants would not have signed leases without the windows being replaced. Tenant comfort is extremely important to the leasing efforts of a building. The first impression they get when they walk into a space can make or break a showing.”

– Greg Prather, senior vice-president and group manager at Jones Lang LaSalle (JLL)

Top Reasons for Façade Renovation

To attract and retain occupants, improving aesthetics and updating image is the top reason given for renovating the building façade.

1. Aesthetic or image update
2. Energy performance
3. Remediation of failure (water or air infiltration, material failure, etc.)
4. Code compliance
5. Green standard compliance (LEED, ENERGY STAR, Living Building Challenge, etc.)²

For many historically influenced window replacement projects, or for “retro” new construction, building owners seek to replicate the look of steel sash or putty-glazed wood framed, or hung windows by using architecturally rated, aluminum windows. This historic look will reduce maintenance and overall cost without sacrificing modern day performance.

Using high-performance glass and aluminum frames with thermal barriers, the exterior face of the glass is set back from the face of the frame to provide an interesting “depth” and texture to windows’ surface. These can be beveled, ogee or cove molding shapes.

The decision on whether to do a complete tear-out of existing frames – or to use a panning to prepare the opening – is one of the most critical decisions facing a major window renovation project. Aluminum extrusions are easily customizable, opening up possibilities for enhancing ease of installation and matching original appearance.

The fidelity to which historic buildings must be preserved depends on regulations, desired tax credits and grants, and the purpose of the building.

**Improved aesthetics and tenant comfort,
while contributing to operational savings**



Case Study: Soho House, Chicago



Transforming a 1900s factory building into modern 40-room hotel and private club, Soho House wanted to maintain the historic aesthetic and update performance for the comfort of its clientele. Soho House's in-house design team and founder, Nick Jones, led the design with additional support from the joint venture development team of Shapack Partners and AJ Capital Partners.

Matching the large scale and fine detail of this vintage property, 500 historically accurate windows simulate the look of original, turn-of-the-century steel windows true divided lites with a narrow, exterior face in cove profiles. The matte Statuary Bronze finish communicates a sense of established longevity and timelessness. Along with providing large views and daylight, the new windows also meet Chicago's stringent energy codes.

"The historic window replacement was essential to maintaining the authentic appearance of our 1900s warehouse building — both on the exterior and on the interior. The windows provide the daylight, engineered performance and attention to detail that we needed."

— Jeffrey Shapack,
president of Shapack
Partners



500 historically accurate windows simulate the look of original, turn-of-the-century steel windows

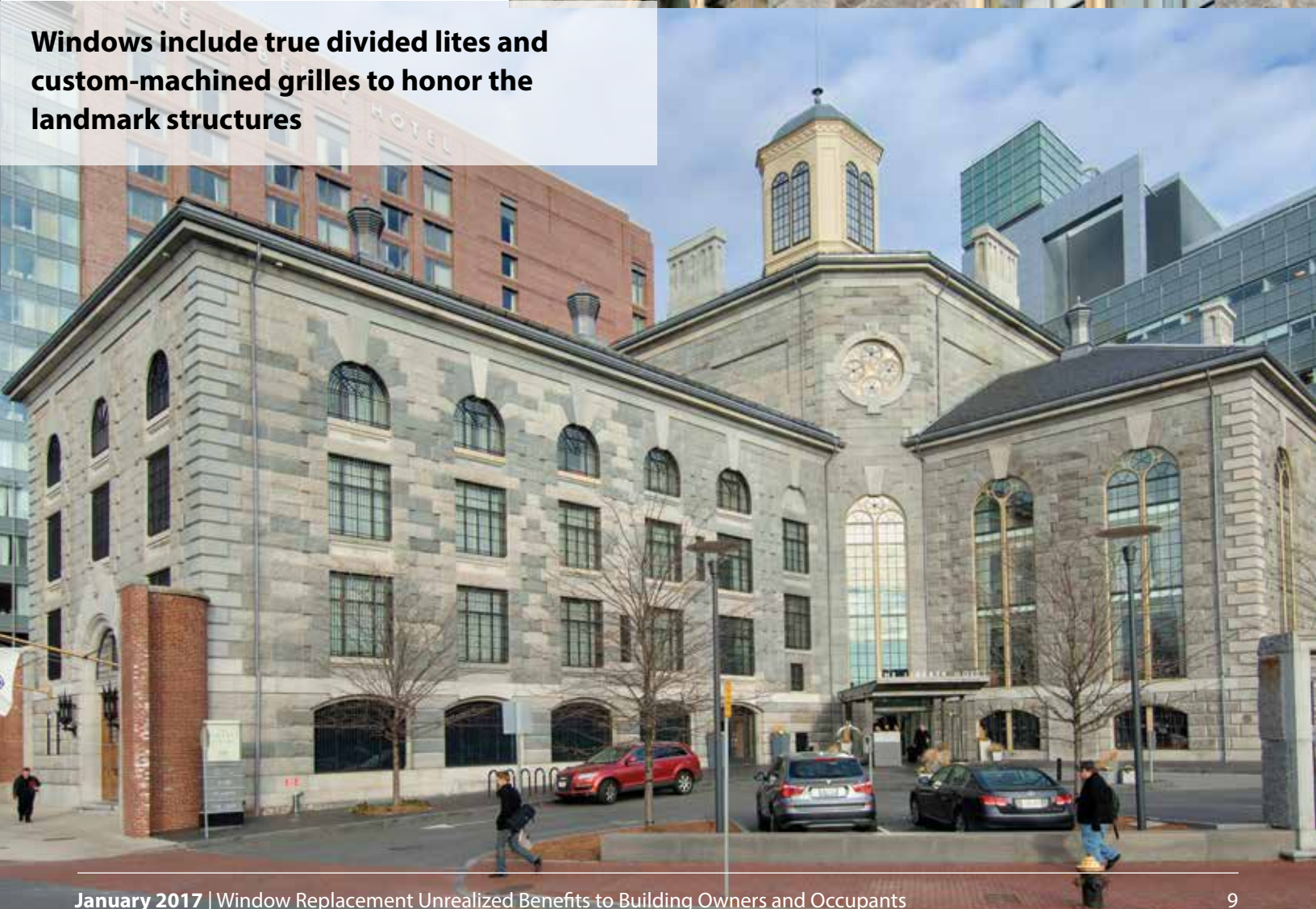
Case Study: The Liberty Hotel, Boston



Now known as The Liberty Hotel, this 298-room, high-end hospitality destination began as the Charles Street Jail in 1851. Through restoration, reuse and reinvention, this abandoned structure was reborn as a vital commercial development that complements the urban fabric of its Beacon Hill neighborhood. Its architectural heritage is retained with its famed rotunda, jail-themed bars and restaurants, and its historically accurate replacement windows. To match exact historical details, the windows include true divided lites and custom-machined grilles to honor the landmark structures in which they are installed.



Windows include true divided lites and custom-machined grilles to honor the landmark structures



Case Study:



State University of New York, D&H Administrative Building, Albany

For nearly a century, the Delaware and Hudson (D&H) railroad company headquarters has anchored State Street and Broadway in Albany, New York. Originally constructed in phases between 1915 and 1918, the large, historic structure today serves as the Administrative Building for the State University of New York (SUNY). Updating the building's performance and preserving its architectural heritage, more than 1,000 windows were provided for the property's 2012 renovation.

The building sat vacant for many years. In 1972, it was added to the National Register of Historic Places (NRHP). Acting in part to preserve this landmark, SUNY purchased the building and the neighboring Federal Building as the University's first permanent home. SUNY moved into its offices in 1978. Including the Federal Building, the entire 260,000-square-foot property is four stories high with a 13-story central tower. In addition to being NRHP-listed, it also is part of the Downtown Albany Historic District.

Mimicking the look of historical windows, simulated double-hung projected windows were selected as they replicate the existing double-hung sash with offset glass planes. Projected windows also overcome inherent issues with counter-balancing added weight of insulating glass in double-hung sashes. High-performance glass with superior acoustics was required as Interstate 787 in downtown Albany runs past the building. For thermal performance in the New York winters, the windows' aluminum frames use an extended polyamide thermal barrier and low-e, insulated, laminated glass.

Accentuating the products' longevity and performance, the aluminum framing members and the mullion covers on the D&H Building were finished in "Albany Brown." The custom color uses a two-coat 70% fluoropolymer paint for a consistent, long-lasting finish – inside and out.

Simulated double-hung projected windows were selected as they replicate existing double-hung sash with offset glass planes



Case Study:



The University of Washington-Tacoma, McDonald-Smith Building

The University of Washington-Tacoma (UW Tacoma) completed its reconstruction and renovation of the 120-year-old, four-story McDonald-Smith Building located in the Union Station Historic District. Meeting the historic aesthetic and modern performance needs, Mission Glass installed more than 116 simulated double-hung, arched top, fixed windows.

As part of an \$11 million renovation project, the university has modified the existing historic building for additional office and meeting spaces. Planning and design for the project started in 2014 led by Bassetti Architects.

The single-pane wood windows were original to the building and were in poor shape. The Landmarks Commission was particularly concerned that the profiles of the new window frames matched the historic windows as closely as possible.

This was the first project using extruded aluminum framed windows approved by the Commission. Given the unique arch of the McDonald-Smith windows, and that 17 different custom arched window


openings exist on the building, the team was challenged to find the best product to use. The selected windows were to exemplify “superior craftsmanship, similar sightlines, closer brickmold profiles” and “fewer long-term warranty issues.”

The simulated double-hung fixed windows that were selected met all of these needs and match the arched openings. The windows feature curved 4-7/8-inch-deep aluminum frames painted in a Black Panther color. Using a two-coat, 70% PVDF resin-based coating helps extend the window systems’ lifespan and reduce maintenance costs.

The fixed windows have offset glass planes to give the appearance of historic double-hungs. Combined with high-performing glass, extra-wide polyamide thermal barriers achieve low U-Factors, high frame condensation resistance, high acoustic performance and are American Architectural Manufacturers Association (AAMA) AW-100 Architectural Performance Class rated.

“The renovation of the McDonald-Smith Building [feels] like a natural extension of the University of Washington Tacoma campus, honoring the heritage of the Union Depot historic district by breathing new life into an aging building.”

– University of Washington Tacoma’s Division of Finance & Administration’s Campus Planning & Real Estate



Meeting the historic aesthetic and modern performance needs, Mission Glass installed more than 116 simulated double-hung, arched top, fixed windows

Improved Performance

Beyond the benefits of improved appearance, window systems directly affect and influence multiple areas of the whole building. In the short term, there are initial cost considerations of materials, equipment, labor and disruption to occupants. Long term, the impact is much greater when considering the cost and function of the building's operation, the marketability of available space, and the comfort and productivity of its occupants.

During the useful life of 30-40 years, window systems in a commercial building:



Use 1.88 quads for annual heating³



Use 3.86 quads for annual cooling³



Contribute to water infiltration³



Contribute to air infiltration³



Contribute to peak electricity use³

- **Impact HVAC sizing**
- **Impact productivity**
- **Impact occupant well being**

Energy Modeling

Commercial buildings are divided into thermal zones, which are served by different HVAC and lighting systems and/or controls. Each space has a different temperature range, a different outside air ventilation requirement and even a different operating schedule.

Perimeter zone modeling results can be used in subsequent whole-building modeling. A perimeter zone is defined as a 10-foot-wide office space extending 15 feet from the window with a ceiling height of 9 feet and a total floor-to-floor height of 12 feet.

The "gold standard" of fenestration energy modeling tools is the COMFEN energy modeling software, developed by the Windows and Daylighting Group at Lawrence Berkeley National Laboratory, under the auspices of the U.S. Department of Energy and other supporting organizations.

COMFEN gives knowledgeable users a tool to systematically evaluate alternatives for fenestration: size, location and commercially available glass types, as well as shading and light re-direction schemes, both interior and exterior. It is both project-specific and site-sensitive, offering evaluation tools for dozens of locations worldwide.

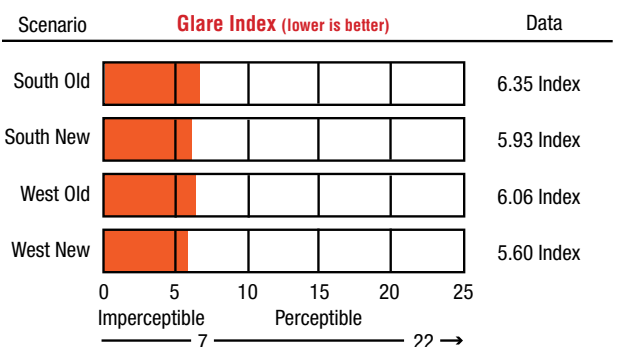
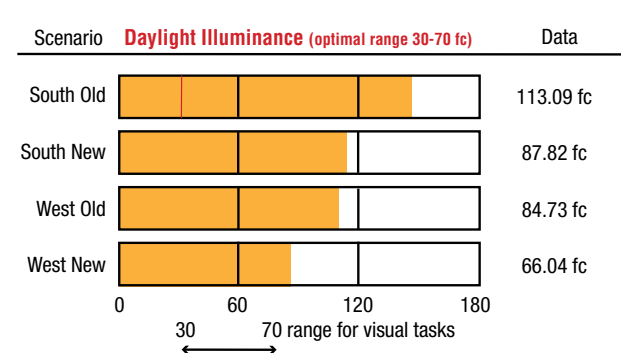
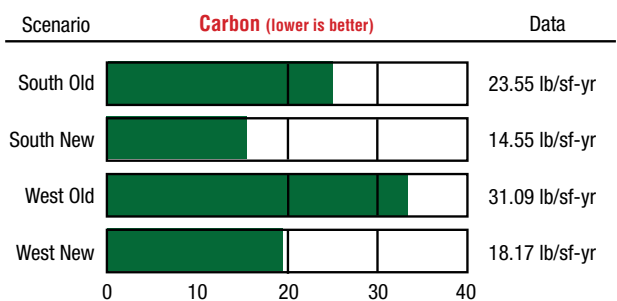
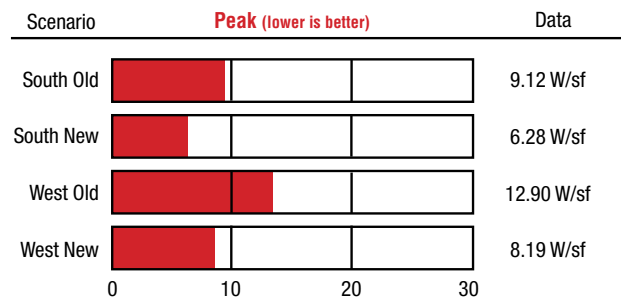
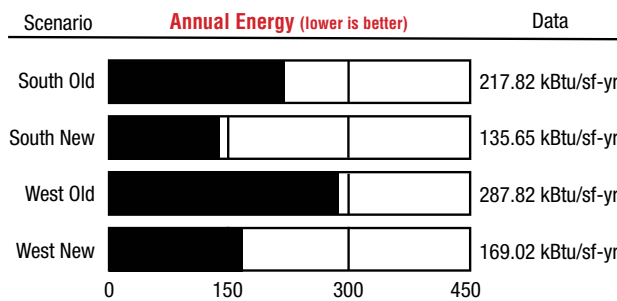
Formatted as tables and graphs for ease of interpretation of thermal comfort and visual comfort for perimeter zones, COMFEN outputs include:

- Annual energy consumption
- Peak energy demand
- Carbon emissions
- Daylight luminance
- Glare
- Condensation

Given its breadth of options, alternatives and powerful functionality, COMFEN's user interface was made as simple as possible. Allied industry groups, as well as some national window and curtain wall manufacturers, use COMFEN to power other applications that further assist in product selection and optimization.

COMFEN was used to determine the data/results shown here for Chicago climate zones with South and West elevations and a window wall ratio of 60%. The effect of excessive air infiltration through existing operable windows is added to COMFEN-calculated energy savings for each replacement window comparison base case. The base case assumes the existing windows are considered operable with no weatherstripping nor interior or exterior shading devices and with 0.25-inch monolithic glass. Replacement windows are based on Wausau Window and Wall Systems 3250i-XLT INvent™ Series with Viracon VE1-2M insulating glass.

Energy modeling tools can compare performance data between a building's existing windows and proposed, new, high-performance, replacements units to provide building performance information on annual energy, peak demand, carbon emissions, daylight, glare, and condensation.



LSG	Effective Aperture	Condensation Prediction	Cost Savings	Carbon Savings
1.08	0.53	Extensive	0.00	0.00
1.85	0.42	None	2.53	37.46
1.08	0.53	Extensive	0.00	0.00
1.85	0.42	None	3.63	54.27

Annual energy is based on site energy, and performance data are given as energy use per perimeter zone floor area (e.g., kWh/sf-yr or kBTu/sf-yr). Total annual electricity use includes electricity end uses: lighting, cooling, and fans for supply, and returns for ventilation, heating, and cooling.

Peak demand is based on source energy and is the greatest amount of electricity required at one point in time during the year. Data are given for the peak condition that occurs in each perimeter zone and are non-coincident with the whole building's peak condition, and includes all electricity end uses: lighting, cooling, fans, and other electric end uses including plug loads.

Carbon emissions are based on source energy. It is multiplied by the electric energy consumption to calculate the pounds of carbon-dioxide emitted due to electricity use (lbs/kWh).

Average annual daylight illuminance is calculated in foot-candles at a point 9 feet from the window in the center of the room.

Weighted glare index is calculated at point 5 feet from the window for a person facing the side wall. Anything under 22 is acceptable for glare.

LSG is the light-to-solar-gain ratio between the visible transmittance (Tvis) of a glazing and its solar heat gain coefficient (SHG). This is a measure of the ability of a glazing to provide light and exclude solar heat.

Effective Aperture is the light-admitting potential of a glazing system determined by multiplying the window-to-wall ratio (WWR) with the visible transmittance (Tvis). This can be useful in evaluating the cost effectiveness and daylighting potential of a glazing system.

Condensation Prediction is reported at "none," "minimal," or "extensive." If the surface temperature is more than 3°F higher than dew point then the condensation prediction is "none."

Annual cost savings represent the differential cost per square foot of glass between the generic base case and a selected product.

Annual carbon savings represent the differential carbon emissions in pounds per square foot of glass between the generic base case and a selected product(s).

The assumptions for the simulations are based on a perimeter zone office module of 10 feet in width, 15 feet in depth, and a 12 feet floor-to-floor height. No daylighting controls were used. Electric prices are averages for the cooling seasons (May-September) of 2011-2013. Gas prices are averages for the heating seasons (November-March) of 2011-2013. The gas and electric prices for each location are provided by the U.S. Energy Information Administration.

Case Study:

Brighton Towers, Syracuse, New York



Brighton Towers provides high-quality, affordable housing to seniors as managed by Rochester Management, Inc. Constructed in the early 1970s, the building's windows had become difficult to operate and were no longer effective for energy conservation and occupant comfort. The \$19 million renovation, which utilized low-income housing tax credits, included asbestos abatement, numerous interior and structural improvements, and new windows for all units.

In total, 1,365 new high-performance windows were installed. The carefully sequenced nine-month schedule minimized disruption to the occupants throughout the renovation, resulting in on-time, on-budget completion. Easier operation, improved energy performance and nicer appearance contributed to both a satisfied owner and contented residents.

“The selected windows met Brighton Towers’ performance requirements for energy; for air, water and structural; and offered an additional improvement for sound transmission. Wind also was a key issue for this project. [These] products are higher end and longer lasting than many on the market.”

– Mike Konopka, president of Konopka Architecture

Easier operation, improved energy performance and nicer appearance contributed to both a satisfied owner and contented residents





ROI on Window Replacement

When considering window replacement or curtain wall re-cladding projects, long-term return on investment is of high interest to building owners and managers. For replacement projects, perimeter zone energy consumption and peak energy demand is estimated for both existing and new fenestration, using one or more energy modeling tools. Equipment costs, as well as regional average energy costs, can then be applied to results to yield energy savings estimates. In the climate of the project site, annual energy savings for one bay of new windows is estimated using simple spreadsheets to generate an energy analysis recap. Assuming that energy cost inflation exceeds the normal inflation rate by a certain percentage, savings will grow year after year.

Look Beyond Simple Energy Payback

In the current economy, when energy cost escalation and interest rates are much more comparable, few installations show an energy-based simple payback time less than 25 years. Facilities professionals are more informed these days, however, and now consider all the factors involved, including carbon footprint reduction, maintenance savings, and safety and occupant productivity.

- 1-2 year payback on energy for lighting – 18% of energy use in commercial buildings
- 5-7 year payback on energy for HVAC – 44% of energy use in commercial buildings
- 15-50 year payback on energy for windows⁴

Important Factors to Consider for Return on Investment

- New window systems reduce lighting and HVAC capacity requirements.
- New window systems reduce maintenance and repair expenditures due to water infiltration, condensation, caulking, painting and glass replacement.
- Employee productivity can be improved by improving the work environment. Even a small increase in employee productivity can have a large, positive financial impact as salary costs are generally 10 times higher than energy costs in U.S. office buildings. Energy-efficient, high-performance buildings provide occupants with access to daylight, comfortable temperatures and better air quality. These environmental characteristics are correlated with lower absenteeism and higher productivity, and can save up to \$2,000 annually per employee.
- Utilization of the perimeter space of a building is becoming more important as the space per employee continues to decline and tenants are trying to be more efficient. New window system technology can keep people in a comfortable environment without experiencing extreme heat or cold.
- A building's aesthetics can be improved with new glass and aluminum framing products, which will attract new tenants and retain existing tenants. Buildings that have upgraded these components have reduced vacancies and increased lease rates. This, in turn, improves the value of a building.
- Some window renovation projects also qualify for federal and state historical tax credits, for the federal Energy-Efficient Commercial Building Deduction (179D), for tangible asset property deduction, for grants and for utility rebates.
- In most cases, window replacement or curtain wall re-cladding is considered to be an imperative – with energy savings characterized as an added, albeit significant, benefit.

Case Study:

SUNY College at Fredonia, Disney, Igoe and Schulz Halls



As the nation's largest comprehensive public university system and one of New York State's largest energy consumers, SUNY is committed to creating more sustainable campuses for its 465,000 students. On its College at Fredonia campus, SUNY serves more than 5,200 students and 1,100 staff on 256 acres. Among the Fredonia students' residences are Disney Hall, Igoe Hall and Schulz Hall.

Disney Hall, part of the Kirkland Complex, is named for Walt Disney and opened in 1967. Igoe Hall and Schulz Hall, part of the Andrews Complex, opened in 1970. Igoe honors former student James Robert Igoe. Schulz Hall is named for famous cartoonist Charles Schulz.

SUNY is improving efficient energy use in these buildings with a window replacement project that upgrades the aging, single-pane, steel-framed windows. The project began in 2013 and is scheduled for completion in 2017. In total, more than 350 windows in SUNY Fredonia residence halls will be replaced with high-performance windows, storefront and entrance systems.

The window systems installed on SUNY Fredonia's student residences feature solar control low-e glass and aluminum framing with polyurethane thermal barriers, which contribute to the building's energy-saving goals and condensation resistance. Durable anodize finishes on the aluminum framing members match the existing design palette, reduce the need for maintenance, and extend the window and entrance systems' lifespans.

Features solar control low-e glass and aluminum framing with polyurethane thermal barriers, which contribute to the building's energy-saving goals and condensation resistance





Code Compliance and Green Standards

Energy codes and other provisions of local building codes may be different for historically significant buildings, and also may depend on the extent of the retrofit.

ENERGY STAR is a program of the U.S. Environmental Protection Agency for certifying energy-efficient buildings. Its methodology and data are used by Green Globes, by the U.S. Guiding Principles for High Performance and Sustainable Buildings, and by the U.S. Green Building Council's (USGBC) LEED green building program. An ENERGY STAR score of 75 is a prerequisite of buildings certified in LEED Operations and Maintenance, version 4, (LEED O+M v4).

Demonstrating their energy efficiency, more than 28,000 facilities have been certified by the ENERGY STAR program. Associated benefits include:⁴



Up to 26% increase in property value



Up to 11% increase in occupancy rates



Up to 15% increase in lease rates

Environmental Stewardship

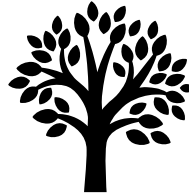
Improving both the performance and the appearance of existing buildings, a new energy-efficient window system is proven to enhance the building's overall value and is a clear demonstration of environmental stewardship. One of the best ways to illustrate this is by converting the energy savings determined by modeling tools into their approximate fossil fuel equivalents. In one such conversion methodology, Wisconsin Public Service Corporation developed environmental conversion factors to be used for analysis (electrical energy generation equivalents).

The most sustainable project is one that improves on what already has been built. Energy-efficient, historically accurate replacement windows can play an important role in improving older buildings' performance and in achieving these designations, through energy savings, recycled content, regional extraction, increased ventilation, thermal comfort, daylight and views.

Fossil Fuel Savings Equivalents



1636.4 kWh of energy =
approximately 1 U.S. ton
(0.907 metric ton) of coal saved



54.7 kWh of energy =
approximately 1 tree's ability
to absorb carbon dioxide



263.7 kWh of energy =
approximately 1 typical, gasoline-fueled
automobile driving around the world
emitting nitrogen oxide

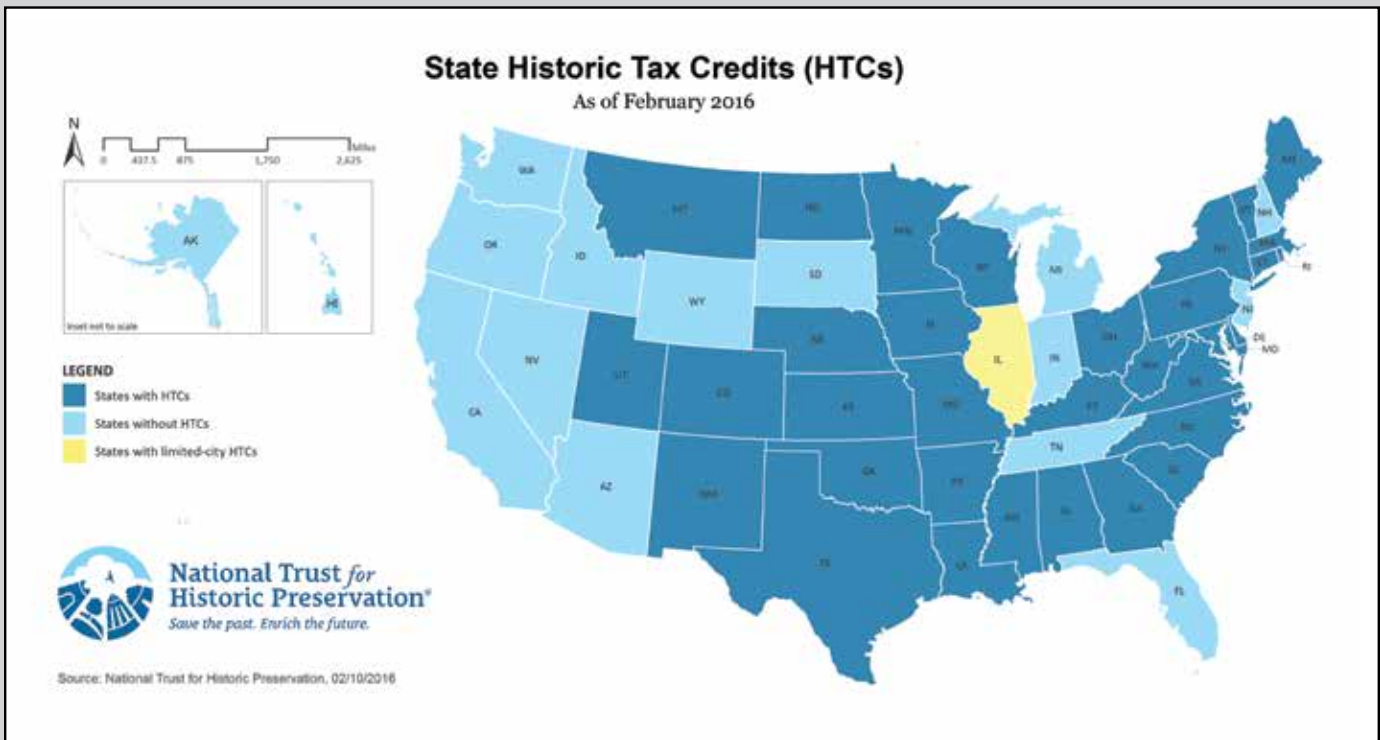


166.3 kWh of energy =
approximately 1 acre of
acid rainfall on forest

“The benefits of green schools go far beyond operational cost savings as these are the facilities where our children spend a majority of their young lives. By providing safe, healthy and comfortable environments, we encourage their learning and show them that we believe they matter.”⁵

– Lisa Laney, Ohio Facilities Construction Commission sustainability administrator





Tax Credits

Of course, every institution's method of calculating return on investment is different. Renovation design teams often provide the savings and cost information to financial staff or energy service companies for economic analysis, so applicable subsidies and tax credits can be factored into the equation.

Depreciation and tax credits also are applicable, using the appropriate rates for the institution or firm in question. Maintenance savings can be considerable, and are either inflation-adjusted only or assumed to increase as existing windows age further. Using the installed budget cost per bay of new windows, and an appropriate after-tax alternative investment rate, a payback time in years is inferred.

Financial assumptions can have a more significant effect on payback time than fenestration design parameters, especially for tax-exempt institutions. For private sector buildings, there are two levels of the Rehabilitation Tax Credit Program:

- A 20% credit for certified rehabilitation of a certified structure
- A 10% credit for non-historic buildings pre-1936

The Rehabilitation Tax Credit program is administered jointly by the U.S. National Park Service (NPS), the U.S. Internal Revenue Service and each State Historical Preservation Office (SHPO). Since its inception in 1976, nearly 30,000 buildings having qualified for the maximum

20% tax credit. To earn this credit, both the structure and the rehabilitation process must be certified.

- Certified structures are those that are either listed on the NRHP, are more than 50 years old or contribute to the historic significance of a registered historic district.
- A certified rehabilitation process is one consistent with the historic character of the building or district, as evidenced by the written review and approval of the SHPO and the NPS.

When window replacement is required, and using the same material is not technically or economically feasible, the referenced standards still require preserving distinctive features, finishes and construction techniques, as well as matching design, color, texture and visual quality of the original building components. The NPS have the last word in acceptability of replacement window aesthetics.

The U.S. General Services Administration (GSA) owns more than 400 buildings listed in, or eligible for, the NRHP. Similar to private sector projects, the GSA is required to use SHPOs to assess the potential adverse impacts per the U.S. Secretary of Interior's "Standards for Rehabilitation." For GSA-owned buildings, blast hazard mitigation and hurricane impact resistance can take precedence over preservation, but other historical renovation parameters still hold.

Case Study:



Byron Rogers Federal Office Building, Denver, Colorado

Preserving its Modern Formalist design style, the 494,156-square-foot Byron G. Rogers Federal Office Building was renovated to upgrade security, seismic and energy performance. The window system replacement also improved daylighting and continued the facility's commitment to LEED certification and ENERGY STAR labeling. As part of the \$154 million design-build retrofit project, more than 1,600 blast hazard-mitigating windows plus curtain wall and light shelves were installed.

The design-build team worked with the GSA to find ways to generate a design model targeting a more aggressive savings goal of 27-30 kBtu per square foot per year. Using continuous whole-building energy modeling that compared various combinations of efficiency measures, predicted hourly energy use and annual energy costs, led the team to a realistic evaluation of various alternatives. This targeted reduction is expected to provide an annual energy savings of up to 65% per year over previous use.

"All together, the Byron Rogers Federal Office Building systems are expected to lower the building energy consumption by up to 65% over its previous rate. The systems are expected to save taxpayers more than \$250,000 per year in energy costs, while providing superior comfort and a modern workplace for various federal agencies."

– U.S. General Services Administration (GSA)

The windows were selected "to maximize the amount of visible light and insulative properties and to minimize solar heat gain. The exterior window must also meet federal blast requirements, and maintain its original gray color to meet historic preservation requirements."

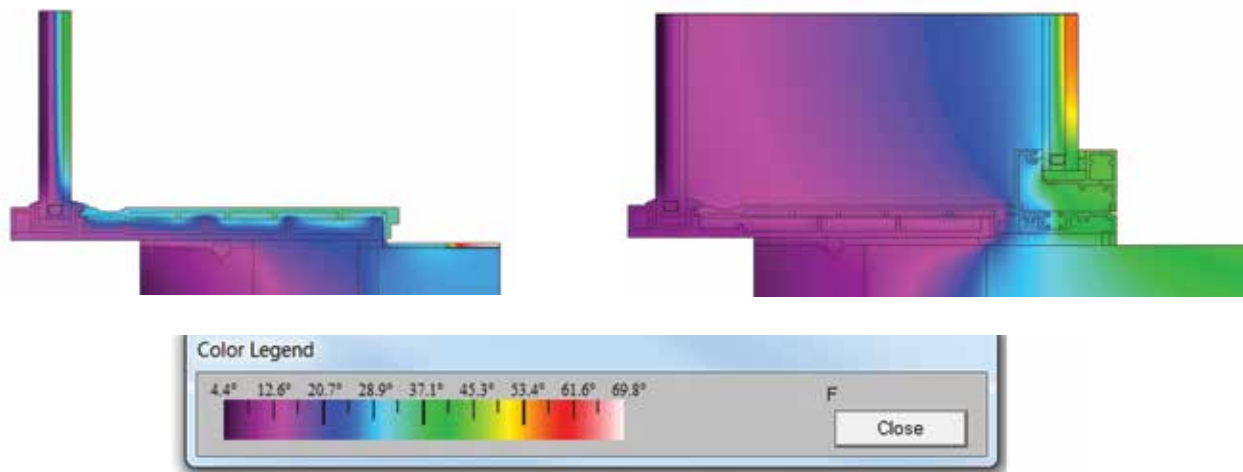
– Rocky Mountain Institute

The systems are expected to save taxpayers more than \$250,000 per year in energy costs



Pre-Renovation Window System with Thermal Problems

Post-Renovation with Improved Thermal Performance



In the picture above, the image on the left shows the existing building, which was built in the mid-1960s with insulated glass. This window system had condensation and conduction issues because of the thermal “short circuit,” where the vertical and horizontal members meet with a U-Factor of 1.11.

In the above picture, the image on the right shows an upgraded, high-performance glass with an interior accessory window installed behind it. This improved the U-Factor to as low as 0.24 and helped reduce the thermal short circuit. To meet the building’s historic and security requirements, the interior accessory windows also are engineered for blast hazard mitigating performance.

Existing Window Sill (Existing Sill.thm)

- Project Design Conditions: -3 °F (outside), 72 °F (inside), 15 mph wind speed
- Relative Humidity: 25%
- Dew point: 34 °F
- Total U-Factor: 1.11
- Center of Glass U-Factor: 0.457
- Glass Makeup: (Existing): 1-inch bronze insulated (¼-inch bronze annealed, ½-inch air space, ¼-inch clear annealed)

New Window Design (Type 3 Sill.thm)

- Project Design Conditions: -3 °F (outside), 72 °F (inside), 15 mph wind speed
- Relative Humidity: 25%
- Dew point: 34 °F
- Total U-Factor: 0.24
- Center of Glass U-Factor 0.11
- Glass Makeup – Exterior: 1-inch insulated (¼-inch gray/clear/crystal gray VE-2M #2, ½-inch air, ¼-inch clear pyrolytic Low-E #4)
- Glass Makeup – Interior: 1-3/32-inch insulated laminated (3/16-inch clear VE-85 #2, ¼-inch air, 13/32-inch laminated (3/16-inch clear, 0.030-inch PVB, 3/16-inch clear)

Case Study:



Edith Green-Wendell Wyatt Federal Building, Portland, Oregon

In Portland, Oregon, an 18-story, 1970s office tower was renovated and transformed from a former “energy hog” into a high-performing, attractive building now known as the Edith Green-Wendell Wyatt Federal Building.

To meet the GSA’s aggressive energy-use-intensity target of 35,000 BTUs per square foot per year for the property, site-specific climate and solar analysis specified 40% vision glazing and 50% shading during summer’s peak loads. Tuned to these requirements, the new curtain wall used elevation-specific shading and reflective elements. In addition to the high thermal performance, the curtain wall also offers blast hazard mitigation.

Exceeding expectations, the improved exterior reduces annual energy usage by 60% and annual operating costs by up to \$400,000. The American Institute of Architects’ Committee on the Environment recognized the renovated facility as a Top Ten green project in 2014.



Prior to renovation.



The improved exterior reduces annual energy usage by 60% and annual operating costs by up to \$400,000

Renovation Specification

Setting aesthetic and performance goals for a successful window replacement involves considerations for thermal transmittance, condensation resistance, acoustics, ventilation, view and solar heat gain. The window replacement project team not only can include facility management and design professionals, but also the building's mechanical engineer and the technical staff from a qualified window manufacturer.

To ensure complete and competitive bids from the building envelope retrofit team, include the following:

- A complete description of work to be performed, including instructions on panning versus tear-out of existing frames
- Specific minimum requirements for performance, materials, fabrication, finish, operation and hardware selection
- Pre-qualification procedures for manufacturers and installers
- Field testing and quality control expectations
- Details ensuring the integrity of the building shell is maintained – air/moisture transmission, compatible materials and thermal expansion
- Related work, such as plaster repair or molding removal/replacement
- General conditions, including bonding, insurance and warranty
- Sequence of work and schedule
- Instructions for deliveries and disposal of materials removed, such as diverting demolition debris from landfills and the recycling of glass
- Access to, and protection of, occupied spaces and their contents
- Working hours
- Available outside and inside storage

Interior Accessory Windows

When original windows are weather-tight, and operation for ventilation is not a requirement, the addition of high-quality, custodian-operable, interior accessory windows (IAWs) can be a viable option. With appropriate caution to avoid between-glass condensation, these economical add-on units improve control of sound, energy, air and light, while leaving existing windows undisturbed.

Demonstrating the successful use of IAWs in NRHP-listed buildings, "Preservation Tech Notes: Windows, Number 5 – Interior Metal Storm Windows," was developed by the NPS and the Center for Architectural Conservation at Georgia Tech. It offers a case study in historical preservation of the 1887 Old Watkins National Bank in Lawrence, Kansas. The property's 102 windows included five styles and 12 sizes with many spanning 5-by-10 feet.

According to the "Tech Notes:"

- "The monumental [existing] windows are elegantly detailed on the interior and contribute to the grandeur of the spacious banking rooms. The original interior shutters are still being used for comfort and light control."
- "The numerous problems with exterior storm windows encountered in this project led to consideration of an interior storm system."
- "An initial cost savings of nearly \$20,000 was realized over exterior storm applications."
- Furthermore, "the storm windows are reducing the energy consumption by more than 40% – a figure that exceeded the theoretical calculations. Long-term maintenance of the storm windows is expected to be low because of the quality of construction."



Working with an experienced building envelope retrofit team that includes the installer and manufacturers, building owners and facility managers can improve their properties' appearance to attract and retain tenants, expand their useable floor space for greater lease value, save energy and operating costs, reduce maintenance costs, enhance occupants' comfort and productivity, and ultimately, increase the value of their buildings.

Glossary

AAMA is the abbreviation for the American Architectural Manufacturers Association, the fenestration industry's source of performance standards, product certification and educational programs.

Anodizing is the process of electrochemically controlling, accelerating and enhancing oxidation of an aluminum substrate. Anodized aluminum resists the ravages of time, temperature, corrosion, humidity and warping, as well as is 100% recyclable.

Building envelope refers to the physical separation between the interior conditioned spaces and exterior unconditioned spaces.

Cladding on a building refers to the application of one material over another to provide a "skin" intended for aesthetic purposes and/or to control the infiltration of air, water and weather elements.


COMFEN energy modeling software is considered by the fenestration industry to be the "gold standard" of fenestration energy modeling tools.

Curtain wall refers to non-load-bearing exterior wall cladding that usually spans from floor-to-floor with vertical framing members running past the face of the floor slabs. Curtain walls are designed to support their own weight and wind loads.

ENERGY STAR® is a program of the U.S. Environmental Protection Agency for certifying energy-efficient buildings.

Entrance systems refer to the building components that form a building's entry, including doors and surrounding windows.

Fenestration refers to the openings in or on the building envelope. This includes windows, doors, curtain wall, storefront, sloped glazing and other systems that are designed to permit air, light or people to pass through them.



Aluminum extrusions are the material of choice for window and curtain wall framing on almost all commercial and institutional building projects. They can be specified with recycled content and recycled once again at the end of their useful product life.

IGU is the abbreviation for insulating glass unit, which increases a window's thermal (heat) performance by reducing the heat gain or loss.

PVDF is the abbreviation for Polyvinylidene Fluoride. PVDF resin-based coatings are applied to aluminum building components. Coatings with 70% PVDF are typical for commercial window systems to provide high-performance protection and a decorative finish in nearly any color.

Glazing is an infill material, such as glass or plastic. It also is the process of installing an infill material into a prepared opening.

HVAC is the abbreviation for heating, ventilation and air conditioning.

IAW is the abbreviation for interior accessory window, which is attached inboard of the existing, weather-tight windows to enhance performance for sound, energy, air leakage, light, as well as for human impact and blast hazard mitigation.

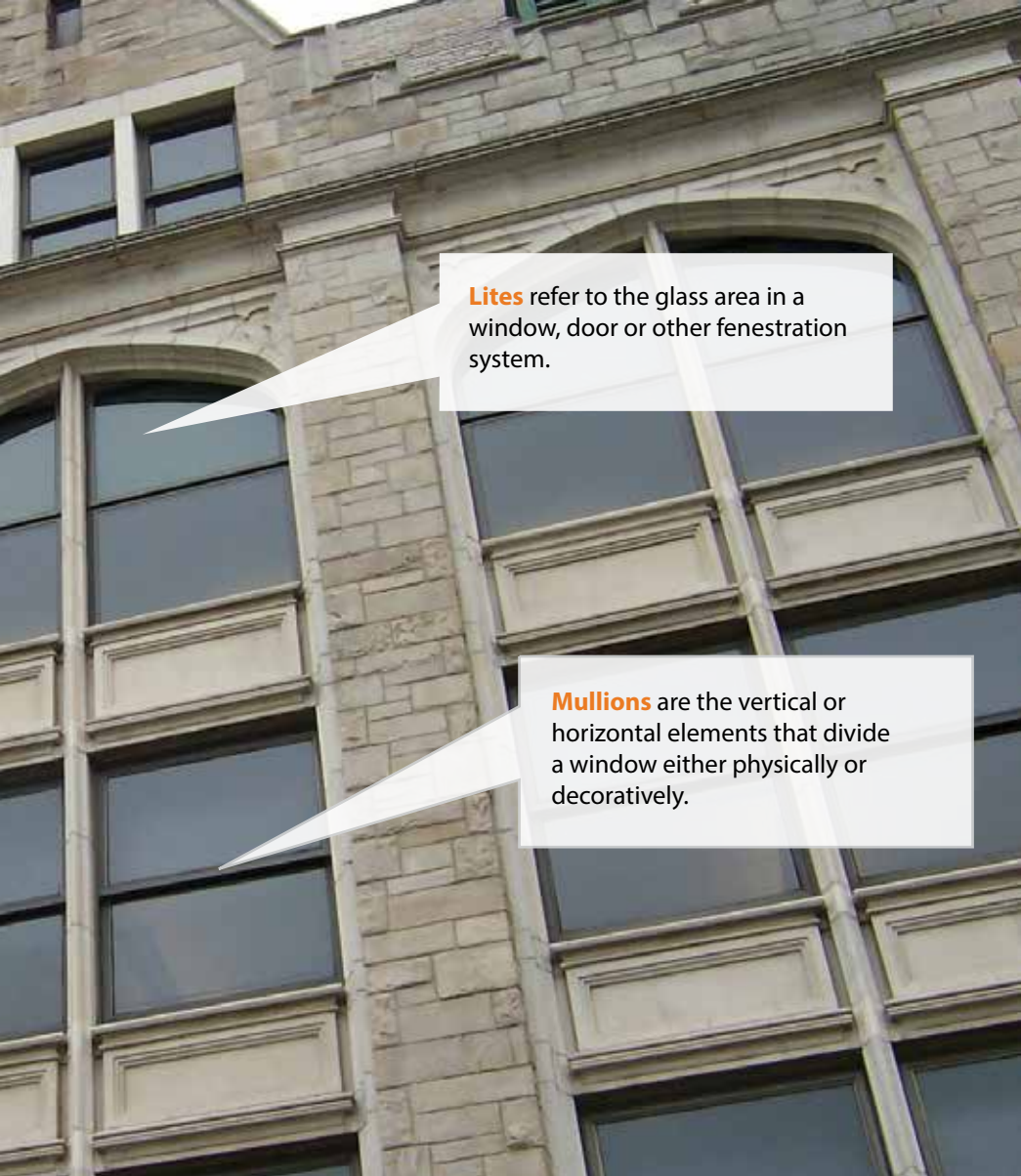
IRT imaging is the abbreviation for infrared thermographic imaging, which shows contrasting colors to indicate warm and cool areas or objects.

kWh is the abbreviation for a kilowatt hour of energy, which is the measure of how energy is sold in the U.S. A 40-watt light bulb operating continuously for 25 hours uses 1 kWh.

LEED® is the acronym for the U.S. Green Building Council (USGBC) program, which formerly was known as the Leadership in Energy and Environmental Design green rating program.

Light shelves are effective at redirecting sunlight deep into occupied spaces when positioned on a building's interior at transom height.

Low-e is the shortened form of low-emissivity, which refers to a surface condition that emits low levels of radiant thermal energy.



Lites refer to the glass area in a window, door or other fenestration system.

Mullions are the vertical or horizontal elements that divide a window either physically or decoratively.

Muntins, or muntin bars, are strips of wood or metal that separate panes of glass in a window. Muntins can be designed to hold panes of glass in a true divided lite (TDL) or applied to the interior and exterior surfaces of glass. TDLs indicate that a lite has been physically separated into smaller sections by muntins. When TDLs are not required, muntins and grids may be applied to the interior and/or exterior surface to simulate this traditional, historic aesthetic.

NPS is an abbreviation for the U.S. National Park Service, an agency of the U.S. Department of the Interior. NPS administers the National Register of Historic Places (NRHP). NPS also jointly administers the Rehabilitation Tax Credit program with the U.S. Internal Revenue Service and State Historical Preservation Offices (SHPOs).

NRHP is an abbreviation for the National Register of Historic Places, which is the official Federal list of districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, engineering and culture.

Panning is the trim used to cover the existing material in a window opening, rather than removing it and potentially exposing unwanted wall conditions.

Quad is a unit of energy equal to 1 quadrillion British Thermal Units (BTUs) or 10 to the 15th power.

U-Factor is the accepted measurement to quantify a commercial window system's thermal performance. The higher the U-Factor, the more heat is transferred (lost) through the window in winter. U-Factors usually range from a high of 1.3 for a typical aluminum-framed, single-pane window to a low of around 0.16 for a multi-paned, high-performance window with low-e coatings and expanded thermal barriers in the aluminum frames.

Simulated double-hung projected windows refer to windows that look like double-hung windows, but actually project from the plane of the wall, either inward or outward. Projected windows are easier to open than hung windows, especially in large sizes with heavy glass. They also have much better air infiltration performance than hung windows.

Storefront systems literally refer to the façade of a store, but more generally describe a commercial system of doors and windows installed together on low- to mid-rise buildings or the lower floors of high-rise buildings.

Sun shades are positioned on a building's exterior and intercept unwanted solar heat gain before it can impact the HVAC system's load.

Thermal barriers are components made of a material with low thermal conductivity and are inserted between metal framing members of a fenestration system to reduce the transfer of heat or cold.

True divided lites, sometimes abbreviated as TDLs, indicate that a lite has been physically separated into smaller sections by muntins. When TDLs are not required, muntins and grids may be applied to the interior and/or exterior surface to simulate this traditional, historic aesthetic.

Window walls in commercial buildings are non-load-bearing fenestration systems that span from the top of a floor slab to the underside of the next higher floor slab.



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