Improving the Energy Efficiency of Aging Commercial Buildings through Window Retrofits

This paper provides an in-depth look at window retrofit options for commercial buildings, including window film, interior commercial storm windows, and the Renovate by Berkowitz™ (Renovate) system. As examined on the following pages, the Renovate system can offer energy savings of up to 25 percent, provide consistent indoor thermal comfort, reduce outside noise transmission, contribute points towards LEED certification, and more, at a significantly lower cost than a traditional window replacement.

Buildings account for roughly 40 percent of all energy consumption in the United States, according to the U.S. Department of Energy (DOE). As a result, improving the energy efficiency of buildings should be a top priority for building owners, design professionals, utility companies, allied industries, the federal government, and cities across the country. These diverse groups are working not just to build efficient new construction, but also to improve aging properties through energy retrofits.

Most energy retrofits for commercial buildings focus on installing high-efficiency boilers, motors, and lighting. However, efficiency gains from equipment can be offset by occupant discomfort due to inefficient windows, which can account for 25 percent of a typical building's heating load in cold climates and 50 percent of the cooling load in warm climates, according to the U.S. Environmental Protection Agency. Because equipment is sized to service a building, improving a building's envelope should be addressed first, so that smaller equipment can be specified, saving on the upfront and ongoing costs.

Energy-efficient glass technologies that are available today, such as low-e glass and insulating glass units (IGUs), were not commonly used in commercial construction until the 1980s. Buildings built prior to that time were mostly constructed with clear and inefficient single-pane windows.

In a 2003 study, the U.S. Energy Information Administration reported 2.7 million commercial buildings were built in the U.S. before 1980. Of these properties, 53 percent still had single-pane windows, and only 7 percent had installed new windows from 1980 through 2003.

While several factors contribute to this low statistic, the cost of replacing windows in large buildings is typically the most prohibitive factor, followed by the disruption of, and inconvenience to, building tenants. Developing and installing cost-effective, energy-efficient glazing solutions for 30- to 60-year-old buildings is critical to achieving any long-term savings goals in the commercial building market.

This paper provides an in-depth look at window retrofit options for commercial buildings, including the Renovate by Berkowitz™ (Renovate) system.

Comparing Window Retrofit Solutions

Window Film

For decades, window film has been used as a quick and low-cost way to reduce solar heat gain, block damaging ultraviolet rays, and provide privacy in older commercial buildings. Applied directly to the interior surface of glass, window film also can help improve a building's safety and security by holding glass together in situations where it would normally shatter. It also has the flexibility to be used on operable and non-operable windows.

On the negative side, window film is only a temporary solution that deteriorates over time. It is susceptible to condensation buildup, air bubbles, scratches, and color changes. In addition, window film offers little-to-no effectiveness in cold weather, and since it is in a permanently tinted state, it can drastically limit outdoor views at night and on cloudy or rainy days.

Complete Window Replacement

Traditional rip-out-and-replace projects can generate significant energy savings by replacing underperforming windows with new, energy-efficient, double- or triple-pane IGUs featuring the latest glass technologies.

Depending on the glass configuration, the new IGUs can offer improved thermal comfort and security, and reduce outside noise transmission. However, a full window

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replacement is highly expensive in terms of material cost, installation labor, and tenant disruption, which often requires temporarily relocating a building's occupants. In addition, a window replacement produces a significant amount of construction-related waste, which must be handled at an approved landfill.

Interior Commercial Storm Windows

Another option is adding interior commercial storm windows to existing windows. Available in single- or double-pane units, and featuring the latest glass technologies, storm windows can improve a building's energy efficiency while preserving its exterior.

Interior commercial storm windows can accommodate windows of non-standard shapes and sizes, and can be opened for cleaning. However, storm windows are not a permanent installation and they are not hermetically sealed to the existing window, which can lead to condensation buildup and air leakage, as well as the collection of dust and bugs. For maintenance and cleaning, interior storm windows must be removed several times a year and reinstalled.

Insulated Low-E Retrofit Panel

Recently, Renovate by Berkowitz, LLC (RbB), based in Pedricktown, New Jersey, developed a cost-effective way to update a building's existing windows that is dramatically more energy efficient than window film and considerably less expensive and disruptive than a traditional window replacement.

The *Renovate* system works by affixing and hermetically sealing a factory-made IGU consisting of two panes of fully tempered, high-performance, low-e glass to the interior surface of an existing, non-operable window. The result is an energy-efficient triple-pane IGU that preserves a building's exterior while creating little or no disruption for existing tenants.

In fact, compared to a traditional window replacement, the *Renovate* system offers similar benefits, but costs about 50 percent less and can be installed two to three times faster.

A Detailed Look at the Renovate System

The *Renovate* system is a factory-made IGU featuring two lites of Cradle-to-Cradle^{cm} certified tempered glass, separated by an argon-gas-filled cavity. A proprietary desiccated spacer system is used to hermetically seal the new IGU to the interior surface of the existing window, creating a permanent, no-maintenance installation.

The *Renovate* system is available in three glass configurations, each designed to accommodate site-specific goals and variables, including climate zone and window orientation. Depending on the chosen configuration, the *Renovate* system may utilize two high-performance, low-e glass coatings by PPG, offering solar heat gain coefficients of as low as 0.27, winter U-values of as low as 0.15, and R-values of up to 6.67. (See Table 1 for performance data.)

Best suited for northern climates, the *Renovate* Platinum system utilizes one lite of low-e *Solarban*® 60 glass by PPG on the No. 2 surface, which dramatically lowers heat loss in winter and heat gain in summer. With its ability to block 62 percent of total solar energy, *Solarban* 60 glass can help buildings achieve improved year-round comfort, and help reduce heating and cooling energy costs.

For colder climates, where higher insulating values are required, the *Renovate* Platinum Plus II system features two lites of low-e glass: *Solarban* 60 glass on the No. 2 surface and *Sungate*® 600 passive low-e glass by PPG on the No. 4 surface.

With its ability to transmit the warming rays of the sun, *Sungate* 600 passive low-e glass offers the perfect balance of energy efficiency and interior comfort for heating-dominated climates.

The *Renovate* Platinum Plus II XL system is optimized for south-facing elevations and southern climates. This configuration features two lites of low-e glass: *Solarban* 70XL and *Sungate* 600 glasses. Due to the exceptional solar control characteristics of *Solarban* 70XL glass, smaller HVAC systems may be specified for buildings glazed with this product, substantially reducing the associated upfront capital investment.

Table 1. Performance Comparison

DATA	EXISTING ¼" Clear	*Renovate* Platinum	*Renovate* Platinum Plus II	*Renovate* Platinum Plus II XL
R-Value[1] *(Center of Glass)*	.97	5.56	6.67	6.67
SHGC[2] *(Solar Heat Gain Coefficient)*	.84	.42	.35	.27
STC[3] *(Sound Transmission)*	30	37	37	37
Winter U-Value[4] *(Center of Glass)*	1.02	.18	.15	.15
VLT *(Visible Light Transmittance)*	89%	63%	57%	50%

[1]R-Value — Higher is better [2]SHGC — Lower is better [3]STC — Higher is better [4]U-Value — Lower is better

Measuring Performance Benefits

A primary factor in choosing to upgrade a building's windows is the reduction in energy consumption and related cost savings.

To quantify the ability of the *Renovate* system to improve a building's energy efficiency and reduce energy costs, the DOE funded a study completed by Home Innovation Research Labs to examine a 12-story office building in Philadelphia from November 2011 through October 2012.

Although the study monitored energy performance throughout the building, the main technical analysis was concentrated in two pairs of unoccupied offices facing different orientations—north and east. One room in each pair was retrofitted with the *Renovate* Platinum system, while its twin was left in its original single-pane configuration with existing window film.

Table 2 details the energy use in the test offices and the reduction in energy consumption. Results show that the east- and north- facing offices, which were exposed to direct solar heat gain, produced heating energy savings of nearly 40 percent, and cooling energy savings of about 36 percent. The north-facing offices, which were exposed to less solar heat gain, showed heating energy savings of about 60 percent, and cooling energy savings of about 9 percent. An analysis of utility bills, shown in Table 3, estimated that the whole building's heating and cooling energy use was reduced by more than 25 percent over two years.

Table 2. Estimated Energy Savings for Test Offices

TEST OFFICE/ORIENTATION	HEATING ENERGY,[A] kWh DECEMBER to FEBRUARY	COOLING ENERGY,[B] kWh JULY 27 to SEPTEMBER[C]
East, Original Glazing, Film	372	341
East, Low-E Retrofit Panels	226	217
East Office Energy Savings	39%	36%
North, Original Glazing, Film	863	222
North, Low-E Retrofit Panels	343	202
North Office Energy Savings	60%	9%

[A] Heating Energy is adjusted to account for minor discrepancies in the Internal Gains in each office pair based on a 1:1 ratio.
[B] Cooling energy is adjusted to account for minor discrepancies in the Internal Gains in each office pair based on an EER of 9.0.
[C] Cooling data period constrained by errant operation of one AC unit.

Table 3. Energy Use Comparison Based on Monthly Utility Billing

HEATING	11/2010 to 03/2011[A]	11/2011 to 03/2012[B]	11/2012 to 03/2013[B]
Heating Degree-Days (HDD)	4,301	3,302	4,058
Gas Use (therms)	47,080	25,895	34,358
Normalized Use (therms/HDD)	10.9	7.8	8.5
Heating Savings Over Base		28%	23%
Estimated Electric for Heating (kWh)	139,923	42,333	116,057
Normalized Use (kWh/HDD)	33	13	29
Electric Savings Over Base		61%	12%
Combined Gas/Electric Heating Savings Over Base[C]		31%	22%

COOLING	05/2011 to 09/2011[A]	05/2012 to 09/2012[A]	05/2013 to 09/2013[B]
Net Cooling Electricity Use, kWh	328,944	341,784	307,583

[A] Pre-window retrofit [B] Post-window retrofit [C] Calculated using a site conversion to Btu and normalizing with HDD

Home Innovation Research Labs. (2013). *Performance Comparison of a Low-e Retrofit Window in a Philadelphia Office Building.* Report #3323.001_10232013.

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Measuring Improvements to Tenant Comfort Levels

Improved Thermal Comfort

By installing the *Renovate* system, building owners can provide tenants with more consistent room temperature throughout the workday. The result can enable the specification of smaller heating and cooling equipment, shorter run times, and faster morning warm-up for the building.

To quantify the benefits, Home Innovation Research Labs studied an office building in Pennsauken, New Jersey. The DOE-funded analysis focused on two controlled offices, one facing west and another facing south. Each had two identical windows. One window in each office was retrofitted with the *Renovate* system, while the other was left in its original configuration with existing window film.

Over a six-month period from December 2012 through June 2013, the glass surface temperatures, mean radiant temperatures, and the room air temperatures were measured in each office.

The retrofitted windows showed a significant reduction in daily variations on the interior window surface temperatures, lowering the maximum temperature and raising the minimum temperature by more than 20 degrees compared to the original single-pane windows.

In addition, because the interior glass surface and radiant temperatures were closer to the room temperature, hours of potential discomfort were reduced by 93 percent on the south orientation and over 66 percent on the west orientation, as detailed in Table 4. The variance is mostly due to differences in direct solar exposure.

Table 4. Mean Radiant Temperature to Indoor Air Temperature Difference

TEST OFFICE/ORIENTATION	HOURS WHEN TEMPERATURE DIFFERENCE IS GREATER THAN	
	5°F	3°F
South, Existing Film	402.25	2,805.00
South, Low-E Retrofit Panel	8.25	200.25
South Office Low-E Panel Reduction	**98%**	**93%**
West, Existing Film	337.25	1,097.50
West, Low-E Retrofit Panel	222.00	369.25
West OfficeLow-E Panel Reduction	**34%**	**66%**

Home Innovation Research Labs. (2013). *Performance Comparison of a Low-E Retrofit Window at the Kevon Office Building.* Report #3323.001_11132013.

Reduced Outside Noise Transmission

To determine the potential acoustical performance benefits provided by the *Renovate* system, *RbB* commissioned Architectural Testing, Inc., to compare the *Renovate* Platinum system with a typical single-pane window. To quantify the improvements, Architectural Testing calculated the Sound Transmission Class (STC) rating and the Outdoor-Indoor Transmission Class (OITC) rating on a test wall with a 44-by-68-inch window with ¼-inch, single-pane glass. The test was repeated after retrofitting the test window with the *Renovate* system.

The results showed that by installing the *Renovate* system, the window's STC rating improved from 30 to 37, which would make a perceptible difference on lower floors of a building in controlling outside noises generated in the frequency range of the human voice.

In addition, the retrofitted window achieved a minimum OITC rating of 28, which would help better insulate against outdoor noises generated in the mid-to low frequency range, such as traffic, aircraft, and trains.

Comparing Installation Costs and Payback Periods

When evaluating options for upgrading a building's under-performing windows, there are several considerations. In addition to potential energy savings and indoor comfort improvements, building owners must thoroughly examine upfront costs and payback periods.

Window Film

Most window film options for commercial buildings can cost up to $15 per square foot. Installing window film only takes a few minutes per window with little-to-no disruption to occupants, but it can take up to a month for the film to completely cure and bond to glass. The payback period for window film can range from two to six years, but ultimately depends on the amount of glass surface area. In addition, window film generally has a service life of 20 years.

■ Complete Window Replacement

Typically, the cost of a complete window replacement varies widely, from $40 to $130 per square foot, depending on the type of specified glass and location. The labor-intensive process can take 60 minutes or more per window to install, but ultimately depends on a number of site-specific variables.

In addition, depending on the time of year, part of the building may be inaccessible during the installation, which usually involves relocating occupants while the work is being completed. Removal of construction-related waste is another consideration. The payback period can range from 20 to 40 years or more.

■ Renovate

The *Renovate* system offers energy-efficiency gains that can exceed those of complete window replacement, but with a much less disruptive installation process. Depending on the glass configuration of the selected *Renovate* system, a window can be retrofitted for one-third to half the price of a complete window replacement. Installation may involve removing existing window film, but generally takes between 20 to 40 minutes per window.

Because the *Renovate* system is installed to the interior surface of the existing window, the building remains completely enclosed during the installation, with minimal disruption to occupants and little-to-no construction-related waste. On average, the payback period ranges from five to seven years, depending on the selected *Renovate* system and other factors, such as location.

Additional Considerations for Building Owners

By updating an aging commercial building's windows with the *Renovate* system, a building owner can earn green building certifications; increase demand for space, resulting in higher rental rates and tenant retention; and meet energy-efficiency goals set by the federal government and cities.

The *Renovate* system can help buildings earn a higher ENERGY STAR rating and potentially contribute a minimum of four points towards the U.S. Green Building Council's Leadership in Energy & Environmental Design (LEED) certification. In addition, the *Renovate* system can admit more visible light into an office building than window film, mostly due to the fact that low-e glass coatings are generally more solar selective than window films.

The benefits of daylighting are well-documented, and include decreased absenteeism, increased productivity in schools and offices, and energy savings resulting from less reliance on artificial lighting.

When looking for a new office, companies are increasingly looking for buildings that are certified by green building programs and that offer healthy, well-lit workspaces. ENERGY STAR, LEED, daylighting, and related issues are common discussion points between prospective tenants and building owners.

These days, many companies are publishing corporate sustainability reports, and because of these reports and their commitments to sustainable practices, they are looking for green office space. Businesses and young talent see environmentally responsible offices as the norm, not an added benefit. In addition, government agencies are required to look for green offices because of their own policies.

Furthermore, the growing concern over energy consumption in commercial buildings is of particular interest to the federal government, which announced the *Better Buildings Initiative* (BBI) in January 2011. The *BBI* is a $4 billion partnership between private industry and the federal government that is focused on improving the energy efficiency of commercial office buildings by 20 percent by 2020. In addition, cities across the country, including Boston, Chicago, New York, Philadelphia, and Washington, D.C., are requiring energy benchmarking for buildings and are creating incentives to make improvements.

The *Renovate* system can contribute a minimum of four points towards LEED certification in the following credit areas:

Energy & Atmosphere
Intent: Reduce environmental and economic impacts from excessive energy use *(EA Prerequisite 2)*
Intent: To achieve increasing levels of energy performance for your building *(EA Credit 1)*

Materials & Resources
Intent: Maintain interior nonstructural elements *(MR Credit 1.2)*

Indoor Environmental Quality
Intent: To provide a comfortable thermal environment that promotes occupant productivity and well-being *(EIQ Credit 7.1)*

Innovation in Design
Intent: To provide design teams and projects the opportunity to achieve exceptional performance above the requirements set by LEED *(ID Credit 1)*

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Case Studies

400 Market Street, Philadelphia, Pa.

Originally opened in 1972, 400 Market Street in Philadelphia was in need of a major upgrade to make it more energy efficient and attractive in a hyper-competitive commercial real estate market.

In 2011, Kaiserman Company, which owns the 200,000-square-foot property, chose to upgrade the efficiency of the building's envelope to reduce operating expenses and improve the comfort level for tenants.

Carolyn Pfeiffer, property manager for Kaiserman Company, said, "We previously used window film, but it would lose effectiveness and was subject to scratching and color changes, and would only help keep the building slightly cooler in the summer. It wouldn't help keep the building warm in the winter. We also considered full window replacement, but the cost was prohibitive even without the supplemental cost of temporarily relocating tenants and disrupting their businesses."

Pfeiffer said the *Renovate* system helped mitigate all of those concerns. "The *Renovate* system was about half the estimated cost of a traditional window replacement project and helped make us eligible for a tax deduction of up to $.60 per square foot," she explained. "The contractor was able to replace 18,000 square feet of glazing (525 windows) in 50 working days, which was two to three times quicker than the estimates for a traditional replacement scenario.

"We are certainly thrilled with the energy savings, but we also accomplished other goals, such as improving the comfort level for our tenants," Pfeiffer said. "As you can imagine, sitting next to inefficient glass can be cold in the winter and warm in the summer, potentially leading to discomfort and decreased productivity for whoever sits next to the window. We've heard comments about how much more comfortable the building has been since the installation of the *Renovate* system, and tenants on the lower floors have mentioned a decrease in street noise.

"The *Renovate* system made transforming 400 Market Street into an energy-efficient competitive building a cost-effective reality," Pfeiffer said. "We anticipate the renovation will be a key factor in retaining and acquiring tenants."

Kevon Office Center, Pennsauken, N.J.

Like many aging commercial buildings, the 100,000-square-foot Kevon Office Center was constructed without the energy-efficient insulating window technologies available today. The building's single-pane windows, originally installed in 1971, lacked a low-e coating and an insulating barrier and, consequently, were notorious for letting solar heat in during the summer and letting furnace heat escape during the winter. That's when Kaiserman Company, which owns the property, began to investigate window retrofit solutions.

"We researched a few options and considered a number of variables, including climate, glass surface area, building orientation, past experiences, and cost," said Carolyn Pfeiffer, property manager for Kaiserman Company. "We had used window film in the past, but found that it deteriorates over time. It is really only effective in warm weather and it also enables condensation to build up, so we knew window film was not going to help us reach our goals."

Pfeiffer said the firm also considered a traditional window replacement, but said, "For this project, we were looking at updating 651 windows with 19,000 square feet of glass surface area. The cost of doing a full window replacement was prohibitive, so we decided to take another look at the *Renovate* system, which produced great results for us the first time we used it.

"When you're upgrading windows with the *Renovate* system, you're adding a factory-made IGU to the existing single-pane glass, so there's relatively no construction waste," Pfeiffer said. "The building remains enclosed and the project moves fast, eliminating the time and cost of temporarily relocating tenants. And with a cost estimate that came in at about half of a traditional window replacement, it was an easy decision to specify the *Renovate* system—it was a win-win-win."

In 2012, the two-building complex's east-, west-, and north-facing offices were retrofitted with the *Renovate* Platinum Plus II system, and the south-facing offices were retrofitted with the *Renovate* Platinum Plus II XL system to combat increased exposure to solar heat gain. Both *Renovate* systems added two lites of high-performance low-e glass to the existing single-pane windows.

Homer Robinson, president and CEO of Kaiserman Company, said, "The installation of the *Renovate* system, along with the other updates we've made, will certainly lower our energy costs, improve the comfort level for our tenants, and help the building earn a higher ENERGY STAR rating."

"The *Renovate* system was about half the estimated cost of a traditional window replacement project and helped make us eligible for a tax deduction of up to $.60 per square foot."

In Summary

The *Renovate* system is a cost-effective solution to upgrading the energy and thermal efficiency of 30- to 60-year-old commercial buildings. The revolutionary window retrofitting system is a permanent solution that offers benefits that exceed those of a traditional window replacement, but at a significantly lower cost. The *Renovate* system also offers:

- Energy savings of up to 25 percent, on average
- Consistent indoor thermal comfort
- Outside noise reduction and better interior acoustics
- Minimal disruption to tenants during installation
- Little-to-no construction-related waste
- Increased security
- Certified installer network
- Potential eligibilty for tax credits and utility rebates
- A minimum of four points towards LEED requirements

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