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Low-e Applied Film Window Retrofit for Insulation and Solar Control

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The Green Proving Ground program leverages GSA's real estate portfolio to evaluate innovative sustainable building technologies and practices. Findings are used to support the development of GSA performance specifications and inform decision-making within GSA, other federal agencies, and the real estate industry. The program aims to drive innovation in environmental performance in federal buildings and help lead market transformation through deployment of new technologies.

DISCLAIMER

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I. Executive Summary

BACKGROUND

Nationwide, on an annual basis, windows in commercial buildings are responsible for 0.96 quadrillion BTUs (quads) of heating energy and 0.52 quads of cooling energy (Apte 2006). This is equal to about 1.5% of the total energy consumption by the United States in 2011, and is equivalent to the energy consumed by more than 8 million U.S. households (US EIA 2012). There is substantial potential for reducing both the heating and cooling energy use in existing commercial buildings associated with windows by using a wide range of technologies and strategies. This study focuses on a new solar control window film retrofit technology that also provides improved thermal insulation, enabling both heating and cooling energy savings. A previous study estimated that there is a potential to save 0.65 quads of heating and cooling energy if the entire U.S. commercial building stock were to be retrofitted with typical solar control, low-emissivity (low-e) double pane glass units (Apte 2006). This represents a 44% savings of window-related heating, ventilation and air-conditioning (HVAC) energy compared to the windows of the existing U.S. building stock, and 15% savings of all the building HVAC energy. Particular buildings may experience higher or lower energy savings depending on window configuration and climate.

Replacing windows in a commercial building can be very expensive. Retrofitting existing windows with applied films is much less complicated, and less expensive, than undertaking a complete window replacement. “Applied films” consist of transparent polymer film with coatings to achieve desired solar optical properties, and an adhesive layer that allows the film to be glued to the glass area of an existing window. Typical applied films can reduce glare and substantially lower the solar gain through the window, which can greatly reduce cooling energy requirements in the building, but they have no significant impact on the insulating value of the window. A new applied film technology is now available that provides both solar gain control and improved thermal insulation by means of a room facing low-e surface. This new type of low-e applied window film is the subject of this study. All plastic substrate applied films provide additional safety benefits in the event of glass breakage, although some specialized products are specifically designed for safety features and even performance during extreme conditions such as blast events. This report does not discuss safety or blast films.

In addition to direct reductions in building cooling energy consumption, reduced solar gain through windows will generally lower peak cooling loads and peak electric demand. In addition, the properties of windows can strongly impact occupant comfort, especially when the occupant is near the windows. Comfort issues associated with poorly performing windows may lead to dissatisfied occupants who request higher heating set-points in winter, lower cooling set-points in summer, or both, resulting in higher energy consumption. The new type of low-e applied window film examined in this study can improve thermal comfort in both heating and cooling seasons in a way traditional applied films cannot.

While reducing solar gain properties of a window can save cooling energy during hot periods, it is important to recognize that reduced solar gain can contribute to increased heating energy consumption in winter. For any particular building, a window retrofit needs to consider the specific internal loads, window area, façade orientation, solar exposure/shading, climate, and other building and user specific factors to determine the appropriate window performance criteria.

The U.S. General Services Administration (GSA) is a leader among federal agencies in aggressively pursuing energy efficiency opportunities for its facilities and installing renewable energy systems to provide heating, cooling and power to these facilities. GSA's Public Buildings Service (PBS) has jurisdiction, custody or control over more than 9,600 assets and is responsible for managing an inventory of diverse Federal buildings totaling more than 354 million square feet. GSA has an abiding interest in examining the technical performance and cost-effectiveness of different energy-efficient technologies in its existing building portfolio, as well as in those buildings currently proposed for construction. Given that the large majority of GSA's buildings include office spaces, identifying appropriate energy-efficient solutions has been a high priority for GSA, as well as for other Federal agencies. Recent legislation and executive orders mandate strong energy use reductions in Federal buildings in coming years. It is expected that GSA's large portfolio of buildings in a wide range of U.S. climates would benefit from the energy savings potential associated with low-E solar control film retrofits.

OVERVIEW OF THE TECHNOLOGY AND TEST SITE

This study evaluates a unique new low emissivity (low-e) applied film window retrofit that both reduces cooling energy consumption associated with direct solar gain through the window, as well as improving the thermal insulating performance of the window during both heating and cooling seasons. Most existing surface-applied solar control films consist of plastic substrate films that are adhered to the existing glass surface using a water-activated adhesive and squeegee application process. These plastic film products achieve solar-optical properties by means of various metallic coatings on the film and, in limited cases, dyes. Applied films can be designed to absorb and reflect visible light, and the near infrared (IR) portion of the solar spectrum, to various degrees, depending on the desired properties for the building. All plastic substrate films also reduce ultraviolet (UV) transmittance, which should reduce the fading impacts of sunlight on interior surfaces.

The insulating value of a window (heat transfer related to indoor/outdoor environmental temperature difference) is typically reported as U-factor, in BTU/hr-ft^2-F, where a smaller number indicates a better insulator. U-factor can be reported for glass area only (often called "center of glass" or COG), or it can include the performance of the framing system in a whole window U-factor. This report discusses glass area U-factors without the frame included. Because plastic films applied with adhesive do not enclose an additional insulating air layer, the U-factor of a base window is unchanged by the application of most retrofit applied films, unless the film has a significantly lower surface emittance than typical glass (0.84). Emittance is a dimensionless number between 0 and 1 that represents the fraction of the thermal radiation emitted by a surface compared to the theoretical maximum. While most traditional applied films do not have a significant impact on the insulation properties of a window, some applied films on the market today have a moderately reduced emittance (typically not lower than 0.4). The particular window retrofit applied film technology examined in this study distinguishes itself from traditional applied films with a very low emittance (~0.05), providing significant insulation benefits. Where a typical single pane window with or without a standard applied film will have a U-factor of 1.025 BTU/hr-ft^2-F, the low-e applied film (~0.05) achieves a U-factor of 0.58 BTU/hr-ft^2-F, nearly doubling the thermal insulation performance and approaching the performance of a double glazed window without a low-e coating. The applied film, with its low-e surface facing the room, also helps to lower the solar heat gain coefficient (SHGC), as a greater fraction of the energy absorbed at the window is rejected to the outside. Occupant thermal comfort is another benefit of the low-e surface, as the radiation exchange is diminished between the occupants and the relatively higher, or lower, surface temperatures of the window, for both heating and cooling conditions.

The overall solar control performance of a window is typically reported as SHGC. Just as with U-factor, solar gain can be reported for the glass area only, or for the whole window including the frame. For the purposes of this report, properties will be specified for the glass area only, without the frame. The SHGC metric includes the performance of all the layers in a glazing system and characterizes the total fraction of incident solar energy that is transferred through the glazing system. Incident solar energy can be directly reflected away from the glazing system, absorbed on one or more glazing layers, or directly transmitted into the room. Solar energy that is absorbed in a glazing layer may eventually be dissipated outside the glazing unit by convection, conduction and long-wave thermal radiation, or it can enter the room by the same processes. The ratio of the absorbed energy flowing inside, versus that which flows outside, is determined by other aspects of the glazing assembly, such as the surface emittance of glazing layers, air movement at each surface, the location of solar absorbing layers in the glazing assembly, and gas fills. It is important to recognize that the optical properties of a retrofit applied film layer alone are not a complete performance indicator for a particular installation. Ultimately, the SHGC performance of the window system, and cooling load reduction potential, will be determined by both the film properties and its context in the overall glazing system in which it is used. For instance, an absorbing film retrofit product will have a much lower solar control impact when mounted on the room side of a double glazing compared to the same film applied on single glazing because of the relative positions of the absorbing and insulating layers in the glazing system. A reflective applied film on single glazing is more effective than an absorbing film on single glazing and it can also work more effectively on the interior of an existing double pane window, by reflecting energy back across the insulating gap. These differences can be directly seen in the relative SHGC values calculated for the complete glazing systems of any particular application.

The low-e applied film product examined in this study is a predominantly solar reflective “spectrally selective” film, providing relatively high transmission in the visible spectrum and high reflection of the solar infrared spectrum. The human eye is not sensitive to solar infrared energy (also known as near infrared radiation, or NIR), so this portion of the sunlight can be rejected from entering the building to reduce cooling load without reducing visible daylighting to the space. Roughly half the energy in the solar spectrum is near infrared radiation. At the time of writing this report, the manufacturer of the product used in this study offers two variations of their low-e applied film with differing optical properties, primarily distinguished by the amount of transmission in the visible spectrum (denoted Tvis or VT). A third version is under development with market introduction expected in 2017. The lowest solar gain version of the film was used in the field installations of this study. When this film is installed on a single layer of clear glass, it has a solar transmission of 0.21 and 0.34 VT (based on independently verified industry standard measurements). The manufacturer provided a pre-release prototype of a new low-e film, under development. It has a higher visible transmission to support more natural daylighting, with 0.301 solar transmission and 0.49 VT. An even higher solar gain version of the low-e applied film is also available, with a solar transmission of 0.46 and 0.70 VT. The highest solar gain version of the low-e applied film is interesting in cases where passive solar gain is more desirable than solar control and on north facing orientations where high visible transmission is desired. However, because this version of the film is substantially more expensive that the other two, it is more likely that the new 50% visible transmission version will be used in most cases that benefit from higher visible transmission. These solar transmission numbers are the direct solar transmission and not the SHGC, which includes the inward flowing fraction (refer to the glazing properties in table 2 or appendix tables AB1 and AB2 later in report for detailed glazing performance parameters). The 50% visible transmission version of the low-e film provides solar control with greater daylighting potential. Most commercial buildings can benefit from solar gain control, even in heating dominated climates; however, there is a tradeoff with passive solar heating that is beneficial to reduce heating energy demand. A previous Green Proving Ground (GPG) report #017 (Curcija 2015) explored the SHGC tradeoff and climate limitations for typical solar control applied films. Annual energy modeling using climate specific weather data helps establish the appropriate glazing properties to optimize this tradeoff. This report focuses on the low solar gain version of the low-e film product, which was the type installed at the two test locations, although modeling results include the performance of all three low-e applied films, on a variety of existing window substrates, as well as benchmark typical applied film products.

There is a mature market of existing competitive applied film products for solar control through windows that is relevant to the film in this study. Applied films are available with a wide array of optical properties, including absorbing and reflective optical properties. These products can have an appearance nearly identical to clear glass or they can include visible tints and colors. Some of the films reduce visible and infrared light roughly equally, as in the case of a flat spectrum tint or a visible mirror-like film. Many competitive applied films are “spectrally selective” like the subject film. They block more solar radiation in the near infrared portion of the solar spectrum compared to the visible, maintaining relatively high visible light transmittance while providing solar control, although the degree of visible light transmission can vary over a wide range for these films, too. Some of these films reduce transmission by absorbing the solar radiation, while others reduce transmission by reflecting the incident radiation back toward the outside environment. Given the wide range of existing absorbing and reflecting products, the best way to compare alternative films is by comparing the SHGC for solar control and the visible transmittance (Tvis or VT). To assess the comparative insulating effect, the emittance of the film should be given or the overall U-factor for the film on glass.

Installed costs of applied films in commercial buildings are typically between \$4.50/ft^2 to \$7.75/ft^2 (with the low-e applied film at the upper end of that range). All of these products are substantially less expensive than complete window replacement, roughly \$40/ft^2, depending on the complexity of the job. A professional commercial installation of a traditional plastic applied film will typically carry a 6 to 15-year warranty (the low-e film installed in this study carries a 15-year warranty) and many installations will be perfectly functional beyond that time period. With proper installation, it is difficult to distinguish the applied film from conventional tinted or reflective glass. Poor preparation and installation can lead to bubbles, and eventually peeling of the applied film. Fading and crazing of plastic applied films can be a long-term durability issue, particularly if a low quality film is used. Proper care and maintenance of a low-e applied film requires a few specific adjustments to cleaning products and processes, but nothing very demanding (see care guide in appendix A).

The manufacturer claims heating energy savings for the low-e applied film are 15-30%, with cooling energy savings of 10-20% in a variety of U.S. climates. The higher end of the range assumes low-e film installation on clear single glazing and lower figures assume low-e film installation on clear double glazing. These savings are based on DOE-2 annual energy simulations of typical large office buildings. The manufacturer suggests a return on investment of 3 years or less for the low-e applied film, compared to 15-20+ years for full window replacement.

The retrofit film installation process involves minimal disruption to building occupants compared to a complete window glazing and frame replacement, and installation can take place after work hours, with minimal loss of business hour occupancy or productivity.

Two buildings in different climates (Ogden, UT and Dallas, TX) were selected for the trial installation and monitoring portion of this study, covering both cold winter, hot summer and mixed seasonal conditions. Both buildings had existing single pane windows with existing applied films (which were removed prior to installation of the VT35 version of the low-e applied film). The window-to-wall ratios for the two buildings were between 30-40%. The Ogden, UT location had all orientations of three of the six floors retrofitted with the low-e film, while a portion of a single floor (out of 16 floors) in Dallas, TX was retrofitted on both the south and north sides. To make heating and cooling season comparisons in a shorter elapsed time, regions of the buildings with original glass conditions were monitored side-by-side and compared with the retrofitted areas. The areas instrumented with sensors during the monitoring period were all in the perimeter zone of the building, with most measurements made on or near the windows. Occupant surveys were distributed to office workers in the areas that received the window retrofit to collect their input before and after the new low-e window film was installed.

PROJECT RESULTS/FINDINGS

A combination of summer and winter field monitoring in two climates, as well as annual energy modeling, was used to study the energy performance of the low-e applied film. It was not possible to monitor window-related energy consumption directly in the particular contexts of each retrofitted building; however, the monitoring of temperatures and solar radiation on and near the windows clearly validated the performance of the applied film and lends confidence to the modeling results based on the validated window properties.

In all cases studied, the annual energy modeling revealed the VT35 low-e applied film to be the best incremental energy improvement of any of the applied films considered (see Table E1). Higher visible transmission low-e applied films also performed very well, especially in cases where passive solar gain to offset heating energy is desired, but the lower solar gain film uses less energy on an annual basis, if the cooling load isn't controlled by another means of shading. High solar gain versions of the low-e film also have higher visible transmission which is helpful for occupant satisfaction and it can reduce electric lighting energy when combined with automatic daylighting controls. Seven climates (ranging from heating dominated Minneapolis to cooling dominated Phoenix), and four base windows (single clear, single bronze, double clear and double bronze) were studied. The good performance across this wide spectrum of conditions supports a very broad deployment recommendation for the low-e applied film products (particularly VT35 and VT50).

It is important to recognize that the energy modeling is only representative of the 15 foot deep perimeter zone. A whole building will have additional loads and considerations and the percent savings will not be as high as when looking at the perimeter interaction with the windows. It is estimated to be no less than 1/3 the reported value using an approximation based on the national average data for window energy use in commercial buildings (see Table 1).

Based on energy savings/cost and installed cost for the film, the simple payback was calculated for the low-e applied film (see Table E2). Full payback refers to installing the film over bare glass or replacing an existing film when it did not need replacement. Incremental payback refers to payback of the incremental cost of the higher performance low-e window film retrofit when another applied film product would be installed anyway. The payback times are quite short compared to other window retrofits, mostly about 2-4 years.

Table E1. Dallas perimeter HVAC energy savings based on COMFEN annual enery results, average of four equal "generic" façade orientations, no lighting controls.

Retrofit Film or Window	Energy savings on single clear	Energy savings on single bronze	Energy savings on double clear	Energy savings on double bronze
VT35 low-e film	**33%**	**26%**	**23%**	**19%**
VT50 low-e film	**28%**	**23%**	**19%**	**16%**
VT70 low-e film	**21%**	**19%**	**13%**	**12%**
VT40 spec. sel. film	18%	10%	11%	6%
Replacement sealed double low-e	35%	28%	25%	17%

Table E2. Simple payback of VT 35 low-e applied film, in years, based on COMFEN annual energy modeling of "as-built" perimeter zone energy cost savings, full or incremental install.

	Material and labor (full or incremental) $\$/ft^2$	Ogden (as- built) years	Dallas (as- built) years
Full payback relative to clear	7.75	4.2	3.6
Full payback relative to absorbing film, with $\$1.50/ft^2$ removal	9.25	6.7	6.0
Full payback relative to spectrally selective film with $\$1.50/ft^2$ removal	9.25	11.9	12.5
Incremental payback relative to absorbing film	3.25	2.4	2.1
Incremental payback relative to spec. sel. film	2.25	2.9	3.0

CONCLUSIONS

- The unique addition of a room-facing low-e surface to a solar control applied film presents a compelling low-cost retrofit to add thermal insulation performance to windows, in addition to the solar control of typical applied film products.
- The energy savings associated with the additional thermal insulation performance of the low-e applied film enables greater energy savings than other applied films and delivers fast payback (2-4 years) of the installed cost with avoided energy costs. The payback is especially favorable when justifying the incremental cost of the higher performance low-e applied film over the selection of a lower performance film product when film replacement is required (reached end of service life).
- Thermal insulation performance of this applied film on single glazing (under rating standard conditions) is nearly doubled, approaching a performance level similar to standard double glazing without a low-e coating.
- In addition to single glazing base windows, the low-e applied film is an effective retrofit on lower performing double glazing that does not already have a low-e coating between panes. The energy savings of the low-e film retrofit are lower on double glazing, but the payback time is still favorable.
- While it was not possible to meter energy savings directly at the test installation facilities due to the context of HVAC zoning and controls, the window performance properties were consistently validated with the deployed monitoring instrumentation.
- Observed window temperatures and solar gain measurements from on-site monitoring were consistent with film performance specifications. Infrared images of the low-e applied film clearly demonstrate the effective radiation exchange suppression offered by the film that results in better thermal insulation performance and enhanced thermal comfort.
- In the annual energy modeling results calculated for this work, the low-e applied film consistently achieved the best incremental performance over the base configurations of any applied film that was considered. The unique insulation performance enhancement offered by the low-e applied film allows it to be less sensitive to summer/winter solar heat gain tradeoffs and, thus, fit a wider deployment scope than other solar control films. The two (soon to be three) visible transmission levels available within the low-e film product range also provides wide adaptability to daylighting needs and site specific factors including climate, orientation, shading and base window configuration.
- The manufacturer's claim for heating and cooling energy savings were confirmed by the modeling performed. For heating and cooling combined (averaged equally over the four façade orientations), savings of about 20% over a standard tint film and up to 30% relative to clear single glazing were consistently demonstrated across the widely varied climates studied (Dallas, Ogden, Chicago, Washington DC, Miami, Minneapolis, and Phoenix). Heating savings (~10%) was smaller than cooling savings (30-40%). The energy savings reported considers perimeter HVAC. Whole building HVAC savings will be smaller (estimated to be no less than 1/3 the perimeter savings), depending on the specifics of the building.
- A simple payback analysis suggests an incremental payback (compared to using a conventional film at the time of replacement) between 2 and 4 years, and a full payback period of 4 to 6 years, in nearly all cases/climates studied. Low-e film retrofitting on single glazing has slightly more energy savings and faster payback than on double glazing, but the low-e film is still a compelling retrofit for double glazing that doesn't already have a low-e coating.

- When evaluating a solar control window retrofit, or any type of window retrofit, a site specific analysis, including an annual energy model, is recommended to evaluate alternatives and select the highest performing solutions for a given building application, including climate, orientation and shading. Attention to maintaining good visible transmission, where appropriate, can improve occupant satisfaction and open potential energy savings with automated daylighting controls that dim electric lighting to only provide the supplemental requirement for proper illumination.
- High and low room-side glass surface temperatures associated with typical single glazing can lead to occupant discomfort. Measured glass temperatures were as high as 105°F (40°C) and as low as 40°F (5°C). The low-e applied film minimizes the radiant portion of the heat exchange and provides a more comfortable environment for occupants near the window in both summer and winter. The physical temperature of the low-e film is not significantly different; however, the apparent radiant temperature leaving the low-e film remains near the comfortable room temperature, resulting in a 27F° (15C°) window temperature increase in the winter and a 27F° (15C°) temperature decrease in the summer.
- Occupants surveyed in the test installation offices reported superior thermal comfort in both winter and summer with the retrofit low-e applied film.
- Visual comfort (glare control) was reported to improve for most occupants; however, there were some negative opinions with regard to color/hue of the low-e applied film, as well the loss of natural daylighting with the VT35 film (using VT50 in cases that suit higher daylight levels is recommended).
- The subtle appearance differences of the low-e applied film may not be appropriate for some historic buildings, and applied films are more expensive to install on traditional divided lites when they are numerous. If changes in appearance are a concern, a trial application on a test window is recommended.
- A strong majority of occupants surveyed recommend the film for use in other offices based on their experiences.
- The low-e applied film could be a compelling complement to a simple uncoated interior storm panel retrofit. The two retrofits don't have to be completed at the same time, but could ultimately work together. The same low-e film suspended in a frame, and attached to an existing window, can also enclose the air space itself and retrofits products are beginning to be designed using this configuration. See GPG report #007 for more information on insulating window panel attachments. To be effective, retrofit panels do not need to have as many layers as the main subject in that report.
- A high-quality retrofit film with a professional installation is generally indistinguishable from other window products and provides an aesthetic retrofit option that can be performed quickly with minimal disruption to building occupants. This makes low-e applied films a relatively unique retrofit opportunity for the building envelope in that it is a fast, low disruption process that delivers significant energy savings and thermal comfort benefits at a reasonable cost with a rapid payback.
- Based on all the findings of this report, low-e applied film products for the retrofit of existing windows are strongly recommended for wide deployment as a result of the favorable energy savings and comfort benefits in a broad spectrum of climates, from heating dominated to cooling dominated. The best applications (shortest payback time) will be sites with clear single glazing or an older applied film that is nearing the end of its service life, but the low-e applied film has proven to have a very favorable applicability in a wide range of base window configurations.

II. Background

A. WINDOW ENERGY SAVINGS OPPORTUNITY

Windows present a significant energy load to buildings, especially in older buildings with poorly insulating windows and inadequate solar control. As summarized in Table 1, previous work by Lawrence Berkeley National Laboratory (LBNL) has estimated that, averaged over the contemporary commercial building stock in the United States, roughly 39% of heating energy consumed annually is associated with windows, or 0.96 quadrillion BTUs (quads) out of 2.45 quads. In addition, windows are a significant factor in the cooling energy used in commercial buildings, with 0.52 out of 1.9 quads, or 28%, of cooling energy demand attributed to windows (Apte 2006). For context, the entire U.S. annual energy consumption (all sectors) has been close to 100 quads for several recent years, and one quad is equivalent to the annual energy consumed by roughly 5.5 million U.S. households (US EIA 2012).

It has been estimated that a hypothetical retrofit the entire existing commercial building window stock with typical low-e double pane windows (U=0.4 BTU/hr-ft^2-F and SHGC=0.29) could save 0.32 quads of the annual commercial building cooling energy (Table 1). The same whole window retrofit would save 0.33 quads of heating energy annually. For both heating and cooling combined, this savings represents about 44% of window-related HVAC energy and about 15% savings of total building HVAC energy, averaged over the U.S. building stock and various climates (Apte 2006). Window replacements in particular buildings may have higher or lower savings depending on factors such as window configuration and climate.

While it is possible to replace existing window systems with modern products to improve energy efficiency, window replacement in commercial buildings is often complicated and expensive, depending on the design of the existing construction. Therefore, it is important to consider retrofit options that provide equivalent energy performance gains, while making use of the existing installed glass and framing.

One retrofit option to improve window insulating values is an interior or exterior storm panel attachment that traps a layer of insulating air between an additional glass or plastic layer that also may include a low-emittance (low-e) coating to further improve the thermal performance (see GPG report #007 (Curcija 2013) for a study of insulating window panel attachments). This approach can reduce air infiltration associated with older windows, as well as diminish some of the heat transfer associated with a poorly insulated window frame. However, it may not work with all existing framing systems and will eliminate ventilation with operable windows, if present.

Window films applied to existing windows are a less expensive window retrofit to install, and typical window films provide a significant performance improvement for control of solar gain into the building. However, there is not a significant change to the thermal insulating performance of the window with typical applied films. New applied film products are now available with a durable low-e surface facing the room that provides improved thermal insulation, as well as solar gain control. This study presents a field test and analysis of this new type of low-e applied film that combines some of the thermal performance improvement of an insulating storm window pane with the typical solar control function of an applied film in a single applied film layer that is installed in the same manner as traditional applied films.

Table 1. U.S. Annual Commercial Building Window Energy Use - reported in quadrillion BTUs (quads) of primary (source) energy, average over all US climate regions. For context, the U.S. total annual energy is ~100 quads. Retrofit double low-e (U= 0.40 BTU/hr-ft^2-F, SHGC = 0.29)

	Commercial Building HVAC energy consumption (quads)	Window-related HVAC energy consumption (quads)	Percent of commercial building HVAC energy-related to windows	Double low-e retrofit energy savings (quads)	Double low-e retrofit percent savings relative to window related energy	Double low-e retrofit percent savings relative to all building HVAC
Heating	2.45	0.96	39%	0.33	34%	13%
Cooling	1.90	0.52	28%	0.32	62%	17%
Total	4.35	1.48	34%	0.65	44%	15%

In addition to the substantial HVAC energy loads associated with low performance windows, occupant comfort is strongly influenced by window properties, especially for occupants located near the windows. For instance, a typical single pane window that achieves solar control through absorption of solar radiation will heat up substantially. A significant fraction of this absorbed energy will be re-radiated into the interior space and can cause direct discomfort for the occupant that might lead to complaints, as well as requiring a lower air-conditioning set-point than would otherwise be necessary. On the other hand, a single pane window in the winter will be significantly cooler than room temperature and cause discomfort for the occupant because they experience a net loss of thermal radiation to this cold surface. In this circumstance, requests for a warmer heating set-point may result from this comfort issue. In both cases, the comfort issue associated with the windows further increases HVAC energy consumption. The thermal insulation improvements of the new low-e coated applied film reduces HVAC energy consumption associated with direct heat transfer. In addition, because the low-e coating diminishes the radiation heat exchange between the occupant and the window surface, occupant thermal comfort is more favorable with this type of low-e applied film, which may save additional energy by allowing more efficient thermostat set-points for the same level of comfort.

Reducing the solar heat gain through the windows, and the associated cooling energy requirements in the building, is typically desirable in most hot climates. However, it is important to recognize that the reduction of solar heat gain increases the heating demand when solar gain through windows would otherwise provide free heating to the occupied space. Window properties are typically static, while the environmental conditions to which they are exposed change on a daily or seasonal basis. The optimal window performance criteria for any particular building are dependent on many factors, including internal loads, window area compared to wall and floor area, façade orientation, solar exposure/shading, climate, and other building and user specific factors. For this reason, it is valuable to use a climate-specific whole building annual energy model, such as those based on the EnergyPlus simulation engine, to assess the annual energy impacts of the window treatment on both cooling and heating energy. Typical criteria that favor lower solar gain include warmer climates (hot summers and mild winters), large window areas relative to floor area, windows exposed to direct sun without overhangs or exterior shading, and dominant glazing area on south, east and west orientations. A solar control applied film with a low-e coating, the technology considered in this study, adds insulating performance that can offset some of the heating energy impacts of diminished solar gain compared to standard applied films that only control solar gain. As a result, the scope of applications for a low-e solar control applied film is expected to be broader than that of typical applied films.

When considering the solar and thermal performance of a window retrofit, it also is important to consider the implications for transmission of light in the visible spectrum. Windows provide valuable natural daylight services to buildings by displacing electric lighting loads, which can result in further energy savings, as well as improve the quality of the work environment for the occupant. Changes in visible transmission, and the associated electric lighting load associated with an applied window film, should be considered as part of the energy analysis.

Roughly half of the United States' existing commercial window stock is estimated to be double pane glass, with the remainder single pane, and the majority are mounted in aluminum frames (Apte 2006). As a large commercial building owner with diverse holdings, it is a reasonable assumption that the U.S. General Services Administration (GSA) window stock has a similar percentage of single and double glazed windows. While retrofit applied solar control films do not provide all the energy performance gains associated with a solar control low-e double glazed window replacement, low-e applied films should further reduce cooling load, as well as potentially reduce the heating load, if the solar gain tradeoff is not dominant in the particular climate and building application (see previous report #017 (Curcija 2015) for a discussion of typical non-low-e applied films).

GSA is a leader among federal agencies in aggressively pursuing energy efficiency opportunities for its facilities and installing renewable energy systems to provide heating, cooling and power to these facilities. GSA's Public Buildings Service (PBS) has jurisdiction, custody or control over more than 9,600 assets and is responsible for managing an inventory of diverse Federal buildings totaling more than 354 million square feet. This includes approximately 400 buildings listed in or eligible for listing in the National Register of Historic Places, and more than 800 buildings that are over 50 years old. GSA has an abiding interest in examining the technical performance and cost-effectiveness of different energy-efficient technologies in its existing building portfolio, as well as in those buildings currently proposed for construction. Given that the large majority of GSA's buildings include office spaces, identifying appropriate energy-efficient solutions has been a high priority for GSA, as well as for other Federal agencies. It is expected that GSA's large portfolio of buildings in diverse climates has a significant energy savings potential associated with both solar control and insulating window retrofits. However, there is significant variability in the existing window configurations and climates in this portfolio and no single window retrofit product is expected to be applicable in all cases.

B. STATE OF THE ART WINDOW TECHNOLOGY

Many years of high-performance window technology development have achieved significant reductions of heat flow through windows by means of controlling the three modes of thermal conduction, convection and radiation (see Figure 1, left). Some of the established high-performance design elements include multiple glazing layers that enclose hermetically sealed insulating gas layers to reduce conduction and convection, low-emissivity (low-e) layers to reduce radiant heat exchange between the layers and more insulating frames and edge of glass spacer materials to reduce conduction at the perimeter of the glass area. These measures address the thermal transfer due to interior-exterior temperature difference, typically reported as a resistance (R-value) for walls, or as a U-factor (inverse of R-value) for windows. A smaller U-factor signifies a better insulator.

Compared to opaque wall insulations, windows have additional performance criteria to consider. Windows can transmit a large fraction of incident solar radiation to the interior of a building. The amount of this type of energy flow through the window is reported by the solar heat gain coefficient (SHGC), a unitless number from zero to one that represents the fraction of solar energy incident on the exterior of a window and frame that is transmitted to the interior. The SHGC includes both the directly transmitted solar radiation (which is subsequently absorbed and reflected on interior surfaces of the room), as well as any portion of the heat from solar radiation that is absorbed in the window glass layers and frame, and subsequently propagated into the room (called the inward flowing fraction). An important feature of the solar properties of a window is the visible light transmission (denoted Tvis or VT). Visible light transmission through windows can reduce electric lighting loads and improve the quality of light and occupant enjoyment of the space, while too much direct light transmission can cause discomfort from glare.

The thermal insulating performance of a single pane of glass is limited by the relatively high conduction of heat through the single glass layer. Multi-layer windows improve thermal performance by trapping layers of air (or another low thermal conductivity gas like Argon) between the panes. The gas layer greatly reduces the heat flow through the window, as long as the dimension of the air space doesn't support too much convection heat transfer (buoyancy driven air current that move heat).

Low-e coatings are a common and highly effective energy saving window technology, typically installed as part of a factory-produced sealed double pane unit called an insulating glass unit (IGU). There is a significant surface temperature difference between the panes of a multi-layer window. Long wavelength infrared thermal radiation will be exchanged between these glass surfaces (third mode of heat transfer); however, a low-e coating on one of the surfaces facing the air space between panes will substantially enhance the insulating performance of a sealed double pane window unit (*i.e.*, lowering U-factor), by minimizing the thermal radiation exchange. This heat transfer can be modified at the surface with a thin coating rather than changing the bulk material below the surface. Most low-e coatings used in hermetically sealed double pane windows are long lasting in that environment, but cannot be used on an exposed surface, such as the side of the window facing the room. There are other durable low-e materials that are used on exposed surfaces.

In addition to improved thermal insulation performance, low-e coatings can be designed to add strong reflection of the short wavelength infrared portion of the solar spectrum, resulting in lower solar heat gains, without a large rise in glass temperature. A low-e coating with these properties is called a spectrally selective, or low solar gain, low-e coating. It preserves a relatively high visible transmission, maintaining the look of clear glass, while reflecting most of the invisible solar infrared portion of sunlight, which carries about half of the radiant energy in the solar spectrum (see Figure 1, right). This combination of properties can reduce both heating and cooling loads in buildings, leading to energy savings potential in both winter and summer. Rejection of solar gain when direct sunlight falls on a window also reduces peak cooling loads at the time of day when electrical demand on the grid is at its maximum.

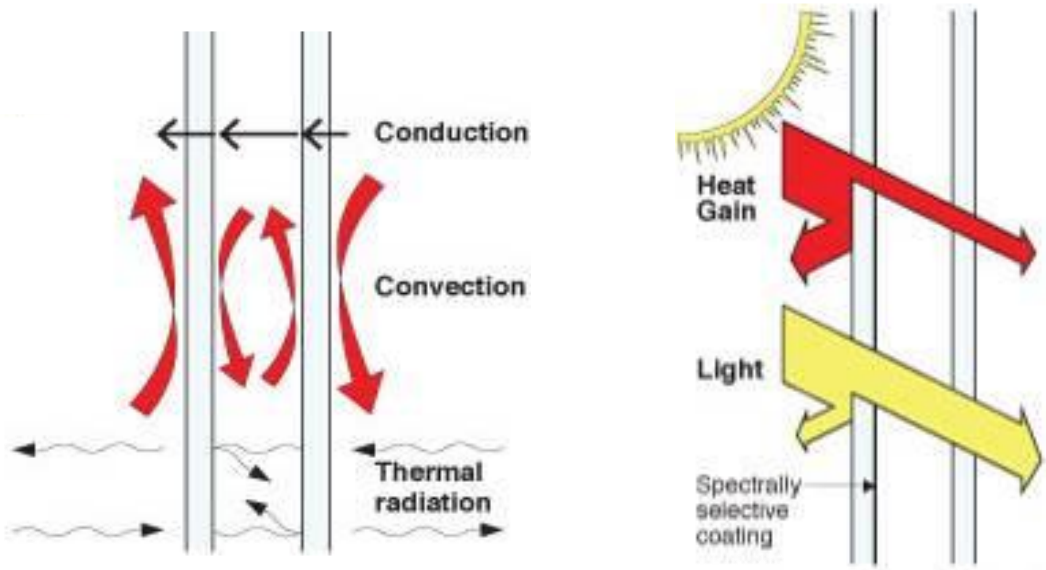


Figure 1. Heat transfer through windows. Conduction, convection and radiation modes of heat transfer resulting from an indoor/outdoor temperature difference (left). Direct solar heat gain and reflection using a spectrally selective or low solar gain low-e coating (right).

The room-side glass surface temperature that a window reaches under typical environmental conditions is an indicator of its thermal insulating performance and has an impact on the thermal comfort of building occupants when they are near the windows. When there is a large indoor-outdoor temperature difference, a more insulating window will have a room-side glass surface temperature closer to room temperature, providing a more comfortable work space near the window and effectively increasing usable space in the building. The room-side window surface temperature also determines the likelihood that condensation will form on the glass under various indoor air humidity conditions. When there is direct sun falling on a window, windows with strong solar absorption will reach higher glass temperatures than windows with high transmission or reflection of solar radiation. It is important to consider which layer in a multi-layer window glazing system has high absorption. The insulating properties of an air space between glass layers will restrict the potential for heat flow in that direction. For that reason, an absorbing glass layer or film on the exterior side of a double pane window has a lower solar heat gain than the same absorbing layer on the interior of a double pane window.

A durable room-facing low-e surface can further reduce radiant heat exchange between the window, the room and occupants when glass surface temperatures are high or low. While this improves energy consumption and occupant comfort, the actual glass temperature difference will be higher than without the low-e coating, such that condensation and convection driven drafts off the window may increase. Room-facing low-e coatings are available as an option on some production double pane windows, but this is a secondary feature to add performance in addition to the gap facing low-e with the primary thermal performance benefit.

While low-e coatings in new windows are typically factory sealed between the layers of a double pane window unit, there are many applied film window retrofit products that provide the spectrally selective visible and solar optical properties associated with solar control low-e products in the form of a field applied film. These products reflect the solar infrared instead of absorbing it and the layers do not have a large temperature rise. Most of these spectrally selective, reflective applied films do not include the long-wave infrared low-e properties that reduce thermal radiation exchange due to surface temperature differences and, thus, they do not change the U-factor (insulating value) of the window, just the solar gain characteristics. The newly available applied film in this study does have a durable room-facing long-wave infrared low-e coating allowing those applied films to offer both solar control and increased insulation properties. These films can be applied to existing single or doubled glazed windows. In general, the incremental improvement compared to a single pane baseline is larger than the same film on double glazing.

Air infiltration, or leakage around joints and gaskets, is important to window performance. Infiltration can be highly variable, especially in older buildings with worn operable windows. Caulking and repair of windows seals can reduce air infiltration. Retrofit panels, such as storm window panels, cover the window and frame with an additional glass/plastic layer and can help improve air tightness without replacing the entire window (see GPG report #007 (Curcija 2013)). Films applied just to the glass area can alter the solar optical properties of the window, but they do not alter the air infiltration characteristics of the base window on which they are installed, and they typically do not improve the insulating value of the window (U-factor), unless they include a durable low-e surface (such as the subject film in this study).

Despite the cooling energy savings associated with low solar gain windows, in some climates the building energy balance will benefit from high solar gain low-e coatings, which can help offset heating energy demand by providing passive solar gain. Commercial buildings with high internal heat loads from people and equipment are often dominated by cooling energy in many climates and, thus, are not frequently considered for accepting passive solar gain. As revealed by the data in Table 1, however, more energy is consumed nationally to heat commercial buildings than to cool them, suggesting potentially large opportunities to take advantage of passive solar heating in commercial buildings. In the case of a retrofit, it is important to determine if a building is already benefiting from passive solar gains that will be diminished by the selection of a low solar gain retrofit. In some cases, the cooling energy saved will be outweighed by the increased heating energy demanded, although details of fuel types, relative fuel costs and time of use pricing should be factored into the cost effectiveness analysis. Selection of higher solar gain windows (or declining a low gain retrofit), where appropriate, should be accompanied by consideration for mitigating that solar gain when it is undesirable. Often, the most optimal solution can be found when a window system includes some form of dynamic/seasonal solar control, including south facing overhangs with the right solar geometry, deployable shading systems, electrochromic or thermochromic coatings, or deciduous trees shading the windows. Passive solar gain should be employed when the building, window orientation, shading, and climate are well suited to this practice. Whole building annual energy analysis of particular buildings under local conditions is advised, including assessment of seasonal shading or other means to control solar gain at the appropriate time.

It should be recognized that a single window performance criteria (*i.e*., U-factor, SHGC or Tvis) is never the optimal choice for all conditions of building type, climate, season, orientation and local shading. It is a best practice to evaluate window performance choices for particular climates and individual building applications. The high degree of variability in commercial building design favors the use of whole-building annual energy simulations using local climate data when selecting the optimal window properties for a building, making use of the specific climate, orientation, and shading criteria for the application. In addition, it is valuable to consider the performance implications of window systems with dynamic shading (solar control) properties, where they are practical.

III. Project Installation and Evaluation

A. OVERVIEW OF RETROFIT TECHNOLOGY

The low-e solar control applied film window retrofit studied in this work is a relatively new and unique retrofit product in that it includes a durable room-facing low-e surface, adding thermal insulating performance that is not available with other solar control applied films. Typical low-e surfaces used in factory-built double pane windows are protected inside the hermetically sealed air space, as they are not durable to moisture exposure. They typically achieve surface emittance of 0.02-0.08. There are durable low-e coatings that can be factory installed directly onto glass, with somewhat higher emittance typically between 0.15 - 0.2 (emittance ranges from 0 – 1 and reports the fraction of thermal radiation exchange supported by the surface compared to the theatrical maximum). The low-e applied film product in this study offers a durable low-e surface that can face the room with an emittance of 0.048, better than commercially available durable low-e surfaces on glass and similar to the typical emittance of low-e coatings used inside sealed double pane windows. The manufacturer stated heating energy savings for the low-e applied film are 15-30%, and the cooling energy savings are 10-20%. The higher figures assume low-e film installation on clear single glazing and lower figures assume low-e film installation on clear double glazing. The manufacturer suggests it is possible to have a return on investment of 3 years or less for their low-e applied film, compared to 15-20+ years for full window replacement.

There are two versions of the low-e applied film product sold today, with different solar gain and visible transmission properties. A third version is under development with market introduction expected in 2017. The manufacturer provided a prototype sample of the new member of the low-e applied film product line for evaluation in this report. Table 2 summarizes the insulating value (U-factor), solar heat gain coefficient (SHGC) and other performance data. There is a complete list of 26 letter coded glazing configurations considered in Tables AB1 and AB2 in the appendix. The lowest solar gain VT35 version of the low-e film is the product that was installed in the two test locations for this study. On single clear substrate, it admits only about ¼ of the incident solar energy. The medium gain VT50 product maintains higher visible transmission, while still only admitting about 1/3 of the incident solar energy. The new VT50 film is still under development. A prototype sample was provided by the manufacturer and measured by LBNL to establish the optical properties presented in this report. The VT70 product has the highest visible and solar transmission of the low-e films, with about ½ of incident solar energy admitted. Like all low-e coatings, there are subtle color shifts/hues, even though they do not have a strong visible tint. The VT35 and VT50 low-e film products have a slightly green hue, while the VT70 film has more of a gold colored hue. The high solar gain VT70 product is a significantly more expensive applied film than the VT35 and VT50 versions. Because of the price difference and the typical need for solar control in commercial buildings (at least in warmer climates), the lower solar gain versions of the film are expected to be used in most commercial building applications and the VT35 version was installed and monitored in the two GSA office buildings in this study. Although the focus of this report is on the performance of the low solar gain low-e applied film, the properties and the modeled annual energy performance of all three low-e applied films are included for context. Table 2 reports center of glass (frame not included) thermal and optical window properties for the three low-e applied films in comparison to typical existing window products (both single and double pane). These values are calculated using the WINDOW7 rating tool according to National Fenestration Rating Council NFRC100/200 standards. While this assures that the different configurations are compared using uniform standard rating conditions, it is worth mentioning that the relative performance of a room facing low-e can change significantly when the environmental conditions (such as exterior wind speed) are changed. Because the NFRC conditions assume a high wind speed on the exterior of the window, a selection of glazing configurations are presented with no wind in Tables AB3 and AB4 in the appendix. The U-factor improves (is lower) with less wind speed because the exterior convection heat transfer driven by the wind is reduced. The SHGC is increased with lower exterior wind speed because less of the absorbed energy is carried to the outside by the wind driven convection heat transfer, and hence a larger fraction of incident solar energy will transfer to the interior.

Compared to single glazing, the retrofit film nearly doubles the insulating performance under standard conditions. Still, the retrofit on single glazing is not quite as insulating as double glazing without low-e (23% higher heat transfer). Compared to a new low-e double glazing (replacement window), the retrofit has twice as much heat transfer.

Table 2. Center of glass performance for various window products, including the low-e applied film retrofit on different base windows (NFRC100 environmental conditions)

Window glass layer configuration	U-factor (winter) (BTU/h-ft-F)	SHGC	Tsol	Tvis	Room side Emittance
Single clear (6mm)	1.025	0.818	0.771	0.884	0.840
Existing applied film (absorbing) on 6mm clear	1.025	0.659	0.532	0.517	0.840
VT35, Low transmission **low-e applied film** on 6mm single clear	0.574	0.261	0.195	0.335	0.048
VT50, Medium transmission **low-e applied film** on 6mm single clear	0.593	0.368	0.301	0.489	0.075
VT70, High transmission **low-e applied film** on 6mm single clear	0.599	0.494	0.424	0.682	0.090
VT40, Low transmission spectrally selective applied film 6mm on clear	1.041	0.381	0.205	0.419	0.871
VT70, High transmission spectrally selective applied film on 6mm clear	0.859	0.447	0.335	0.672	0.529
VT66, “triple silver” low solar gain low-e sealed factory IGU, with 6mm glass	0.286	0.278	0.233	0.623	0.022 internal

Low-e films measured on 3mm clear glass and calculated on 6mm using WINDOW7/OPTICS6

The low-e film achieves its control of solar radiation principally by reflection rather than absorption. This is important because the final energy balance of a window, including where the absorbed energy is dissipated, depends on the construction of the original window (single versus double glazing), as well as environmental factors, such as the interior and exterior air temperatures and wind velocities near the window. Because the film reflects much of the solar infrared and some of the visible light, it is more versatile and can provide useful solar gain even on the interior side of a double pane window (unlike solar absorbing applied films). It is not recommended to use a low-e retrofit film on double glazing that has a factory installed low-e layer in the glazing unit.

The solar control is quite strong with the lowest solar gain version of the low-e applied film. On single clear substrate, the retrofit film has an SHGC of 0.261, which is comparable to a modern “triple silver” low-e in a factory-produced double glazing at 0.278. However, the visible daylight transmission is reduced more strongly with the applied film, as the visible transmission of 0.335 is nearly half that of the triple silver low-e product (0.623) for roughly the same SHGC.

Natural daylighting of office space with windows featuring high visible transmission can be highly desirable for both energy efficiency (offsetting electric light use) and improving the quality of light in the space. Most occupants have a strong preference for natural daylight and it can be an important factor in worker productivity. However, relatively high transmission windows can lead to glare issues, especially for workers at computer screens. Automated or manual shading systems are generally needed to block strong direct sunlight when it is undesirable.

Because the low-e applied film can be installed on a variety of existing window systems, both single and double glazing, it is important to consider the optical properties of the existing system in the context of the added film. While the VT35 film may be appropriate on clear glass substrates, windows that already have some tint to them may sacrifice too much visible transmission when combined with the VT35 film. In this case, the higher transmission films allow achieving the thermal performance of the low-e applied film without a large reduction in visible transmission.

While not as large of a component of total solar energy as the infrared, it is worth noting that the ultraviolet (UV) transmission is dramatically reduced to ~1% of the incident UV radiation (as is the case for most plastic substrate applied films, as well as low-e coatings in replacement windows). Blockage of this portion of the spectrum is important to reduce damaging UV rays from fading carpets, furniture and other surfaces in the room.

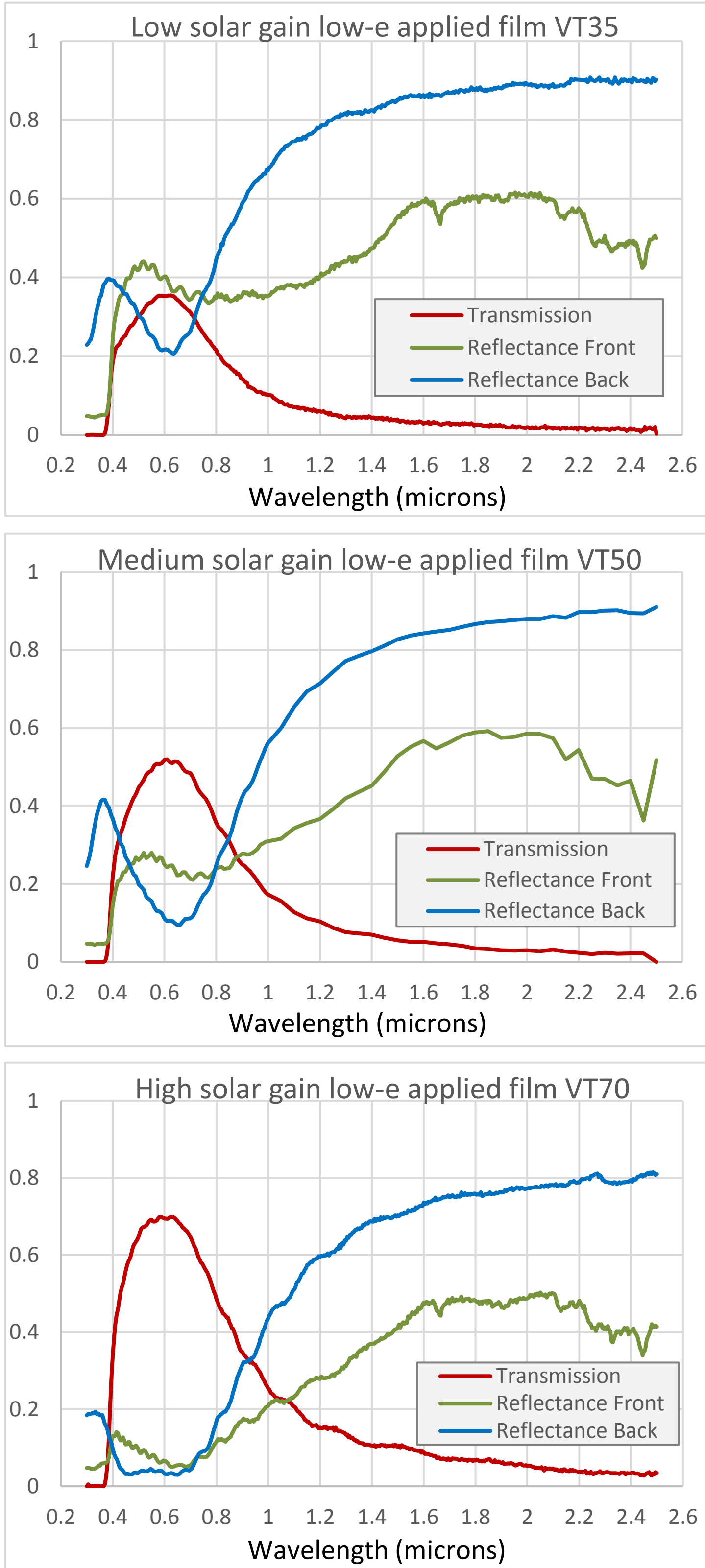


Figure 2. Measured optical properties for the three types of low-e applied film. Data from the International Glazing Database (ID 2545, custom measurement, 2546) applied to 6mm clear.

The film is intended for installation on the interior (*i.e.*, the room side) of an existing single or double pane window that generally does not already have strong solar heat gain mitigating properties. It also can be used as a replacement for an existing applied film that is lower performance or has reached the end of its useful life. Installation of the low-e applied films proceeds similarly to other plastic substrate applied films, a well-established and familiar process. The manufacturer has established certified trained installers across the country to assure excellent quality control and attention to the finer details of installation associated with the low-e applied film product.

Compared to complete window and framing system replacement, installation disruptions to building occupants are minimal, as work can take place after hours without major impacts to the office space, apart from possibly temporarily moving some office furniture. Applying film on many windows in a large building can proceed in stages during unoccupied times. The product can be applied to fixed and operable windows alike and it does not interfere with the operation of any existing window shades/blinds.

Installed costs of applied films in commercial buildings are typically between \$4.50/ft^2 to \$7.75/ft^2 of glass area (with the low-e applied film at the upper end of that range). These prices are based on an average cost over approximately 20 large-scale installations that were quoted by contractors bidding on projects over the past 2 years. The high end of the installed cost of the low-e film can be as much as \$10/ft^2, or possibly higher for especially difficult installations. Difficult installations would include situations where there is furniture blocking access to the windows or other similar logistical constraints. Removing existing film will add about \$1.50/ft^2 to the labor rate.

In addition to a higher material cost, part of the low-e film cost differential is related to installation, as it is a little slower to install, requiring special training and more squeegee work. However, all of these applied film products are substantially less expensive than complete window replacement, which can run roughly \$25-40/ft^2, or more, depending on the complexity of the job. Windows last a long time (30-50 years+), but the large cost differential between film retrofit and glass replacement means that you can install film 3-4 times over the life of the glass substrate and still not exceed the cost of replacing the base window.

A professional commercial installation of a traditional plastic applied film will typically carry a 6-15 year warranty and many installations will be functional beyond that time period. The subject film carries a 15 year warranty. With proper installation, it is difficult to distinguish the applied film from conventional tinted or reflective glass. Poor preparation and installation can lead to bubbles, and eventually peeling of the applied film. Fading and crazing of plastic applied films can be a long-term durability issue, particularly if a low quality film is used.

Operations and maintenance procedures for the low-e applied film require some attention, but nothing out of the ordinary. Basic non-abrasive cleaning is required, and ammonia-based cleaners are not allowed. To avoid scratching the film, squeegees should not be part of the cleaning process, because when they have nicks, or carry hard particles, they may scratch the film. The low-e applied films are a little more susceptible to scratching due to the unique low-e properties, so there will be some adjustments required for proper operations and maintenance (see appendix A for further information on care for low-e films).

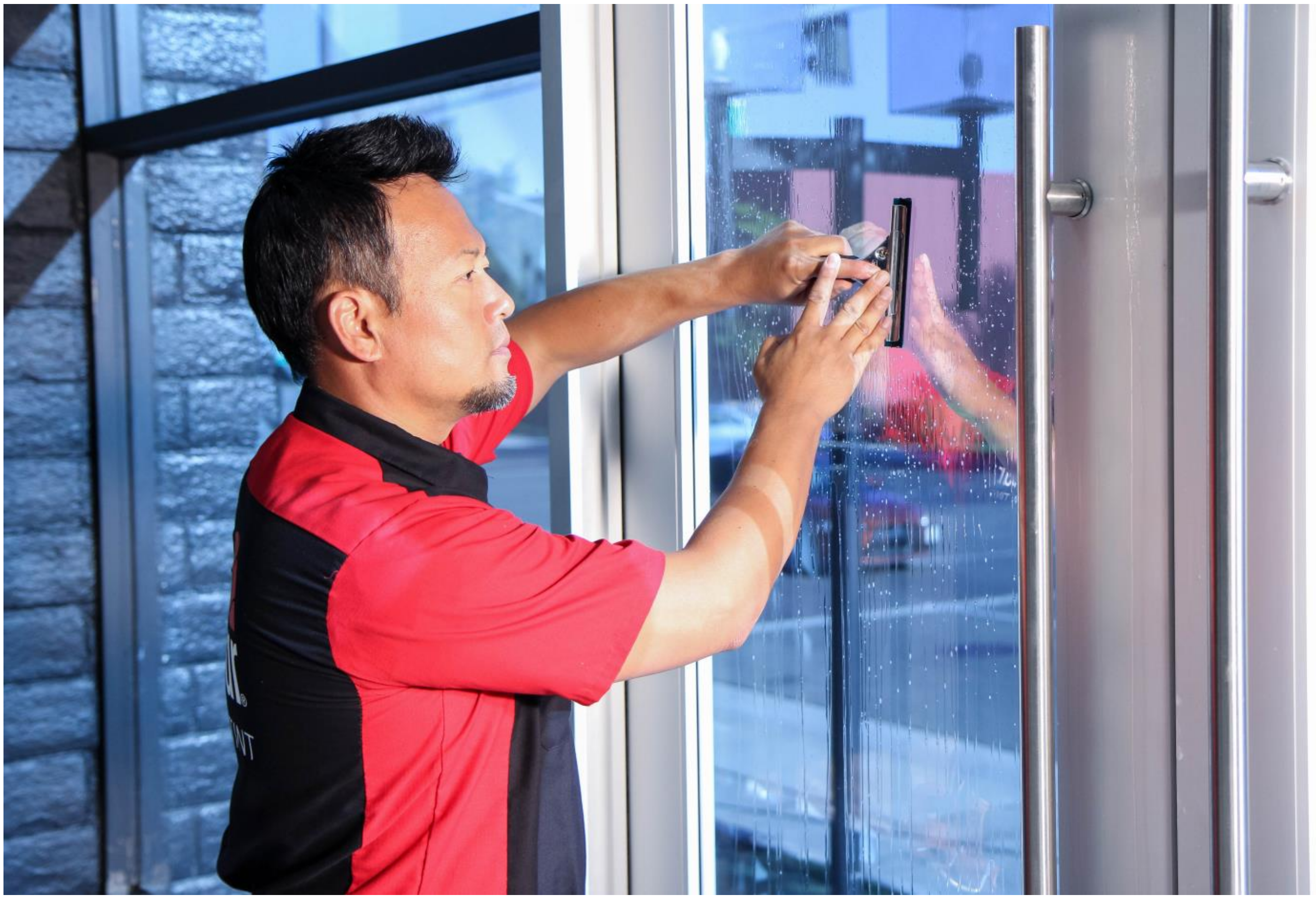


Figure 3. Installation of low-e applied film is similar to other plastic substrate applied films

B. DEMONSTRATION PROJECT LOCATION AND DESCRIPTION

Two buildings in two different climates were selected for the trial installation and monitoring portion of this study. The Hansen Federal Building in Ogden, Utah experiences highly mixed conditions with cold winter temperatures as well as significant solar gain in the summer. The Cabell Federal Building in Dallas, Texas is located in a hot, cooling load dominated climate, but still can experience fairly cool winter temperatures. Both buildings are in central urban locations.

The Hansen Building is a 206,346 ft^2, 6-story building. It has existing single pane windows with an existing applied film that is at the end of its life. The window-to-wall ratio is ~40%. The low-e applied film was installed on all four orientations of three floors (2nd, 3rd and 4th). The 5th and 6th floors retained the existing film. An unoccupied portion of the south facing 2nd floor façade had the original film removed and left without any applied film (clear glass) during testing to serve as a baseline comparison case without applied film. The 5th floor was used as a side-by-side comparison of the existing film compared to the retrofitted low-e film on other floors. Both south-facing and north-facing facades were monitored.

Figure 4. South façade of the Hansen Federal Building in Ogden, UT

The Cabell Building is an approximately 1 million gross ft^2, 16-story building. It has existing single pane windows with an existing applied film. The window-to-wall ratio is ~30-40%. The low-e applied film was installed on a portion of the south orientation of the 7th floor. Locations directly above on the 8th floor served as the baseline side-by-side monitoring location. The north facing portion of the 3rd floor also received the retrofit and the north facing portion of the 4th floor was used as the reference base case.

For both sites, side-by-side testing of partially retrofitted buildings was chosen instead of sequentially monitoring the base condition followed by an entire retrofit of the building, which would have required twice as much elapsed time. This approach allowed both heating and cooling season comparisons with only one winter and summer season during the monitoring period. The areas instrumented with sensors during the monitoring period were all in the perimeter zone of the building, mostly placed directly on or near the windows. Occupants working close to windows generally sat within approximately 6 feet of the windows in their office.

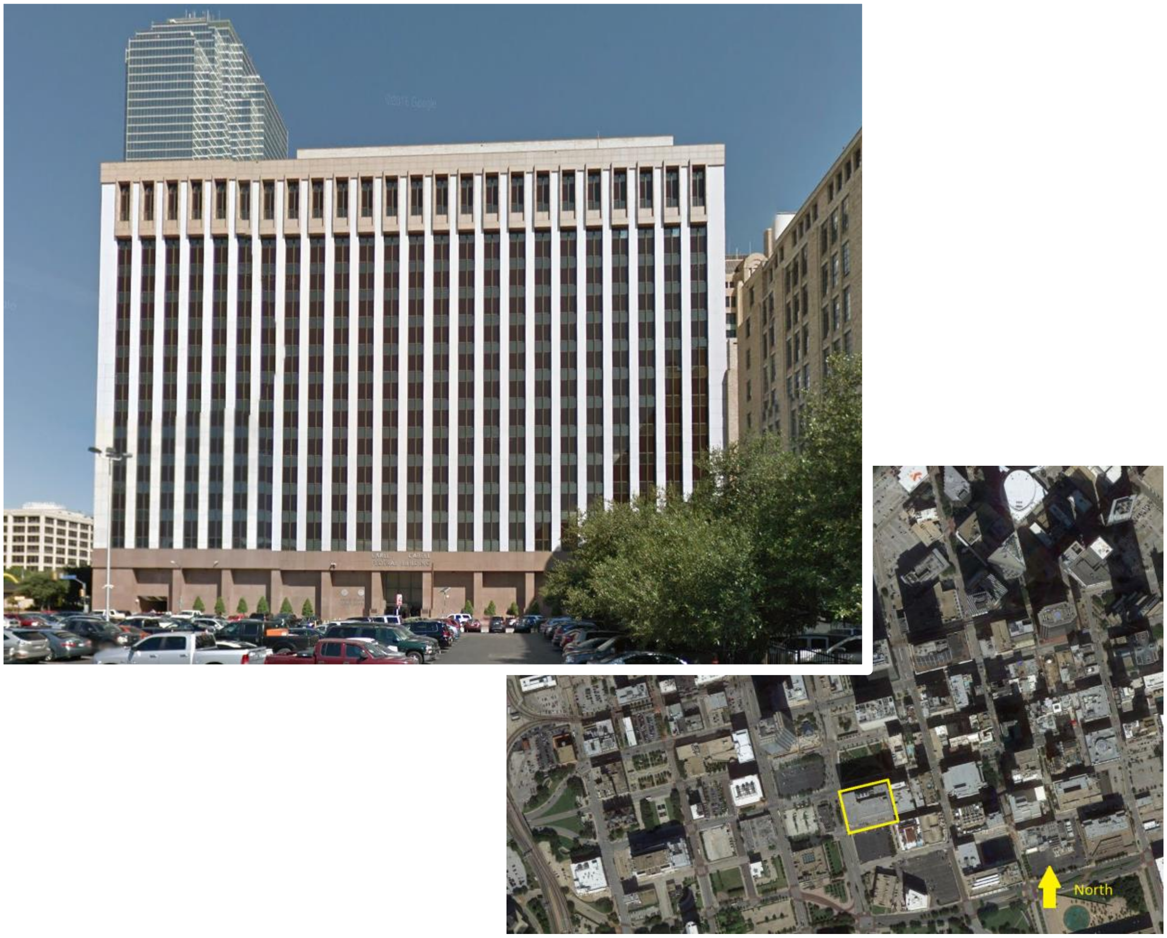


Figure 5. South-southeast façade of the Cabell Federal Building in Dallas, TX

C. TEST AND INSTRUMENTATION PLAN

To compare the performance of the window film retrofit over the entire building to that of the existing condition, during both heating and cooling conditions, a period of monitoring including two winters and two summers would be required. A side-by-side test of existing and retrofit conditions in a partially retrofitted building was chosen to allow completing all conditions in a shorter elapsed time. The side-by-side monitoring approach also eliminated the need to correct for weather variations during pre- and post-retrofit monitoring periods. Following the installation of the low-e applied film, the monitoring period of installed sensors at the Dallas site ran from January 2015 to January 2016. The Ogden site was installed a few months later and the monitoring period of installed sensors at that site extended from August 2015 through February 2016.

A series of autonomous data logging sensors were deployed with 10-30 minute monitoring intervals. While most of these sensors stored months of data read out upon completion, some of the sensors used wireless transmission to a laptop computer operating in the building. This computer provided a remote connection that allowed live monitoring of some of the data to confirm that measurements were proceeding successfully. A summary of the installed sensors is presented in Table 3. Each office measurement package generally included interior room air temperatures, globe (radiant) temperatures, glass surface temperature, and solar radiation. Globe temperatures allow the measurement of the mean radiant temperature, or a temperature that is more heavily influenced by the surrounding room surface temperatures, rather than the air temperature. This helps to assess thermal comfort associated with window surfaces that are substantially higher or lower than room temperature (sphere on slender stand in yellow ovals pictured in Figure 6).

Table 3. Summary of logged measurements over eight months, December to August

Location	Measurements Taken
Each South Façade Station	• Air temperature • Globe temperature • Contact glass surface temperature (30 gauge type T thermocouple) • Black/white absorber surface for solar radiation (one per window type)
Each North Façade Station	• Air temperature • Globe temperature • Contact glass surface temperature (30 gauge type T thermocouple)

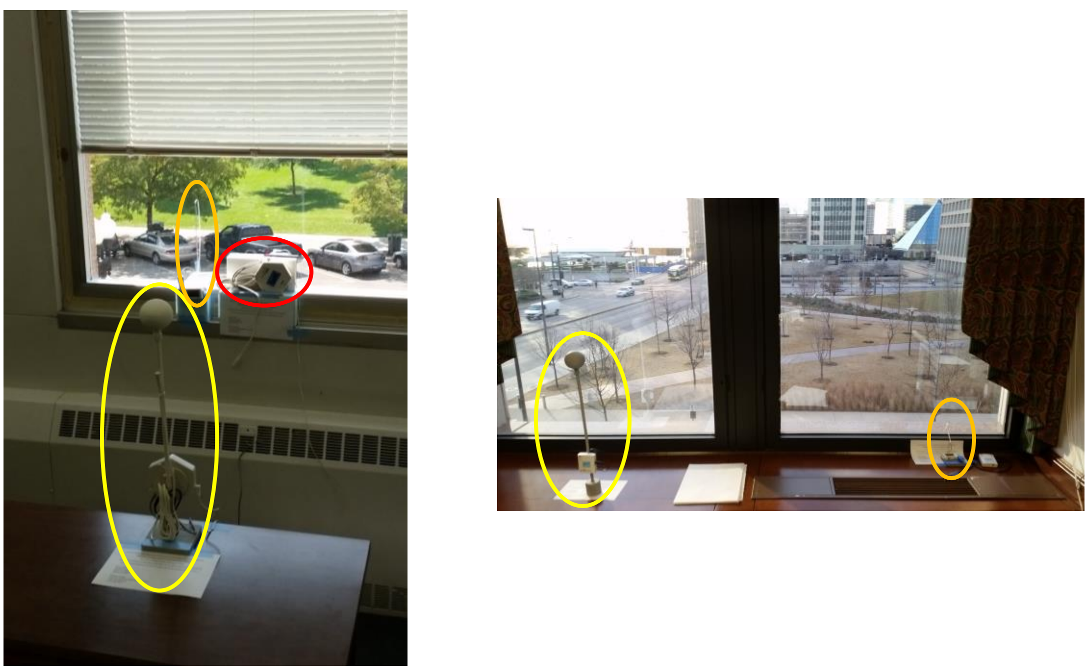


Figure 6. Globe temperature sensor on cabinet near occupant to measure effective radiant temperature, important to thermal comfort (left Ogden, right Dallas)

Interior glass surface temperatures were monitored with a fine wire (30-gauge type T) thermocouple. To avoid damaging the applied film, these sensors were not fastened with glue or tape, but rather a spring loaded stand maintained pressure for good thermal contact to the film surface (pictured in orange ovals in Figure 6). It can be challenging to measure a glass temperature with a contact sensor when the glass is receiving solar radiation because any change in the local optical properties (transmission, absorption and reflection) changes the local temperature. This is especially true for large temperature sensors and sensors applied with a large area of opaque glue or tape. Non-contact infrared measurements have been used in past work to avoid disrupting the glass temperature to be measured; however, the low-e film does not emit enough thermal radiation to allow this type of measurement.

Solar radiation sensors were placed on the room side of the glass behind each window and applied film type to compare the relative solar transmission. Each sensor is comprised of a side-by-side black and white absorber plates with a contact temperature sensor on each plate. The plates are placed vertically on the window sill exposed to direct sun through the window and insulated with a sheet of foam toward the room side (pictured in the red oval in Figure 6). An energy balance calculation (incident radiation versus heat flow to the room) calibrated against standard pyranometers allow these sensors to serve as low cost pyranometers with reasonable accuracy.

During both winter and summer site visits, an infrared camera was used to measure window surface temperatures and provide visual imagery of surface temperature distributions. The quantitative thermography laboratory techniques described in previous thermography work (Griffith 2000) were adapted under the constraints of the field test environment. Global infrared background corrections were made assuming a relatively uniform room enclosure surface temperature. Because the low-e applied film does not emit enough thermal radiation to make a direct measurement of window surface temperature, the main utility of the visualization provided by the infrared thermography was to demonstrate the strong infrared reflective properties of the low-e film and its impact on the radiant environment experienced by occupants. The infrared camera helps to demonstrate visually how the low-e film contributes to both window energy flow reduction, as well as improved occupant comfort.

Past GPG program window monitoring projects were able to use building automation system data as part of the evaluation. After completing the site selection process, the most suitable sites for the window film installation happened to have HVAC systems configured in a way that did not support achieving useful monitoring data from a building automation system at a level that could reveal specific information related to the windows. For this reason, it was not feasible to extract window-related energy flow data from field measurements. The field measurements described above provide a validation of published window properties and confirm that the film properties are consistent with stated values. Window performance and annual energy modeling tools will be used to compare the relative energy consumption of different window configurations.

IV. Project Installation and Evaluation

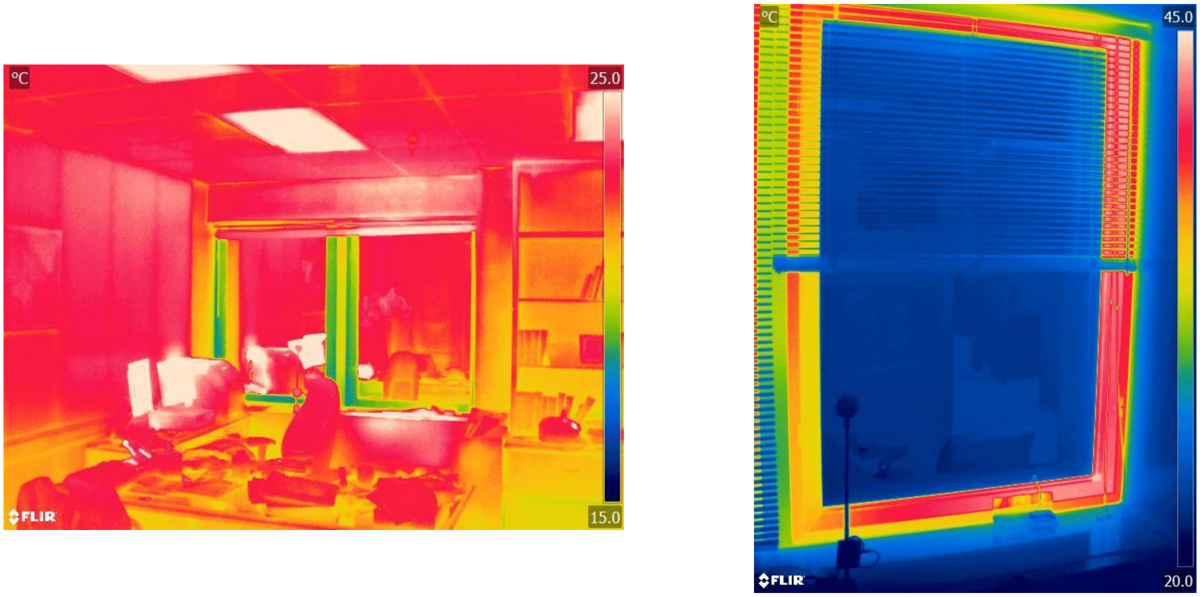
A. DIRECT MEASUREMENTS

The logged surface and radiant temperatures were consistent with the expected window properties of the various window configurations (no film, existing absorbing film and low-e retrofit film). The infrared thermography of apparent surface temperatures of the windows and walls provides compelling images that clearly demonstrate the room-side low-e function of the film that provide thermal insulation and improves SHGC and thermal comfort. Figure 7 shows that whether the season is winter or summer, the low-e film reflects long-wave infrared radiation from the room, rather than emitting according to its own temperature. Compared to the window frame, the glass appears warmer in the winter and cooler in the summer.

To demonstrate the change in transmitted solar radiation of the low-e film, Figure 8 shows an infrared image of the windows and floor surface temperatures where patches of direct sunlight warm the carpet. It can be seen that the low-e film is reducing the directly transmitted energy in the sunlight that reaches the interior room surfaces.

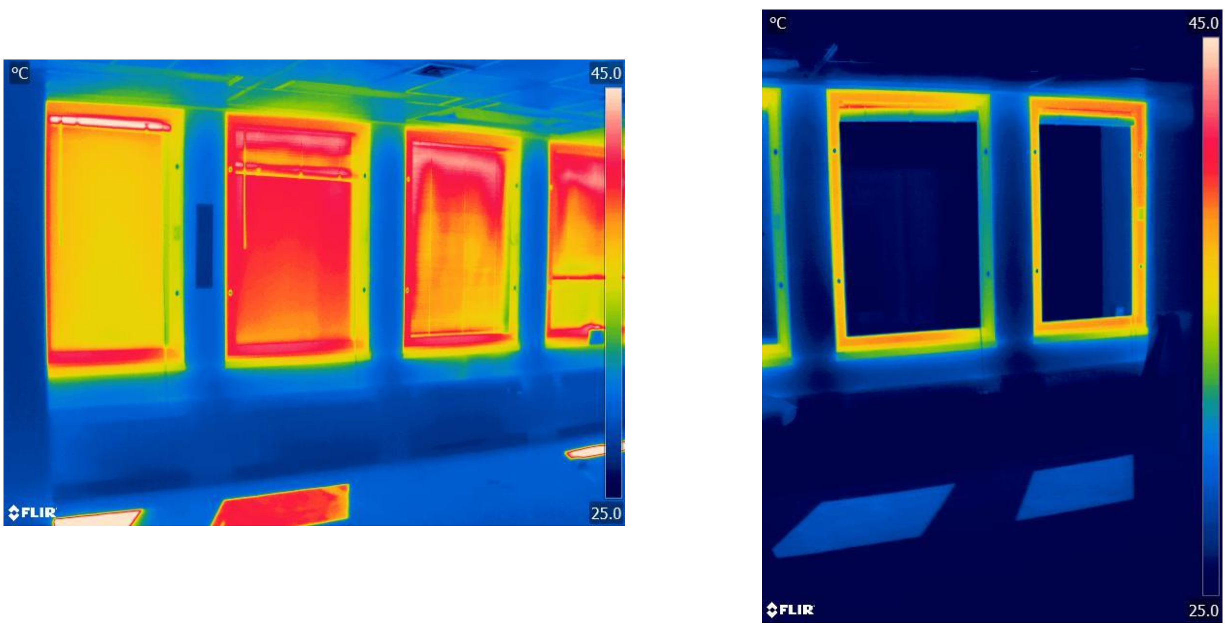
Single glazing, the existing condition in both buildings, will expose the room to elevated glass temperatures in the summer, as well as low glass temperatures in the winter. This can lead to occupant discomfort associated with radiative and convective heat exchange, particularly for occupants sitting close to a window. In addition to improving the thermal insulation and SHGC of the window by restricting radiant heat exchange, the low-e applied film changes the apparent radiative temperature of the window, which improves occupant thermal comfort. Figure 9 shows a south facing pair of windows in Ogden during the summer. The window in the left image has the existing applied film and the glass surface achieves a high room side surface temperature (40°C or 105°F). The window in the right image has been retrofitted with low-e film. While the physical temperature of the glass is not much different than the previous case, the infrared image demonstrates that the glass surface has a much cooler apparent radiant temperature because it is reflecting the radiation from the room temperature surfaces of the surroundings. While measured glass temperatures in this study were as high as 105°F (40°C) and as low as 40°F (5°C), greater extremes are possible. In the cases measured, the apparent radiant temperature of windows with the low-e film was 27F° (15C°) higher under winter conditions and a 27F° (15C°) lower under summer conditions, contributing to improved thermal comfort near the windows in both seasons.

North facing windows benefit from the low-e applied film during both the winter and summer, even though there is minimal direct sun on a north façade. The low-e characteristic of the film improves thermal insulation performance for an indoor/outdoor temperature difference, independent of incident solar radiation. Most applied films provide little or no benefit on a north orientation, but the low-e applied film has notable benefits on all orientations during all seasons, as shown in Figure 10. An exterior infrared image of the north façade of the Hansen building on a cold winter night is presented in Figure 13. The warmer surface temperatures of the windows on the 5th and 6th floors (with no applied film) clearly show more heat loss than the low-e film retrofitted windows on the 2nd, 3rd and 4th floors. The window frames still show up as warmer than the glass area of the windows with low-e applied film. Contact measurement confirm the physical glass temperature with low-e films falls a few degrees C under cold winter conditions compared to windows without low-e. This is consistent with better insulating performance of low-e, but it does raise condensation risk on the glass a small amount.



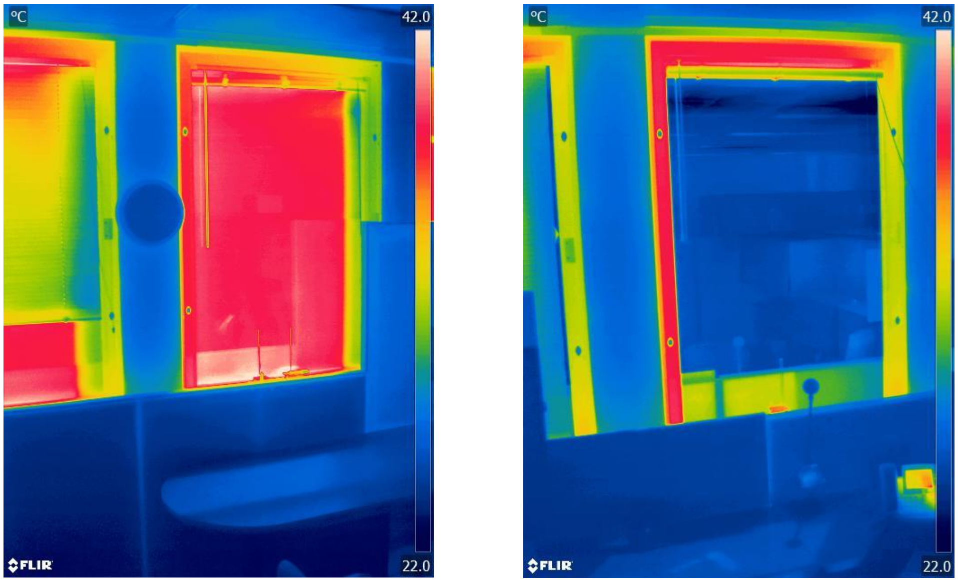
Left NORTH façade in WINTER, Right SOUTH façade in SUMMER
both low-e film (different temperature scales)

Figure 7. Infrared thermograms of windows with low-e applied film in Dallas, showing reflection of room temperature on the glass area and colder or warmer framing depending on the season (not the actual temperature of the low-e surface, rather an apparent radiant temperature)



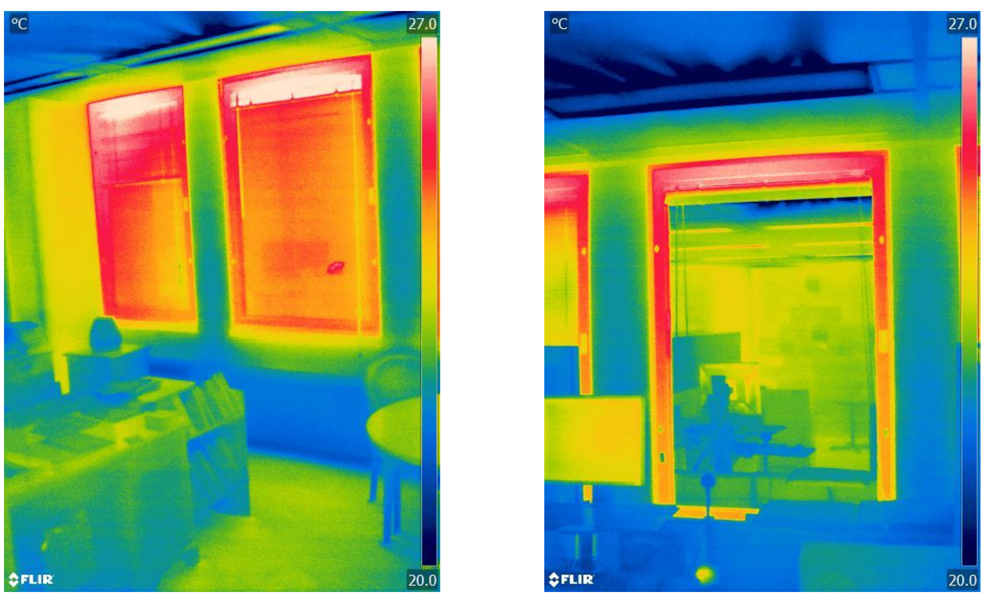
Left NO FILM, Right LOW-E FILM, both south façades in summer (same temperature scale)

Figure 8. Infrared thermograms of south façade windows in Ogden during the summer comparing no film to low-e film. Temperature rise of patches on floor shows different solar transmission. Glass temp. without film is true; low-e film temp. is apparent (room reflection)



Left image existing ABSORBING film, Right image LOW-E FILM
both south side, Ogden, summer (same temperature scale)

Figure 9. Infrared images comparing the radiant energy leaving the very warm existing (absorbing) applied film as opposed to the low-e applied film that reflects the room temp



Left image NO FILM, Right image LOW-E FILM
both north side, Ogden, summer (same temperature scale)

Figure 10. Infrared images demonstrates north side heat gain difference in the summer without direct sun. Low-e film reveals (apparent) high thermal contrast with frame

The difference in measured temperature between air and globe temperatures confirmed that high or low radiant temperatures from hot or cold glass surfaces impact occupant comfort. The contact glass temperatures and the black and white solar absorption temperatures are consistent with the optical properties of the various window configurations. For instance, much more direct solar radiation is admitted by the clear glass with no film compared to the low-e applied film (as shown in Figure 11).

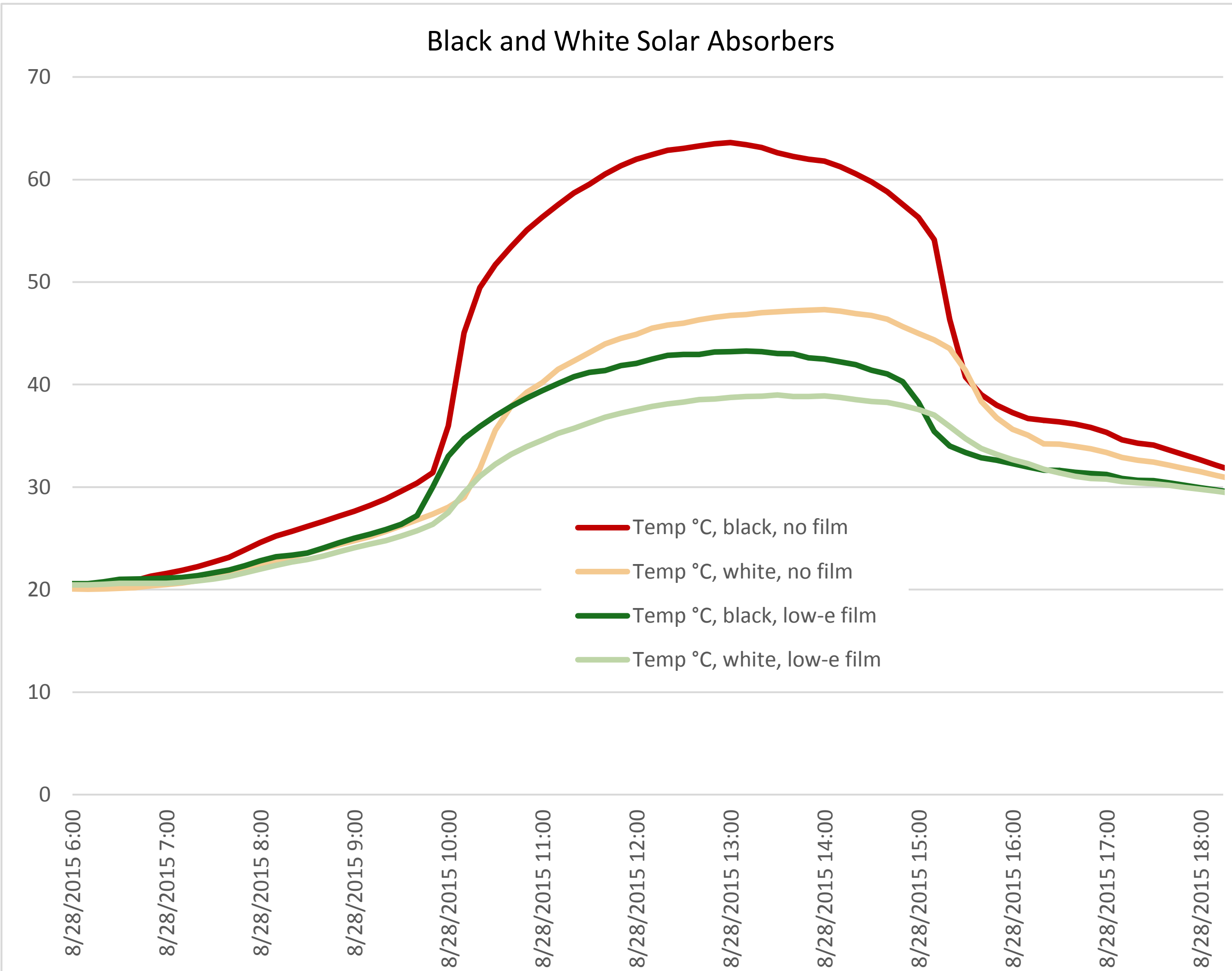


Figure 11. Black and white absorber surface temperature differences for no film and the low-e film on the south façade in Ogden during the summer

As with most high performance reflection-based applied films, and other low-e coatings in modern sealed IGUs, there is a visible appearance difference compared to clear glass or neutral absorbing tinted glass or films. Most often, the subtle differences are not highly noticeable because the occupant views the same type of glass all at once and there is no direct comparison that can make the difference more apparent. A small color shift may be apparent, as well as increased reflection of visible light toward the inside and outside (see the difference in appearance between the top two floors and the lower floors in Figure 12, for example). The increased exterior reflection can make the windows look more uniform from the exterior, but it also reduces daylighting.

Figure 12. North facing side of the Hansen Building in Ogden, UT. The top two floors have no applied film. The lower floors have the low-e applied film installed and they appear more reflective from the exterior, providing a more uniform appearance.

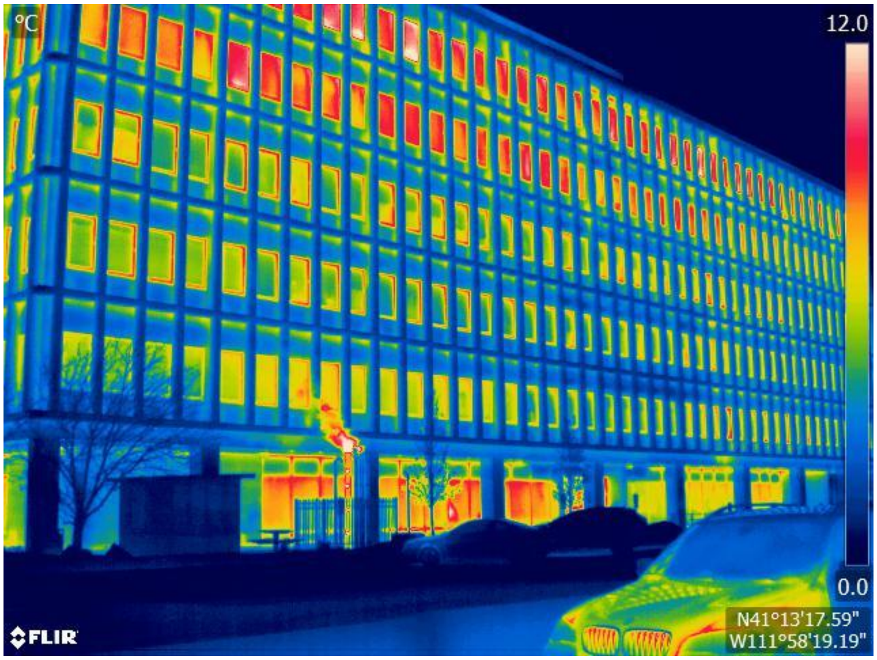


Figure 13. North facing side of the Hansen Building in Ogden, UT. Infrared image at night during the winter. The top two floors have no applied film (warmer surface tempreature indicate more heat loss). The lower floors have the low-e applied film installed (less heat loss).

B. MODELED WINDOW PERFORMANCE RESULTS

With the full spectrum of solar optical data and the long-wave emittance of the exposed film surface measured and available in the International Glazing Database (IGDB), window glazing assemblies of various multiple layer configurations can be calculated using the WINDOW7 software by LBNL, including placing the applied film on tinted glass layers even when it was originally measured on clear glass. This software was developed with the support of the U.S. Department of Energy and is available at no cost to users. The National Fenestration Rating Council (NFRC) uses this window modeling software to calculate the performance of window assemblies for performance rating purposes. For center of glass properties, WINDOW7 can calculate the U-factor, solar heat gain coefficient (SHGC), visible transmittance (Tvis), and solar transmission (Tsol) of multiple layer window assemblies defined by the user, pulling data for thousands of glass and film layers from the IGDB. The modeling techniques for multi-layer specular glazings and films are mature and well validated. Using some of the validation measurements as initial confirmation of window performance, modeling of further comparisons can expand the scope of this study. Modeled results are particularly useful for examining incremental changes resulting from a variety of glazing choices because the differences between models can be carefully limited and, thus, the comparisons are less prone to some of the variability between different physical measurements. It is difficult to hold the numerous parameters consistent between different cases of physical measurement in a complex system like a whole building. Optics6 by LBNL was used to construct custom glazing layers of the applied film on 6mm clear and bronze tinted substrates. All glass layer properties presented in this report are 6mm glass and the properties of all applied films are based on 6mm glass substrates.

Window glazing system properties for 26 glazing configurations labeled A-Z area are tabulated in the Appendix Tables AB1 and AB2. The A-Z letters match those used in further annual energy modeling tables. A second group of configurations (not used in the annual energy simulations) are provided for reference in Appendix Tables AB3 and AB4, denoted with an X followed by a number. These configurations demonstrate different properties associated with varied environmental conditions, such as reduced exterior wind speed. The Appendix Tables AB2 and AB4 include room-side surface temperatures modeled under standard (and modified) winter and summer environmental conditions. Glazing C is the VT35 low-e applied film that is the major focus of this study (mounted on clear single glazing). It also is in configurations I, O, U, X3, X4 and X6. Glazing B is an absorbing applied film that represents the properties of typical existing applied films. Glazing F (also L, R, X, X5 and X7) is a typical spectrally selective reflective applied film (not low-e) for comparison to the low-e film. Glazing Z is a typical modern sealed double pane IGU with a triple silver low-e coating and VT > 60.

Compared to the thermal insulation performance of single and double glazed base windows, most applied films will have essentially the same U-factor as their base window because applied films do not improve the thermal insulation performance of the window, unless there is a significantly lower surface emittance associated with the film. Some applied films, such as glazing F, do have a moderately lower emittance and, hence, a slightly lower U-factor. The subject low-e applied film (glazing C) is unique in that it provides a much lower emittance (~0.05), delivering significant insulation performance improvement. The low-e applied film achieves a U-factor of 0.574 BTU/hr-ft^2-F, which is approaching the value of 0.474 BTU/hr-ft^2-F for a double pane window without a low-e coating.

To examine the relative solar gain control, consider the SHGC of the window systems. Compared to solar absorption-based films, it is clear that films that reduce solar gain by reflection (even if most of that reflection is in the invisible solar infrared wavelengths) have lower SHGC on double pane configurations. Reflective film can more easily dissipate heat to the exterior from the installed position on the room side of the window. An absorbing film on the room side of a double pane window will not be able to dissipate as much of the solar energy back to the exterior because the heat is trapped behind the insulating layer of air between the glass panes. The low-e applied film further improves the redirection of absorbed energy in the windows system back outside by minimizing the longwave infrared thermal radiation exchange path toward the room. This reduces the SHGC and improves occupant comfort. It is worth noting that the actual room side temperature of the glass can be higher with a low-e applied film because it is preventing energy from entering the room. The low-e film prevents occupants from feeling the thermal comfort impact of this temperature rise, although it may create a slightly stronger convective “draft” of air off the window.

It is worth noting that the low-e aspect of the applied film under study improves the applicability of this applied film to various configurations. For instance, if you compare the performance for various single and double pane configurations to similar films without low-e, it is clear that the low-e property helps achieve a lower SHGC, and the thermal insulation can offset some of the seasonal tradeoff between beneficial passive solar gain in the winter versus undesirable solar gain in the summer.

C. ANNUAL ENERGY SIMULATION

With knowledge of the window system performance and other parameters of the building, a whole building annual energy simulation program, such as those utilizing the EnergyPlus simulation engine, can be run using typical weather files for a particular climate, providing whole building annual energy savings results for different configurations. COMFEN is a public domain software front end, developed by LBNL with funding from DOE, that is designed to simplify the annual energy modeling problem for commercial buildings, while still providing powerful tools to evaluate the many impacts of different window choices for a particular building. COMFEN simulates a single perimeter zone portion of a large commercial façade, providing heating, cooling, fan and lighting energy implications, as well as other analysis. It should not be expected that the energy consumption predictions from COMFEN will exactly match utility bills for a real building. Instead, COMFEN is primarily useful for exploring relative changes associated with different window choices for a particular building orientation, shading and climate application.

Three façade configurations were studied. One for each of the two installation locations (Ogden and Dallas) using "as-built" parameters for each facade. These models capture the façade geometry of each building (including exterior fins and overhangs). A third set of "generic" facade cases were modeled in Ogden and Dallas with five additional climates (Chicago, Washington DC, Miami, Minneapolis and Phoenix). The generic façade used the same window area and spacing as the Hansen Building in Ogden (40% window-to-wall ratio), without the small fins and overhangs. Each model considered a variety of glass configurations. Base case windows included single clear single tinted (bronze), double clear and double bronze. These base windows were combined with a selection of applied film products including the existing film configuration, retrofit low-e applied film, as other competing applied film products for comparison. These generic facade cases were calculated with many more window configurations, (see Table AB1 and AB2 for the complete list of glazing configurations and properties). All the runs were run with and without daylighting controls to demonstrate the energy impacts of the visible daylight admitted by different configuration with an adaptive electric lighting system that takes advantage of the natural daylight by dimming electric lighting to provide only this necessary additional lighting for workspace productivity.

A schematic of the façade configuration modeled for Ogden, Dallas and the generic case perimeter zone are presented in Figures 14, 15 and 16. The window-to-wall ratio for Ogden and the generic case is 40%. The window-to-wall ratio for Dallas is 32%. In all cases, aluminum window frames (2.5" wide) with a U-factor of 0.7 BTU/hr-ft^2-F and walls with an R-value of 5.45 hr-ft^2-F/BTU were used. These values have been estimated to be consistent with older commercial buildings typically in need of retrofit. The floor area of the perimeter zone model is 25 feet wide by 15 feet deep, for 375 ft^2. The ceiling is 10 feet high and there are 5 windows that total 100 ft^2 with window frames and 82 ft^2 for the glass area only of the Hansen Building in Ogden, and the generic cases. The as-built façade for the Cabell Building in Dallas has four windows totaling 80 ft^2 with window frames or 65.7 ft^2 for the glass area only.

Default COMFEN electricity and gas energy costs were replaced with appropriate average annual values for each state taken from the 2015/2016 Energy Information Administration reports. The retail commercial electricity and gas prices used are summarized in the Appendix, Table AD1. The cost structure of electrical power for a particular facility can vary significantly from the state average reported for commercial buildings. The incremental kWh charge may be smaller, with a large fraction of the bill resulting from fixed costs. Reducing peak demand may bring down the capacity charge portion of the bill.

Table 4 presents the site energy consumption and energy cost for various window configurations with the actual Cabell Building façade configuration including shading from the vertical columns. Table 5 reports the site energy consumption and energy cost for various window configurations with the actual Hansen Building façade configuration including the grid of overhangs and vertical shading fins. Tables 6 and 7 provide the results for the same buildings/climates with daylighting controls.

The annual energy results for even more window configurations with the generic case façade (the same as Ogden without the fins and overhangs) are tabulated in Appendix Tables AC1 through AC70. There are 10 tables for each of 7 climates. Half of the simulations assume no lighting controls (on and off based on typical office work schedule only). The other half use continuously dimmable electric lighting that is automatically controlled to make up for the needed working light level as a supplement to natural daylight. This allows examination of the interplay of window visible light transmission and overall HVAC and lighting energy use. Lighting energy is coupled to heating and cooling because electric lights dissipate heat into the conditioned space (augmenting space heating in the winter and adding to the cooling load in the summer). There is a table for each orientation (S, N, W, E), as well as an averaged table that represents a building with the same window treatment on four symmetrical facades.

Higher solar gain versions (VT50 and VT70) of the low-e film have the greatest reduction in heating load, while the lower solar gain version (VT35) has the lowest cooling load. When averaged over the four equal orientations, without using daylighting controls, the VT35 low-e applied film delivered the lowest annual energy consumption of all the applied films that were modeled in all seven climates (ranging from heating dominated Minneapolis to cooling dominated Phoenix), even on single bronze, double clear and double bronze substrates. Low-e applied film on single clear ranged between 22-38% savings, low-e on single bronze 21-27%, low-e on double clear 9-28%, and low-e on double bronze 12-23%. The low-e film is also fairly close and in some cases equal (Phoenix) to the energy savings of a new sealed double pane low-e window (glazing Z). The savings for replacement double low-e glazing compared to single clear is 30-38%.

Tables 8 and 9 presents further energy savings based on heating, cooling and fan energy results only (HVAC energy), without lighting controls and without lighting energy as part of the baseline. The heating and cooling associated with a fixed schedule lighting control is included. All the results in those tables use the generic façade configuration to allow consistent comparisons between climates.

Because the simulations are based on perimeter zones (window influenced regions of the building), these energy savings results do not directly translate to whole building HVAC energy savings. The details of building core to perimeter size, internal loads (equipment/people), humidity of climate and other factors will influence how perimeter savings correlate to whole building savings. One approximation is to consider the average national estimates for commercial building energy presented in Table 1. That work revealed that windows are responsible for 34% of building HVAC energy. Thus, a very conservative approximation for whole building HVAC savings would be 1/3 the perimeter HVAC energy savings. However, the savings is expected to be higher than this estimate, because the perimeter HVAC results already include some energy associated with the walls, and internal loads of occupants and heat dissipated by lighting.

Coupling the low-e films with daylighting controls also revealed larger potential energy savings, with as high as 45-70% lighting energy savings in the perimeter zone compared to a fixed lighting schedule. Greater lighting energy savings are achieved with higher visible transmission versions of the low-e film, however the total annual energy for the VT35 and VT50 films remains quite close in most cases, because of the trade-off with cooling load.

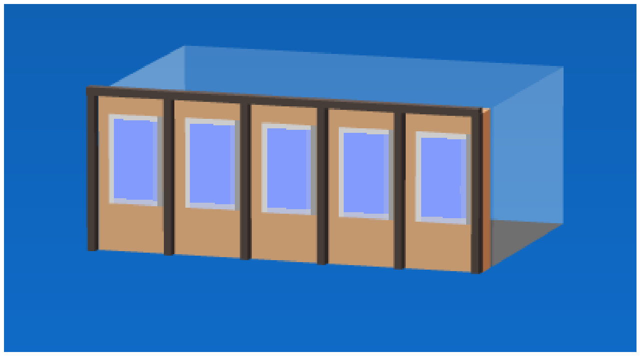


Figure 14. Schematic model of the Ogden, UT, Hansen Building perimeter zone modeled by COMFEN (including as-built grid of shallow fins and overhangs)

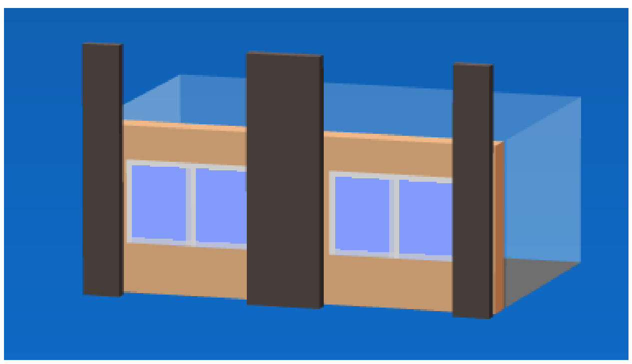


Figure 15. Schematic model of the Dallas, TX, Cabell Building perimeter zone modeled by COMFEN (including as-built shallow veritcal fins, extended upward for high sun angles)

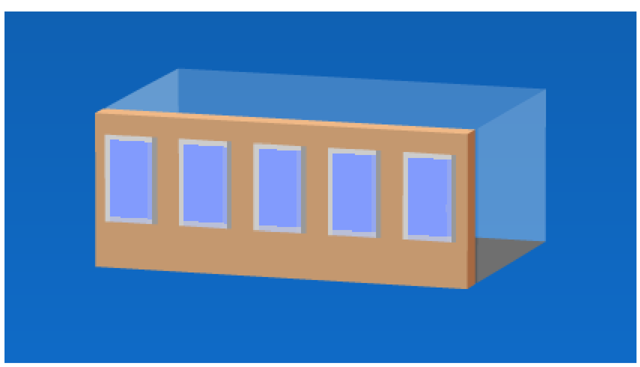


Figure 16. Schematic model of the multiple climate, generic building perimeter zone modeled by COMFEN (same glass area as Ogden, but without any fins or overhangs)

Table 4. COMFEN annual site energy and cost results for different base window configurations for the Cabell Building in Dallas (as-built) perimeter zone, no daylighting controls

ID	Orient-ation	Applied film (on single clear)	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	S	none	5.30	32.09	13.96	10.73	62.07	$1.51
B	S	absorbing	6.45	28.86	12.65	10.73	58.70	$1.40
C	**S**	**VT35 low-e**	**6.24**	**22.98**	**9.27**	**10.73**	**49.21**	**$1.16**
D	**S**	**VT50 low-e**	**5.30**	**24.78**	**10.05**	**10.73**	**50.86**	**$1.22**
F	S	VT40 spec. sel.	8.98	24.80	10.91	10.73	55.41	$1.27
A	N	none	13.01	23.82	9.88	10.73	57.44	$1.25
B	N	absorbing	13.76	22.69	9.39	10.73	56.57	$1.21
C	**N**	**VT35 low-e**	**10.44**	**18.79**	**7.62**	**10.73**	**47.58**	**$1.04**
D	**N**	**VT50 low-e**	**10.20**	**20.89**	**8.02**	**10.73**	**49.84**	**$1.10**
F	N	VT40 spec. sel.	15.05	21.07	8.72	10.73	55.56	$1.16
A	W	none	6.92	35.30	20.39	10.73	73.34	$1.77
B	W	absorbing	8.31	31.65	17.79	10.73	68.48	$1.62
C	**W**	**VT35 low-e**	**7.73**	**24.29**	**11.41**	**10.73**	**54.16**	**$1.26**
D	**W**	**VT50 low-e**	**6.86**	**26.51**	**13.02**	**10.73**	**57.13**	**$1.35**
F	W	VT40 spec. sel.	10.92	26.71	14.14	10.73	62.51	$1.42
A	E	none	6.42	33.38	18.79	10.73	69.33	$1.68
B	E	absorbing	7.89	30.14	16.52	10.73	65.28	$1.55
C	**E**	**VT35 low-e**	**7.43**	**23.58**	**11.17**	**10.73**	**52.91**	**$1.23**
D	**E**	**VT50 low-e**	**6.53**	**25.58**	**12.59**	**10.73**	**55.43**	**$1.32**
F	E	VT40 spec. sel.	10.65	25.71	13.26	10.73	60.35	$1.37
A	Avg.	none	7.91	31.15	15.75	10.73	65.54	$1.55
B	Avg.	absorbing	9.10	28.34	14.09	10.73	62.26	$1.44
C	**Avg.**	**VT35 low-e**	**7.96**	**22.41**	**9.87**	**10.73**	**50.97**	**$1.17**
D	**Avg.**	**VT50 low-e**	**7.22**	**24.44**	**10.92**	**10.73**	**53.31**	**$1.25**
F	Avg.	VT40 spec. sel.	11.40	24.57	11.76	10.73	58.46	$1.30

Table 5. COMFEN annual site energy and cost results for different base window configurations for the Hansen Building in Ogden (as-built) perimeter zone, no daylighting controls

ID	Orient-ation	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	S	none	22.38	14.34	16.18	10.73	63.64	$1.23
B	S	absorbing	26.66	11.50	14.55	10.73	63.44	$1.14
C	**S**	**VT35 low-e**	**24.01**	**7.85**	**10.25**	**10.73**	**52.84**	**$0.92**
D	**S**	**VT50 low-e**	**21.06**	**9.22**	**11.25**	**10.73**	**52.27**	**$0.96**
E	**S**	**VT70 low-e**	**17.67**	**11.21**	**12.55**	**10.73**	**52.15**	**$1.02**
F	S	VT40 spec. sel.	34.89	8.22	12.35	10.73	66.19	$1.06
G	S	VT70 spec. sel.	26.91	9.59	12.62	10.73	59.85	$1.05
A	N	none	42.77	7.47	11.59	10.73	72.56	$1.08
B	N	absorbing	44.92	6.66	10.89	10.73	73.20	$1.05
C	**N**	**VT35 low-e**	**33.55**	**5.85**	**8.52**	**10.73**	**58.66**	**$0.89**
D	**N**	**VT50 low-e**	**33.00**	**6.31**	**8.97**	**10.73**	**59.00**	**$0.91**
E	**N**	**VT70 low-e**	**31.77**	**6.93**	**9.49**	**10.73**	**58.92**	**$0.93**
F	N	VT40 spec. sel.	48.56	5.57	9.92	10.73	74.79	$1.02
G	N	VT70 spec. sel.	41.64	6.18	9.87	10.73	68.42	$0.99
A	W	none	25.14	18.85	27.80	10.73	82.52	$1.67
C	**W**	**VT35 low-e**	**26.53**	**9.68**	**13.96**	**10.73**	**60.90**	**$1.08**
D	**W**	**VT50 low-e**	**24.01**	**11.68**	**16.39**	**10.73**	**62.81**	**$1.18**
E	**W**	**VT70 low-e**	**20.71**	**14.29**	**19.38**	**10.73**	**65.11**	**$1.30**
F	W	VT40 spec. sel.	37.39	10.73	18.35	10.73	77.20	$1.30
A	Avg.	none	28.97	14.62	20.37	10.73	74.69	$1.39
B	Avg.	absorbing	32.78	11.99	17.92	10.73	73.42	$1.29
C	**Avg.**	**VT35 low-e**	**27.69**	**8.17**	**11.57**	**10.73**	**58.16**	**$0.99**
D	**Avg.**	**VT50 low-e**	**25.56**	**9.60**	**13.11**	**10.73**	**59.01**	**$1.05**
E	**Avg.**	**VT70 low-e**	**22.77**	**11.54**	**15.03**	**10.73**	**60.07**	**$1.13**
F	Avg.	VT40 spec. sel.	39.79	8.62	14.36	10.73	73.50	$1.16
G	Avg.	VT70 spec. sel.	32.18	10.03	15.00	10.73	67.94	$1.16

Table 6. COMFEN annual site energy and cost results for different base window configurations for the Cabell Building in Dallas (as-built) perimeter zone, with automatic daylighting controls

ID	Orient-ation	Applied film (on single clear)	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	S	none	6.54	28.94	12.37	2.56	50.41	$1.19
B	S	absorbing	7.75	26.00	11.15	3.17	48.08	$1.10
C	**S**	**VT35 low-e**	**7.84**	**20.35**	**7.88**	**4.01**	**40.08**	**$0.89**
D	**S**	**VT50 low-e**	**6.78**	**21.80**	**8.59**	**3.24**	**40.41**	**$0.92**
F	S	VT40 spec. sel.	10.73	22.19	9.47	3.53	45.92	$0.99
A	N	none	15.60	21.22	8.34	2.90	48.06	$0.95
B	N	absorbing	15.76	18.90	7.72	4.32	46.71	$0.92
C	**N**	**VT35 low-e**	**11.44**	**17.38**	**7.31**	**6.27**	**42.40**	**$0.88**
D	**N**	**VT50 low-e**	**11.73**	**17.47**	**7.28**	**4.52**	**41.00**	**$0.84**
F	N	VT40 spec. sel.	16.68	17.82	7.59	5.26	47.35	$0.91
A	W	none	8.66	32.24	18.58	2.59	62.06	$1.45
B	W	absorbing	9.95	28.90	16.09	3.51	58.46	$1.33
C	**W**	**VT35 low-e**	**9.31**	**21.84**	**9.88**	**4.74**	**45.77**	**$1.01**
D	**W**	**VT50 low-e**	**8.58**	**23.67**	**11.35**	**3.64**	**47.24**	**$1.06**
F	W	VT40 spec. sel.	12.78	24.27	12.55	4.10	53.70	$1.15
A	E	none	8.05	30.65	17.37	2.81	58.89	$1.38
B	E	absorbing	9.48	27.76	15.17	3.83	56.24	$1.28
C	**E**	**VT35 low-e**	**9.00**	**21.36**	**9.89**	**5.08**	**45.34**	**$1.01**
D	**E**	**VT50 low-e**	**8.21**	**23.03**	**11.27**	**3.97**	**46.48**	**$1.05**
F	E	VT40 spec. sel.	12.46	23.56	11.96	4.44	52.41	$1.13
A	Avg.	none	9.71	28.26	14.16	2.71	54.85	$1.24
B	Avg.	absorbing	10.74	25.39	12.53	3.71	52.37	$1.16
C	**Avg.**	**VT35 low-e**	**9.40**	**20.23**	**8.74**	**5.03**	**43.40**	**$0.95**
D	**Avg.**	**VT50 low-e**	**8.83**	**21.50**	**9.62**	**3.84**	**43.78**	**$0.97**
F	Avg.	VT40 spec. sel.	13.16	21.96	10.39	4.33	49.85	$1.05

Table 7. COMFEN annual site energy and cost results for different base window configurations for the Hansen Building in Ogden (as-built) perimeter zone, with automatic daylighting controls

ID	Orient-ation	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	S	none	26.16	12.26	14.36	2.55	55.33	$0.94
B	S	absorbing	30.61	9.69	12.80	2.99	56.09	$0.88
C	**S**	**VT35 low-e**	**28.53**	**6.26**	**8.58**	**3.66**	**47.02**	**$0.68**
D	**S**	**VT50 low-e**	**25.47**	**7.38**	**9.52**	**3.05**	**45.43**	**$0.70**
E	**S**	**VT70 low-e**	**21.73**	**9.14**	**10.75**	**2.72**	**44.34**	**$0.74**
F	S	VT40 spec. sel.	39.60	6.73	10.63	3.29	60.24	$0.82
G	S	VT70 spec. sel.	31.53	7.82	10.84	2.73	52.92	$0.78
A	N	none	48.36	5.97	9.69	2.81	66.82	$0.82
B	N	absorbing	49.65	5.26	9.00	3.91	67.83	$0.82
C	**N**	**VT35 low-e**	**36.74**	**4.74**	**7.35**	**5.82**	**54.65**	**$0.73**
D	**N**	**VT50 low-e**	**37.55**	**4.80**	**7.19**	**4.08**	**53.61**	**$0.68**
E	**N**	**VT70 low-e**	**37.02**	**5.30**	**7.66**	**3.19**	**53.17**	**$0.68**
F	N	VT40 spec. sel.	52.90	4.34	8.05	4.75	70.04	$0.82
G	N	VT70 spec. sel.	47.04	4.72	8.01	3.22	62.99	$0.75
A	W	none	29.54	16.80	25.70	2.59	74.63	$1.38
C	**W**	**VT35 low-e**	**30.60**	**8.07**	**12.07**	**4.43**	**55.16**	**$0.85**
D	**W**	**VT50 low-e**	**28.46**	**9.79**	**14.38**	**3.40**	**56.03**	**$0.92**
E	**W**	**VT70 low-e**	**25.25**	**12.24**	**17.35**	**2.84**	**57.68**	**$1.02**
F	W	VT40 spec. sel.	42.04	9.15	16.33	3.81	71.33	$1.06
A	Avg.	none	33.48	12.74	18.49	2.65	67.37	$1.12
B	Avg.	absorbing	37.06	10.30	16.08	3.41	66.85	$1.04
C	**Avg.**	**VT35 low-e**	**31.62**	**6.72**	**9.99**	**4.63**	**52.96**	**$0.78**
D	**Avg.**	**VT50 low-e**	**29.99**	**7.86**	**11.32**	**3.52**	**52.70**	**$0.80**
E	**Avg.**	**VT70 low-e**	**27.32**	**9.62**	**13.20**	**2.92**	**53.06**	**$0.86**
F	Avg.	VT40 spec. sel.	44.32	7.19	12.54	3.96	68.00	$0.93
G	Avg.	VT70 spec. sel.	37.13	8.34	13.15	2.94	61.57	$0.90

Table 8. Dallas and Ogden perimeter HVAC energy savings based on COMFEN annual enery results, average of four equal "generic" façade orientations, no lighting controls.

	Dallas Energy savings on single clear	Dallas Energy savings on single abs. film (B)	Dallas Energy savings on single bronze	Dallas Energy savings on double clear	Dallas Energy savings on double bronze	Ogden Energy savings on single clear	Ogden Energy savings on single abs. film (B)	Ogden Energy savings on single bronze	Ogden Energy savings on double clear	Ogden Energy savings on double bronze
B	8%					3%				
C, I, O, U	**33%**	**27%**	**26%**	**23%**	**19%**	**30%**	**27%**	**27%**	**18%**	**17%**
D, J, P, V	**28%**	**21%**	**23%**	**19%**	**16%**	**28%**	**25%**	**25%**	**16%**	**16%**
E, K, Q, W	**21%**	**14%**	**19%**	**13%**	**12%**	**25%**	**22%**	**24%**	**13%**	**15%**
F, L, R, X	18%	11%	10%	11%	6%	4%	1%	0%	1%	1%
G, M S, Y	19%	11%	13%	11%	8%	13%	10%	10%	5%	6%
Z	35%	29%	28%	25%	17%	35%	33%	33%	18%	17%

Table 9. Phoenix and Minneapolis perimeter HVAC energy savings based on COMFEN annual enery results, average of four equal "generic" façade orientations, no lighting controls. (neg. not savings)

	Phnx. Energy savings on single clear	Phnx. Energy savings on single abs. film (B)	Phnx. Energy savings on single bronze	Phnx. Energy savings on double clear	Phnx. Energy savings on double bronze	Minn. Energy savings on single clear	Minn. Energy savings on single abs. film (B)	Minn. Energy savings on single bronze	Minn. Energy savings on double clear	Minn. Energy savings on double bronze
B	11%					0%				
C, I, O, U	**38%**	**31%**	**30%**	**28%**	**23%**	**22%**	**22%**	**21%**	**9%**	**12%**
D, J, P, V	**31%**	**23%**	**26%**	**22%**	**18%**	**21%**	**21%**	**21%**	**9%**	**12%**
E, K, Q, W	**23%**	**14%**	**21%**	**15%**	**14%**	**21%**	**21%**	**21%**	**8%**	**12%**
F, L, R, X	25%	16%	15%	14%	10%	-2%	-2%	-3%	-5%	-1%
G, M S, Y	23%	14%	16%	14%	10%	8%	7%	7%	0%	3%
Z	38%	31%	29%	30%	19%	30%	30%	30%	10%	13%

D. PAYBACK OPTIMIZATION

The potential cost payback for solar control film retrofit products will vary substantially depending on the particular building, climate and other factors. The payback estimated for the Cabell Building in Dallas and the Hansen Building in Ogden, based on COMFEN annual energy modeling runs, are presented in Table 10. When evaluating the potential for payback, it is useful to keep in mind that higher window-to-wall ratios, climates with sunny, hot summers and moderate winters, as well as buildings with a large area of unshaded glass exposure are most likely to benefit from a solar control film retrofit and have a more rapid payback using a solar control film retrofit product. However, because the low-e film also improves insulation performance, energy savings and payback time are more favorable in a variety of climates and conditions.

Four payback times are calculated for each site (presented in Table 10). The average material and installation cost for the low-e applied film (provided by the manufacturer) is $\$7.75/ft^2$ ($\$4.25/ft^2$ material and $\$3.50/ft^2$ installation). If an existing film needs to be removed, $\$1.50/ft^2$ is added to the labor cost. The material cost of the VT70 version of the low-e film is about 4 times higher than the other two low-e films. It was omitted from the payback analysis, because the times are significantly longer. The average material and installation cost for typical non-low-e applied film (also provided by the manufacturer) is $\$4.50\text{-}5.50/ft^2$ ($\$2.00\text{-}3.00/ft^2$ material and $\$2.50/ft^2$ installation) depending on the performance level of the non-low-e film. The incremental cost for both material and installation of the low-e film instead of a lower performance typical applied film is $\$3.25/ft^2$, and the differential for the low-e film instead of a higher performance typical applied film is $\$2.25/ft^2$. Payback is calculated both as a full payback of the material and labor, as well as an incremental payback relative to a competitive product (with the corresponding incremental energy consumption). The incremental figure is relevant if a window film is going to be replaced because it is at the end of its life and only the incremental cost and performance needs to be considered. If there is already a serviceable film in place, or no film is in place, the full payback should be considered.

A simple payback analysis was achieved by using the average energy use per square foot over the four façade orientations and multiplying the relative energy cost savings per square foot by the 375 square feet of floor area in the modeled perimeter zone. The total or incremental cost of the installed film per square foot was multiplied by the 82 square feet of glass area modeled in the same zone.

The payback times in four additional cities are presented in Table 11 using the “generic” façade case data (from Appendix Tables AC1-AC70). Full and incremental payback (relative to a spectrally selective applied film) are presented for four base windows (single clear, single bronze, double clear, and double bronze). Payback are generally shorter for single glazing (2-6 years), but retrofitting low-e films on double glazing also shows compelling payback times. As a reference comparison, a complete window retrofit is included (factory-sealed double pane IGU with low-e coating, glazing Z). This retrofit is substantially more expensive to install (assumed to be $\$40/ft^2$, for the purposes of this calculation). The actual cost depends on the complexity of the work and whether the window framing system has to be replaced. Because the annual energy savings are not that much more than that of the low-e applied films and the cost is much higher, the payback is about 20 years in most cases (relative to a single clear base window).

Table 10. VT35 low-e film simple payback in years based on COMFEN modeling of "as-built" perimeter zone energy cost savings (no lighting controls), full or incremental install.

	Material and labor (full or incremental) $\$/ft^2$	Ogden (as- built) years	Dallas (as- built) years
Full payback relative to clear (A)	7.75	4.2	3.6
Full payback relative to abs. film (B), with $1.50/ft² removal	9.25	6.7	6.0
Full payback relative to spec. sel. film (F), with $1.50/ft² removal	9.25	11.9	12.5
Incremental payback relative to abs. film (B)	3.25	2.4	2.1
Incremental payback relative to spec. sel. film (F)	2.25	2.9	3.0

Table 11. VT35 and VT50 film simple payback on four base windows, from COMFEN annual enery results, average of four equal "generic" façade orientations, no lighting controls. (payback time in years)

	Phoenix full	Phoenix incr. spec. sel.	Minn. full	Minn. incr. spec. sel.	Chicago full	Chicago incr. spec. sel.	Miami full	Miami spec. sel.	Wash. DC full	Wash. DC spec. sel.
C	2.3	2.1	4.1	2.8	4.8	3.0	3.5	4.8	3.7	2.8
D	2.8	5.1	4.8	4.2	5.6	4.4	4.4	N/A	4.5	5.3
I	3.3	2.1	5.7	2.7	6.4	2.9	5.2	4.6	5.4	2.8
J	3.9	3.1	6.5	3.4	7.3	3.6	6.6	11.9	6.4	3.9
O	3.5	2.2	7.1	3.9	8.2	4.2	4.9	3.7	5.9	3.6
P	4.4	4.0	8.8	6.1	10.1	6.4	6.4	9.8	7.5	6.6
U	5.0	2.6	10.2	4.7	11.3	5.3	7.8	5.2	9.0	4.4
V	6.4	4.2	12.0	6.3	13.2	6.9	9.6	9.0	10.7	6.1
Z	11.8		19.6		22.7		18.7		18.6	

E. OCCUPANT RESPONSE SURVEY

Two website-based surveys were distributed to the occupants of each of the window retrofit buildings studied, for a total of four separate surveys. The 10 survey questions and the summary data collected are presented in the Appendix (Tables AE1-4). The surveys acquired feedback regarding occupant thermal comfort and other impressions before and after the retrofit, for both winter and summer conditions. The occupants only had experience with the retrofit film during one season for the first survey in each location. The second survey covered post installation feedback following experiences with both winter and summer seasons. Both surveys allowed input on window-related experiences before the retrofits.

In both cooling and heating seasons, there was a strong improvement reported in occupant comfort, particularly with regard to reducing the number of incidences of the highest discomfort levels (see example in Figure 17).

Figure 17. Occupant survey responses regarding thermal comfort Ogden, UT site (29-34 responses)

The appearance of the film and glare reduction was generally viewed as a favorable improvement for most occupants (see Figure 18). The existing film in the Hansen Building in Ogden was at the end of its service life. As applied film ages, it can develop a hazy or blurry appearance. Because the existing condition of the film was noticeably degraded in this location, there was a more dramatic improvement and the responses strongly reflect that context. Despite the generally positive feedback on appearance, there were some survey responses that were dissatisfied with the color/hue of the film and the loss of daylight, particularly on north facing windows that previously had no film (and hence very high visible transmission). Some occupants reported that the loss of daylight resulted in an increase in the use of electric lighting, which has implications for lighting, cooling and heating energy. However, it is uncommon for occupants to have individual control over a significant amount of electric lighting (at least in open plan offices), so the daylighting energy savings are likely to be realized only in the case of automated dimming controls that augment the natural daylighting to provide the correct amount of working illumination. Attention should be given to existing conditions with high visible transmission (particularly on north facing facades where glare and solar gain are not dominant considerations). Also, there is an opportunity to save energy and improve the quality of office spaces with a general increase visible transmission, where appropriate (particularly mixed heating and cooling climates), in combination with appropriate use of automated daylighting controls and shading systems to mitigate glare.

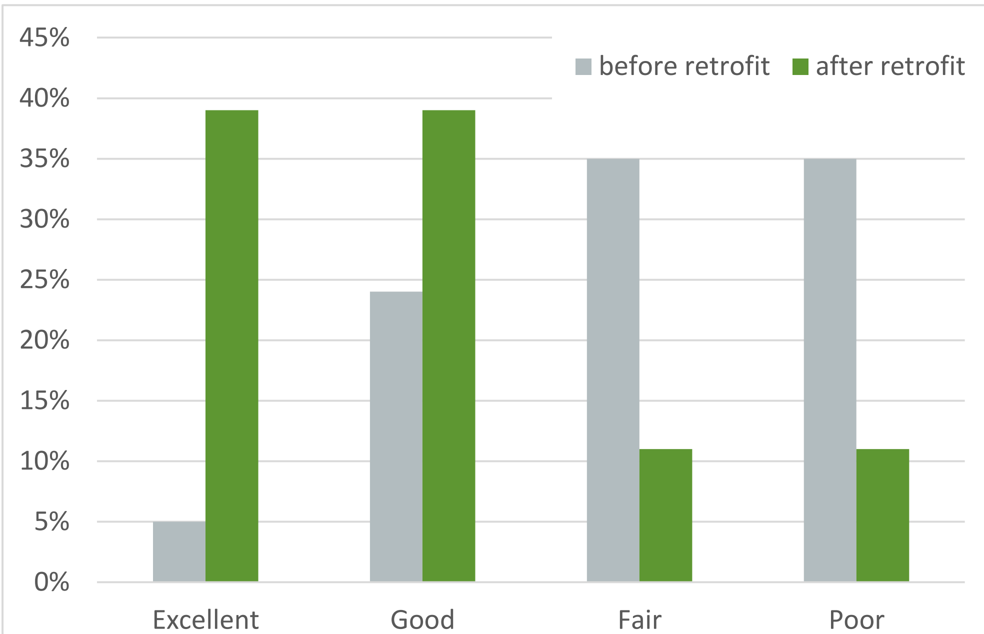


Figure 18. Occupant survey response to: How would you characterize the visual appearance of the windows? Ogden, UT site (36 responses)

In most cases, survey responses were from building occupants who worked within 15 feet of windows in open plan offices. Most occupants highly value the views and daylight from their windows (see Figure 19) and the survey results generally reported that blinds are often up and they are not frequently adjusted.

All things considered, a strong majority of building occupants recommended the film for use elsewhere, based on their experience with the window retrofit in their office (see Figure 20).

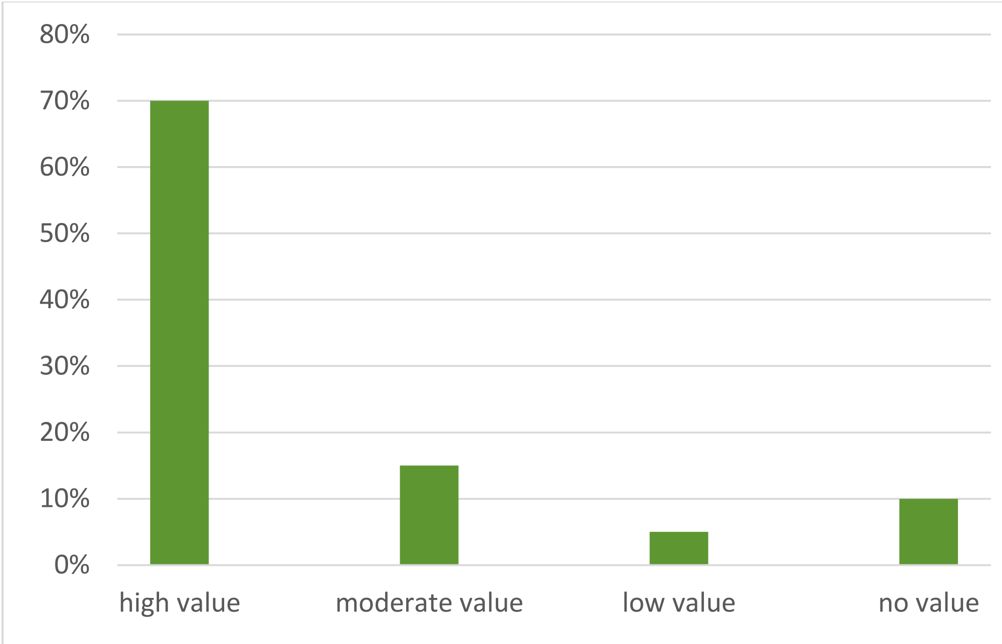


Figure 19. Occupant survey response to: How much do you value the view and visible light provided by the windows in your workspaces? Dallas, TX site (20 responses)

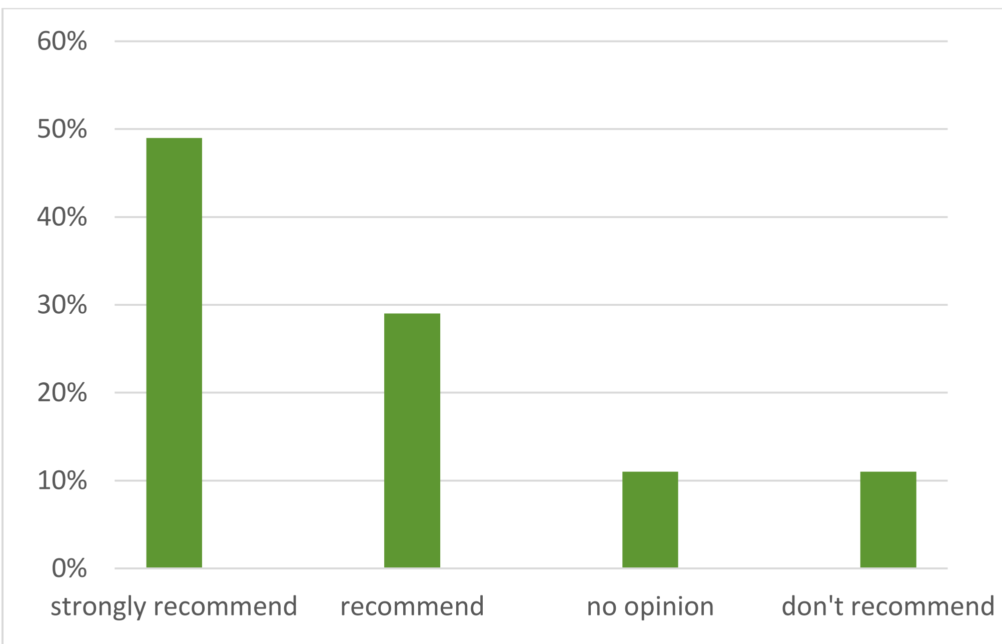


Figure 20. Occupant survey response to: Would you recommend similar retrofits in other office buildings? Ogden, UT site (35 responses)

F. ASSOCIATED OBSERVATIONS

In the process of monitoring window performance over several months, non-window-related observations were made to assess general energy efficiency measures in the building. Weekend and holiday temperature setbacks appeared to occur reliably, as expected. Both sites have supplemental heating or heating and cooling at the perimeter near the windows. These systems do not have controls that are as sophisticated or locally refined as other HVAC in the buildings. Because the subject film significantly improve thermal performance and solar gain near the windows, it is expected that modifications to the perimeter conditioning may be necessary to achieve the best energy savings and occupant comfort. It stands as a useful reminder that the intended subject for energy retrofit in a building is not always an isolated consideration, and that it is always wise to diagnose and understand the operation of a building comprehensively to provide the necessary context for appropriate energy efficiency upgrade decisions.

As noted in the technology description, installation of low-e applied films is relatively non-invasive for the occupants and the survey did not reveal any comments of major inconvenience or conflicts during the installation process. There are occasionally small bubbles trapped under the film that slowly dissipate after the installation. This may lead to occupant callbacks following installation. In extreme cases, if there was improper installation technique, a window may need to have the film re-applied. For the building manager, the applied film installation process is considerably less complicated than other large construction and retrofit projects; however, the context of furniture placement with respect to the windows and the need to remove existing film, can add to the complexity and cost of the installation.

V. Conclusions and Recommendations

The subject of this study, a low-e solar control applied film technology, stands out from competitive applied films as a high performance product with a wide range of applicability to various climates, both cooling dominated and mixed heating and cooling. The ability to add thermal insulation performance to a low performance base window in the form of a cost-effective applied film enables greater energy savings than other applied films and delivers a fast payback, as well as occupant comfort improvements.

In the annual energy modeling results calculated for this work, the low-e applied film consistently achieved the best incremental performance over the base configurations of any applied film that was considered. In most configurations and climates, the VT35 version of the film had the optimum performance averaged over the year and four orientations; however, in cases where passive solar gain to offset heating is more important (and unwanted summer solar gain is controlled by another shading means), choosing a higher solar gain version of the low-e film may be preferred. Higher solar gain versions of the low-e film also allow more visible daylight into the building, which improves occupant satisfaction and reduces electric lighting energy and associated HVAC loads. For this reason, the new VT50 version of the low-e applied film is also highly compelling. The VT70 version of the film is useful for applications that require the highest possible visible light transmission, but the material cost is about 4 times higher than the other films, which significantly increases the payback time of this film.

The unique insulation performance offered by the low-e applied films enable them to be less sensitive to the typical summer/winter solar heat gain tradeoff. Normally, passive solar gain is sacrificed in the winter, when it would offset heating load, to minimize the cooling load in the summer. This choice is reinforced by the fact that cooling energy is typically more expensive than heating energy. The GPG program report #017 (Curcija 2015) includes a discussion of the SHGC tradeoff for typical applied films and the associated climate limitations. However, the insulation benefit introduced by the low-e applied film offsets some of the lost passive solar gain by reducing heat loss in the winter and this proves to be a strong mitigation of the SHGC tradeoff, especially when starting with a low thermal performance single glazed window.

In addition to modeling, multiple window film configurations were measured side-by-side in two climates over both winter and summer seasons. While it was not possible to meter HVAC energy savings directly, the window performance properties were consistently validated with the deployed monitoring instrumentation and provide confidence that the low-e film performs in the field as designed, consistent with lab measured optical properties for the film.

The manufacturer's claim for a range of heating and cooling energy savings was confirmed by the annual energy modeling results. Savings of about 20% over a standard tint film for annual heating and cooling energy was demonstrated in both the Dallas and Ogden climates. The other climates (Chicago, Washington DC, Miami, Minneapolis, and Phoenix) also demonstrated a consistent roughly 20% savings over a traditional tint film and about 30% savings in the hotter climates when compared to clear single glazing. Heating savings (~10%) was typically considerably smaller than cooling savings (30-40%). The reported energy savings considers perimeter HVAC energy. Whole building HVAC savings will be smaller (estimates to be no less than 1/3 of perimeter savings), depending on the specifics of the building, based on national averages for commercial buildings (see Table 1). A whole building will have additional loads beyond just HVAC (equipment and lighting), resulting in smaller savings at the level of whole building utility bills.

The simple payback analysis conducted, based on the COMFEN perimeter zone modeling results, suggests an incremental payback between two and four years, instead of installing a conventional film, and a full payback period of four to six years when there is no existing film, or the existing film is not ready to be replaced. When a window film purchase is already planned (*e.g.*, end of life of existing film), the incremental cost of the higher performance low-e film can payback very quickly (about 2 years). Even for cases that are not suitable to consider an incremental payback, the full payback term is still very compelling. Payback times less than 10 years are rare with window retrofit because the installation costs are typically very high (particularly for replacement windows). The example included as a reference in this report estimated a 20 year payback time for a full window replace with a sealed double pane low-e unit. The short payback times for the low-e applied film distinguishes it from most other window retrofit technologies. The only cases when the low-e film payback crept up to around 10-12 years was the full payback for the replacement of an already relatively high performance spectrally selective applied film that was not ready for replacement, on double glazing, in some locations.

When evaluating a solar control window retrofit, or any type of window retrofit, a site-specific analysis, including an annual energy model, is recommended to evaluate alternatives and select the highest performing solutions for a given building application and orientation. Both heating and cooling impacts should be considered. Under some conditions, solar control cooling energy savings can be overshadowed by the additional heating energy requirements resulting from lost passive solar gains during heating periods in some climates. However, that effect is noticeably diminished in the case of the low-e applied film because the insulation improvement offsets a good portion of the beneficial passive solar gain that is lost with the lower SHGC. As a result the VT35 film retrofit consistently demonstrated the lowest annual energy use. Strongly heating-dominated climates can benefit from higher solar gain (especially if summer solar gain is shaded by another means). Also, natural daylighting is an important energy service to a building, and improves occupant satisfaction in the space. The new VT50 version of the low-e applied film provides more design options for north facing facades, use on monolithic tinted glass and other applications where higher visible transmission is desired. In most cases the annual energy performance is very similar between VT35 and VT50, with small energy trades-off between heating and cooling and lighting and cooling.

Typical single glazing often exposes the room to both high and low glass surface temperatures depending on the season. This can lead to occupant discomfort associated with radiative and convective heat exchange, particularly for occupants sitting close to a window. Measured glass temperatures in this study were as high as 105°F (40°C) and as low as 40°F (5°C), although greater extremes are possible. In addition to reducing heat flow and making the window a better insulator, the low-e applied film minimizes this radiant exchange experienced by nearby occupants and provides a more comfortable environment near the window, in both summer and winter. While the physical temperature of the low-e film is not significantly different, the apparent radiant temperature leaving the low-e film remains near the comfortable room temperature, resulting in a 27F° (15C°) window temperature increase under winter conditions and a 27F° (15C°) temperature decrease under summer conditions.

The occupant surveys distributed at both of the test installation sites (Dallas and Ogden) indicated that there was a strong improvement in occupant comfort for both heating and cooling seasons, particularly in reducing the number of incidences of the highest discomfort level. The appearance of the film and glare reduction was generally viewed as a favorable improvement (particularly compared to one of the existing films that was at the end of its life and had a degraded visual appearance). Some occupants were dissatisfied with the color/hue of the low-e applied film, as well as the loss of daylight through north facing windows that previously had no film. This loss of daylight may have energy implications associated with increased electric light use if dimmable lighting controls are used. Still, the heating and cooling savings associated with the low-e film on the north façade remains compelling in all the climates examined and the addition of the VT50 version of the film allows an option for higher visible transmission where it is desired. All things considered, a strong majority of building occupants recommended the film for use elsewhere based on their experiences with the film.

Insulating window panel retrofits (a.k.a. storm panels), can more dramatically improve thermal performance, as well as improve sound transmission and thermally break conduction and air infiltration through an older window frames, but they are considerably more expensive and less universal to install (see GPG program report #007 (Curcija 2013)). Fixed panels may not be compatible with all window framing and may restrict access to operable windows. Also, as shown in the modeling results of this report, single glazing with a low-e film approaches the thermal performance of double glazing without low-e (the most basic storm panel configuration). Even a modern, sealed double pane IGU with a low-e coating did not demonstrate substantially better annual energy savings than the low-e film and the return-on-investment of the applied low-e film is far superior. However, it is compelling to consider combining the low-e applied film with simple, uncoated fixed interior insulating panels for further thermal performance and to improve frame and air infiltration performance along with improved performance of the glass area. A single layer of glass or plastic, over an original single pane window with retrofit low-e applied film, will closely approach the thermal performance of a sealed double glazed low-e window for a considerably lower installed cost. To aid deployment flexibility, the two retrofits can be installed at different times without reducing the effectiveness of the combined installation. In an alternative use of the low-e film a lightweight storm panel can be made by suspending the film in a frame that creates an air space with low-e coating without an additional rigid pane.

A high-quality retrofit film with a professional installation is generally indistinguishable from other window products and provides an aesthetic retrofit option that can be performed quickly with minimal disruption to building occupants. This makes low-e applied films a relatively unique retrofit opportunity for the building envelope in that it is a fast, low disruption process that delivers significant energy savings and thermal comfort benefits at a reasonable cost with a rapid payback.

Based on all the findings of this report, low-e applied film products for the retrofit of existing windows are strongly recommended for wide deployment, as a result of the favorable energy savings and comfort benefits in a broad spectrum of climates from heating dominated to cooling dominated. The best applications (shortest payback time) will be sites with clear single glazing or an older applied film that is nearing the end of its service life, but the low-e applied film has proven to have a very favorable applicability in a wide range of base window configurations and climates.

VI. Appendices

A. TECHNOLOGY SPECIFICATION

Energy Cost Savings in Every Season

While most commercial window film provides beneficial savings during cooling season, many films have one big drawback: they reduce solar heat gain from windows all year long. In climates where solar heat gain may be desired during the heating season, traditional commercial window film can actually increase the amount of heat required from the HVAC system.

Most Efficient Low-E Film Available for Commercial Buildings

And that's where EnerLogic® comes in. EnerLogic commercial window film's low-e coating was developed to offer all the benefits of year-round energy savings while also minimizing iridescent shine. The result is a more aesthetically pleasing, ultra-efficient low-e commercial window film. Why EnerLogic instead of new low-e windows or another low-e window film?

New windows may be efficient, but they ...

• Can cost 3-5 times more than window film

• Can take 15-20+ years to provide a return on investment

• Generate significant waste during installation

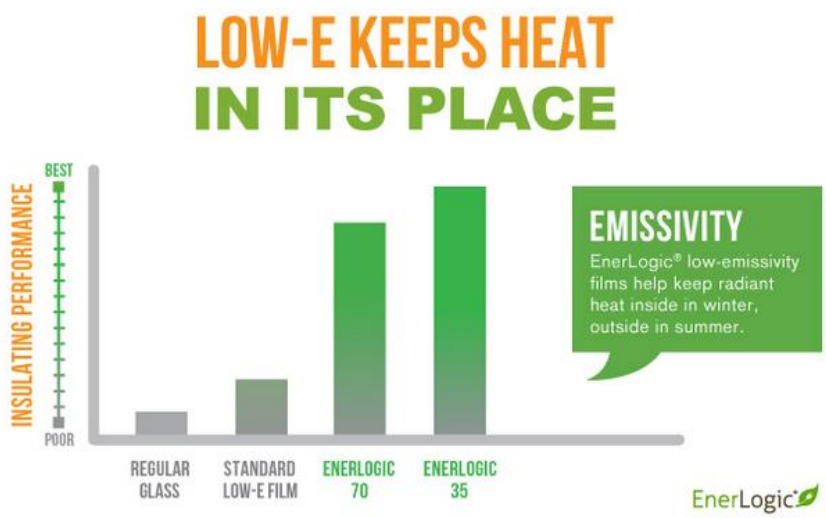
Other low-e window films may be less expensive, but they ...

• Offer significantly less energy savings than EnerLogic film

• Can block views to the outdoors at night and on cloudy days

• Considerably diminish the amount of natural light entering the building

• Appear iridescent



Typical ROI in 3 Years or Less

EnerLogic balances the equation by lowering upfront costs and environmental impact without compromising energy efficiency or visibility. It costs a fraction of the price of new windows, and provides up to three times as much heating and cooling savings vs. comparable visible light transmission film.

Savings of 5% to 15% in total electricity costs may be expected in commercial facilities. Savings vary based on glass type, window-to-wall ratio, exterior overhangs, climate, the type of window film, and cooling equipment efficiency. Because of the energy savings it affords, facilities managers may expect to see a 100% return on investment with window film in as quickly as three years.

Count the Savings. Count the Benefits.

Of course, EnerLogic also provides all the benefits of traditional window film to facilities of any size in government, healthcare, office, retail, multifamily, hospitality, and education sectors:

• Lowers cooling load and costs by reducing solar heat gain

• Extend HVAC equipment life by decreasing run time

• Reduces use of artificial lighting

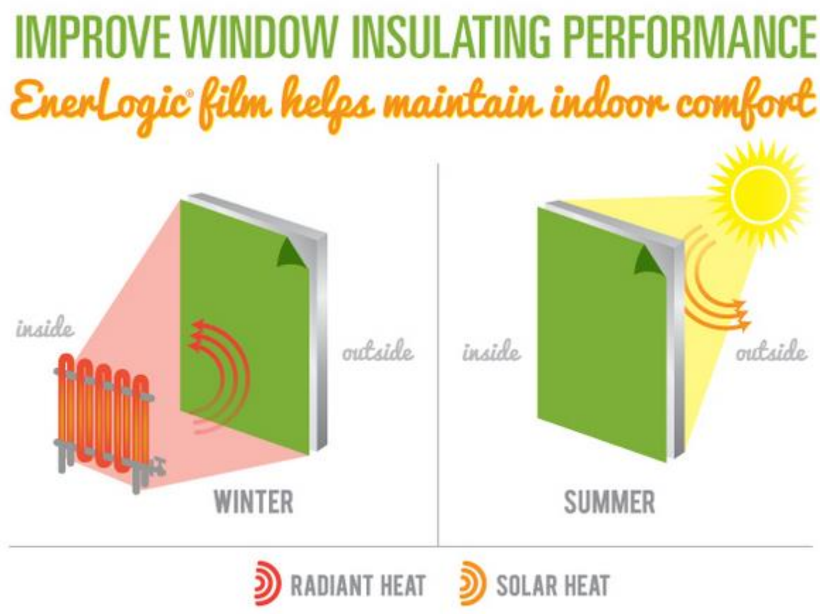
• Helps eliminate hot/cold spots throughout a space

• Reduces glare

• Preserves views to the outdoors

• Protects against harmful UV rays

With these energy savings and ROI, is EnerLogic window film an investment you can afford not to make?



EnerLogic

CARE & MAINTENANCE INSTRUCTIONS

READ BEFORE CLEANING:

Make these instructions and warnings available to all EnerLogic Film purchasers and those responsible for window care and maintenance

EnerLogic® 35 and 70 window film products are unique in composition. They require special care to avoid permanent damage to surface coatings. EnerLogic films have a special anti-smudge coating and therefore should require far less frequent cleanings than either glass alone or glass with other film types installed. Should any cleaning be necessary, wait at least 2 weeks after installation. Strict adherence to the following rules is required for warranty maintenance.

REQUIRED CLEANING CLOTHS, COMPOUNDS, AND PROCEDURES:

CLEAN YOUR WINDOWS ONLY WITH THE FOLLOWING CLEANING CLOTHS AND LIQUIDS:

CLEANING CLOTHS

You may use either a new (or extremely clean) soft cotton cloth, or a new microfiber cloth. Microfiber towels are ideal so long as they are new or have not been subjected to prolonged use that would cause gritty contamination to become entrapped within the cleaning cloth. Clean microfiber towels are unsurpassed for streak-free cleaning performance.

LIQUIDS

Create your own liquid window cleaner in a one quart (or one liter) spray bottle filled with **DISTILLED OR MINERAL FREE WATER** by adding **3 DROPS OF LIQUID DISH DETERGENT** in a one quart (one liter) spray bottle. Shake well. **DO NOT** use common household window cleaners such as Windex®, GlassPlus®, or silicone cleaner/polishing compounds.

CLEANING PROCESS

Mist the window lightly and uniformly with your liquid cleaner in the spray bottle. Use the soft cotton or microfiber cloth to very gently stroke dry the window, turning the cloth/towel often. Never rub aggressively or forcefully or for a longer period of time than is necessary to remove any dust or smudges.

Never use the following items in the cleaning process: Razor blades, squeegees of any kind, metal tools, newspaper, paper towels, abrasive fabrics or pads, chemicals or liquids other than the approved liquid above.

MISC WARNINGS

Do not affix any items to the surface of the installed EnerLogic film. For example, never use suction cups, adhesive tapes, or affix static cling vinyl films or materials to the film surface. Never install or re-install vinyl (plastic) grids or dividers to the filmed side of the window installed with EnerLogic 35; it is permissible to do so with EnerLogic 70.

GENERAL WARRANTY INFORMATION:

If your residential or commercial window film is provided with a warranty, see that form for specific details, which may vary according to product type. Neither the Performance Films Division of the Eastman Chemical Company nor the installation dealership can be responsible for damage that is the result of improper cleaning, physical impact or abuse, nor for glass breakage subsequent to installation from any cause except as expressly provided for by warranties from Performance Films or the installing Dealership.

For questions or service, contact your installing dealership or Customer Service at Performance Films.
If in the USA or Canada call 1-800-528-4481.

ENERLOGIC® SERIES GUIDE SPECIFICATIONS

SECTION 08 87 13

SOLAR CONTROL FILMS

PART 1 - GENERAL

1.1 CONDITIONS AND REQUIREMENTS

A. The General Conditions, Supplementary Conditions, and Division 01 – General Requirements apply.

1.2 SECTION INCLUDES

A. Solar control films.

B. [Insert item description.]

1.3 RELATED SECTIONS

A. Section 08 80 00 - Glazing: Substrate for application of solar control film.

B. Section [xxxxxx] – [Section Title]: [Include brief description of work specified in another section that is related to the work of this section.]

1.4 REFERENCES

A. ASTM International (ASTM):
1. ASTM D1044 - Test for Resistance of Transparent Plastics to Surface Abrasion (Taber Abrader Test).
2. ASTM E903 - Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres.

B. National Fenestration Rating Council, Inc. (NFRC):
1. NFRC 302 - Optical Spectral Data Verification Program.

1.5 DEFINITIONS

A. Emissivity: The ability of a surface to absorb far-infrared heat and to reflect it. The lower the emissivity, the lower the far-infrared heat absorption and the greater the far-infrared heat reflectance.

B. Far-Infrared Heat: Heat radiated from objects at temperatures below 1300 degrees F such as heat radiated from: room objects, objects heated by the sun, or a home heating system. Far-infrared heat is different from near-infrared heat that is radiated from objects at highly elevated temperatures such as the sun.

C. Light to Solar Heat Gain Ratio: Ratio of visible light transmission to solar heat gain coefficient for a glazing system.

D. Low Emissivity (Low-E) Films: Films with improved far-infrared heat reflection, with the ability to reduce winter heat loss through windows. The reflection of far-infrared heat also reduces the need for summer cooling by reducing the transmission of far-infrared heat from outdoor objects through windows into the interior of a home or building.

E. Spectrally Selective Solar Control Films: Film products that reduce solar heat gain mainly by reducing the transmission of near-infrared solar radiation with minimal reduction of visible light transmission. Films with a light to solar heat gain ratio of above 1.00 are spectrally selective.

1.6 PERFORMANCE REQUIREMENTS

A. Scratch Resistance: Solar control films shall average less than 12 percent increase in haze when tested according to ASTM D1044 using a Teledyne Taber Abrader using CS10F Type III wheels each loaded to 0.5 kg for 100 cycles in a 70 percent vacuum.

B. Scratch resistance and emissivity testing shall be performed by an independent third party agency.

C. Ultraviolet Transmission: Provide solar control films with UV absorbing materials that limit the weighted UV transmission to less than 1.0 percent when measured according to ASTM E903.

D. Provide solar control films that do not have a masking sheet.

E. Product Standard: Comply with NFRC 302 for window film energy performance ratings.
   1. Window Film Energy Performance Certification: NFRC certified with label attached to each product package.

1.7 SUBMITTALS

A. Submit under provisions of Section [01 33 00] [______].

B. Product Data: Submit for each product specified indicating:
   1. Physical and performance properties.
   2. Preparation and installation instructions and recommendations.
   3. Storage and handling recommendations.

C. Samples: For each type of solar control film specified, two (2) samples, 12 inches square.

D. Qualification Data: Submit documentation indicating qualifications of solar control film manufacturer.

E. Operation and Maintenance Data: Submit for solar control film to include in maintenance manuals.

F. Warranty: Submit sample special warranty specified in this section.

1.8 QUALITY ASSURANCE

A. Manufacturer Qualifications: A qualified manufacturer that has a minimum of [40] [________] years of documented experience manufacturing solar control films similar to that used for this project.

B. Installer Qualifications: A firm that is authorized by solar control film manufacturer to install film in accordance with guidelines set forth by the manufacturer.

C. Source Limitations: Obtain each type of solar control film from same manufacturer.

D. Mockups: Build mockups to verify selections made under sample submittals and to evaluate surface preparation techniques and application workmanship.
1. Construct mockups in the location and of the size indicated or, if not indicated, as directed by Architect.
2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

E. Preinstallation Conference: Conduct conference at project site to discuss methods and procedures relating to installation of the solar control films.

1.9 DELIVERY, STORAGE AND HANDLING

A. Deliver, store, and handle materials in manufacturer's protective packaging.

B. Store and protect materials according to manufacturer's written recommendations to prevent damage from condensation, temperature changes, direct exposure to sun, or other causes.

1.10 SITE CONDITIONS

A. Ambient Conditions: Maintain temperature, humidity, and ventilation within limits recommended by manufacturer.

1.11 WARRANTY

A. Manufacturer's Warranty: Manufacturer's standard form in which manufacturer agrees to replace films that fail within specified warranty period.
1. Warranty Period: [15] [Insert number] years from date of original installation.

2. Warranty coverage limited to owner of property at time of installation.
3. Manufacturer's obligation is limited to furnishing replacement film for any film covered by limited warranty which manufacturer determines to be defective. Manufacturer will not be liable for installation costs of replacement film or for any special, indirect, incidental or consequential damages.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Basis-of-Design Product: EnerLogic Window Films manufactured by Eastman Chemical Company, 575 Maryville Centre Drive, St. Louis, MO 63141; telephone: 800-851-7781; Email: Vista-films@solutia.com; Web Site: www.enerlogicfilms.com.

B. Substitutions will not be considered.

C. Substitutions will be considered, subject to compliance with requirements of this section, under provisions of Section 01 25 00.

2.2 SOLAR CONTROL FILMS

A. Solar Control Film: Vista EnerLogic 35 Low-E Solar Control Film (VEP35SRCDF) with the following performance characteristics when applied to the interior surface of single-pane, 3-mm clear glass:
1. Total Solar Transmittance: 19 percent.
2. Total Solar Reflectance: 49 percent.
3. Total Solar Absorptance: 32 percent.
4. Visible Light Transmission: 33 percent.
5. Visible Light Reflection - Exterior: 48 percent.
6. Visible Light Reflection - Interior: 30 percent.
7. U-Value, Winter Median: 0.60.
8. Shading Coefficient: 0.28.
9. Total Solar Energy Rejected (TSER): 76 percent.
10. Emissivity: 0.07.
11. Solar Heat Gain Coefficient (SHGC): 0.24.
12. Ultraviolet Rejection: 99 percent.
13. Light-to-Solar Heat Gain Ratio (LSG): 1.38.
14. Winter Heat Loss Reduction: 42 percent.
15. Summer Solar Heat Gain Reduction: 72 percent.
16. Glare Reduction: 63 percent.
17. Thickness without Liner: 60μ.
18. Film Color: Warm neutral.
19. NFRC Certification No.: CPF-K-049.

2.3 SOLAR CONTROL FILM ACCESSORIES

A. General: Provide accessories either manufactured by or acceptable to solar control film manufacturer for application indicated, and with a proven record of compatibility with surfaces contacted in installation.

B. Adhesive: Water-activated, dry-adhesive system that forms a molecular bond between the film and glass. Protect adhesive from contamination by applying a release liner that will be removed and discarded at installation.

C. Cleaners, Primers, and Sealers: Types recommended by solar control film manufacturer.

D. Edge Sealant: [No edge sealant required] [Edge sealant required if within 10 kilometers (5-7 miles) of the ocean or other large body of salt water. Dow Corning 795 Clear Silicone Sealant, SpectraSeal, or similar neutral cure silicone sealant acceptable to solar control film manufacturer].

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates for compliance with requirements and for conditions affecting performance of solar control film including glass that is broken, chipped, cracked, abraded, or damaged in any way.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Comply with manufacturer's written instructions for surface preparation.

B. Clean substrates thoroughly prior to installation. Provide additional scrubbing of perimeter area with X-100 solution.

C. Prepare substrates using methods recommended by film manufacturer to achieve the best results for the substrate under project conditions.

D. Protect window frames and surrounding surfaces to prevent damage during installation.

3.3 INSTALLATION

A. Install in accordance with manufacturer's written instructions.

B. [No edge sealant required.] [Edge seal interior solar control films with a neutral cure silicone sealant within 10km of the ocean. Use an interior type silicone sealant with good adhesion to plastics and glass.]

C. Install film continuously, but not necessarily in one (1) continuous length. Install with no gaps or overlaps.

D. If seamed, make seams non-overlapping. [No seam sealant required.] [Seal with a 0.25-inch wide band of seam sealant in accordance with sealant manufacturer's instructions if within 10km of the ocean.]

E. Do not remove release liner from film until just before each piece of film is cut and ready for installation.

F. Custom cut to the glass with neat, square corners and edges to within 1/8-inch of the window frame. [Use X-100 solution for the application.] [Install film with Film-On mounting solution and purified water. X-100 solution should never be used as the application solution for any reason.]

G. Remove air bubbles, blisters, and other defects. Be careful to remove "fingers" to eliminate any contamination or excess water pockets. It is crucial to remove as much water as possible during installation.

H. A final squeegee pass over the entire pane using a Blue Max Blade with an extended handle design (or Thor's Hammer) is recommended.

3.4 FIELD QUALITY CONTROL

A. After installation, view film from a distance of 10 feet against a bright uniform sky or background. Film shall appear uniform in appearance with no visible streaks, wrinkles, banding, thin spots or pinholes.

B. If installed film does not meet these criteria, remove and replace with new film.

3.5 CLEANING AND PROTECTION

A. Remove excess mounting solution at finished seams, perimeter edges, and adjacent surfaces.

B. Use cleaning methods recommended by solar control film manufacturer.

C. Replace films that cannot be cleaned.

D. Protect installed products until completion of project.

E. Touch-up, repair or replace damaged products before Substantial Completion.

END OF SECTION

B. WINDOW7 GLAZING PERFORMANCE COMPARISON

Table AB1. Window ID definitions for configurations used in COMFEN models

ID	number of layers	Glass substrate	Applied film
A	1	clear	none
B	1	clear	existing absorbing
C	1	clear	Low-e, VT35
D	1	clear	Low-e, VT50
E	1	clear	Low-e, VT70
F	1	clear	spectrally selective, VT40
G	1	clear	spectrally selective, VT70
H	1	bronze	none
I	1	bronze	Low-e, VT35
J	1	bronze	Low-e, VT50
K	1	bronze	Low-e, VT70
L	1	bronze	spectrally selective, VT40
M	1	bronze	spectrally selective, VT70
N	2	clear/clear	none
O	2	clear/clear	Low-e, VT35
P	2	clear/clear	Low-e, VT50
Q	2	clear/clear	Low-e, VT70
R	2	clear/clear	spectrally selective, VT40
S	2	clear/clear	spectrally selective, VT70
T	2	bronze/clear	none
U	2	bronze/clear	Low-e, VT35
V	2	bronze/clear	Low-e, VT50
W	2	bronze/clear	Low-e, VT70
X	2	bronze/clear	spectrally selective, VT40
Y	2	bronze/clear	spectrally selective, VT70
Z	2	clear/clear	triple silver low solar gain low-e factory IGU

Table AB2. Window properties using in COMFEN models

ID	U-factor (BTU/hr-ft^2-F)	SHGC	Tsol	Tvis	Room Emis.	Room side glass Temp (C) summer solar	Room side glass Temp (C) winter
A	1.025	0.818	0.771	0.884	0.840	34.1	-9.0
B	1.025	0.659	0.532	0.517	0.840	40.9	-9.0
C	0.574	0.261	0.195	0.335	0.048	44.7	-12.8
D	0.593	0.368	0.301	0.489	0.075	44.2	-12.8
E	0.599	0.494	0.424	0.682	0.090	44.3	-12.6
F	1.041	0.381	0.205	0.419	0.871	44.5	-8.8
G	0.859	0.447	0.335	0.672	0.529	42.9	-10.4
H	1.025	0.628	0.486	0.533	0.840	42.2	-9.0
I	0.575	0.237	0.121	0.201	0.048	53.6	-12.8
J	0.593	0.303	0.189	0.295	0.075	52.4	-12.8
K	0.599	0.378	0.266	0.412	0.090	51.6	-12.6
L	1.040	0.366	0.126	0.252	0.871	49.3	-8.8
M	0.859	0.384	0.207	0.405	0.529	49.4	-10.4
N	0.474	0.704	0.607	0.786	0.840	36.3	6.7
O	0.325	0.323	0.163	0.306	0.048	59.8	-0.3
P	0.333	0.406	0.248	0.441	0.075	58.3	0.0
Q	0.335	0.503	0.345	0.606	0.090	57.7	0.2
R	0.478	0.483	0.174	0.374	0.871	52.5	6.9
S	0.427	0.501	0.283	0.599	0.529	51.6	4.5
T	0.473	0.505	0.382	0.473	0.840	38.5	6.7
U	0.325	0.249	0.102	0.183	0.048	57.8	-0.3
V	0.332	0.300	0.155	0.265	0.075	56.3	0.0
W	0.335	0.360	0.215	0.365	0.090	55.5	0.2
X	0.478	0.366	0.107	0.224	0.871	48.9	6.9
Y	0.427	0.371	0.174	0.360	0.529	49.5	4.5
Z	0.286	0.278	0.233	0.623	0.840 (0.022 internal)	30.3	12.1

Table AB3. Window ID definitions for extra glazing configurations

ID	number of layers	Glass substrate	Applied film	Exterior wind
X1	1	bronze	none	no wind
X2	2	bronze	none	no wind
X3	1	clear	Low-e, VT35	no wind
X4	1	bronze	Low-e, VT35	no wind
X5	1	clear	spectrally selective, VT40	no wind
X6	2	clear	Low-e, VT35	no wind
X7	2	clear	spectrally selective, VT40	no wind

Table AB4. Window properties for extra glazing configurations

ID	U-factor (BTU/hr-ft^2-F)	SHGC	Tsol	Tvis	Room Emis.	Room side glass Temp (C) summer solar	Room side glass Temp (C) winter
X1	0.646	0.709	0.486	0.533	0.840	47.5	1.8
X2	0.374	0.569	0.382	0.473	0.840	43.5	9.6
X3	0.415	0.314	0.195	0.335	0.048	53.6	-5.0
X4	0.415	0.326	0.121	0.201	0.048	67.7	-5.0
X5	0.653	0.479	0.205	0.419	0.871	50.9	2.0
X6	0.271	0.362	0.163	0.306	0.048	65.9	2.6
X7	0.377	0.531	0.174	0.374	0.871	55.6	9.7

C. COMFEN MODELING SPECIFICATION AND RESULTS

Table AC1. COMFEN site energy, generic four side AVERAGE, NO daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	22.64	15.78	20.96	10.73	70.12	$1.39
B	1, clear	absorbing	26.18	12.85	18.41	10.73	68.17	$1.28
C	1, clear	low-e VT35	21.19	8.65	11.82	10.73	52.39	$0.96
D	1, clear	low-e VT50	19.20	10.27	13.47	10.73	53.67	$1.03
E	1, clear	low-e VT70	16.68	12.44	15.46	10.73	55.31	$1.12
F	1, clear	spec. sel. VT40	32.90	9.10	14.73	10.73	67.46	$1.13
G	1, clear	spec. sel. VT70	25.54	10.70	15.41	10.73	62.37	$1.14
H	1, bronze	none	26.93	12.33	17.95	10.73	67.94	$1.26
I	1, bronze	low-e VT35	21.96	8.21	11.68	10.73	52.58	$0.95
J	1, bronze	low-e VT50	20.88	9.14	12.67	10.73	53.41	$0.99
K	1, bronze	low-e VT70	19.32	10.31	13.79	10.73	54.14	$1.04
L	1, bronze	spec. sel. VT40	33.57	8.82	14.58	10.73	67.70	$1.12
M	1, bronze	spec. sel. VT70	27.50	9.56	14.48	10.73	62.27	$1.10
N	2, clear	none	13.85	15.10	18.03	10.73	57.71	$1.24
O	2, clear	low-e VT35	16.74	9.41	12.44	10.73	49.32	$0.96
P	2, clear	low-e VT50	15.36	10.67	13.59	10.73	50.35	$1.02
Q	2, clear	low-e VT70	13.63	12.29	15.06	10.73	51.72	$1.09
R	2, clear	spec. sel. VT40	20.34	10.98	15.07	10.73	57.12	$1.10
S	2, clear	spec. sel. VT70	17.60	11.69	15.26	10.73	55.27	$1.10
T	2, bronze	none	19.72	11.36	15.26	10.73	57.07	$1.11
U	2, bronze	low-e VT35	18.38	8.40	11.60	10.73	49.10	$0.93
V	2, bronze	low-e VT50	17.61	9.08	12.24	10.73	49.66	$0.96
W	2, bronze	low-e VT70	16.53	9.92	13.00	10.73	50.17	$0.99
X	2, bronze	spec. sel. VT40	22.90	9.39	13.57	10.73	56.60	$1.04
Y	2, bronze	spec. sel. VT70	20.43	9.70	13.48	10.73	54.34	$1.03
Z	2, clear	factory low-e IGU VT66	17.47	9.20	11.90	10.73	49.30	$0.95

Table AC2. COMFEN site energy, generic four side AVERAGE, daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	26.74	13.80	19.11	2.63	62.28	$1.11
B	1, clear	absorbing	30.17	11.06	16.56	3.35	61.14	$1.02
C	1, clear	low-e VT35	24.82	7.12	10.28	4.52	46.73	$0.74
D	1, clear	low-e VT50	23.25	8.43	11.72	3.46	46.86	$0.78
E	1, clear	low-e VT70	20.77	10.39	13.61	2.88	47.65	$0.85
F	1, clear	spec. sel. VT40	37.25	7.59	12.90	3.87	61.60	$0.90
G	1, clear	spec. sel. VT70	30.19	8.91	13.56	2.91	55.57	$0.87
H	1, bronze	none	31.01	10.57	16.11	3.33	61.03	$1.00
I	1, bronze	low-e VT35	24.79	7.01	10.34	6.05	48.19	$0.78
J	1, bronze	low-e VT50	24.23	7.65	11.11	4.94	47.94	$0.79
K	1, bronze	low-e VT70	23.08	8.53	12.05	3.91	47.57	$0.80
L	1, bronze	spec. sel. VT40	36.98	7.60	12.98	5.45	63.01	$0.94
M	1, bronze	spec. sel. VT70	31.62	7.97	12.67	3.98	56.25	$0.86
N	2, clear	none	17.49	12.96	16.17	2.75	49.36	$0.95
O	2, clear	low-e VT35	19.87	7.87	10.97	4.90	43.61	$0.76
P	2, clear	low-e VT50	18.89	8.83	11.97	3.77	43.47	$0.77
Q	2, clear	low-e VT70	17.35	10.23	13.29	3.08	43.96	$0.81
R	2, clear	spec. sel. VT40	23.86	9.31	13.27	4.33	50.77	$0.87
S	2, clear	spec. sel. VT70	21.62	9.76	13.44	3.11	47.94	$0.84
T	2, bronze	none	23.50	9.57	13.47	3.66	50.20	$0.86
U	2, bronze	low-e VT35	20.80	7.29	10.38	6.56	45.04	$0.78
V	2, bronze	low-e VT50	20.48	7.71	10.86	5.53	44.58	$0.77
W	2, bronze	low-e VT70	19.82	8.27	11.47	4.48	44.04	$0.77
X	2, bronze	spec. sel. VT40	25.67	8.18	12.11	6.07	52.03	$0.87
Y	2, bronze	spec. sel. VT70	23.96	8.14	11.81	4.55	48.46	$0.81
Z	2, clear	factory low-e IGU VT66	21.83	7.39	10.22	3.04	42.49	$0.69

Table AC3. COMFEN site energy, generic SOUTH façade case, NO daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	16.52	16.41	17.40	10.73	61.06	$1.27
B	1, clear	absorbing	20.29	13.03	15.54	10.73	59.60	$1.16
C	1, clear	low-e VT35	17.44	8.65	10.77	10.73	47.59	$0.91
D	1, clear	low-e VT50	14.91	10.32	11.89	10.73	47.86	$0.96
E	1, clear	low-e VT70	12.05	12.75	13.36	10.73	48.88	$1.04
F	1, clear	spec. sel. VT40	27.86	9.06	13.04	10.73	60.69	$1.05
G	1, clear	spec. sel. VT70	20.40	10.74	13.39	10.73	55.27	$1.05
H	1, bronze	none	21.13	12.43	15.20	10.73	59.49	$1.15
I	1, bronze	low-e VT35	18.63	8.21	10.72	10.73	48.29	$0.90
J	1, bronze	low-e VT50	17.06	9.14	11.39	10.73	48.32	$0.93
K	1, bronze	low-e VT70	15.12	10.36	12.15	10.73	48.36	$0.97
L	1, bronze	spec. sel. VT40	28.76	8.80	13.00	10.73	61.29	$1.05
M	1, bronze	spec. sel. VT70	22.82	9.54	12.78	10.73	55.88	$1.02
N	2, clear	none	9.25	15.52	14.72	10.73	50.21	$1.13
O	2, clear	low-e VT35	13.30	9.38	11.03	10.73	44.44	$0.90
P	2, clear	low-e VT50	11.57	10.67	11.79	10.73	44.77	$0.94
Q	2, clear	low-e VT70	9.66	12.41	12.73	10.73	45.53	$1.00
R	2, clear	spec. sel. VT40	15.73	10.97	12.84	10.73	50.27	$1.01
S	2, clear	spec. sel. VT70	13.13	11.72	12.90	10.73	48.49	$1.01
T	2, bronze	none	15.03	11.30	12.87	10.73	49.92	$1.01
U	2, bronze	low-e VT35	15.38	8.34	10.47	10.73	44.93	$0.88
V	2, bronze	low-e VT50	14.27	9.00	10.87	10.73	44.87	$0.90
W	2, bronze	low-e VT70	12.90	9.84	11.35	10.73	44.82	$0.92
X	2, bronze	spec. sel. VT40	18.67	9.32	11.87	10.73	50.59	$0.96
Y	2, bronze	spec. sel. VT70	16.38	9.61	11.73	10.73	48.45	$0.95
Z	2, clear	factory low-e IGU VT66	13.63	9.15	10.50	10.73	44.02	$0.89

Table AC4. COMFEN site energy, generic SOUTH façade case, daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	19.80	14.18	15.57	2.53	52.08	$0.98
B	1, clear	absorbing	23.86	11.04	13.75	2.96	51.61	$0.89
C	1, clear	low-e VT35	21.49	6.90	9.08	3.56	41.03	$0.66
D	1, clear	low-e VT50	18.72	8.31	10.15	3.01	40.19	$0.69
E	1, clear	low-e VT70	15.43	10.47	11.54	2.69	40.14	$0.75
F	1, clear	spec. sel. VT40	32.19	7.44	11.31	3.22	54.16	$0.80
G	1, clear	spec. sel. VT70	24.52	8.82	11.60	2.71	47.65	$0.77
H	1, bronze	none	24.81	10.50	13.43	2.95	51.68	$0.87
I	1, bronze	low-e VT35	22.23	6.74	9.16	4.68	42.81	$0.69
J	1, bronze	low-e VT50	20.82	7.41	9.73	3.81	41.77	$0.69
K	1, bronze	low-e VT70	18.81	8.40	10.43	3.24	40.87	$0.71
L	1, bronze	spec. sel. VT40	32.64	7.36	11.32	4.16	55.47	$0.82
M	1, bronze	spec. sel. VT70	26.90	7.81	11.04	3.28	49.03	$0.77
N	2, clear	none	12.01	13.11	12.91	2.61	40.63	$0.83
O	2, clear	low-e VT35	16.81	7.55	9.39	3.79	37.54	$0.66
P	2, clear	low-e VT50	14.99	8.61	10.07	3.18	36.85	$0.67
Q	2, clear	low-e VT70	12.82	10.12	10.96	2.81	36.72	$0.71
R	2, clear	spec. sel. VT40	19.12	9.08	11.14	3.47	42.81	$0.75
S	2, clear	spec. sel. VT70	16.62	9.61	11.14	2.82	40.20	$0.73
T	2, bronze	none	18.50	9.32	11.14	3.13	42.08	$0.74
U	2, bronze	low-e VT35	18.47	7.04	9.20	5.30	40.01	$0.69
V	2, bronze	low-e VT50	17.68	7.34	9.30	4.27	38.59	$0.67
W	2, bronze	low-e VT70	16.40	7.94	9.68	3.55	37.57	$0.67
X	2, bronze	spec. sel. VT40	21.92	7.86	10.31	4.77	44.86	$0.75
Y	2, bronze	spec. sel. VT70	20.04	7.84	10.06	3.59	41.53	$0.70
Z	2, clear	factory low-e IGU VT66	17.71	7.20	8.75	2.79	36.44	$0.61

Table AC5. COMFEN site energy, generic NORTH façade case, NO daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	35.64	8.13	12.03	10.73	66.53	$1.05
B	1, clear	absorbing	37.88	7.14	11.24	10.73	66.99	$1.02
C	1, clear	low-e VT35	27.04	6.09	8.53	10.73	52.39	$0.85
D	1, clear	low-e VT50	26.33	6.68	9.19	10.73	52.93	$0.88
E	1, clear	low-e VT70	25.06	7.43	9.79	10.73	53.00	$0.90
F	1, clear	spec. sel. VT40	41.69	5.83	10.14	10.73	68.40	$0.99
G	1, clear	spec. sel. VT70	34.76	6.56	10.15	10.73	62.20	$0.96
H	1, bronze	none	38.32	6.96	11.09	10.73	67.10	$1.02
I	1, bronze	low-e VT35	27.46	5.88	8.43	10.73	52.50	$0.84
J	1, bronze	low-e VT50	27.23	6.24	8.90	10.73	53.09	$0.86
K	1, bronze	low-e VT70	26.59	6.65	9.24	10.73	53.20	$0.88
L	1, bronze	spec. sel. VT40	42.04	5.71	10.06	10.73	68.55	$0.99
M	1, bronze	spec. sel. VT70	35.82	6.12	9.82	10.73	62.49	$0.95
N	2, clear	none	23.67	8.02	10.39	10.73	52.81	$0.92
O	2, clear	low-e VT35	22.72	6.34	8.52	10.73	48.32	$0.83
P	2, clear	low-e VT50	22.29	6.74	8.74	10.73	48.50	$0.84
Q	2, clear	low-e VT70	21.25	7.33	9.37	10.73	48.68	$0.86
R	2, clear	spec. sel. VT40	29.13	6.58	9.65	10.73	56.09	$0.91
S	2, clear	spec. sel. VT70	26.12	6.94	9.62	10.73	53.41	$0.89
T	2, bronze	none	28.66	6.75	9.73	10.73	55.87	$0.91
U	2, bronze	low-e VT35	23.54	5.99	8.35	10.73	48.60	$0.82
V	2, bronze	low-e VT50	23.46	6.20	8.46	10.73	48.84	$0.83
W	2, bronze	low-e VT70	23.05	6.47	8.60	10.73	48.84	$0.83
X	2, bronze	spec. sel. VT40	30.51	6.04	9.20	10.73	56.48	$0.89
Y	2, bronze	spec. sel. VT70	27.71	6.25	9.10	10.73	53.79	$0.87
Z	2, clear	factory low-e IGU VT66	23.82	6.12	8.28	10.73	48.95	$0.82

Table AC6. COMFEN site energy, generic NORTH façade case, daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	41.03	6.56	10.14	2.77	60.49	$0.80
B	1, clear	absorbing	42.49	5.68	9.34	3.82	61.33	$0.79
C	1, clear	low-e VT35	30.02	4.96	7.57	5.66	48.20	$0.68
D	1, clear	low-e VT50	30.63	5.14	7.57	3.98	47.31	$0.65
E	1, clear	low-e VT70	30.12	5.73	7.93	3.13	46.90	$0.65
F	1, clear	spec. sel. VT40	45.99	4.53	8.26	4.60	63.37	$0.78
G	1, clear	spec. sel. VT70	40.06	5.03	8.26	3.17	56.51	$0.71
H	1, bronze	none	42.98	5.50	9.19	3.79	61.47	$0.78
I	1, bronze	low-e VT35	29.24	5.20	7.85	7.69	49.98	$0.75
J	1, bronze	low-e VT50	30.00	5.18	7.76	6.29	49.24	$0.71
K	1, bronze	low-e VT70	30.41	5.19	7.63	4.66	47.90	$0.67
L	1, bronze	spec. sel. VT40	44.68	4.90	8.86	6.98	65.42	$0.85
M	1, bronze	spec. sel. VT70	39.91	4.77	7.96	4.79	57.43	$0.74
N	2, clear	none	28.68	6.33	8.56	2.94	46.51	$0.67
O	2, clear	low-e VT35	25.25	5.32	7.69	6.22	44.47	$0.68
P	2, clear	low-e VT50	25.86	5.31	7.54	4.45	43.16	$0.63
Q	2, clear	low-e VT70	25.81	5.66	7.70	3.42	42.59	$0.62
R	2, clear	spec. sel. VT40	32.86	5.24	7.72	5.36	51.18	$0.71
S	2, clear	spec. sel. VT70	30.92	5.33	7.79	3.46	47.51	$0.65
T	2, bronze	none	32.87	5.26	7.90	4.29	50.32	$0.69
U	2, bronze	low-e VT35	24.97	5.41	7.88	8.17	46.43	$0.73
V	2, bronze	low-e VT50	25.52	5.37	7.79	7.05	45.73	$0.71
W	2, bronze	low-e VT70	25.93	5.31	7.65	5.59	44.48	$0.67
X	2, bronze	spec. sel. VT40	32.56	5.31	8.25	7.66	53.78	$0.78
Y	2, bronze	spec. sel. VT70	31.03	5.05	7.59	5.70	49.37	$0.70
Z	2, clear	factory low-e IGU VT66	28.42	4.64	6.98	3.36	43.40	$0.59

Table AC7. COMFEN site energy, generic WEST façade case, NO daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	18.91	19.91	28.31	10.73	77.86	$1.66
B	1, clear	absorbing	22.95	16.14	24.38	10.73	74.20	$1.49
C	1, clear	low-e VT35	20.01	10.16	14.27	10.73	55.17	$1.05
D	1, clear	low-e VT50	17.61	12.32	16.78	10.73	57.44	$1.16
E	1, clear	low-e VT70	14.64	15.13	19.80	10.73	60.30	$1.29
F	1, clear	spec. sel. VT40	30.52	11.19	18.71	10.73	71.15	$1.27
G	1, clear	spec. sel. VT70	23.20	13.15	19.77	10.73	66.85	$1.30
H	1, bronze	none	23.78	15.49	23.68	10.73	73.68	$1.46
I	1, bronze	low-e VT35	20.76	9.66	14.10	10.73	55.25	$1.04
J	1, bronze	low-e VT50	19.47	10.89	15.54	10.73	56.63	$1.10
K	1, bronze	low-e VT70	17.65	12.45	17.27	10.73	58.09	$1.18
L	1, bronze	spec. sel. VT40	31.17	10.85	18.49	10.73	71.24	$1.26
M	1, bronze	spec. sel. VT70	25.33	11.70	18.34	10.73	66.10	$1.24
N	2, clear	none	11.02	18.89	24.20	10.73	64.83	$1.48
O	2, clear	low-e VT35	15.40	11.22	15.35	10.73	52.70	$1.08
P	2, clear	low-e VT50	13.71	12.92	17.21	10.73	54.57	$1.16
Q	2, clear	low-e VT70	11.69	15.04	19.42	10.73	56.88	$1.26
R	2, clear	spec. sel. VT40	18.00	13.57	19.50	10.73	61.80	$1.26
S	2, clear	spec. sel. VT70	15.37	14.41	19.76	10.73	60.27	$1.27
T	2, bronze	none	17.32	14.08	19.81	10.73	61.94	$1.28
U	2, bronze	low-e VT35	17.22	9.90	14.02	10.73	51.88	$1.02
V	2, bronze	low-e VT50	16.27	10.84	15.07	10.73	52.91	$1.07
W	2, bronze	low-e VT70	14.97	11.97	16.30	10.73	53.98	$1.12
X	2, bronze	spec. sel. VT40	20.88	11.48	17.19	10.73	60.27	$1.17
Y	2, bronze	spec. sel. VT70	18.58	11.82	17.03	10.73	58.16	$1.16
Z	2, clear	factory low-e IGU VT66	16.04	10.96	14.69	10.73	52.42	$1.06

Table AC8. COMFEN site energy, generic WEST façade case, daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	22.82	17.76	26.26	2.58	69.41	$1.37
B	1, clear	absorbing	26.85	14.22	22.36	3.25	66.67	$1.22
C	1, clear	low-e VT35	23.79	8.45	12.37	4.34	48.95	$0.82
D	1, clear	low-e VT50	21.73	10.33	14.78	3.35	50.19	$0.89
E	1, clear	low-e VT70	18.62	12.94	17.76	2.81	52.13	$1.00
F	1, clear	spec. sel. VT40	34.93	9.54	16.71	3.74	64.92	$1.03
G	1, clear	spec. sel. VT70	27.80	11.24	17.73	2.84	59.61	$1.02
H	1, bronze	none	27.80	13.58	21.67	3.23	66.28	$1.20
I	1, bronze	low-e VT35	23.71	8.27	12.41	5.80	50.19	$0.86
J	1, bronze	low-e VT50	22.93	9.24	13.68	4.74	50.60	$0.88
K	1, bronze	low-e VT70	21.45	10.53	15.29	3.77	51.05	$0.92
L	1, bronze	spec. sel. VT40	34.74	9.47	16.61	5.22	66.04	$1.06
M	1, bronze	spec. sel. VT70	29.51	9.99	16.37	3.84	59.70	$0.99
N	2, clear	none	14.45	16.56	22.09	2.69	55.78	$1.18
O	2, clear	low-e VT35	18.68	9.50	13.51	4.69	46.38	$0.85
P	2, clear	low-e VT50	17.32	10.91	15.25	3.65	47.14	$0.90
Q	2, clear	low-e VT70	15.32	12.82	17.40	3.00	48.53	$0.97
R	2, clear	spec. sel. VT40	21.50	11.78	17.58	4.15	55.02	$1.02
S	2, clear	spec. sel. VT70	19.32	12.34	17.76	3.02	52.45	$1.00
T	2, bronze	none	21.10	12.16	17.83	3.54	54.63	$1.02
U	2, bronze	low-e VT35	19.80	8.57	12.38	6.27	47.02	$0.85
V	2, bronze	low-e VT50	19.29	9.26	13.29	5.29	47.14	$0.86
W	2, bronze	low-e VT70	18.42	10.13	14.38	4.29	47.22	$0.88
X	2, bronze	spec. sel. VT40	23.79	10.08	15.41	5.80	55.09	$0.98
Y	2, bronze	spec. sel. VT70	22.20	10.10	15.10	4.36	51.76	$0.92
Z	2, clear	factory low-e IGU VT66	20.48	9.00	12.69	2.96	45.14	$0.79

Table AC9. COMFEN site energy, generic EAST façade case, NO daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	19.48	18.70	26.11	10.73	75.02	$1.58
B	1, clear	absorbing	23.61	15.07	22.48	10.73	71.89	$1.42
C	1, clear	low-e VT35	20.28	9.71	13.69	10.73	54.40	$1.03
D	1, clear	low-e VT50	17.92	11.76	16.03	10.73	56.45	$1.13
E	1, clear	low-e VT70	14.99	14.45	18.91	10.73	59.08	$1.25
F	1, clear	spec. sel. VT40	31.51	10.33	17.02	10.73	69.59	$1.21
G	1, clear	spec. sel. VT70	23.80	12.34	18.32	10.73	65.18	$1.24
H	1, bronze	none	24.47	14.44	21.84	10.73	71.48	$1.39
I	1, bronze	low-e VT35	20.99	9.08	13.48	10.73	54.28	$1.01
J	1, bronze	low-e VT50	19.76	10.28	14.84	10.73	55.60	$1.07
K	1, bronze	low-e VT70	17.92	11.77	16.49	10.73	56.91	$1.14
L	1, bronze	spec. sel. VT40	32.30	9.92	16.77	10.73	69.72	$1.20
M	1, bronze	spec. sel. VT70	26.04	10.86	16.97	10.73	64.60	$1.19
N	2, clear	none	11.46	17.98	22.80	10.73	62.97	$1.42
O	2, clear	low-e VT35	15.53	10.70	14.87	10.73	51.83	$1.05
P	2, clear	low-e VT50	13.88	12.34	16.63	10.73	53.58	$1.13
Q	2, clear	low-e VT70	11.93	14.39	18.74	10.73	55.79	$1.22
R	2, clear	spec. sel. VT40	18.51	12.80	18.30	10.73	60.33	$1.22
S	2, clear	spec. sel. VT70	15.77	13.68	18.74	10.73	58.92	$1.23
T	2, bronze	none	17.87	13.31	18.63	10.73	60.54	$1.23
U	2, bronze	low-e VT35	17.37	9.35	13.54	10.73	50.99	$1.00
V	2, bronze	low-e VT50	16.45	10.28	14.57	10.73	52.03	$1.04
W	2, bronze	low-e VT70	15.18	11.38	15.73	10.73	53.02	$1.09
X	2, bronze	spec. sel. VT40	21.53	10.74	16.04	10.73	59.04	$1.13
Y	2, bronze	spec. sel. VT70	19.06	11.12	16.06	10.73	56.97	$1.12
Z	2, clear	factory low-e IGU VT66	16.40	10.56	14.12	10.73	51.81	$1.04

Table AC10. COMFEN site energy, generic EAST façade case, daylight controls, Ogden, UT

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	23.31	16.72	24.45	2.65	67.13	$1.30
B	1, clear	absorbing	27.49	13.31	20.79	3.39	64.97	$1.17
C	1, clear	low-e VT35	23.97	8.15	12.10	4.53	48.75	$0.81
D	1, clear	low-e VT50	21.92	9.93	14.39	3.50	49.74	$0.88
E	1, clear	low-e VT70	18.89	12.42	17.22	2.90	51.43	$0.98
F	1, clear	spec. sel. VT40	35.88	8.84	15.33	3.90	63.94	$0.98
G	1, clear	spec. sel. VT70	28.36	10.57	16.64	2.93	58.49	$0.98
H	1, bronze	none	28.44	12.70	20.16	3.37	64.67	$1.14
I	1, bronze	low-e VT35	23.98	7.83	11.96	6.02	49.79	$0.84
J	1, bronze	low-e VT50	23.14	8.78	13.27	4.94	50.13	$0.86
K	1, bronze	low-e VT70	21.65	10.01	14.84	3.94	50.44	$0.90
L	1, bronze	spec. sel. VT40	35.85	8.68	15.13	5.43	65.09	$1.01
M	1, bronze	spec. sel. VT70	30.18	9.31	15.32	4.01	58.82	$0.96
N	2, clear	none	14.81	15.83	21.11	2.77	54.53	$1.14
O	2, clear	low-e VT35	18.74	9.12	13.31	4.89	46.06	$0.84
P	2, clear	low-e VT50	17.41	10.49	15.02	3.81	46.74	$0.88
Q	2, clear	low-e VT70	15.46	12.33	17.10	3.11	48.00	$0.95
R	2, clear	spec. sel. VT40	21.95	11.15	16.64	4.34	54.08	$0.99
S	2, clear	spec. sel. VT70	19.63	11.76	17.07	3.13	51.60	$0.97
T	2, bronze	none	21.54	11.54	16.99	3.70	53.77	$0.99
U	2, bronze	low-e VT35	19.96	8.15	12.08	6.51	46.70	$0.84
V	2, bronze	low-e VT50	19.45	8.85	13.04	5.50	46.84	$0.85
W	2, bronze	low-e VT70	18.54	9.71	14.16	4.48	46.89	$0.87
X	2, bronze	spec. sel. VT40	24.42	9.49	14.46	6.03	54.39	$0.95
Y	2, bronze	spec. sel. VT70	22.59	9.57	14.47	4.55	51.18	$0.90
Z	2, clear	factory low-e IGU VT66	20.71	8.73	12.45	3.07	44.96	$0.78

Table AC11. COMFEN site energy, generic four side AVERAGE, NO daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	6.03	33.56	18.34	10.73	68.67	$1.44
B	1, clear	absorbing	7.13	29.82	16.15	10.73	63.83	$1.32
C	1, clear	low-e VT35	5.56	22.62	10.68	10.73	49.59	$1.02
D	1, clear	low-e VT50	4.89	24.86	12.01	10.73	52.49	$1.10
E	1, clear	low-e VT70	4.13	27.71	13.69	10.73	56.27	$1.19
F	1, clear	spec. sel. VT40	9.51	24.80	13.07	10.73	58.11	$1.15
G	1, clear	spec. sel. VT70	6.94	26.43	13.64	10.73	57.74	$1.18
H	1, bronze	none	7.37	29.13	15.76	10.73	62.99	$1.29
I	1, bronze	low-e VT35	5.85	22.01	10.56	10.73	49.15	$1.01
J	1, bronze	low-e VT50	5.46	23.37	11.36	10.73	50.91	$1.05
K	1, bronze	low-e VT70	4.93	24.96	12.28	10.73	52.90	$1.11
L	1, bronze	spec. sel. VT40	9.77	24.42	12.93	10.73	57.85	$1.14
M	1, bronze	spec. sel. VT70	7.65	24.90	12.85	10.73	56.13	$1.13
N	2, clear	none	3.38	31.25	15.90	10.73	61.26	$1.32
O	2, clear	low-e VT35	4.14	23.41	11.20	10.73	49.48	$1.04
P	2, clear	low-e VT50	3.72	25.14	12.19	10.73	51.78	$1.10
Q	2, clear	low-e VT70	3.24	27.25	13.38	10.73	54.60	$1.17
R	2, clear	spec. sel. VT40	5.28	26.35	13.39	10.73	55.75	$1.16
S	2, clear	spec. sel. VT70	4.42	27.00	13.58	10.73	55.73	$1.18
T	2, bronze	none	5.10	26.75	13.52	10.73	56.10	$1.17
U	2, bronze	low-e VT35	4.71	21.70	10.41	10.73	47.55	$0.99
V	2, bronze	low-e VT50	4.44	22.67	10.95	10.73	48.79	$1.02
W	2, bronze	low-e VT70	4.08	24.12	11.65	10.73	50.58	$1.07
X	2, bronze	spec. sel. VT40	6.15	24.18	12.10	10.73	53.16	$1.09
Y	2, bronze	spec. sel. VT70	5.34	24.34	12.03	10.73	52.44	$1.09
Z	2, clear	factory low-e IGU VT66	4.36	22.82	10.65	10.73	48.57	$1.02

Table AC12. COMFEN site energy, generic four side AVERAGE, daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	7.51	30.56	16.72	2.47	57.26	$1.16
B	1, clear	absorbing	8.61	27.05	14.58	3.14	53.38	$1.06
C	1, clear	low-e VT35	6.88	19.83	9.41	4.18	40.29	$0.79
D	1, clear	low-e VT50	6.32	21.71	10.58	3.23	41.84	$0.84
E	1, clear	low-e VT70	5.52	24.31	12.10	2.71	44.63	$0.91
F	1, clear	spec. sel. VT40	11.30	22.03	11.54	3.59	48.45	$0.91
G	1, clear	spec. sel. VT70	8.76	23.60	12.10	2.73	47.20	$0.92
H	1, bronze	none	8.92	26.37	14.20	3.12	52.61	$1.04
I	1, bronze	low-e VT35	6.89	19.79	9.43	5.79	41.91	$0.83
J	1, bronze	low-e VT50	6.64	20.70	10.08	4.60	42.03	$0.84
K	1, bronze	low-e VT70	6.23	21.93	10.88	3.62	42.66	$0.86
L	1, bronze	spec. sel. VT40	11.12	22.39	11.64	5.14	50.29	$0.95
M	1, bronze	spec. sel. VT70	9.23	22.06	11.37	3.69	46.35	$0.89
N	2, clear	none	4.53	28.09	14.29	2.59	49.51	$1.04
O	2, clear	low-e VT35	5.17	20.68	9.98	4.55	40.38	$0.82
P	2, clear	low-e VT50	4.84	22.01	10.83	3.51	41.19	$0.84
Q	2, clear	low-e VT70	4.41	23.86	11.89	2.89	43.04	$0.89
R	2, clear	spec. sel. VT40	6.46	23.47	11.96	3.99	45.87	$0.92
S	2, clear	spec. sel. VT70	5.80	23.77	12.06	2.92	44.55	$0.90
T	2, bronze	none	6.40	23.71	12.01	3.41	45.53	$0.92
U	2, bronze	low-e VT35	5.53	19.96	9.45	6.34	41.27	$0.84
V	2, bronze	low-e VT50	5.39	20.50	9.84	5.22	40.95	$0.83
W	2, bronze	low-e VT70	5.15	21.25	10.37	4.12	40.90	$0.83
X	2, bronze	spec. sel. VT40	7.13	21.95	10.86	5.80	45.74	$0.91
Y	2, bronze	spec. sel. VT70	6.55	21.59	10.71	4.20	43.05	$0.86
Z	2, clear	factory low-e IGU VT66	5.91	19.98	9.35	2.86	38.10	$0.76

Table AC13. COMFEN site energy, generic SOUTH façade case, NO daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	3.85	35.29	16.25	10.73	66.115	$1.42
B	1, clear	absorbing	4.76	30.92	14.48	10.73	60.88	$1.29
C	1, clear	low-e VT35	3.98	23.13	10.00	10.73	47.85	$1.01
D	1, clear	low-e VT50	3.25	25.60	11.03	10.73	50.62	$1.08
E	1, clear	low-e VT70	2.57	28.90	12.41	10.73	54.61	$1.18
F	1, clear	spec. sel. VT40	7.04	25.28	12.10	10.73	55.15	$1.12
G	1, clear	spec. sel. VT70	4.74	27.21	12.46	10.73	55.14	$1.16
H	1, bronze	none	4.98	30.11	14.17	10.73	59.99	$1.26
I	1, bronze	low-e VT35	4.36	22.44	9.91	10.73	47.44	$0.99
J	1, bronze	low-e VT50	3.86	23.93	10.54	10.73	49.06	$1.04
K	1, bronze	low-e VT70	3.30	25.69	11.26	10.73	50.98	$1.09
L	1, bronze	spec. sel. VT40	7.36	24.86	12.01	10.73	54.96	$1.11
M	1, bronze	spec. sel. VT70	5.48	25.46	11.84	10.73	53.52	$1.11
N	2, clear	none	2.01	32.69	13.74	10.73	59.17	$1.29
O	2, clear	low-e VT35	2.84	23.95	10.24	10.73	47.76	$1.02
P	2, clear	low-e VT50	2.40	25.85	10.95	10.73	49.93	$1.08
Q	2, clear	low-e VT70	2.00	28.21	11.84	10.73	52.78	$1.15
R	2, clear	spec. sel. VT40	3.45	27.12	12.01	10.73	53.32	$1.14
S	2, clear	spec. sel. VT70	2.81	27.89	12.09	10.73	53.52	$1.15
T	2, bronze	none	3.30	27.54	12.03	10.73	53.59	$1.15
U	2, bronze	low-e VT35	3.43	22.39	9.67	10.73	46.23	$0.98
V	2, bronze	low-e VT50	3.11	23.45	10.07	10.73	47.35	$1.01
W	2, bronze	low-e VT70	2.74	24.68	10.51	10.73	48.66	$1.04
X	2, bronze	spec. sel. VT40	4.28	24.72	11.06	10.73	50.79	$1.07
Y	2, bronze	spec. sel. VT70	3.65	24.89	10.93	10.73	50.20	$1.07
Z	2, clear	factory low-e IGU VT66	2.88	23.69	9.75	10.73	47.06	$1.01

Table AC14. COMFEN site energy, generic SOUTH façade case, daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	4.73	32.07	14.65	2.40	53.84	$1.13
B	1, clear	absorbing	5.76	27.90	12.94	2.83	49.43	$1.01
C	1, clear	low-e VT35	5.21	20.18	8.55	3.40	37.35	$0.75
D	1, clear	low-e VT50	4.29	22.42	9.52	2.88	39.12	$0.81
E	1, clear	low-e VT70	3.40	25.53	10.84	2.56	42.33	$0.89
F	1, clear	spec. sel. VT40	8.54	22.58	10.65	3.08	44.84	$0.87
G	1, clear	spec. sel. VT70	6.04	24.14	10.92	2.57	43.67	$0.88
H	1, bronze	none	6.04	27.12	12.63	2.82	48.61	$0.99
I	1, bronze	low-e VT35	5.50	20.02	8.60	4.67	38.79	$0.78
J	1, bronze	low-e VT50	4.95	21.08	9.11	3.66	38.81	$0.79
K	1, bronze	low-e VT70	4.30	22.60	9.78	3.10	39.78	$0.82
L	1, bronze	spec. sel. VT40	8.69	22.45	10.62	4.06	45.82	$0.89
M	1, bronze	spec. sel. VT70	6.80	22.63	10.39	3.13	42.94	$0.85
N	2, clear	none	2.63	29.28	12.14	2.47	46.52	$1.00
O	2, clear	low-e VT35	3.76	21.01	8.80	3.64	37.21	$0.77
P	2, clear	low-e VT50	3.22	22.64	9.47	3.04	38.37	$0.81
Q	2, clear	low-e VT70	2.70	24.82	10.27	2.68	40.46	$0.86
R	2, clear	spec. sel. VT40	4.33	24.16	10.54	3.30	42.33	$0.88
S	2, clear	spec. sel. VT70	3.68	24.66	10.56	2.69	41.60	$0.87
T	2, bronze	none	4.20	24.47	10.51	2.99	42.17	$0.88
U	2, bronze	low-e VT35	4.33	20.25	8.59	5.32	38.50	$0.79
V	2, bronze	low-e VT50	4.04	20.72	8.68	4.16	37.61	$0.78
W	2, bronze	low-e VT70	3.63	21.66	9.08	3.38	37.75	$0.79
X	2, bronze	spec. sel. VT40	5.22	22.33	9.72	4.73	42.01	$0.86
Y	2, bronze	spec. sel. VT70	4.68	22.00	9.48	3.43	39.59	$0.81
Z	2, clear	factory low-e IGU VT66	4.03	20.51	8.24	2.66	35.44	$0.73

Table AC15. COMFEN site energy, generic NORTH façade case, NO daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	10.95	24.18	11.00	10.73	56.86	$1.10
B	1, clear	absorbing	11.87	22.68	10.36	10.73	55.65	$1.06
C	1, clear	low-e VT35	8.02	19.36	8.05	10.73	46.16	$0.91
D	1, clear	low-e VT50	7.75	20.37	8.52	10.73	47.37	$0.94
E	1, clear	low-e VT70	7.25	21.59	9.02	10.73	48.59	$0.97
F	1, clear	spec. sel. VT40	13.47	20.56	9.44	10.73	54.20	$1.00
G	1, clear	spec. sel. VT70	10.82	21.19	9.39	10.73	52.13	$1.00
H	1, bronze	none	12.05	22.39	10.25	10.73	55.42	$1.05
I	1, bronze	low-e VT35	8.18	19.03	7.97	10.73	45.91	$0.90
J	1, bronze	low-e VT50	8.10	19.66	8.26	10.73	46.75	$0.92
K	1, bronze	low-e VT70	7.84	20.37	8.56	10.73	47.50	$0.94
L	1, bronze	spec. sel. VT40	13.63	20.36	9.37	10.73	54.09	$1.00
M	1, bronze	spec. sel. VT70	11.26	20.50	9.13	10.73	51.62	$0.98
N	2, clear	none	6.75	22.76	9.58	10.73	49.82	$1.01
O	2, clear	low-e VT35	6.47	19.54	7.98	10.73	44.72	$0.90
P	2, clear	low-e VT50	6.26	20.30	8.32	10.73	45.60	$0.92
Q	2, clear	low-e VT70	5.90	21.19	8.69	10.73	46.51	$0.95
R	2, clear	spec. sel. VT40	8.81	20.80	8.94	10.73	49.28	$0.96
S	2, clear	spec. sel. VT70	7.69	21.11	8.93	10.73	48.46	$0.96
T	2, bronze	none	8.64	21.01	8.99	10.73	49.38	$0.97
U	2, bronze	low-e VT35	6.83	17.77	7.65	10.73	42.98	$0.85
V	2, bronze	low-e VT50	6.80	18.13	7.73	10.73	43.39	$0.86
W	2, bronze	low-e VT70	6.56	19.85	8.15	10.73	45.29	$0.91
X	2, bronze	spec. sel. VT40	9.38	19.87	8.54	10.73	48.53	$0.94
Y	2, bronze	spec. sel. VT70	8.34	19.96	8.44	10.73	47.47	$0.93
Z	2, clear	factory low-e IGU VT66	6.90	18.11	7.72	10.73	43.46	$0.86

Table AC16. COMFEN site energy, generic NORTH façade case, daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	13.47	21.59	9.45	2.58	47.09	$0.84
B	1, clear	absorbing	14.03	20.22	8.84	3.50	46.59	$0.82
C	1, clear	low-e VT35	9.29	16.36	7.33	5.05	38.02	$0.70
D	1, clear	low-e VT50	9.60	16.81	7.35	3.63	37.39	$0.69
E	1, clear	low-e VT70	9.50	17.63	7.40	2.90	37.43	$0.69
F	1, clear	spec. sel. VT40	15.57	17.10	7.74	4.16	44.57	$0.75
G	1, clear	spec. sel. VT70	13.32	18.59	7.87	2.93	42.71	$0.75
H	1, bronze	none	14.25	19.93	8.72	3.47	46.37	$0.81
I	1, bronze	low-e VT35	8.96	16.75	7.45	7.28	40.44	$0.76
J	1, bronze	low-e VT50	9.25	16.78	7.45	5.68	39.17	$0.73
K	1, bronze	low-e VT70	9.43	16.94	7.44	4.21	38.02	$0.70
L	1, bronze	spec. sel. VT40	14.84	18.84	8.43	6.46	48.57	$0.85
M	1, bronze	spec. sel. VT70	13.11	17.08	7.65	4.31	42.14	$0.74
N	2, clear	none	8.94	19.98	8.02	2.73	39.67	$0.75
O	2, clear	low-e VT35	7.50	16.69	7.38	5.60	37.18	$0.71
P	2, clear	low-e VT50	7.74	16.86	7.36	4.04	36.01	$0.68
Q	2, clear	low-e VT70	7.82	17.38	7.38	3.14	35.72	$0.68
R	2, clear	spec. sel. VT40	10.31	17.52	7.67	4.75	40.25	$0.74
S	2, clear	spec. sel. VT70	9.81	17.38	7.48	3.18	37.85	$0.69
T	2, bronze	none	10.46	17.48	7.60	3.90	39.44	$0.72
U	2, bronze	low-e VT35	7.39	16.85	7.44	7.82	39.50	$0.77
V	2, bronze	low-e VT50	7.60	16.82	7.43	6.55	38.39	$0.74
W	2, bronze	low-e VT70	7.75	16.77	7.40	4.97	36.89	$0.70
X	2, bronze	spec. sel. VT40	10.29	17.46	7.71	7.24	42.71	$0.79
Y	2, bronze	spec. sel. VT70	9.66	16.93	7.53	5.08	39.20	$0.72
Z	2, clear	factory low-e IGU VT66	8.85	15.87	7.07	3.10	34.89	$0.64

Table AC17. COMFEN site energy, generic WEST façade case, NO daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	4.89	38.62	24.20	10.73	78.44	$1.68
B	1, clear	absorbing	6.20	33.84	20.79	10.73	71.56	$1.50
C	1, clear	low-e VT35	5.29	24.40	12.52	10.73	52.95	$1.10
D	1, clear	low-e VT50	4.48	27.29	14.58	10.73	57.08	$1.21
E	1, clear	low-e VT70	3.56	30.93	17.15	10.73	62.36	$1.34
F	1, clear	spec. sel. VT40	8.93	27.31	15.96	10.73	62.94	$1.27
G	1, clear	spec. sel. VT70	6.30	29.38	16.95	10.73	63.36	$1.32
H	1, bronze	none	6.48	32.95	20.17	10.73	70.33	$1.47
I	1, bronze	low-e VT35	5.61	23.71	12.35	10.73	52.40	$1.08
J	1, bronze	low-e VT50	5.14	25.45	13.57	10.73	54.88	$1.15
K	1, bronze	low-e VT70	4.51	27.49	14.99	10.73	57.73	$1.22
L	1, bronze	spec. sel. VT40	9.23	26.83	15.76	10.73	62.55	$1.25
M	1, bronze	spec. sel. VT70	7.12	27.43	15.72	10.73	61.00	$1.25
N	2, clear	none	2.53	35.76	20.85	10.73	69.87	$1.52
O	2, clear	low-e VT35	3.84	25.56	13.43	10.73	53.56	$1.14
P	2, clear	low-e VT50	3.31	27.82	15.01	10.73	56.86	$1.22
Q	2, clear	low-e VT70	2.72	30.50	16.84	10.73	60.79	$1.32
R	2, clear	spec. sel. VT40	4.62	29.44	16.82	10.73	61.61	$1.31
S	2, clear	spec. sel. VT70	3.78	30.25	17.12	10.73	61.88	$1.32
T	2, bronze	none	4.41	29.94	17.05	10.73	62.13	$1.32
U	2, bronze	low-e VT35	4.47	23.76	12.27	10.73	51.23	$1.08
V	2, bronze	low-e VT50	4.14	25.03	13.15	10.73	53.05	$1.12
W	2, bronze	low-e VT70	3.71	26.54	14.18	10.73	55.17	$1.18
X	2, bronze	spec. sel. VT40	5.63	26.61	14.81	10.73	57.77	$1.20
Y	2, bronze	spec. sel. VT70	4.85	26.83	14.73	10.73	57.14	$1.20
Z	2, clear	factory low-e IGU VT66	3.96	25.16	12.79	10.73	52.63	$1.11

Table AC18. COMFEN site energy, generic WEST façade case, daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	6.24	35.39	22.29	2.37	66.28	$1.38
B	1, clear	absorbing	7.61	30.85	18.97	2.98	60.41	$1.23
C	1, clear	low-e VT35	6.72	21.67	10.93	3.96	43.27	$0.86
D	1, clear	low-e VT50	5.91	24.22	12.87	3.06	46.06	$0.94
E	1, clear	low-e VT70	4.85	27.62	15.35	2.58	50.40	$1.05
F	1, clear	spec. sel. VT40	10.73	24.69	14.32	3.40	53.15	$1.02
G	1, clear	spec. sel. VT70	8.10	26.40	15.22	2.60	52.33	$1.04
H	1, bronze	none	7.98	30.03	18.39	2.96	59.35	$1.20
I	1, bronze	low-e VT35	6.74	21.48	10.90	5.44	44.56	$0.89
J	1, bronze	low-e VT50	6.39	22.81	11.98	4.35	45.54	$0.92
K	1, bronze	low-e VT70	5.83	24.53	13.30	3.43	47.09	$0.96
L	1, bronze	spec. sel. VT40	10.65	24.61	14.22	4.84	54.32	$1.05
M	1, bronze	spec. sel. VT70	8.73	24.72	14.07	3.49	51.01	$1.00
N	2, clear	none	3.51	32.39	19.00	2.47	57.37	$1.23
O	2, clear	low-e VT35	4.93	22.86	11.88	4.30	43.97	$0.91
P	2, clear	low-e VT50	4.45	24.74	13.31	3.32	45.82	$0.95
Q	2, clear	low-e VT70	3.81	27.20	15.10	2.75	48.86	$1.03
R	2, clear	spec. sel. VT40	5.80	26.67	15.17	3.78	51.42	$1.06
S	2, clear	spec. sel. VT70	5.09	27.12	15.39	2.77	50.37	$1.05
T	2, bronze	none	5.68	27.01	15.31	3.22	51.22	$1.06
U	2, bronze	low-e VT35	5.38	21.66	10.90	5.93	43.87	$0.90
V	2, bronze	low-e VT50	5.17	22.56	11.64	4.90	44.27	$0.91
W	2, bronze	low-e VT70	4.83	23.69	12.56	3.90	44.98	$0.93
X	2, bronze	spec. sel. VT40	6.66	24.45	13.32	5.43	49.86	$1.01
Y	2, bronze	spec. sel. VT70	6.11	24.14	13.12	3.97	47.35	$0.96
Z	2, clear	factory low-e IGU VT66	5.54	22.06	11.09	2.71	41.41	$0.84

Table AC19. COMFEN site energy, generic EAST façade case, NO daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	4.43	36.16	21.92	10.73	73.24	$1.57
B	1, clear	absorbing	5.71	31.85	18.96	10.73	67.25	$1.41
C	1, clear	low-e VT35	4.95	23.59	12.14	10.73	51.41	$1.07
D	1, clear	low-e VT50	4.08	26.17	13.93	10.73	54.90	$1.16
E	1, clear	low-e VT70	3.14	29.43	16.20	10.73	59.50	$1.28
F	1, clear	spec. sel. VT40	8.60	26.05	14.77	10.73	60.15	$1.21
G	1, clear	spec. sel. VT70	5.92	27.94	15.75	10.73	60.34	$1.26
H	1, bronze	none	6.00	31.07	18.44	10.73	66.24	$1.39
I	1, bronze	low-e VT35	5.24	22.87	12.00	10.73	50.85	$1.05
J	1, bronze	low-e VT50	4.74	24.43	13.06	10.73	52.95	$1.11
K	1, bronze	low-e VT70	4.08	26.28	14.32	10.73	55.40	$1.17
L	1, bronze	spec. sel. VT40	8.89	25.62	14.58	10.73	59.81	$1.20
M	1, bronze	spec. sel. VT70	6.74	26.20	14.71	10.73	58.38	$1.20
N	2, clear	none	2.23	33.78	19.44	10.73	66.17	$1.44
O	2, clear	low-e VT35	3.42	24.59	13.12	10.73	51.86	$1.11
P	2, clear	low-e VT50	2.90	26.61	14.49	10.73	54.73	$1.18
Q	2, clear	low-e VT70	2.34	29.09	16.17	10.73	58.34	$1.27
R	2, clear	spec. sel. VT40	4.23	28.02	15.80	10.73	58.78	$1.25
S	2, clear	spec. sel. VT70	3.39	28.76	16.17	10.73	59.05	$1.27
T	2, bronze	none	4.06	28.52	16.00	10.73	59.31	$1.26
U	2, bronze	low-e VT35	4.09	22.89	12.05	10.73	49.76	$1.05
V	2, bronze	low-e VT50	3.74	24.05	12.84	10.73	51.36	$1.09
W	2, bronze	low-e VT70	3.30	25.41	13.75	10.73	53.19	$1.14
X	2, bronze	spec. sel. VT40	5.32	25.52	13.98	10.73	55.55	$1.16
Y	2, bronze	spec. sel. VT70	4.51	25.67	14.03	10.73	54.94	$1.16
Z	2, clear	factory low-e IGU VT66	3.71	24.33	12.36	10.73	51.13	$1.08

Table AC20. COMFEN site energy, generic EAST façade case, daylight controls, Dallas, TX

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	5.60	33.20	20.48	2.55	61.84	$1.29
B	1, clear	absorbing	7.04	29.24	17.57	3.26	57.11	$1.17
C	1, clear	low-e VT35	6.33	21.10	10.82	4.29	42.54	$0.85
D	1, clear	low-e VT50	5.47	23.37	12.59	3.35	44.79	$0.92
E	1, clear	low-e VT70	4.32	26.43	14.81	2.81	48.37	$1.01
F	1, clear	spec. sel. VT40	10.33	23.75	13.44	3.72	51.25	$0.98
G	1, clear	spec. sel. VT70	7.60	25.28	14.39	2.83	50.10	$1.00
H	1, bronze	none	7.40	28.42	17.04	3.24	56.10	$1.14
I	1, bronze	low-e VT35	6.37	20.92	10.76	5.78	43.83	$0.88
J	1, bronze	low-e VT50	5.98	22.13	11.78	4.70	44.59	$0.90
K	1, bronze	low-e VT70	5.36	23.66	12.98	3.75	45.75	$0.94
L	1, bronze	spec. sel. VT40	10.30	23.67	13.28	5.19	52.44	$1.01
M	1, bronze	spec. sel. VT70	8.30	23.81	13.37	3.81	49.29	$0.97
N	2, clear	none	3.05	30.72	18.02	2.67	54.47	$1.17
O	2, clear	low-e VT35	4.50	22.16	11.86	4.65	43.17	$0.89
P	2, clear	low-e VT50	3.96	23.81	13.18	3.63	44.58	$0.93
Q	2, clear	low-e VT70	3.29	26.03	14.80	3.00	47.13	$1.00
R	2, clear	spec. sel. VT40	5.38	25.53	14.47	4.11	49.48	$1.02
S	2, clear	spec. sel. VT70	4.60	25.94	14.81	3.03	48.38	$1.01
T	2, bronze	none	5.26	25.88	14.63	3.53	49.30	$1.02
U	2, bronze	low-e VT35	5.01	21.05	10.87	6.27	43.19	$0.89
V	2, bronze	low-e VT50	4.77	21.89	11.61	5.26	43.52	$0.90
W	2, bronze	low-e VT70	4.39	22.89	12.45	4.24	43.97	$0.91
X	2, bronze	spec. sel. VT40	6.36	23.55	12.71	5.78	48.39	$0.98
Y	2, bronze	spec. sel. VT70	5.74	23.29	12.72	4.31	46.07	$0.94
Z	2, clear	factory low-e IGU VT66	5.22	21.48	11.00	2.96	40.67	$0.83

Table AC21. COMFEN site energy, generic four side AVERAGE, NO daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	32.33	14.53	17.86	10.73	75.45	$1.37
B	1, clear	absorbing	36.12	12.12	15.58	10.73	74.55	$1.29
C	1, clear	low-e VT35	30.36	8.87	10.21	10.73	60.18	$1.02
D	1, clear	low-e VT50	28.48	10.19	11.53	10.73	60.93	$1.07
E	1, clear	low-e VT70	25.85	11.95	13.17	10.73	61.70	$1.13
F	1, clear	spec. sel. VT40	42.89	9.03	12.38	10.73	75.04	$1.18
G	1, clear	spec. sel. VT70	35.30	10.45	13.07	10.73	69.55	$1.17
H	1, bronze	none	36.89	11.68	15.17	10.73	74.48	$1.27
I	1, bronze	low-e VT35	31.10	8.45	10.02	10.73	60.30	$1.01
J	1, bronze	low-e VT50	30.14	9.21	10.79	10.73	60.87	$1.04
K	1, bronze	low-e VT70	28.62	10.16	11.72	10.73	61.23	$1.07
L	1, bronze	spec. sel. VT40	43.57	8.76	12.17	10.73	75.23	$1.18
M	1, bronze	spec. sel. VT70	37.28	9.46	12.20	10.73	69.67	$1.14
N	2, clear	none	21.69	14.20	15.29	10.73	61.90	$1.21
O	2, clear	low-e VT35	24.97	9.56	10.75	10.73	56.01	$1.00
P	2, clear	low-e VT50	23.56	10.61	11.71	10.73	56.61	$1.04
Q	2, clear	low-e VT70	21.75	11.92	12.86	10.73	57.26	$1.09
R	2, clear	spec. sel. VT40	28.91	10.76	12.82	10.73	63.23	$1.12
S	2, clear	spec. sel. VT70	26.04	11.29	12.96	10.73	61.02	$1.11
T	2, bronze	none	28.35	11.05	12.90	10.73	63.03	$1.12
U	2, bronze	low-e VT35	26.67	8.66	9.97	10.73	56.02	$0.97
V	2, bronze	low-e VT50	25.92	9.23	10.50	10.73	56.38	$1.00
W	2, bronze	low-e VT70	24.83	9.94	11.13	10.73	56.62	$1.02
X	2, bronze	spec. sel. VT40	31.59	9.29	11.39	10.73	62.99	$1.07
Y	2, bronze	spec. sel. VT70	29.01	9.60	11.39	10.73	60.74	$1.05
Z	2, clear	factory low-e IGU VT66	25.34	9.37	10.23	10.73	55.67	$0.99

Table AC22. COMFEN site energy, generic four side AVERAGE, daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	36.45	12.64	16.23	2.85	68.16	$1.12
B	1, clear	absorbing	40.14	10.40	13.96	3.54	68.04	$1.05
C	1, clear	low-e VT35	33.91	7.28	8.83	4.57	54.59	$0.81
D	1, clear	low-e VT50	32.46	8.37	10.02	3.64	54.48	$0.84
E	1, clear	low-e VT70	29.97	9.98	11.63	3.09	54.68	$0.88
F	1, clear	spec. sel. VT40	47.01	7.56	10.85	4.00	69.41	$0.97
G	1, clear	spec. sel. VT70	39.87	8.70	11.45	3.12	63.14	$0.93
H	1, bronze	none	41.00	9.99	13.56	3.52	68.08	$1.04
I	1, bronze	low-e VT35	33.84	7.21	8.84	6.12	56.01	$0.85
J	1, bronze	low-e VT50	33.41	7.70	9.46	4.98	55.56	$0.85
K	1, bronze	low-e VT70	32.31	8.42	10.24	4.03	54.99	$0.85
L	1, bronze	spec. sel. VT40	46.82	7.55	10.79	5.49	70.66	$1.00
M	1, bronze	spec. sel. VT70	41.31	7.79	10.58	4.09	63.77	$0.92
N	2, clear	none	25.54	12.02	13.67	2.97	54.19	$0.95
O	2, clear	low-e VT35	28.13	7.99	9.44	4.92	50.47	$0.81
P	2, clear	low-e VT50	27.17	8.76	10.24	3.91	50.09	$0.81
Q	2, clear	low-e VT70	25.61	9.92	11.35	3.28	50.16	$0.84
R	2, clear	spec. sel. VT40	32.35	9.01	11.33	4.38	57.07	$0.90
S	2, clear	spec. sel. VT70	30.04	9.43	11.45	3.31	54.24	$0.87
T	2, bronze	none	32.12	9.19	11.33	3.82	56.45	$0.89
U	2, bronze	low-e VT35	29.03	7.53	8.90	6.61	52.07	$0.83
V	2, bronze	low-e VT50	28.80	7.82	9.26	5.55	51.44	$0.82
W	2, bronze	low-e VT70	28.16	8.26	9.76	4.51	50.69	$0.81
X	2, bronze	spec. sel. VT40	34.24	8.09	10.18	6.09	58.60	$0.91
Y	2, bronze	spec. sel. VT70	32.42	8.05	10.02	4.58	55.07	$0.85
Z	2, clear	factory low-e IGU VT66	29.62	7.54	8.74	3.25	49.15	$0.75

Table AC23. COMFEN site energy, generic SOUTH façade case, NO daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	24.14	15.30	15.08	10.73	65.25	$1.25
B	1, clear	absorbing	28.74	12.55	13.46	10.73	65.48	$1.18
C	1, clear	low-e VT35	26.34	9.19	9.32	10.73	55.58	$0.97
D	1, clear	low-e VT50	23.43	10.62	10.28	10.73	55.06	$1.01
E	1, clear	low-e VT70	19.83	12.57	11.50	10.73	54.63	$1.06
F	1, clear	spec. sel. VT40	37.31	9.25	11.22	10.73	68.51	$1.11
G	1, clear	spec. sel. VT70	29.18	10.78	11.59	10.73	62.27	$1.09
H	1, bronze	none	29.70	12.07	13.17	10.73	65.67	$1.17
I	1, bronze	low-e VT35	27.53	8.74	9.22	10.73	56.22	$0.96
J	1, bronze	low-e VT50	25.86	9.55	9.80	10.73	55.94	$0.99
K	1, bronze	low-e VT70	23.61	10.58	10.46	10.73	55.39	$1.01
L	1, bronze	spec. sel. VT40	38.32	8.97	11.10	10.73	69.12	$1.11
M	1, bronze	spec. sel. VT70	31.92	9.71	10.98	10.73	63.34	$1.07
N	2, clear	none	15.16	14.82	12.60	10.73	53.30	$1.10
O	2, clear	low-e VT35	21.05	9.87	9.52	10.73	51.16	$0.95
P	2, clear	low-e VT50	18.92	10.98	10.16	10.73	50.79	$0.97
Q	2, clear	low-e VT70	16.45	12.39	10.93	10.73	50.50	$1.01
R	2, clear	spec. sel. VT40	23.29	11.06	11.11	10.73	56.19	$1.04
S	2, clear	spec. sel. VT70	20.38	11.74	11.14	10.73	53.99	$1.03
T	2, bronze	none	22.52	11.31	11.04	10.73	55.60	$1.04
U	2, bronze	low-e VT35	23.42	8.92	9.00	10.73	52.08	$0.93
V	2, bronze	low-e VT50	22.18	9.50	9.34	10.73	51.75	$0.94
W	2, bronze	low-e VT70	20.56	10.23	9.73	10.73	51.25	$0.96
X	2, bronze	spec. sel. VT40	26.81	9.60	10.16	10.73	57.30	$1.00
Y	2, bronze	spec. sel. VT70	24.34	9.92	10.07	10.73	55.05	$0.99
Z	2, clear	factory low-e IGU VT66	21.11	9.70	9.02	10.73	50.57	$0.93

Table AC24. COMFEN site energy, generic SOUTH façade case, daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	27.57	13.24	13.50	2.76	57.07	$0.99
B	1, clear	absorbing	32.48	10.71	11.89	3.15	58.24	$0.93
C	1, clear	low-e VT35	30.48	7.43	7.85	3.67	49.42	$0.74
D	1, clear	low-e VT50	27.49	8.66	8.75	3.20	48.10	$0.76
E	1, clear	low-e VT70	23.61	10.45	9.94	2.91	46.91	$0.79
F	1, clear	spec. sel. VT40	41.76	7.68	9.68	3.38	62.51	$0.88
G	1, clear	spec. sel. VT70	33.47	8.93	10.01	2.93	55.34	$0.84
H	1, bronze	none	33.57	10.27	11.61	3.15	58.59	$0.92
I	1, bronze	low-e VT35	31.22	7.25	7.87	4.71	51.05	$0.77
J	1, bronze	low-e VT50	29.79	7.83	8.35	3.88	49.85	$0.76
K	1, bronze	low-e VT70	27.55	8.68	8.95	3.40	48.58	$0.77
L	1, bronze	spec. sel. VT40	42.39	7.58	9.65	4.20	63.81	$0.90
M	1, bronze	spec. sel. VT70	36.19	8.03	9.46	3.43	57.11	$0.84
N	2, clear	none	18.33	12.58	11.04	2.84	44.79	$0.83
O	2, clear	low-e VT35	24.80	8.07	8.12	3.85	44.85	$0.72
P	2, clear	low-e VT50	22.67	8.98	8.69	3.34	43.69	$0.73
Q	2, clear	low-e VT70	20.08	10.23	9.40	3.02	42.73	$0.75
R	2, clear	spec. sel. VT40	26.96	9.24	9.61	3.57	49.39	$0.80
S	2, clear	spec. sel. VT70	24.13	9.74	9.63	3.03	46.53	$0.78
T	2, bronze	none	26.25	9.42	9.53	3.29	48.50	$0.79
U	2, bronze	low-e VT35	26.66	7.56	7.87	5.25	47.34	$0.75
V	2, bronze	low-e VT50	25.82	7.83	7.97	4.25	45.88	$0.73
W	2, bronze	low-e VT70	24.35	8.34	8.27	3.64	44.60	$0.72
X	2, bronze	spec. sel. VT40	30.25	8.15	8.81	4.71	51.92	$0.81
Y	2, bronze	spec. sel. VT70	28.22	8.18	8.61	3.67	48.67	$0.76
Z	2, clear	factory low-e IGU VT66	25.30	7.76	7.50	3.00	43.56	$0.68

Table AC25. COMFEN site energy, generic NORTH façade case, NO daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	44.66	9.27	10.34	10.73	75.00	$1.15
B	1, clear	absorbing	46.76	8.23	9.64	10.73	75.35	$1.12
C	1, clear	low-e VT35	35.37	6.88	7.77	10.73	60.75	$0.95
D	1, clear	low-e VT50	34.93	7.42	8.07	10.73	61.15	$0.96
E	1, clear	low-e VT70	33.82	8.16	8.46	10.73	61.17	$0.98
F	1, clear	spec. sel. VT40	50.36	6.86	8.71	10.73	76.66	$1.09
G	1, clear	spec. sel. VT70	43.47	7.63	8.75	10.73	70.58	$1.06
H	1, bronze	none	47.16	8.03	9.51	10.73	75.42	$1.12
I	1, bronze	low-e VT35	35.79	6.65	7.63	10.73	60.79	$0.94
J	1, bronze	low-e VT50	35.76	6.95	7.81	10.73	61.26	$0.95
K	1, bronze	low-e VT70	35.23	7.36	8.03	10.73	61.34	$0.96
L	1, bronze	spec. sel. VT40	50.72	6.71	8.61	10.73	76.77	$1.09
M	1, bronze	spec. sel. VT70	44.49	7.16	8.45	10.73	70.83	$1.05
N	2, clear	none	31.42	9.33	8.96	10.73	60.44	$1.01
O	2, clear	low-e VT35	30.31	7.18	7.71	10.73	55.93	$0.91
P	2, clear	low-e VT50	29.90	7.61	7.91	10.73	56.15	$0.92
Q	2, clear	low-e VT70	29.12	8.15	8.17	10.73	56.17	$0.94
R	2, clear	spec. sel. VT40	36.89	7.73	8.31	10.73	63.66	$0.99
S	2, clear	spec. sel. VT70	34.07	7.63	8.11	10.73	60.54	$0.96
T	2, bronze	none	36.48	7.90	8.36	10.73	63.47	$1.00
U	2, bronze	low-e VT35	31.11	6.79	7.52	10.73	56.14	$0.90
V	2, bronze	low-e VT50	31.04	7.02	7.63	10.73	56.41	$0.91
W	2, bronze	low-e VT70	30.64	7.31	7.77	10.73	56.44	$0.92
X	2, bronze	spec. sel. VT40	38.35	6.66	7.70	10.73	63.45	$0.96
Y	2, bronze	spec. sel. VT70	35.54	6.93	7.76	10.73	60.96	$0.95
Z	2, clear	factory low-e IGU VT66	30.83	6.99	7.59	10.73	56.14	$0.91

Table AC26. COMFEN site energy, generic NORTH façade case, daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	49.67	7.66	8.68	2.96	68.97	$0.91
B	1, clear	absorbing	51.01	6.73	7.99	4.02	69.75	$0.91
C	1, clear	low-e VT35	38.22	5.60	6.73	5.58	56.13	$0.78
D	1, clear	low-e VT50	38.80	5.86	6.73	4.17	55.56	$0.75
E	1, clear	low-e VT70	38.31	6.49	7.10	3.31	55.21	$0.75
F	1, clear	spec. sel. VT40	54.18	5.56	7.28	4.72	71.75	$0.90
G	1, clear	spec. sel. VT70	48.47	6.07	7.10	3.35	65.00	$0.83
H	1, bronze	none	51.48	6.55	7.86	4.00	69.88	$0.90
I	1, bronze	low-e VT35	37.47	5.87	7.00	7.64	57.98	$0.84
J	1, bronze	low-e VT50	38.22	5.83	6.90	6.21	57.16	$0.80
K	1, bronze	low-e VT70	38.60	5.88	6.75	4.77	56.01	$0.77
L	1, bronze	spec. sel. VT40	53.15	5.83	7.59	6.91	73.48	$0.97
M	1, bronze	spec. sel. VT70	48.41	5.37	6.66	4.86	65.30	$0.84
N	2, clear	none	36.12	7.07	7.28	3.12	53.59	$0.75
O	2, clear	low-e VT35	32.71	5.99	6.80	6.12	51.62	$0.76
P	2, clear	low-e VT50	33.29	6.05	6.63	4.60	50.57	$0.72
Q	2, clear	low-e VT70	33.23	6.45	6.83	3.62	50.13	$0.71
R	2, clear	spec. sel. VT40	40.05	5.96	6.93	5.30	58.24	$0.80
S	2, clear	spec. sel. VT70	38.30	6.07	6.78	3.66	54.81	$0.74
T	2, bronze	none	40.33	5.95	6.74	4.46	57.47	$0.78
U	2, bronze	low-e VT35	32.47	6.12	7.01	8.12	53.71	$0.82
V	2, bronze	low-e VT50	33.00	6.06	6.91	6.97	52.94	$0.79
W	2, bronze	low-e VT70	33.37	5.97	6.75	5.50	51.60	$0.75
X	2, bronze	spec. sel. VT40	40.06	5.95	7.11	7.60	60.71	$0.86
Y	2, bronze	spec. sel. VT70	38.31	5.72	6.77	5.60	56.40	$0.78
Z	2, clear	factory low-e IGU VT66	35.20	5.41	6.25	3.56	50.42	$0.68

Table AC27. COMFEN site energy, generic WEST façade case, NO daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	30.26	16.90	23.76	10.73	81.64	$1.57
B	1, clear	absorbing	34.38	13.99	20.31	10.73	79.41	$1.44
C	1, clear	low-e VT35	29.96	9.85	12.05	10.73	62.59	$1.09
D	1, clear	low-e VT50	27.87	11.50	14.09	10.73	64.19	$1.16
E	1, clear	low-e VT70	24.94	13.64	16.61	10.73	65.92	$1.26
F	1, clear	spec. sel. VT40	41.87	10.19	15.43	10.73	78.22	$1.28
G	1, clear	spec. sel. VT70	34.25	11.85	16.47	10.73	73.30	$1.29
H	1, bronze	none	35.23	13.46	19.66	10.73	79.08	$1.42
I	1, bronze	low-e VT35	30.66	9.35	11.80	10.73	62.53	$1.07
J	1, bronze	low-e VT50	29.58	10.31	13.00	10.73	63.62	$1.12
K	1, bronze	low-e VT70	27.93	11.51	14.42	10.73	64.58	$1.17
L	1, bronze	spec. sel. VT40	42.54	9.86	15.12	10.73	78.25	$1.27
M	1, bronze	spec. sel. VT70	36.35	10.67	15.19	10.73	72.94	$1.24
N	2, clear	none	20.18	16.37	20.13	10.73	67.41	$1.38
O	2, clear	low-e VT35	24.41	10.75	12.98	10.73	58.87	$1.09
P	2, clear	low-e VT50	22.85	12.04	14.47	10.73	60.09	$1.14
Q	2, clear	low-e VT70	20.84	13.65	16.30	10.73	61.52	$1.22
R	2, clear	spec. sel. VT40	27.76	12.26	16.30	10.73	67.06	$1.24
S	2, clear	spec. sel. VT70	24.93	13.01	16.57	10.73	65.25	$1.24
T	2, bronze	none	27.22	12.60	16.44	10.73	66.99	$1.25
U	2, bronze	low-e VT35	26.23	9.63	11.74	10.73	58.33	$1.04
V	2, bronze	low-e VT50	25.39	10.35	12.60	10.73	59.07	$1.07
W	2, bronze	low-e VT70	24.20	11.24	13.61	10.73	59.78	$1.11
X	2, bronze	spec. sel. VT40	30.63	10.58	14.21	10.73	66.16	$1.17
Y	2, bronze	spec. sel. VT70	28.17	10.92	14.14	10.73	63.96	$1.15
Z	2, clear	factory low-e IGU VT66	24.80	10.49	12.26	10.73	58.28	$1.06

Table AC28. COMFEN site energy, generic WEST façade case, daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	34.38	14.89	21.96	2.72	73.95	$1.30
B	1, clear	absorbing	38.59	12.15	18.52	3.29	72.55	$1.19
C	1, clear	low-e VT35	33.72	8.10	10.41	4.28	56.51	$0.87
D	1, clear	low-e VT50	32.02	9.53	12.37	3.37	57.30	$0.92
E	1, clear	low-e VT70	29.21	11.54	14.85	2.92	58.53	$0.99
F	1, clear	spec. sel. VT40	46.15	8.60	13.71	3.71	72.18	$1.05
G	1, clear	spec. sel. VT70	38.90	10.00	14.71	2.94	66.54	$1.03
H	1, bronze	none	39.55	11.66	17.92	3.27	72.39	$1.17
I	1, bronze	low-e VT35	33.55	7.95	10.32	5.83	57.65	$0.90
J	1, bronze	low-e VT50	33.05	8.64	11.40	4.68	57.77	$0.91
K	1, bronze	low-e VT70	31.78	9.61	12.74	3.74	57.87	$0.93
L	1, bronze	spec. sel. VT40	45.92	8.52	13.51	5.19	73.14	$1.08
M	1, bronze	spec. sel. VT70	40.46	8.96	13.45	3.80	66.68	$1.01
N	2, clear	none	24.02	14.21	18.37	2.82	59.42	$1.11
O	2, clear	low-e VT35	27.78	8.99	11.37	4.62	52.76	$0.87
P	2, clear	low-e VT50	26.65	10.04	12.78	3.63	53.10	$0.90
Q	2, clear	low-e VT70	24.83	11.51	14.55	3.07	53.97	$0.95
R	2, clear	spec. sel. VT40	31.36	10.49	14.62	4.09	60.56	$1.01
S	2, clear	spec. sel. VT70	29.09	11.01	14.85	3.10	58.04	$0.98
T	2, bronze	none	31.14	10.72	14.73	3.53	60.12	$1.00
U	2, bronze	low-e VT35	28.76	8.29	10.30	6.32	53.67	$0.88
V	2, bronze	low-e VT50	28.45	8.75	11.06	5.24	53.51	$0.88
W	2, bronze	low-e VT70	27.75	9.39	11.97	4.21	53.32	$0.89
X	2, bronze	spec. sel. VT40	33.43	9.19	12.66	5.80	61.07	$0.99
Y	2, bronze	spec. sel. VT70	31.78	9.21	12.49	4.28	57.76	$0.93
Z	2, clear	factory low-e IGU VT66	29.24	8.53	10.56	3.04	51.38	$0.81

Table AC29. COMFEN site energy, generic EAST façade case, NO daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	30.27	16.65	22.26	10.73	79.90	$1.52
B	1, clear	absorbing	34.61	13.70	18.93	10.73	77.98	$1.40
C	1, clear	low-e VT35	29.77	9.57	11.71	10.73	61.78	$1.07
D	1, clear	low-e VT50	27.69	11.22	13.67	10.73	63.31	$1.14
E	1, clear	low-e VT70	24.80	13.44	16.11	10.73	65.08	$1.24
F	1, clear	spec. sel. VT40	42.02	9.84	14.17	10.73	76.76	$1.24
G	1, clear	spec. sel. VT70	34.29	11.53	15.49	10.73	72.04	$1.25
H	1, bronze	none	35.48	13.18	18.34	10.73	77.73	$1.38
I	1, bronze	low-e VT35	30.44	9.06	11.44	10.73	61.67	$1.05
J	1, bronze	low-e VT50	29.36	10.02	12.57	10.73	62.68	$1.10
K	1, bronze	low-e VT70	27.73	11.21	13.95	10.73	63.62	$1.15
L	1, bronze	spec. sel. VT40	42.71	9.50	13.83	10.73	76.76	$1.23
M	1, bronze	spec. sel. VT70	36.37	10.31	14.18	10.73	71.59	$1.21
N	2, clear	none	19.99	16.28	19.47	10.73	66.47	$1.36
O	2, clear	low-e VT35	24.11	10.44	12.79	10.73	58.07	$1.07
P	2, clear	low-e VT50	22.58	11.82	14.29	10.73	59.42	$1.13
Q	2, clear	low-e VT70	20.57	13.49	16.04	10.73	60.83	$1.20
R	2, clear	spec. sel. VT40	27.70	12.01	15.57	10.73	66.01	$1.21
S	2, clear	spec. sel. VT70	24.78	12.78	16.00	10.73	64.29	$1.22
T	2, bronze	none	27.17	12.40	15.77	10.73	66.07	$1.22
U	2, bronze	low-e VT35	25.90	9.30	11.61	10.73	57.54	$1.03
V	2, bronze	low-e VT50	25.08	10.07	12.42	10.73	58.30	$1.06
W	2, bronze	low-e VT70	23.91	10.97	13.41	10.73	59.03	$1.10
X	2, bronze	spec. sel. VT40	30.57	10.29	13.48	10.73	65.07	$1.14
Y	2, bronze	spec. sel. VT70	28.01	10.64	13.60	10.73	62.97	$1.13
Z	2, clear	factory low-e IGU VT66	24.61	10.29	12.05	10.73	57.68	$1.05

Table AC30. COMFEN site energy, generic EAST façade case, daylight controls, Chicago, IL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	34.19	14.76	20.76	2.96	72.67	$1.27
B	1, clear	absorbing	38.47	12.00	17.44	3.70	71.61	$1.17
C	1, clear	low-e VT35	33.23	8.01	10.33	4.75	56.31	$0.87
D	1, clear	low-e VT50	31.53	9.42	12.23	3.79	56.98	$0.92
E	1, clear	low-e VT70	28.76	11.45	14.63	3.23	58.07	$0.99
F	1, clear	spec. sel. VT40	45.94	8.38	12.71	4.17	71.20	$1.03
G	1, clear	spec. sel. VT70	38.62	9.82	14.00	3.25	65.69	$1.02
H	1, bronze	none	39.40	11.51	16.87	3.67	71.45	$1.15
I	1, bronze	low-e VT35	33.11	7.78	10.17	6.28	57.35	$0.90
J	1, bronze	low-e VT50	32.59	8.52	11.20	5.15	57.46	$0.91
K	1, bronze	low-e VT70	31.30	9.49	12.52	4.20	57.52	$0.93
L	1, bronze	spec. sel. VT40	45.84	8.29	12.41	5.65	72.20	$1.06
M	1, bronze	spec. sel. VT70	40.19	8.82	12.73	4.27	66.00	$1.00
N	2, clear	none	23.67	14.22	17.99	3.09	58.96	$1.10
O	2, clear	low-e VT35	27.21	8.91	11.46	5.09	52.67	$0.88
P	2, clear	low-e VT50	26.07	9.97	12.86	4.08	52.98	$0.91
Q	2, clear	low-e VT70	24.28	11.49	14.61	3.43	53.81	$0.96
R	2, clear	spec. sel. VT40	31.02	10.37	14.14	4.56	60.09	$1.00
S	2, clear	spec. sel. VT70	28.64	10.91	14.56	3.45	57.56	$0.98
T	2, bronze	none	30.75	10.66	14.33	3.98	59.72	$1.00
U	2, bronze	low-e VT35	28.22	8.15	10.40	6.78	53.55	$0.88
V	2, bronze	low-e VT50	27.94	8.66	11.10	5.71	53.42	$0.89
W	2, bronze	low-e VT70	27.18	9.32	12.04	4.69	53.22	$0.89
X	2, bronze	spec. sel. VT40	33.22	9.07	12.13	6.26	60.68	$0.98
Y	2, bronze	spec. sel. VT70	31.36	9.11	12.21	4.75	57.44	$0.93
Z	2, clear	factory low-e IGU VT66	28.73	8.47	10.64	3.39	51.23	$0.82

Table AC31. COMFEN site energy, generic four side AVERAGE, NO daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	18.64	17.22	16.15	10.73	62.74	$1.70
B	1, clear	absorbing	21.40	14.62	14.22	10.73	60.97	$1.57
C	1, clear	low-e VT35	18.13	10.82	9.43	10.73	49.12	$1.25
D	1, clear	low-e VT50	16.52	12.44	10.66	10.73	50.35	$1.33
E	1, clear	low-e VT70	14.50	14.39	12.16	10.73	51.78	$1.42
F	1, clear	spec. sel. VT40	26.72	11.26	11.51	10.73	60.23	$1.42
G	1, clear	spec. sel. VT70	21.15	12.73	12.04	10.73	56.66	$1.43
H	1, bronze	none	21.99	14.15	13.87	10.73	60.74	$1.55
I	1, bronze	low-e VT35	18.75	10.41	9.33	10.73	49.22	$1.23
J	1, bronze	low-e VT50	17.86	11.41	10.06	10.73	50.05	$1.28
K	1, bronze	low-e VT70	16.61	12.47	10.88	10.73	50.69	$1.34
L	1, bronze	spec. sel. VT40	27.26	11.00	11.37	10.73	60.36	$1.41
M	1, bronze	spec. sel. VT70	22.72	11.70	11.34	10.73	56.49	$1.39
N	2, clear	none	11.98	16.69	14.00	10.73	53.40	$1.54
O	2, clear	low-e VT35	14.56	11.55	9.94	10.73	46.78	$1.25
P	2, clear	low-e VT50	13.42	12.85	10.83	10.73	47.83	$1.31
Q	2, clear	low-e VT70	12.05	14.29	11.89	10.73	48.95	$1.39
R	2, clear	spec. sel. VT40	17.06	13.00	11.79	10.73	52.58	$1.39
S	2, clear	spec. sel. VT70	14.99	13.67	11.97	10.73	51.36	$1.40
T	2, bronze	none	16.59	13.33	11.88	10.73	52.53	$1.40
U	2, bronze	low-e VT35	15.89	10.61	9.28	10.73	46.51	$1.21
V	2, bronze	low-e VT50	15.25	11.23	9.75	10.73	46.96	$1.24
W	2, bronze	low-e VT70	14.38	11.99	10.30	10.73	47.40	$1.28
X	2, bronze	spec. sel. VT40	19.09	11.56	10.63	10.73	52.00	$1.32
Y	2, bronze	spec. sel. VT70	17.25	11.87	10.61	10.73	50.46	$1.31
Z	2, clear	factory low-e IGU VT66	14.87	11.31	9.43	10.73	46.34	$1.23

Table AC32. COMFEN site energy, generic four side AVERAGE, daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	21.83	15.05	14.62	2.70	54.19	$1.33
B	1, clear	absorbing	24.60	12.65	12.71	3.35	53.32	$1.23
C	1, clear	low-e VT35	21.10	9.01	8.16	4.33	42.60	$0.95
D	1, clear	low-e VT50	19.75	10.21	9.20	3.44	42.61	$0.98
E	1, clear	low-e VT70	17.73	11.96	10.60	2.93	43.22	$1.05
F	1, clear	spec. sel. VT40	30.27	9.51	10.03	3.79	53.59	$1.11
G	1, clear	spec. sel. VT70	24.88	10.73	10.54	2.95	49.10	$1.08
H	1, bronze	none	25.27	12.21	12.38	3.34	53.20	$1.21
I	1, bronze	low-e VT35	21.08	9.02	8.22	5.89	44.20	$1.01
J	1, bronze	low-e VT50	20.59	9.53	8.76	4.74	43.61	$1.00
K	1, bronze	low-e VT70	19.62	10.32	9.45	3.82	43.20	$1.01
L	1, bronze	spec. sel. VT40	30.09	9.56	10.04	5.25	54.94	$1.16
M	1, bronze	spec. sel. VT70	26.06	9.88	9.86	3.88	49.67	$1.07
N	2, clear	none	14.77	14.35	12.48	2.81	44.41	$1.17
O	2, clear	low-e VT35	17.09	9.75	8.72	4.68	40.25	$0.97
P	2, clear	low-e VT50	16.24	10.61	9.44	3.71	40.01	$0.98
Q	2, clear	low-e VT70	14.98	11.86	10.39	3.11	40.34	$1.02
R	2, clear	spec. sel. VT40	19.84	10.97	10.31	4.16	45.28	$1.07
S	2, clear	spec. sel. VT70	18.15	11.52	10.49	3.14	43.30	$1.05
T	2, bronze	none	19.56	11.32	10.40	3.62	44.90	$1.07
U	2, bronze	low-e VT35	17.87	9.32	8.26	6.40	41.85	$1.00
V	2, bronze	low-e VT50	17.59	9.62	8.58	5.31	41.10	$0.98
W	2, bronze	low-e VT70	17.01	10.09	9.02	4.28	40.40	$0.97
X	2, bronze	spec. sel. VT40	21.38	10.01	9.35	5.87	46.60	$1.08
Y	2, bronze	spec. sel. VT70	20.08	9.92	9.22	4.35	43.56	$1.01
Z	2, clear	factory low-e IGU VT66	18.34	9.25	8.06	3.08	38.73	$0.88

Table AC33. COMFEN site energy, generic SOUTH façade case, NO daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	11.87	18.45	13.50	10.73	54.55	$1.58
B	1, clear	absorbing	14.83	15.30	12.11	10.73	52.97	$1.46
C	1, clear	low-e VT35	14.24	11.24	8.67	10.73	44.88	$1.19
D	1, clear	low-e VT50	11.88	12.87	9.52	10.73	45.00	$1.25
E	1, clear	low-e VT70	9.32	15.13	10.63	10.73	45.81	$1.34
F	1, clear	spec. sel. VT40	21.34	11.51	10.28	10.73	53.86	$1.33
G	1, clear	spec. sel. VT70	15.49	13.17	10.55	10.73	49.94	$1.34
H	1, bronze	none	15.50	14.74	11.86	10.73	52.84	$1.44
I	1, bronze	low-e VT35	15.29	10.77	8.61	10.73	45.40	$1.19
J	1, bronze	low-e VT50	13.81	11.70	9.10	10.73	45.34	$1.22
K	1, bronze	low-e VT70	12.04	12.88	9.69	10.73	45.34	$1.26
L	1, bronze	spec. sel. VT40	22.18	11.23	10.20	10.73	54.34	$1.33
M	1, bronze	spec. sel. VT70	17.63	12.00	10.09	10.73	50.45	$1.30
N	2, clear	none	6.73	17.81	11.63	10.73	46.90	$1.44
O	2, clear	low-e VT35	10.85	12.01	8.89	10.73	42.48	$1.19
P	2, clear	low-e VT50	9.23	13.28	9.47	10.73	42.71	$1.24
Q	2, clear	low-e VT70	7.51	14.91	10.18	10.73	43.33	$1.30
R	2, clear	spec. sel. VT40	11.95	13.45	10.17	10.73	46.31	$1.30
S	2, clear	spec. sel. VT70	10.00	14.21	10.26	10.73	45.20	$1.31
T	2, bronze	none	11.35	13.79	10.19	10.73	46.06	$1.30
U	2, bronze	low-e VT35	12.73	10.96	8.43	10.73	42.86	$1.16
V	2, bronze	low-e VT50	11.65	11.63	8.76	10.73	42.77	$1.18
W	2, bronze	low-e VT70	10.39	12.46	9.11	10.73	42.68	$1.21
X	2, bronze	spec. sel. VT40	14.54	11.83	9.38	10.73	46.47	$1.24
Y	2, bronze	spec. sel. VT70	12.85	12.16	9.33	10.73	45.07	$1.23
Z	2, clear	factory low-e IGU VT66	10.82	11.78	8.41	10.73	41.75	$1.17

Table AC34. COMFEN site energy, generic SOUTH façade case, daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	14.08	16.02	11.99	2.60	44.70	$1.19
B	1, clear	absorbing	17.48	13.12	10.65	2.98	44.23	$1.09
C	1, clear	low-e VT35	17.56	9.18	7.26	3.48	37.47	$0.86
D	1, clear	low-e VT50	14.88	10.59	8.06	3.02	36.55	$0.89
E	1, clear	low-e VT70	11.85	12.65	9.13	2.75	36.38	$0.96
F	1, clear	spec. sel. VT40	24.93	9.62	8.84	3.20	46.59	$1.00
G	1, clear	spec. sel. VT70	18.72	10.99	9.09	2.76	41.56	$0.97
H	1, bronze	none	18.27	12.61	10.42	2.97	44.27	$1.08
I	1, bronze	low-e VT35	18.34	9.05	7.32	4.50	39.22	$0.90
J	1, bronze	low-e VT50	16.90	9.69	7.73	3.70	38.02	$0.90
K	1, bronze	low-e VT70	14.95	10.65	8.25	3.21	37.07	$0.91
L	1, bronze	spec. sel. VT40	25.48	9.55	8.84	4.01	47.88	$1.03
M	1, bronze	spec. sel. VT70	21.00	10.02	8.66	3.24	42.92	$0.96
N	2, clear	none	8.57	15.19	10.12	2.68	36.56	$1.05
O	2, clear	low-e VT35	13.69	9.91	7.53	3.67	34.79	$0.86
P	2, clear	low-e VT50	11.87	10.96	8.05	3.16	34.05	$0.88
Q	2, clear	low-e VT70	9.83	12.41	8.70	2.85	33.79	$0.92
R	2, clear	spec. sel. VT40	14.59	11.33	8.75	3.39	38.06	$0.95
S	2, clear	spec. sel. VT70	12.60	11.85	8.80	2.86	36.10	$0.93
T	2, bronze	none	13.97	11.57	8.73	3.11	37.39	$0.94
U	2, bronze	low-e VT35	15.39	9.37	7.30	5.03	37.09	$0.90
V	2, bronze	low-e VT50	14.48	9.67	7.42	4.07	35.64	$0.87
W	2, bronze	low-e VT70	13.16	10.28	7.71	3.45	34.60	$0.87
X	2, bronze	spec. sel. VT40	17.28	10.12	8.07	4.51	39.99	$0.95
Y	2, bronze	spec. sel. VT70	15.80	10.11	7.93	3.49	37.33	$0.90
Z	2, clear	factory low-e IGU VT66	13.98	9.51	6.98	2.83	33.31	$0.80

Table AC35. COMFEN site energy, generic NORTH façade case, NO daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	28.67	11.62	10.12	10.73	61.13	$1.40
B	1, clear	absorbing	30.44	10.46	9.45	10.73	61.08	$1.36
C	1, clear	low-e VT35	22.74	8.49	7.16	10.73	49.13	$1.13
D	1, clear	low-e VT50	22.12	9.82	7.76	10.73	50.43	$1.19
E	1, clear	low-e VT70	21.11	10.73	8.28	10.73	50.85	$1.23
F	1, clear	spec. sel. VT40	33.53	8.84	8.50	10.73	61.60	$1.30
G	1, clear	spec. sel. VT70	28.30	9.71	8.53	10.73	57.27	$1.28
H	1, bronze	none	30.78	10.24	9.32	10.73	61.07	$1.35
I	1, bronze	low-e VT35	23.04	8.26	7.09	10.73	49.12	$1.13
J	1, bronze	low-e VT50	22.81	9.27	7.51	10.73	50.32	$1.17
K	1, bronze	low-e VT70	22.29	9.78	7.80	10.73	50.61	$1.20
L	1, bronze	spec. sel. VT40	33.81	8.69	8.42	10.73	61.65	$1.30
M	1, bronze	spec. sel. VT70	29.14	9.18	8.25	10.73	57.30	$1.26
N	2, clear	none	19.64	11.50	8.79	10.73	50.66	$1.26
O	2, clear	low-e VT35	19.23	8.82	7.19	10.73	45.97	$1.11
P	2, clear	low-e VT50	18.76	9.98	7.59	10.73	47.06	$1.16
Q	2, clear	low-e VT70	18.05	10.66	7.96	10.73	47.40	$1.19
R	2, clear	spec. sel. VT40	23.85	9.75	8.11	10.73	52.44	$1.22
S	2, clear	spec. sel. VT70	21.63	10.19	8.12	10.73	50.66	$1.21
T	2, bronze	none	23.51	9.95	8.16	10.73	52.35	$1.23
U	2, bronze	low-e VT35	19.86	8.41	7.04	10.73	46.03	$1.10
V	2, bronze	low-e VT50	19.77	8.66	7.12	10.73	46.28	$1.11
W	2, bronze	low-e VT70	19.44	8.98	7.24	10.73	46.39	$1.12
X	2, bronze	spec. sel. VT40	24.96	9.07	7.70	10.73	52.46	$1.20
Y	2, bronze	spec. sel. VT70	22.87	9.33	7.64	10.73	50.57	$1.18
Z	2, clear	factory low-e IGU VT66	19.81	8.59	6.99	10.73	46.12	$1.10

Table AC36. COMFEN site energy, generic NORTH façade case, daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	33.02	9.77	8.57	2.81	54.18	$1.06
B	1, clear	absorbing	34.19	8.73	7.90	3.79	54.60	$1.05
C	1, clear	low-e VT35	25.15	7.05	6.32	5.30	43.82	$0.90
D	1, clear	low-e VT50	25.58	7.39	6.35	3.93	43.24	$0.87
E	1, clear	low-e VT70	25.19	8.11	6.62	3.14	43.07	$0.87
F	1, clear	spec. sel. VT40	37.02	7.23	6.97	4.45	55.67	$1.02
G	1, clear	spec. sel. VT70	32.65	7.86	7.00	3.17	50.69	$0.95
H	1, bronze	none	34.59	8.51	7.77	3.76	54.63	$1.04
I	1, bronze	low-e VT35	24.47	7.39	6.58	7.45	45.89	$0.98
J	1, bronze	low-e VT50	25.06	7.33	6.49	5.93	44.81	$0.93
K	1, bronze	low-e VT70	25.35	7.44	6.41	4.50	43.70	$0.89
L	1, bronze	spec. sel. VT40	36.03	7.58	7.32	6.67	57.61	$1.11
M	1, bronze	spec. sel. VT70	32.45	7.50	6.73	4.59	51.27	$0.97
N	2, clear	none	23.57	9.51	7.27	2.97	43.32	$0.92
O	2, clear	low-e VT35	21.24	7.48	6.44	5.85	41.01	$0.89
P	2, clear	low-e VT50	21.67	7.60	6.36	4.34	39.96	$0.85
Q	2, clear	low-e VT70	21.66	8.05	6.48	3.41	39.60	$0.83
R	2, clear	spec. sel. VT40	26.78	7.54	6.50	5.03	45.86	$0.93
S	2, clear	spec. sel. VT70	25.43	8.27	6.61	3.45	43.76	$0.89
T	2, bronze	none	26.83	8.16	6.66	4.20	45.86	$0.92
U	2, bronze	low-e VT35	21.01	7.65	6.62	7.96	43.23	$0.97
V	2, bronze	low-e VT50	21.41	7.57	6.53	6.74	42.26	$0.93
W	2, bronze	low-e VT70	21.73	7.49	6.39	5.22	40.83	$0.88
X	2, bronze	spec. sel. VT40	26.74	7.53	6.64	7.41	48.31	$1.01
Y	2, bronze	spec. sel. VT70	25.51	7.24	6.37	5.32	44.45	$0.91
Z	2, clear	factory low-e IGU VT66	23.56	6.83	5.90	3.36	39.65	$0.79

Table AC37. COMFEN site energy, generic WEST façade case, NO daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	17.16	19.79	21.33	10.73	69.01	$1.95
B	1, clear	absorbing	20.29	16.72	18.42	10.73	66.17	$1.78
C	1, clear	low-e VT35	17.94	11.97	11.19	10.73	51.83	$1.34
D	1, clear	low-e VT50	16.22	13.76	13.00	10.73	53.71	$1.45
E	1, clear	low-e VT70	13.97	16.10	15.27	10.73	56.07	$1.58
F	1, clear	spec. sel. VT40	26.08	12.60	14.27	10.73	63.68	$1.55
G	1, clear	spec. sel. VT70	20.53	14.31	15.10	10.73	60.68	$1.58
H	1, bronze	none	20.96	16.17	17.88	10.73	65.75	$1.75
I	1, bronze	low-e VT35	18.52	11.52	11.06	10.73	51.83	$1.33
J	1, bronze	low-e VT50	17.60	12.57	12.11	10.73	53.01	$1.39
K	1, bronze	low-e VT70	16.27	13.86	13.35	10.73	54.21	$1.46
L	1, bronze	spec. sel. VT40	26.62	12.30	14.07	10.73	63.72	$1.54
M	1, bronze	spec. sel. VT70	22.19	13.07	14.03	10.73	60.02	$1.52
N	2, clear	none	10.96	19.04	18.34	10.73	59.08	$1.76
O	2, clear	low-e VT35	14.30	12.92	12.06	10.73	50.01	$1.37
P	2, clear	low-e VT50	13.06	14.32	13.38	10.73	51.49	$1.45
Q	2, clear	low-e VT70	11.54	16.05	15.00	10.73	53.31	$1.55
R	2, clear	spec. sel. VT40	16.38	14.68	14.90	10.73	56.69	$1.55
S	2, clear	spec. sel. VT70	14.34	15.42	15.16	10.73	55.65	$1.56
T	2, bronze	none	15.89	15.06	15.05	10.73	56.73	$1.56
U	2, bronze	low-e VT35	15.69	11.76	11.01	10.73	49.19	$1.31
V	2, bronze	low-e VT50	15.01	12.54	11.76	10.73	50.03	$1.35
W	2, bronze	low-e VT70	14.06	13.49	12.65	10.73	50.93	$1.41
X	2, bronze	spec. sel. VT40	18.55	12.89	13.12	10.73	55.29	$1.45
Y	2, bronze	spec. sel. VT70	16.81	13.24	13.09	10.73	53.87	$1.44
Z	2, clear	factory low-e IGU VT66	14.55	12.61	11.39	10.73	49.27	$1.34

Table AC38. COMFEN site energy, generic WEST façade case, daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	20.33	17.54	19.68	2.59	60.13	$1.57
B	1, clear	absorbing	23.54	14.64	16.78	3.17	58.13	$1.42
C	1, clear	low-e VT35	21.06	10.01	9.64	4.11	44.81	$1.03
D	1, clear	low-e VT50	19.51	11.55	11.38	3.26	45.70	$1.10
E	1, clear	low-e VT70	17.22	13.73	13.57	2.79	47.31	$1.21
F	1, clear	spec. sel. VT40	29.72	10.76	12.68	3.58	56.74	$1.23
G	1, clear	spec. sel. VT70	24.28	12.21	13.47	2.81	52.77	$1.22
H	1, bronze	none	24.28	14.11	16.28	3.16	57.83	$1.40
I	1, bronze	low-e VT35	20.97	9.94	9.65	5.64	46.20	$1.08
J	1, bronze	low-e VT50	20.44	10.67	10.57	4.49	46.17	$1.09
K	1, bronze	low-e VT70	19.35	11.73	11.77	3.61	46.46	$1.13
L	1, bronze	spec. sel. VT40	29.54	10.73	12.55	4.99	57.82	$1.27
M	1, bronze	spec. sel. VT70	25.60	11.15	12.43	3.67	52.84	$1.19
N	2, clear	none	13.70	16.60	16.67	2.68	49.65	$1.37
O	2, clear	low-e VT35	16.98	10.95	10.52	4.44	42.89	$1.06
P	2, clear	low-e VT50	15.98	12.10	11.77	3.50	43.36	$1.10
Q	2, clear	low-e VT70	14.49	13.66	13.34	2.95	44.44	$1.17
R	2, clear	spec. sel. VT40	19.20	12.69	13.31	3.93	49.14	$1.22
S	2, clear	spec. sel. VT70	17.53	13.17	13.54	2.98	47.21	$1.19
T	2, bronze	none	18.92	12.95	13.44	3.41	48.72	$1.21
U	2, bronze	low-e VT35	17.77	10.27	9.64	6.15	43.84	$1.07
V	2, bronze	low-e VT50	17.48	10.74	10.26	5.05	43.53	$1.07
W	2, bronze	low-e VT70	16.85	11.43	11.08	4.05	43.40	$1.08
X	2, bronze	spec. sel. VT40	20.89	11.34	11.67	5.61	49.52	$1.19
Y	2, bronze	spec. sel. VT70	19.73	11.29	11.50	4.11	46.63	$1.12
Z	2, clear	factory low-e IGU VT66	18.11	10.40	9.78	2.92	41.21	$0.98

Table AC39. COMFEN site energy, generic EAST façade case, NO daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	16.85	19.02	19.65	10.73	66.25	$1.86
B	1, clear	absorbing	20.05	15.99	16.90	10.73	63.67	$1.70
C	1, clear	low-e VT35	17.61	11.58	10.71	10.73	50.63	$1.31
D	1, clear	low-e VT50	15.86	13.30	12.36	10.73	52.25	$1.41
E	1, clear	low-e VT70	13.60	15.59	14.47	10.73	54.39	$1.53
F	1, clear	spec. sel. VT40	25.94	12.10	13.00	10.73	61.76	$1.49
G	1, clear	spec. sel. VT70	20.29	13.75	13.98	10.73	58.75	$1.52
H	1, bronze	none	20.71	15.46	16.40	10.73	63.29	$1.67
I	1, bronze	low-e VT35	18.14	11.09	10.56	10.73	50.53	$1.29
J	1, bronze	low-e VT50	17.20	12.10	11.52	10.73	51.55	$1.35
K	1, bronze	low-e VT70	15.85	13.34	12.69	10.73	52.61	$1.42
L	1, bronze	spec. sel. VT40	26.44	11.79	12.78	10.73	61.74	$1.48
M	1, bronze	spec. sel. VT70	21.90	12.56	12.98	10.73	58.17	$1.46
N	2, clear	none	10.60	18.39	17.24	10.73	56.97	$1.70
O	2, clear	low-e VT35	13.88	12.44	11.63	10.73	48.68	$1.33
P	2, clear	low-e VT50	12.63	13.82	12.89	10.73	50.07	$1.41
Q	2, clear	low-e VT70	11.10	15.53	14.41	10.73	51.77	$1.51
R	2, clear	spec. sel. VT40	16.05	14.12	13.98	10.73	54.89	$1.49
S	2, clear	spec. sel. VT70	14.00	14.85	14.35	10.73	53.93	$1.51
T	2, bronze	none	15.61	14.53	14.10	10.73	54.97	$1.51
U	2, bronze	low-e VT35	15.27	11.32	10.66	10.73	47.98	$1.28
V	2, bronze	low-e VT50	14.59	12.10	11.35	10.73	48.77	$1.32
W	2, bronze	low-e VT70	13.63	13.03	12.19	10.73	49.59	$1.37
X	2, bronze	spec. sel. VT40	18.31	12.44	12.30	10.73	53.78	$1.40
Y	2, bronze	spec. sel. VT70	16.47	12.75	12.37	10.73	52.33	$1.40
Z	2, clear	factory low-e IGU VT66	14.31	12.26	10.93	10.73	48.23	$1.31

Table AC40. COMFEN site energy, generic EAST façade case, daylight controls, Wash., DC

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	19.87	16.86	18.24	2.79	57.76	$1.50
B	1, clear	absorbing	23.20	14.13	15.52	3.48	56.33	$1.37
C	1, clear	low-e VT35	20.63	9.81	9.41	4.45	44.29	$1.02
D	1, clear	low-e VT50	19.04	11.30	11.03	3.57	44.94	$1.08
E	1, clear	low-e VT70	16.67	13.36	13.07	3.05	46.15	$1.18
F	1, clear	spec. sel. VT40	29.40	10.42	11.64	3.91	55.37	$1.19
G	1, clear	spec. sel. VT70	23.87	11.84	12.62	3.07	51.40	$1.19
H	1, bronze	none	23.95	13.63	15.04	3.46	56.07	$1.34
I	1, bronze	low-e VT35	20.52	9.69	9.33	5.97	45.52	$1.06
J	1, bronze	low-e VT50	19.94	10.42	10.25	4.83	45.44	$1.08
K	1, bronze	low-e VT70	18.81	11.44	11.37	3.94	45.56	$1.11
L	1, bronze	spec. sel. VT40	29.28	10.38	11.46	5.33	56.45	$1.23
M	1, bronze	spec. sel. VT70	25.17	10.84	11.63	4.00	51.65	$1.16
N	2, clear	none	13.25	16.11	15.85	2.91	48.12	$1.33
O	2, clear	low-e VT35	16.46	10.67	10.38	4.78	42.29	$1.05
P	2, clear	low-e VT50	15.45	11.80	11.58	3.83	42.66	$1.09
Q	2, clear	low-e VT70	13.94	13.33	13.04	3.23	43.53	$1.16
R	2, clear	spec. sel. VT40	18.79	12.32	12.67	4.28	48.06	$1.19
S	2, clear	spec. sel. VT70	17.04	12.81	13.00	3.26	46.11	$1.17
T	2, bronze	none	18.53	12.61	12.77	3.74	47.64	$1.19
U	2, bronze	low-e VT35	17.31	10.00	9.47	6.46	43.24	$1.06
V	2, bronze	low-e VT50	16.98	10.49	10.11	5.39	42.97	$1.06
W	2, bronze	low-e VT70	16.31	11.15	10.89	4.39	42.74	$1.07
X	2, bronze	spec. sel. VT40	20.59	11.04	11.03	5.94	48.60	$1.17
Y	2, bronze	spec. sel. VT70	19.29	11.02	11.06	4.46	45.83	$1.11
Z	2, clear	factory low-e IGU VT66	17.72	10.25	9.59	3.20	40.76	$0.97

Table AC41. COMFEN site energy, generic four side AVERAGE, NO daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	0.08	41.23	15.26	10.73	67.30	$1.80
B	1, clear	absorbing	0.09	37.13	13.31	10.73	61.26	$1.64
C	1, clear	low-e VT35	0.07	29.07	9.03	10.73	48.90	$1.31
D	1, clear	low-e VT50	0.06	31.86	10.19	10.73	52.84	$1.41
E	1, clear	low-e VT70	0.06	35.07	11.70	10.73	57.55	$1.54
F	1, clear	spec. sel. VT40	0.12	31.36	10.55	10.73	52.76	$1.41
G	1, clear	spec. sel. VT70	0.09	33.56	11.30	10.73	55.68	$1.49
H	1, bronze	none	0.10	36.39	12.93	10.73	60.15	$1.61
I	1, bronze	low-e VT35	0.07	28.31	8.89	10.73	48.00	$1.28
J	1, bronze	low-e VT50	0.07	30.10	9.57	10.73	50.46	$1.35
K	1, bronze	low-e VT70	0.06	31.91	10.36	10.73	53.06	$1.42
L	1, bronze	spec. sel. VT40	0.13	30.81	10.38	10.73	52.05	$1.39
M	1, bronze	spec. sel. VT70	0.09	31.70	10.53	10.73	53.05	$1.42
N	2, clear	none	0.05	38.97	13.67	10.73	63.42	$1.69
O	2, clear	low-e VT35	0.06	30.01	9.59	10.73	50.38	$1.35
P	2, clear	low-e VT50	0.05	32.22	10.48	10.73	53.48	$1.43
Q	2, clear	low-e VT70	0.05	34.56	11.57	10.73	56.91	$1.52
R	2, clear	spec. sel. VT40	0.07	33.33	11.24	10.73	55.37	$1.48
S	2, clear	spec. sel. VT70	0.06	34.21	11.56	10.73	56.55	$1.51
T	2, bronze	none	0.07	34.06	11.40	10.73	56.25	$1.50
U	2, bronze	low-e VT35	0.06	28.40	8.95	10.73	48.14	$1.29
V	2, bronze	low-e VT50	0.06	29.49	9.39	10.73	49.67	$1.33
W	2, bronze	low-e VT70	0.05	31.06	9.98	10.73	51.83	$1.38
X	2, bronze	spec. sel. VT40	0.08	30.83	10.08	10.73	51.72	$1.38
Y	2, bronze	spec. sel. VT70	0.07	31.14	10.13	10.73	52.07	$1.39
Z	2, clear	factory low-e IGU VT66	0.06	29.77	9.22	10.73	49.78	$1.33

Table AC42. COMFEN site energy, generic four side AVERAGE, daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	0.10	37.59	13.70	2.37	53.76	$1.44
B	1, clear	absorbing	0.12	33.69	11.81	2.80	48.41	$1.29
C	1, clear	low-e VT35	0.08	25.91	8.05	3.62	37.66	$1.01
D	1, clear	low-e VT50	0.07	28.09	8.98	2.87	40.01	$1.07
E	1, clear	low-e VT70	0.07	30.99	10.21	2.52	43.78	$1.17
F	1, clear	spec. sel. VT40	0.16	27.61	9.20	3.14	40.10	$1.07
G	1, clear	spec. sel. VT70	0.11	29.71	9.86	2.53	42.22	$1.13
H	1, bronze	none	0.12	32.67	11.40	2.79	46.97	$1.25
I	1, bronze	low-e VT35	0.08	25.86	8.07	5.27	39.27	$1.05
J	1, bronze	low-e VT50	0.08	26.85	8.56	4.00	39.49	$1.05
K	1, bronze	low-e VT70	0.07	28.26	9.17	3.16	40.66	$1.09
L	1, bronze	spec. sel. VT40	0.15	27.64	9.20	4.54	41.54	$1.11
M	1, bronze	spec. sel. VT70	0.11	27.92	9.26	3.21	40.50	$1.08
N	2, clear	none	0.06	35.01	12.10	2.44	49.61	$1.33
O	2, clear	low-e VT35	0.06	27.01	8.64	3.95	39.66	$1.06
P	2, clear	low-e VT50	0.06	28.52	9.31	3.07	40.96	$1.09
Q	2, clear	low-e VT70	0.05	30.56	10.18	2.63	43.43	$1.16
R	2, clear	spec. sel. VT40	0.08	29.89	10.03	3.46	43.46	$1.16
S	2, clear	spec. sel. VT70	0.07	30.30	10.15	2.65	43.17	$1.15
T	2, bronze	none	0.08	30.15	10.05	3.00	43.28	$1.16
U	2, bronze	low-e VT35	0.06	26.19	8.19	5.85	40.29	$1.08
V	2, bronze	low-e VT50	0.06	26.78	8.51	4.61	39.97	$1.07
W	2, bronze	low-e VT70	0.06	27.61	8.91	3.57	40.15	$1.07
X	2, bronze	spec. sel. VT40	0.08	28.16	9.13	5.25	42.62	$1.14
Y	2, bronze	spec. sel. VT70	0.08	27.78	9.04	3.63	40.53	$1.08
Z	2, clear	factory low-e IGU VT66	0.07	26.22	8.11	2.61	37.01	$0.99

Table AC43. COMFEN site energy, generic SOUTH façade case, NO daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.08	40.91	10.36	10.73	62.08	$1.66
B	1, clear	absorbing	0.09	37.05	9.49	10.73	57.36	$1.53
C	1, clear	low-e VT35	0.06	28.58	7.17	10.73	46.54	$1.24
D	1, clear	low-e VT50	0.06	32.19	7.89	10.73	50.87	$1.36
E	1, clear	low-e VT70	0.06	35.28	8.62	10.73	54.69	$1.46
F	1, clear	spec. sel. VT40	0.11	31.43	8.19	10.73	50.45	$1.35
G	1, clear	spec. sel. VT70	0.08	33.64	8.53	10.73	52.98	$1.41
H	1, bronze	none	0.09	36.28	9.31	10.73	56.41	$1.51
I	1, bronze	low-e VT35	0.07	27.78	7.08	10.73	45.65	$1.22
J	1, bronze	low-e VT50	0.06	30.34	7.53	10.73	48.67	$1.30
K	1, bronze	low-e VT70	0.06	32.15	7.94	10.73	50.88	$1.36
L	1, bronze	spec. sel. VT40	0.11	30.87	8.09	10.73	49.79	$1.33
M	1, bronze	spec. sel. VT70	0.09	31.74	8.11	10.73	50.67	$1.35
N	2, clear	none	0.05	38.62	9.36	10.73	58.76	$1.57
O	2, clear	low-e VT35	0.05	29.33	7.24	10.73	47.35	$1.26
P	2, clear	low-e VT50	0.05	32.35	7.86	10.73	50.99	$1.36
Q	2, clear	low-e VT70	0.05	34.54	8.34	10.73	53.66	$1.43
R	2, clear	spec. sel. VT40	0.07	33.55	8.32	10.73	52.67	$1.41
S	2, clear	spec. sel. VT70	0.06	34.32	8.42	10.73	53.53	$1.43
T	2, bronze	none	0.07	34.00	8.38	10.73	53.18	$1.42
U	2, bronze	low-e VT35	0.06	27.84	7.09	10.73	45.72	$1.22
V	2, bronze	low-e VT50	0.06	28.81	7.18	10.73	46.78	$1.25
W	2, bronze	low-e VT70	0.05	31.16	7.60	10.73	49.55	$1.32
X	2, bronze	spec. sel. VT40	0.07	31.09	7.76	10.73	49.66	$1.33
Y	2, bronze	spec. sel. VT70	0.06	31.35	7.75	10.73	49.90	$1.33
Z	2, clear	factory low-e IGU VT66	0.05	29.34	7.23	10.73	47.36	$1.26

Table AC44. COMFEN site energy, generic SOUTH façade case, daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.08	37.28	8.81	2.33	48.50	$1.30
B	1, clear	absorbing	0.09	33.54	8.02	2.62	44.27	$1.18
C	1, clear	low-e VT35	0.07	25.64	6.73	3.07	35.51	$0.95
D	1, clear	low-e VT50	0.07	27.72	6.85	2.66	37.29	$1.00
E	1, clear	low-e VT70	0.06	30.30	6.97	2.44	39.77	$1.06
F	1, clear	spec. sel. VT40	0.12	27.00	6.76	2.80	36.68	$0.98
G	1, clear	spec. sel. VT70	0.09	29.94	7.05	2.45	39.53	$1.06
H	1, bronze	none	0.09	32.76	7.83	2.61	43.30	$1.16
I	1, bronze	low-e VT35	0.07	25.35	6.78	4.31	36.51	$0.97
J	1, bronze	low-e VT50	0.07	26.36	6.83	3.29	36.55	$0.98
K	1, bronze	low-e VT70	0.07	27.77	6.89	2.82	37.54	$1.00
L	1, bronze	spec. sel. VT40	0.12	26.89	6.88	3.66	37.56	$1.00
M	1, bronze	spec. sel. VT70	0.09	27.34	6.83	2.84	37.11	$0.99
N	2, clear	none	0.05	34.89	7.80	2.39	45.13	$1.21
O	2, clear	low-e VT35	0.06	26.50	6.83	3.27	36.66	$0.98
P	2, clear	low-e VT50	0.06	27.98	6.90	2.77	37.70	$1.01
Q	2, clear	low-e VT70	0.05	29.79	6.97	2.52	39.33	$1.05
R	2, clear	spec. sel. VT40	0.07	29.17	7.07	2.98	39.29	$1.05
S	2, clear	spec. sel. VT70	0.06	29.57	6.95	2.53	39.11	$1.04
T	2, bronze	none	0.07	29.46	7.03	2.73	39.30	$1.05
U	2, bronze	low-e VT35	0.06	25.67	6.85	4.95	37.53	$1.00
V	2, bronze	low-e VT50	0.06	26.21	6.85	3.74	36.86	$0.98
W	2, bronze	low-e VT70	0.06	27.06	6.85	3.05	37.02	$0.99
X	2, bronze	spec. sel. VT40	0.08	27.52	7.01	4.31	38.92	$1.04
Y	2, bronze	spec. sel. VT70	0.07	27.22	6.87	3.08	37.24	$0.99
Z	2, clear	factory low-e IGU VT66	0.06	26.14	6.58	2.50	35.28	$0.94

Table AC45. COMFEN site energy, generic NORTH façade case, NO daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.14	31.76	9.70	10.73	52.34	$1.40
B	1, clear	absorbing	0.16	29.54	8.87	10.73	49.30	$1.32
C	1, clear	low-e VT35	0.09	25.31	7.27	10.73	43.40	$1.16
D	1, clear	low-e VT50	0.09	26.50	7.52	10.73	44.84	$1.20
E	1, clear	low-e VT70	0.09	28.23	8.11	10.73	47.15	$1.26
F	1, clear	spec. sel. VT40	0.20	26.61	7.81	10.73	45.35	$1.21
G	1, clear	spec. sel. VT70	0.13	27.92	8.05	10.73	46.83	$1.25
H	1, bronze	none	0.16	29.29	8.73	10.73	48.91	$1.30
I	1, bronze	low-e VT35	0.09	24.87	7.23	10.73	42.92	$1.15
J	1, bronze	low-e VT50	0.09	25.60	7.38	10.73	43.79	$1.17
K	1, bronze	low-e VT70	0.09	26.45	7.55	10.73	44.82	$1.20
L	1, bronze	spec. sel. VT40	0.20	26.28	7.73	10.73	44.94	$1.20
M	1, bronze	spec. sel. VT70	0.14	26.86	7.72	10.73	45.45	$1.21
N	2, clear	none	0.09	30.65	8.69	10.73	50.16	$1.34
O	2, clear	low-e VT35	0.08	25.73	7.40	10.73	43.94	$1.17
P	2, clear	low-e VT50	0.07	26.64	7.59	10.73	45.03	$1.20
Q	2, clear	low-e VT70	0.07	27.94	8.03	10.73	46.78	$1.25
R	2, clear	spec. sel. VT40	0.10	26.70	7.64	10.73	45.16	$1.21
S	2, clear	spec. sel. VT70	0.09	27.48	7.96	10.73	46.26	$1.23
T	2, bronze	none	0.11	28.02	7.90	10.73	46.76	$1.25
U	2, bronze	low-e VT35	0.08	24.93	7.25	10.73	42.99	$1.15
V	2, bronze	low-e VT50	0.08	25.45	7.35	10.73	43.61	$1.16
W	2, bronze	low-e VT70	0.08	26.07	7.46	10.73	44.33	$1.18
X	2, bronze	spec. sel. VT40	0.11	25.52	7.39	10.73	43.75	$1.17
Y	2, bronze	spec. sel. VT70	0.10	25.83	7.44	10.73	44.09	$1.18
Z	2, clear	factory low-e IGU VT66	0.08	25.35	7.23	10.73	43.38	$1.16

Table AC46. COMFEN site energy, generic NORTH façade case, daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.19	28.14	8.16	2.41	38.91	$1.04
B	1, clear	absorbing	0.21	26.28	7.43	2.98	36.90	$0.98
C	1, clear	low-e VT35	0.10	22.56	6.63	4.23	33.53	$0.89
D	1, clear	low-e VT50	0.10	23.28	6.72	3.07	33.18	$0.89
E	1, clear	low-e VT70	0.10	24.61	6.95	2.60	34.25	$0.91
F	1, clear	spec. sel. VT40	0.27	22.76	6.72	3.48	33.22	$0.88
G	1, clear	spec. sel. VT70	0.18	23.57	6.79	2.62	33.15	$0.88
H	1, bronze	none	0.22	24.92	7.12	2.96	35.22	$0.94
I	1, bronze	low-e VT35	0.10	23.15	6.85	6.60	36.70	$0.98
J	1, bronze	low-e VT50	0.10	23.13	6.82	4.81	34.85	$0.93
K	1, bronze	low-e VT70	0.10	23.43	6.80	3.52	33.85	$0.90
L	1, bronze	spec. sel. VT40	0.24	23.33	6.95	5.61	36.13	$0.96
M	1, bronze	spec. sel. VT70	0.18	23.05	6.79	3.60	33.61	$0.90
N	2, clear	none	0.10	26.02	7.18	2.50	35.80	$0.96
O	2, clear	low-e VT35	0.08	23.20	6.83	4.72	34.85	$0.93
P	2, clear	low-e VT50	0.08	23.53	6.82	3.39	33.82	$0.90
Q	2, clear	low-e VT70	0.08	24.37	6.94	2.75	34.14	$0.91
R	2, clear	spec. sel. VT40	0.12	24.04	7.02	3.98	35.16	$0.94
S	2, clear	spec. sel. VT70	0.11	24.03	6.88	2.77	33.79	$0.90
T	2, bronze	none	0.12	24.00	6.89	3.27	34.29	$0.91
U	2, bronze	low-e VT35	0.08	23.48	6.94	7.24	37.74	$1.01
V	2, bronze	low-e VT50	0.08	23.35	6.89	5.71	36.03	$0.96
W	2, bronze	low-e VT70	0.09	23.31	6.83	4.16	34.38	$0.92
X	2, bronze	spec. sel. VT40	0.12	23.87	7.03	6.55	37.57	$1.00
Y	2, bronze	spec. sel. VT70	0.11	23.21	6.84	4.25	34.41	$0.92
Z	2, clear	factory low-e IGU VT66	0.10	21.98	6.38	2.72	31.18	$0.83

Table AC47. COMFEN site energy, generic WEST façade case, NO daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.06	46.18	21.06	10.73	78.04	$2.08
B	1, clear	absorbing	0.08	40.99	17.84	10.73	69.65	$1.86
C	1, clear	low-e VT35	0.07	31.16	10.84	10.73	52.80	$1.41
D	1, clear	low-e VT50	0.06	34.37	12.74	10.73	57.90	$1.55
E	1, clear	low-e VT70	0.05	38.34	15.17	10.73	64.30	$1.72
F	1, clear	spec. sel. VT40	0.11	33.71	13.34	10.73	57.90	$1.55
G	1, clear	spec. sel. VT70	0.08	36.32	14.53	10.73	61.67	$1.65
H	1, bronze	none	0.08	40.02	17.25	10.73	68.08	$1.82
I	1, bronze	low-e VT35	0.07	30.27	10.60	10.73	51.67	$1.38
J	1, bronze	low-e VT50	0.07	32.20	11.70	10.73	54.70	$1.46
K	1, bronze	low-e VT70	0.06	34.50	13.06	10.73	58.35	$1.56
L	1, bronze	spec. sel. VT40	0.12	33.06	13.09	10.73	57.00	$1.52
M	1, bronze	spec. sel. VT70	0.09	34.07	13.34	10.73	58.23	$1.55
N	2, clear	none	0.04	43.32	18.61	10.73	72.69	$1.94
O	2, clear	low-e VT35	0.06	32.48	11.82	10.73	55.09	$1.47
P	2, clear	low-e VT50	0.05	34.91	13.24	10.73	58.93	$1.57
Q	2, clear	low-e VT70	0.04	37.82	15.02	10.73	63.61	$1.70
R	2, clear	spec. sel. VT40	0.06	36.53	14.67	10.73	61.99	$1.66
S	2, clear	spec. sel. VT70	0.05	37.49	15.07	10.73	63.34	$1.69
T	2, bronze	none	0.06	37.08	14.84	10.73	62.71	$1.68
U	2, bronze	low-e VT35	0.06	30.39	10.67	10.73	51.85	$1.38
V	2, bronze	low-e VT50	0.06	31.82	11.47	10.73	54.08	$1.44
W	2, bronze	low-e VT70	0.06	33.48	12.43	10.73	56.70	$1.51
X	2, bronze	spec. sel. VT40	0.07	33.34	12.71	10.73	56.86	$1.52
Y	2, bronze	spec. sel. VT70	0.07	33.66	12.75	10.73	57.21	$1.53
Z	2, clear	factory low-e IGU VT66	0.05	32.12	11.21	10.73	54.11	$1.45

Table AC48. COMFEN site energy, generic WEST façade case, daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.08	42.41	19.33	2.27	64.08	$1.71
B	1, clear	absorbing	0.10	37.35	16.18	2.64	56.26	$1.50
C	1, clear	low-e VT35	0.08	27.56	9.27	3.43	40.34	$1.08
D	1, clear	low-e VT50	0.07	30.49	11.09	2.70	44.36	$1.18
E	1, clear	low-e VT70	0.06	34.35	13.44	2.39	50.24	$1.34
F	1, clear	spec. sel. VT40	0.14	30.20	11.78	2.96	45.08	$1.20
G	1, clear	spec. sel. VT70	0.10	32.52	12.89	2.40	47.91	$1.28
H	1, bronze	none	0.10	36.36	15.57	2.63	54.66	$1.46
I	1, bronze	low-e VT35	0.08	27.35	9.20	4.96	41.58	$1.11
J	1, bronze	low-e VT50	0.08	28.79	10.19	3.80	42.86	$1.14
K	1, bronze	low-e VT70	0.07	30.73	11.40	2.99	45.19	$1.21
L	1, bronze	spec. sel. VT40	0.14	30.08	11.63	4.30	46.15	$1.23
M	1, bronze	spec. sel. VT70	0.11	30.50	11.77	3.04	45.42	$1.21
N	2, clear	none	0.05	39.41	16.84	2.33	58.62	$1.57
O	2, clear	low-e VT35	0.07	29.01	10.27	3.74	43.09	$1.15
P	2, clear	low-e VT50	0.06	31.10	11.61	2.90	45.67	$1.22
Q	2, clear	low-e VT70	0.05	33.86	13.31	2.49	49.71	$1.33
R	2, clear	spec. sel. VT40	0.07	33.03	13.05	3.27	49.42	$1.32
S	2, clear	spec. sel. VT70	0.06	33.63	13.38	2.50	49.57	$1.32
T	2, bronze	none	0.07	33.39	13.17	2.82	49.45	$1.32
U	2, bronze	low-e VT35	0.07	27.70	9.32	5.48	42.58	$1.14
V	2, bronze	low-e VT50	0.07	28.61	9.99	4.35	43.02	$1.15
W	2, bronze	low-e VT70	0.06	29.85	10.82	3.38	44.11	$1.18
X	2, bronze	spec. sel. VT40	0.09	30.50	11.28	4.92	46.79	$1.25
Y	2, bronze	spec. sel. VT70	0.08	30.17	11.17	3.43	44.86	$1.20
Z	2, clear	factory low-e IGU VT66	0.07	28.17	9.58	2.47	40.29	$1.08

Table AC49. COMFEN site energy, generic EAST façade case, NO daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.04	46.05	19.93	10.73	76.75	$2.05
B	1, clear	absorbing	0.05	40.95	17.01	10.73	68.74	$1.84
C	1, clear	low-e VT35	0.05	31.21	10.85	10.73	52.84	$1.41
D	1, clear	low-e VT50	0.04	34.40	12.60	10.73	57.77	$1.54
E	1, clear	low-e VT70	0.04	38.42	14.88	10.73	64.07	$1.71
F	1, clear	spec. sel. VT40	0.08	33.69	12.84	10.73	57.34	$1.53
G	1, clear	spec. sel. VT70	0.06	36.36	14.09	10.73	61.25	$1.64
H	1, bronze	none	0.05	39.97	16.44	10.73	67.19	$1.80
I	1, bronze	low-e VT35	0.05	30.33	10.64	10.73	51.74	$1.38
J	1, bronze	low-e VT50	0.04	32.26	11.66	10.73	54.69	$1.46
K	1, bronze	low-e VT70	0.04	34.53	12.90	10.73	58.20	$1.55
L	1, bronze	spec. sel. VT40	0.08	33.05	12.59	10.73	56.45	$1.51
M	1, bronze	spec. sel. VT70	0.06	34.11	12.97	10.73	57.86	$1.55
N	2, clear	none	0.03	43.31	18.01	10.73	72.08	$1.93
O	2, clear	low-e VT35	0.04	32.50	11.88	10.73	55.15	$1.47
P	2, clear	low-e VT50	0.03	34.98	13.23	10.73	58.97	$1.58
Q	2, clear	low-e VT70	0.03	37.92	14.91	10.73	63.59	$1.70
R	2, clear	spec. sel. VT40	0.04	36.55	14.32	10.73	61.64	$1.65
S	2, clear	spec. sel. VT70	0.04	37.54	14.78	10.73	63.08	$1.69
T	2, bronze	none	0.05	37.14	14.46	10.73	62.37	$1.67
U	2, bronze	low-e VT35	0.04	30.45	10.80	10.73	52.01	$1.39
V	2, bronze	low-e VT50	0.04	31.88	11.56	10.73	54.21	$1.45
W	2, bronze	low-e VT70	0.03	33.52	12.44	10.73	56.73	$1.52
X	2, bronze	spec. sel. VT40	0.05	33.37	12.46	10.73	56.61	$1.51
Y	2, bronze	spec. sel. VT70	0.04	33.72	12.58	10.73	57.07	$1.52
Z	2, clear	factory low-e IGU VT66	0.05	32.26	11.22	10.73	54.26	$1.45

Table AC50. COMFEN site energy, generic EAST façade case, daylight controls, Miami, FL

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.05	42.55	18.50	2.46	63.57	$1.70
B	1, clear	absorbing	0.06	37.59	15.61	2.96	56.22	$1.50
C	1, clear	low-e VT35	0.06	27.90	9.54	3.76	41.26	$1.10
D	1, clear	low-e VT50	0.05	30.86	11.26	3.03	45.19	$1.21
E	1, clear	low-e VT70	0.04	34.70	13.47	2.65	50.86	$1.36
F	1, clear	spec. sel. VT40	0.10	30.46	11.55	3.30	45.41	$1.21
G	1, clear	spec. sel. VT70	0.07	32.82	12.73	2.66	48.29	$1.29
H	1, bronze	none	0.06	36.62	15.07	2.95	54.71	$1.46
I	1, bronze	low-e VT35	0.05	27.58	9.44	5.23	42.30	$1.13
J	1, bronze	low-e VT50	0.05	29.13	10.39	4.11	43.69	$1.17
K	1, bronze	low-e VT70	0.05	31.12	11.58	3.32	46.06	$1.23
L	1, bronze	spec. sel. VT40	0.10	30.28	11.34	4.60	46.31	$1.24
M	1, bronze	spec. sel. VT70	0.07	30.78	11.65	3.37	45.87	$1.22
N	2, clear	none	0.04	39.73	16.59	2.55	58.91	$1.57
O	2, clear	low-e VT35	0.04	29.34	10.63	4.06	44.06	$1.18
P	2, clear	low-e VT50	0.04	31.47	11.91	3.23	46.64	$1.25
Q	2, clear	low-e VT70	0.03	34.22	13.50	2.78	50.53	$1.35
R	2, clear	spec. sel. VT40	0.05	33.33	12.98	3.60	49.96	$1.33
S	2, clear	spec. sel. VT70	0.04	33.98	13.39	2.80	50.22	$1.34
T	2, bronze	none	0.05	33.77	13.11	3.16	50.09	$1.34
U	2, bronze	low-e VT35	0.04	27.94	9.63	5.72	43.33	$1.16
V	2, bronze	low-e VT50	0.04	28.95	10.33	4.65	43.97	$1.17
W	2, bronze	low-e VT70	0.04	30.23	11.14	3.70	45.11	$1.21
X	2, bronze	spec. sel. VT40	0.06	30.74	11.21	5.20	47.21	$1.26
Y	2, bronze	spec. sel. VT70	0.05	30.51	11.28	3.76	45.61	$1.22
Z	2, clear	factory low-e IGU VT66	0.06	28.60	9.89	2.75	41.30	$1.10

Table AC51. COMFEN site energy, generic four side AVERAGE, NO daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	1.07	42.07	20.49	10.73	74.36	$2.28
B	1, clear	absorbing	1.33	37.41	18.17	10.73	67.65	$2.07
C	1, clear	low-e VT35	0.87	26.83	11.82	10.73	50.25	$1.54
D	1, clear	low-e VT50	0.74	29.80	13.25	10.73	54.51	$1.67
E	1, clear	low-e VT70	0.59	33.49	15.01	10.73	59.81	$1.84
F	1, clear	spec. sel. VT40	1.95	30.89	14.94	10.73	58.51	$1.77
G	1, clear	spec. sel. VT70	1.26	32.60	15.36	10.73	59.95	$1.83
H	1, bronze	none	1.39	36.56	17.76	10.73	66.43	$2.03
I	1, bronze	low-e VT35	0.94	26.16	11.65	10.73	49.47	$1.51
J	1, bronze	low-e VT50	0.85	27.95	12.50	10.73	52.04	$1.59
K	1, bronze	low-e VT70	0.75	30.03	13.48	10.73	54.99	$1.69
L	1, bronze	spec. sel. VT40	2.02	30.43	14.75	10.73	57.92	$1.75
M	1, bronze	spec. sel. VT70	1.43	30.66	14.46	10.73	57.28	$1.74
N	2, clear	none	0.49	38.01	17.40	10.73	66.63	$2.06
O	2, clear	low-e VT35	0.59	27.65	12.18	10.73	51.15	$1.57
P	2, clear	low-e VT50	0.52	29.89	13.23	10.73	54.37	$1.67
Q	2, clear	low-e VT70	0.44	32.54	14.46	10.73	58.17	$1.79
R	2, clear	spec. sel. VT40	0.88	32.12	14.86	10.73	58.59	$1.80
S	2, clear	spec. sel. VT70	0.69	32.72	14.93	10.73	59.08	$1.82
T	2, bronze	none	0.84	32.71	15.03	10.73	59.31	$1.82
U	2, bronze	low-e VT35	0.70	25.58	11.34	10.73	48.35	$1.48
V	2, bronze	low-e VT50	0.64	27.20	12.00	10.73	50.58	$1.55
W	2, bronze	low-e VT70	0.58	28.70	12.68	10.73	52.68	$1.62
X	2, bronze	spec. sel. VT40	1.07	29.38	13.48	10.73	54.66	$1.67
Y	2, bronze	spec. sel. VT70	0.87	29.40	13.31	10.73	54.31	$1.66
Z	2, clear	factory low-e IGU VT66	0.65	26.99	11.70	10.73	50.07	$1.54

Table AC52. COMFEN site energy, generic four side AVERAGE, daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	1.48	38.51	18.65	2.35	60.98	$1.86
B	1, clear	absorbing	1.75	34.07	16.41	2.88	55.10	$1.67
C	1, clear	low-e VT35	1.21	23.46	10.32	3.86	38.86	$1.18
D	1, clear	low-e VT50	1.09	26.01	11.55	2.96	41.62	$1.27
E	1, clear	low-e VT70	0.92	29.82	13.27	2.53	46.54	$1.42
F	1, clear	spec. sel. VT40	2.51	27.79	13.26	3.30	46.86	$1.40
G	1, clear	spec. sel. VT70	1.79	29.17	13.63	2.54	47.13	$1.42
H	1, bronze	none	1.83	33.22	16.00	2.86	53.91	$1.63
I	1, bronze	low-e VT35	1.20	23.39	10.35	5.42	40.36	$1.23
J	1, bronze	low-e VT50	1.15	24.70	11.02	4.27	41.14	$1.25
K	1, bronze	low-e VT70	1.06	26.38	11.83	3.33	42.60	$1.30
L	1, bronze	spec. sel. VT40	2.44	27.86	13.25	4.79	48.34	$1.45
M	1, bronze	spec. sel. VT70	1.89	27.51	12.81	3.39	45.60	$1.37
N	2, clear	none	0.76	34.31	15.59	2.43	53.08	$1.63
O	2, clear	low-e VT35	0.81	24.41	10.77	4.23	40.22	$1.23
P	2, clear	low-e VT50	0.76	26.21	11.64	3.22	41.84	$1.28
Q	2, clear	low-e VT70	0.69	28.59	12.73	2.67	44.68	$1.37
R	2, clear	spec. sel. VT40	1.19	28.63	13.16	3.69	46.66	$1.42
S	2, clear	spec. sel. VT70	1.03	29.22	13.23	2.69	46.16	$1.41
T	2, bronze	none	1.17	29.36	13.32	3.13	46.99	$1.43
U	2, bronze	low-e VT35	0.87	23.43	10.28	5.97	40.56	$1.24
V	2, bronze	low-e VT50	0.85	24.23	10.66	4.88	40.62	$1.24
W	2, bronze	low-e VT70	0.81	25.29	11.20	3.82	41.12	$1.26
X	2, bronze	spec. sel. VT40	1.33	26.62	12.06	5.45	45.45	$1.38
Y	2, bronze	spec. sel. VT70	1.18	26.05	11.76	3.89	42.88	$1.30
Z	2, clear	factory low-e IGU VT66	1.03	23.61	10.22	2.64	37.51	$1.14

Table AC53. COMFEN site energy, generic SOUTH façade case, NO daylight controls, Phoenix,AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.56	44.86	17.04	10.73	73.19	$2.26
B	1, clear	absorbing	0.70	39.68	15.53	10.73	66.64	$2.05
C	1, clear	low-e VT35	0.48	28.07	10.75	10.73	50.03	$1.54
D	1, clear	low-e VT50	0.40	31.43	11.76	10.73	54.31	$1.68
E	1, clear	low-e VT70	0.32	35.57	12.95	10.73	59.57	$1.84
F	1, clear	spec. sel. VT40	1.08	32.31	13.34	10.73	57.46	$1.76
G	1, clear	spec. sel. VT70	0.67	34.42	13.49	10.73	59.30	$1.82
H	1, bronze	none	0.74	38.72	15.26	10.73	65.44	$2.01
I	1, bronze	low-e VT35	0.54	27.28	10.61	10.73	49.16	$1.51
J	1, bronze	low-e VT50	0.47	29.31	11.23	10.73	51.75	$1.59
K	1, bronze	low-e VT70	0.40	31.66	11.91	10.73	54.71	$1.69
L	1, bronze	spec. sel. VT40	1.13	31.83	13.22	10.73	56.91	$1.74
M	1, bronze	spec. sel. VT70	0.77	32.22	12.85	10.73	56.57	$1.74
N	2, clear	none	0.25	40.22	14.16	10.73	65.37	$2.02
O	2, clear	low-e VT35	0.34	28.93	10.78	10.73	50.78	$1.57
P	2, clear	low-e VT50	0.30	31.42	11.47	10.73	53.91	$1.67
Q	2, clear	low-e VT70	0.25	34.31	12.24	10.73	57.53	$1.78
R	2, clear	spec. sel. VT40	0.45	33.83	12.76	10.73	57.78	$1.78
S	2, clear	spec. sel. VT70	0.37	34.52	12.71	10.73	58.32	$1.80
T	2, bronze	none	0.43	34.49	12.88	10.73	58.53	$1.81
U	2, bronze	low-e VT35	0.41	27.00	10.27	10.73	48.40	$1.49
V	2, bronze	low-e VT50	0.37	28.42	10.67	10.73	50.19	$1.55
W	2, bronze	low-e VT70	0.33	30.07	11.11	10.73	52.25	$1.61
X	2, bronze	spec. sel. VT40	0.57	30.84	11.91	10.73	54.04	$1.66
Y	2, bronze	spec. sel. VT70	0.46	30.83	11.69	10.73	53.72	$1.66
Z	2, clear	factory low-e IGU VT66	0.34	28.72	10.44	10.73	50.24	$1.55

Table AC54. COMFEN site energy, generic SOUTH façade case, daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.72	41.15	15.22	2.29	59.39	$1.83
B	1, clear	absorbing	0.88	36.13	13.79	2.61	53.41	$1.64
C	1, clear	low-e VT35	0.67	24.58	9.18	3.05	37.48	$1.15
D	1, clear	low-e VT50	0.55	27.74	10.12	2.65	41.05	$1.26
E	1, clear	low-e VT70	0.45	31.75	11.24	2.42	45.85	$1.41
F	1, clear	spec. sel. VT40	1.38	28.95	11.70	2.80	44.83	$1.36
G	1, clear	spec. sel. VT70	0.89	30.78	11.78	2.43	45.87	$1.40
H	1, bronze	none	0.93	35.16	13.50	2.60	52.19	$1.60
I	1, bronze	low-e VT35	0.71	24.26	9.20	4.12	38.29	$1.17
J	1, bronze	low-e VT50	0.64	25.91	9.70	3.26	39.51	$1.21
K	1, bronze	low-e VT70	0.55	28.09	10.30	2.81	41.76	$1.28
L	1, bronze	spec. sel. VT40	1.41	28.77	11.67	3.59	45.44	$1.38
M	1, bronze	spec. sel. VT70	1.02	28.75	11.22	2.84	43.82	$1.34
N	2, clear	none	0.35	36.42	12.40	2.36	51.53	$1.59
O	2, clear	low-e VT35	0.46	25.52	9.25	3.26	38.48	$1.18
P	2, clear	low-e VT50	0.41	27.75	9.84	2.77	40.77	$1.26
Q	2, clear	low-e VT70	0.35	30.53	10.55	2.50	43.93	$1.35
R	2, clear	spec. sel. VT40	0.60	30.35	11.12	2.99	45.05	$1.38
S	2, clear	spec. sel. VT70	0.50	30.82	11.03	2.51	44.86	$1.38
T	2, bronze	none	0.58	30.90	11.19	2.73	45.40	$1.40
U	2, bronze	low-e VT35	0.53	24.37	9.17	4.75	38.82	$1.19
V	2, bronze	low-e VT50	0.50	25.21	9.18	3.72	38.61	$1.19
W	2, bronze	low-e VT70	0.45	26.55	9.53	3.06	39.59	$1.22
X	2, bronze	spec. sel. VT40	0.71	27.93	10.49	4.22	43.36	$1.33
Y	2, bronze	spec. sel. VT70	0.63	27.42	10.10	3.09	41.24	$1.27
Z	2, clear	factory low-e IGU VT66	0.50	25.03	8.79	2.49	36.81	$1.13

Table AC55. COMFEN site energy, generic NORTH façade case, NO daylight controls, Phoenix,AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	2.46	28.88	13.76	10.73	55.83	$1.68
B	1, clear	absorbing	2.82	27.05	12.87	10.73	53.47	$1.60
C	1, clear	low-e VT35	1.60	22.10	9.55	10.73	43.98	$1.33
D	1, clear	low-e VT50	1.49	23.34	10.13	10.73	45.69	$1.38
E	1, clear	low-e VT70	1.30	24.83	10.81	10.73	47.67	$1.45
F	1, clear	spec. sel. VT40	3.47	24.50	11.69	10.73	50.40	$1.49
G	1, clear	spec. sel. VT70	2.51	24.91	11.52	10.73	49.67	$1.49
H	1, bronze	none	2.89	26.70	12.70	10.73	53.02	$1.58
I	1, bronze	low-e VT35	1.67	21.77	9.43	10.73	43.59	$1.32
J	1, bronze	low-e VT50	1.62	22.53	9.80	10.73	44.68	$1.35
K	1, bronze	low-e VT70	1.52	23.40	10.21	10.73	45.85	$1.39
L	1, bronze	spec. sel. VT40	3.53	24.29	11.59	10.73	50.14	$1.48
M	1, bronze	spec. sel. VT70	2.69	24.09	11.14	10.73	48.64	$1.45
N	2, clear	none	1.21	26.30	11.60	10.73	49.84	$1.52
O	2, clear	low-e VT35	1.16	22.15	9.38	10.73	43.42	$1.32
P	2, clear	low-e VT50	1.08	23.06	9.81	10.73	44.69	$1.36
Q	2, clear	low-e VT70	0.96	24.14	10.28	10.73	46.11	$1.41
R	2, clear	spec. sel. VT40	1.91	24.14	10.84	10.73	47.61	$1.43
S	2, clear	spec. sel. VT70	1.53	24.34	10.75	10.73	47.36	$1.43
T	2, bronze	none	1.84	24.39	10.92	10.73	47.88	$1.44
U	2, bronze	low-e VT35	1.29	20.10	8.86	10.73	40.98	$1.24
V	2, bronze	low-e VT50	1.25	21.97	9.33	10.73	43.28	$1.31
W	2, bronze	low-e VT70	1.18	22.57	9.60	10.73	44.07	$1.34
X	2, bronze	spec. sel. VT40	2.12	23.04	10.31	10.73	46.21	$1.39
Y	2, bronze	spec. sel. VT70	1.77	23.02	10.13	10.73	45.64	$1.38
Z	2, clear	factory low-e IGU VT66	1.33	20.44	8.98	10.73	41.49	$1.26

Table AC56. COMFEN site energy, generic NORTH façade case, daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	3.44	25.69	12.03	2.44	43.60	$1.28
B	1, clear	absorbing	3.68	24.06	11.19	3.22	42.16	$1.23
C	1, clear	low-e VT35	2.10	18.40	8.31	4.86	33.68	$1.00
D	1, clear	low-e VT50	2.19	18.90	8.41	3.36	32.86	$0.97
E	1, clear	low-e VT70	2.07	21.47	9.16	2.68	35.39	$1.05
F	1, clear	spec. sel. VT40	4.35	21.74	10.04	3.91	40.04	$1.15
G	1, clear	spec. sel. VT70	3.54	21.80	9.85	2.71	37.90	$1.10
H	1, bronze	none	3.78	23.71	11.02	3.20	41.72	$1.21
I	1, bronze	low-e VT35	1.97	18.98	8.55	7.16	36.67	$1.09
J	1, bronze	low-e VT50	2.07	19.03	8.56	5.54	35.19	$1.05
K	1, bronze	low-e VT70	2.12	19.17	8.57	3.97	33.82	$1.00
L	1, bronze	spec. sel. VT40	4.09	22.37	10.34	6.32	43.12	$1.25
M	1, bronze	spec. sel. VT70	3.45	21.31	9.52	4.07	38.34	$1.11
N	2, clear	none	1.94	22.96	9.92	2.55	37.37	$1.12
O	2, clear	low-e VT35	1.52	18.75	8.42	5.46	34.14	$1.03
P	2, clear	low-e VT50	1.59	18.90	8.43	3.79	32.71	$0.98
Q	2, clear	low-e VT70	1.61	19.44	8.48	2.90	32.43	$0.97
R	2, clear	spec. sel. VT40	2.50	20.15	9.11	4.57	36.33	$1.07
S	2, clear	spec. sel. VT70	2.30	21.15	9.09	2.93	35.47	$1.05
T	2, bronze	none	2.53	21.43	9.28	3.64	36.89	$1.09
U	2, bronze	low-e VT35	1.48	19.00	8.54	7.73	36.75	$1.11
V	2, bronze	low-e VT50	1.55	18.96	8.51	6.42	35.43	$1.06
W	2, bronze	low-e VT70	1.60	18.87	8.46	4.79	33.71	$1.01
X	2, bronze	spec. sel. VT40	2.50	20.15	9.16	7.14	38.95	$1.15
Y	2, bronze	spec. sel. VT70	2.28	19.33	8.79	4.91	35.31	$1.04
Z	2, clear	factory low-e IGU VT66	2.07	17.66	8.04	2.85	30.62	$0.90

Table AC57. COMFEN site energy, generic WEST façade case, NO daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.61	48.47	26.96	10.73	86.76	$2.68
B	1, clear	absorbing	0.90	42.49	23.26	10.73	77.38	$2.38
C	1, clear	low-e VT35	0.74	29.00	13.77	10.73	54.24	$1.67
D	1, clear	low-e VT50	0.55	32.76	15.96	10.73	60.00	$1.85
E	1, clear	low-e VT70	0.38	37.48	18.74	10.73	67.33	$2.08
F	1, clear	spec. sel. VT40	1.68	34.09	18.12	10.73	64.62	$1.97
G	1, clear	spec. sel. VT70	0.96	36.31	18.97	10.73	66.97	$2.06
H	1, bronze	none	0.98	41.39	22.58	10.73	75.68	$2.33
I	1, bronze	low-e VT35	0.84	28.25	13.53	10.73	53.36	$1.64
J	1, bronze	low-e VT50	0.71	30.48	14.82	10.73	56.74	$1.74
K	1, bronze	low-e VT70	0.56	33.10	16.31	10.73	60.71	$1.87
L	1, bronze	spec. sel. VT40	1.77	33.53	17.82	10.73	63.85	$1.94
M	1, bronze	spec. sel. VT70	1.18	33.87	17.55	10.73	63.33	$1.94
N	2, clear	none	0.25	43.71	22.92	10.73	77.62	$2.40
O	2, clear	low-e VT35	0.46	30.24	14.50	10.73	55.94	$1.72
P	2, clear	low-e VT50	0.37	33.10	16.13	10.73	60.33	$1.86
Q	2, clear	low-e VT70	0.29	36.52	18.09	10.73	65.62	$2.03
R	2, clear	spec. sel. VT40	0.60	35.96	18.54	10.73	65.83	$2.03
S	2, clear	spec. sel. VT70	0.43	36.77	18.73	10.73	66.66	$2.06
T	2, bronze	none	0.54	36.70	18.86	10.73	66.83	$2.06
U	2, bronze	low-e VT35	0.60	28.08	13.31	10.73	52.72	$1.62
V	2, bronze	low-e VT50	0.52	29.68	14.21	10.73	55.14	$1.70
W	2, bronze	low-e VT70	0.43	31.59	15.28	10.73	58.04	$1.79
X	2, bronze	spec. sel. VT40	0.83	32.42	16.36	10.73	60.34	$1.85
Y	2, bronze	spec. sel. VT70	0.65	32.45	16.17	10.73	60.01	$1.85
Z	2, clear	factory low-e IGU VT66	0.46	29.78	14.00	10.73	54.97	$1.69

Table AC58. COMFEN site energy, generic WEST façade case, daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft²-yr
A	1, clear	none	0.87	44.67	24.87	2.26	72.67	$2.23
B	1, clear	absorbing	1.23	38.90	21.23	2.74	64.11	$1.96
C	1, clear	low-e VT35	1.09	25.72	12.04	3.65	42.51	$1.29
D	1, clear	low-e VT50	0.85	29.09	14.07	2.82	46.83	$1.43
E	1, clear	low-e VT70	0.59	33.57	16.73	2.42	53.32	$1.64
F	1, clear	spec. sel. VT40	2.23	30.81	16.24	3.13	52.41	$1.58
G	1, clear	spec. sel. VT70	1.41	32.66	17.00	2.43	53.50	$1.63
H	1, bronze	none	1.34	37.83	20.59	2.73	62.49	$1.91
I	1, bronze	low-e VT35	1.13	25.57	12.00	5.08	43.77	$1.33
J	1, bronze	low-e VT50	1.01	27.33	13.10	4.03	45.47	$1.39
K	1, bronze	low-e VT70	0.84	29.58	14.47	3.16	48.06	$1.47
L	1, bronze	spec. sel. VT40	2.22	30.74	16.09	4.50	53.54	$1.61
M	1, bronze	spec. sel. VT70	1.62	30.54	15.71	3.22	51.08	$1.55
N	2, clear	none	0.36	39.74	20.80	2.33	63.24	$1.95
O	2, clear	low-e VT35	0.69	27.03	12.78	3.98	44.48	$1.36
P	2, clear	low-e VT50	0.56	29.49	14.27	3.06	47.38	$1.46
Q	2, clear	low-e VT70	0.43	32.69	16.19	2.55	51.86	$1.60
R	2, clear	spec. sel. VT40	0.84	32.60	16.65	3.49	53.58	$1.64
S	2, clear	spec. sel. VT70	0.67	33.04	16.81	2.57	53.08	$1.63
T	2, bronze	none	0.80	33.13	16.91	2.97	53.82	$1.65
U	2, bronze	low-e VT35	0.81	25.54	11.82	5.57	43.74	$1.34
V	2, bronze	low-e VT50	0.74	26.73	12.56	4.57	44.61	$1.37
W	2, bronze	low-e VT70	0.65	28.23	13.52	3.61	46.01	$1.41
X	2, bronze	spec. sel. VT40	1.09	29.71	14.68	5.09	50.56	$1.54
Y	2, bronze	spec. sel. VT70	0.94	29.17	14.34	3.67	48.13	$1.47
Z	2, clear	factory low-e IGU VT66	0.79	26.12	12.17	2.52	41.60	$1.27

Table AC59. COMFEN site energy, generic EAST façade case, NO daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.65	46.07	24.19	10.73	81.65	$2.52
B	1, clear	absorbing	0.90	40.44	21.03	10.73	73.10	$2.25
C	1, clear	low-e VT35	0.65	28.14	13.21	10.73	52.73	$1.62
D	1, clear	low-e VT50	0.51	31.67	15.14	10.73	58.05	$1.79
E	1, clear	low-e VT70	0.36	36.07	17.52	10.73	64.69	$2.00
F	1, clear	spec. sel. VT40	1.58	32.66	16.59	10.73	61.56	$1.87
G	1, clear	spec. sel. VT70	0.91	34.77	17.46	10.73	63.87	$1.96
H	1, bronze	none	0.96	39.43	20.47	10.73	71.59	$2.20
I	1, bronze	low-e VT35	0.70	27.32	13.01	10.73	51.76	$1.59
J	1, bronze	low-e VT50	0.61	29.47	14.17	10.73	54.97	$1.69
K	1, bronze	low-e VT70	0.50	31.96	15.50	10.73	58.69	$1.81
L	1, bronze	spec. sel. VT40	1.63	32.06	16.36	10.73	60.78	$1.85
M	1, bronze	spec. sel. VT70	1.08	32.48	16.31	10.73	60.60	$1.86
N	2, clear	none	0.25	41.82	20.91	10.73	73.71	$2.28
O	2, clear	low-e VT35	0.39	29.27	14.07	10.73	54.46	$1.68
P	2, clear	low-e VT50	0.32	31.98	15.50	10.73	58.54	$1.81
Q	2, clear	low-e VT70	0.25	35.21	17.23	10.73	63.42	$1.96
R	2, clear	spec. sel. VT40	0.57	34.55	17.30	10.73	63.16	$1.95
S	2, clear	spec. sel. VT70	0.42	35.27	17.54	10.73	63.96	$1.97
T	2, bronze	none	0.55	35.27	17.46	10.73	64.00	$1.97
U	2, bronze	low-e VT35	0.49	27.16	12.94	10.73	51.31	$1.58
V	2, bronze	low-e VT50	0.43	28.74	13.79	10.73	53.70	$1.66
W	2, bronze	low-e VT70	0.37	30.55	14.73	10.73	56.38	$1.74
X	2, bronze	spec. sel. VT40	0.77	31.22	15.35	10.73	58.07	$1.78
Y	2, bronze	spec. sel. VT70	0.60	31.28	15.24	10.73	57.86	$1.78
Z	2, clear	factory low-e IGU VT66	0.46	29.01	13.40	10.73	53.59	$1.65

Table AC60. COMFEN site energy, generic EAST façade case, daylight controls, Phoenix, AZ

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	0.90	42.52	22.46	2.40	68.27	$2.10
B	1, clear	absorbing	1.19	37.18	19.42	2.94	60.73	$1.86
C	1, clear	low-e VT35	0.98	25.15	11.76	3.88	41.77	$1.27
D	1, clear	low-e VT50	0.77	28.33	13.61	3.02	45.74	$1.40
E	1, clear	low-e VT70	0.56	32.50	15.94	2.59	51.59	$1.59
F	1, clear	spec. sel. VT40	2.09	29.64	15.06	3.35	50.15	$1.51
G	1, clear	spec. sel. VT70	1.31	31.45	15.90	2.61	51.27	$1.56
H	1, bronze	none	1.28	36.18	18.87	2.93	59.25	$1.81
I	1, bronze	low-e VT35	0.96	24.77	11.64	5.33	42.70	$1.30
J	1, bronze	low-e VT50	0.87	26.53	12.73	4.26	44.39	$1.36
K	1, bronze	low-e VT70	0.74	28.67	13.99	3.38	46.78	$1.43
L	1, bronze	spec. sel. VT40	2.06	29.54	14.90	4.74	51.24	$1.54
M	1, bronze	spec. sel. VT70	1.48	29.46	14.79	3.44	49.16	$1.49
N	2, clear	none	0.38	38.10	19.23	2.49	60.20	$1.86
O	2, clear	low-e VT35	0.58	26.34	12.64	4.21	43.77	$1.34
P	2, clear	low-e VT50	0.48	28.70	14.03	3.27	46.49	$1.43
Q	2, clear	low-e VT70	0.38	31.68	15.69	2.74	50.49	$1.56
R	2, clear	spec. sel. VT40	0.79	31.42	15.76	3.71	51.68	$1.59
S	2, clear	spec. sel. VT70	0.64	31.86	15.98	2.76	51.24	$1.57
T	2, bronze	none	0.78	31.97	15.90	3.18	51.84	$1.59
U	2, bronze	low-e VT35	0.67	24.82	11.60	5.83	42.93	$1.32
V	2, bronze	low-e VT50	0.63	26.03	12.37	4.82	43.85	$1.35
W	2, bronze	low-e VT70	0.56	27.49	13.29	3.84	45.17	$1.39
X	2, bronze	spec. sel. VT40	1.01	28.69	13.90	5.34	48.94	$1.50
Y	2, bronze	spec. sel. VT70	0.86	28.27	13.80	3.90	46.83	$1.43
Z	2, clear	factory low-e IGU VT66	0.77	25.65	11.89	2.71	41.01	$1.25

Table AC61. COMFEN site energy, generic four side AVERAGE, NO daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	44.22	13.20	18.92	10.73	87.07	$1.53
B	1, clear	absorbing	48.75	10.82	16.39	10.73	86.69	$1.42
C	1, clear	low-e VT35	41.25	7.75	10.58	10.73	70.32	$1.11
D	1, clear	low-e VT50	38.97	8.97	11.99	10.73	70.66	$1.17
E	1, clear	low-e VT70	35.77	10.64	13.75	10.73	70.90	$1.25
F	1, clear	spec. sel. VT40	56.96	7.91	12.94	10.73	88.53	$1.29
G	1, clear	spec. sel. VT70	47.56	9.24	13.67	10.73	81.20	$1.29
H	1, bronze	none	49.70	10.41	15.94	10.73	86.78	$1.40
I	1, bronze	low-e VT35	42.19	7.35	10.35	10.73	70.63	$1.10
J	1, bronze	low-e VT50	41.01	8.05	11.18	10.73	70.98	$1.14
K	1, bronze	low-e VT70	39.14	8.94	12.16	10.73	70.98	$1.18
L	1, bronze	spec. sel. VT40	57.81	7.64	12.67	10.73	88.85	$1.28
M	1, bronze	spec. sel. VT70	49.98	8.31	12.69	10.73	81.71	$1.25
N	2, clear	none	30.36	12.74	15.97	10.73	69.80	$1.34
O	2, clear	low-e VT35	34.21	8.38	11.14	10.73	64.46	$1.10
P	2, clear	low-e VT50	32.49	9.35	12.16	10.73	64.73	$1.14
Q	2, clear	low-e VT70	30.29	10.61	13.39	10.73	65.02	$1.20
R	2, clear	spec. sel. VT40	39.18	9.43	13.32	10.73	72.65	$1.23
S	2, clear	spec. sel. VT70	35.57	10.03	13.54	10.73	69.88	$1.23
T	2, bronze	none	38.50	9.70	13.40	10.73	72.32	$1.23
U	2, bronze	low-e VT35	36.29	7.55	10.26	10.73	64.83	$1.06
V	2, bronze	low-e VT50	35.40	8.07	10.84	10.73	65.04	$1.09
W	2, bronze	low-e VT70	34.05	8.72	11.51	10.73	65.00	$1.12
X	2, bronze	spec. sel. VT40	42.41	8.15	11.85	10.73	73.14	$1.17
Y	2, bronze	spec. sel. VT70	39.22	8.44	11.83	10.73	70.22	$1.15
Z	2, clear	factory low-e IGU VT66	34.53	8.21	10.61	10.73	64.08	$1.08

Table AC62. COMFEN site energy, generic four side AVERAGE, daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	48.89	11.47	17.22	2.84	80.42	$1.24
B	1, clear	absorbing	53.22	9.30	14.79	3.62	80.93	$1.15
C	1, clear	low-e VT35	45.29	6.37	9.19	4.68	65.53	$0.89
D	1, clear	low-e VT50	43.44	7.37	10.46	3.72	64.99	$0.91
E	1, clear	low-e VT70	40.42	8.89	12.19	3.13	64.62	$0.97
F	1, clear	spec. sel. VT40	61.35	6.56	11.61	4.09	83.62	$1.05
G	1, clear	spec. sel. VT70	52.65	7.62	12.09	3.16	75.52	$1.01
H	1, bronze	none	54.23	8.91	14.37	3.60	81.11	$1.14
I	1, bronze	low-e VT35	45.35	6.28	9.14	6.16	66.93	$0.93
J	1, bronze	low-e VT50	44.72	6.74	9.84	5.08	66.39	$0.92
K	1, bronze	low-e VT70	43.30	7.41	10.67	4.13	65.51	$0.93
L	1, bronze	spec. sel. VT40	61.32	6.60	11.43	5.57	84.92	$1.09
M	1, bronze	spec. sel. VT70	54.31	6.85	11.23	4.19	76.58	$1.01
N	2, clear	none	34.57	10.89	14.41	2.98	62.86	$1.05
O	2, clear	low-e VT35	37.79	7.01	9.81	5.03	59.65	$0.88
P	2, clear	low-e VT50	36.55	7.73	10.68	4.01	58.97	$0.89
Q	2, clear	low-e VT70	34.60	8.83	11.85	3.34	58.63	$0.92
R	2, clear	spec. sel. VT40	42.98	8.01	11.90	4.49	67.38	$0.99
S	2, clear	spec. sel. VT70	40.08	8.38	12.00	3.37	63.83	$0.95
T	2, bronze	none	42.66	8.16	11.89	3.91	66.63	$0.98
U	2, bronze	low-e VT35	39.08	6.55	9.14	6.63	61.41	$0.90
V	2, bronze	low-e VT50	38.67	6.85	9.59	5.63	60.75	$0.89
W	2, bronze	low-e VT70	37.79	7.26	10.14	4.63	59.82	$0.89
X	2, bronze	spec. sel. VT40	45.43	7.11	10.62	6.14	69.30	$0.99
Y	2, bronze	spec. sel. VT70	43.03	7.08	10.45	4.70	65.26	$0.93
Z	2, clear	factory low-e IGU VT66	39.41	6.61	9.08	3.30	58.41	$0.81

Table AC63. COMFEN site energy, generic SOUTH façade case, NO daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	32.69	14.20	16.41	10.73	74.04	$1.41
B	1, clear	absorbing	38.43	11.36	14.49	10.73	75.01	$1.31
C	1, clear	low-e VT35	35.64	8.06	9.76	10.73	64.18	$1.06
D	1, clear	low-e VT50	31.89	9.39	10.82	10.73	62.84	$1.10
E	1, clear	low-e VT70	27.34	11.32	12.21	10.73	61.60	$1.17
F	1, clear	spec. sel. VT40	49.21	8.16	11.96	10.73	80.06	$1.22
G	1, clear	spec. sel. VT70	39.01	9.60	12.36	10.73	71.70	$1.20
H	1, bronze	none	39.63	10.88	14.14	10.73	75.38	$1.29
I	1, bronze	low-e VT35	37.16	7.64	9.65	10.73	65.18	$1.06
J	1, bronze	low-e VT50	35.00	8.39	10.27	10.73	64.40	$1.08
K	1, bronze	low-e VT70	32.09	9.36	11.00	10.73	63.19	$1.11
L	1, bronze	spec. sel. VT40	50.49	7.89	11.81	10.73	80.92	$1.21
M	1, bronze	spec. sel. VT70	42.46	8.58	11.66	10.73	73.43	$1.18
N	2, clear	none	21.08	13.72	13.53	10.73	59.06	$1.23
O	2, clear	low-e VT35	28.64	8.70	10.01	10.73	58.08	$1.04
P	2, clear	low-e VT50	25.92	9.74	10.71	10.73	57.10	$1.07
Q	2, clear	low-e VT70	22.77	11.16	11.61	10.73	56.28	$1.12
R	2, clear	spec. sel. VT40	31.23	9.86	11.78	10.73	63.60	$1.14
S	2, clear	spec. sel. VT70	27.61	10.52	11.84	10.73	60.69	$1.14
T	2, bronze	none	30.27	10.10	11.68	10.73	62.78	$1.14
U	2, bronze	low-e VT35	31.71	7.80	9.38	10.73	59.62	$1.02
V	2, bronze	low-e VT50	30.11	8.34	9.75	10.73	58.94	$1.03
W	2, bronze	low-e VT70	28.01	9.01	10.19	10.73	57.94	$1.05
X	2, bronze	spec. sel. VT40	35.73	8.48	10.74	10.73	65.68	$1.10
Y	2, bronze	spec. sel. VT70	32.63	8.76	10.59	10.73	62.71	$1.08
Z	2, clear	factory low-e IGU VT66	28.60	8.53	9.47	10.73	57.33	$1.02

Table AC64. COMFEN site energy, generic SOUTH façade case, daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	36.56	12.27	14.78	2.70	66.31	$1.10
B	1, clear	absorbing	42.58	9.69	12.90	3.15	68.32	$1.03
C	1, clear	low-e VT35	40.35	6.50	8.26	3.69	58.80	$0.80
D	1, clear	low-e VT50	36.52	7.66	9.26	3.21	56.65	$0.82
E	1, clear	low-e VT70	31.60	9.38	10.60	2.88	54.47	$0.87
F	1, clear	spec. sel. VT40	54.20	6.74	10.39	3.40	74.73	$0.96
G	1, clear	spec. sel. VT70	43.90	7.96	10.75	2.90	65.51	$0.92
H	1, bronze	none	43.93	9.24	12.54	3.14	68.85	$1.01
I	1, bronze	low-e VT35	41.41	6.32	8.26	4.67	60.65	$0.83
J	1, bronze	low-e VT50	39.46	6.87	8.80	3.90	59.03	$0.83
K	1, bronze	low-e VT70	36.58	7.68	9.47	3.42	57.16	$0.84
L	1, bronze	spec. sel. VT40	55.05	6.63	10.29	4.21	76.18	$0.98
M	1, bronze	spec. sel. VT70	47.26	7.08	10.10	3.45	67.89	$0.91
N	2, clear	none	24.54	11.59	11.93	2.79	50.86	$0.92
O	2, clear	low-e VT35	32.91	7.11	8.57	3.88	52.47	$0.78
P	2, clear	low-e VT50	30.16	7.97	9.21	3.36	50.70	$0.79
Q	2, clear	low-e VT70	26.79	9.19	10.04	3.00	49.03	$0.82
R	2, clear	spec. sel. VT40	35.38	8.25	10.28	3.60	57.52	$0.87
S	2, clear	spec. sel. VT70	31.88	8.71	10.28	3.02	53.89	$0.85
T	2, bronze	none	34.50	8.42	10.15	3.31	56.38	$0.86
U	2, bronze	low-e VT35	35.56	6.58	8.12	5.16	55.42	$0.81
V	2, bronze	low-e VT50	34.24	6.87	8.37	4.27	53.76	$0.79
W	2, bronze	low-e VT70	32.30	7.37	8.72	3.67	52.06	$0.79
X	2, bronze	spec. sel. VT40	39.71	7.19	9.34	4.68	60.92	$0.88
Y	2, bronze	spec. sel. VT70	37.02	7.21	9.10	3.71	57.04	$0.82
Z	2, clear	factory low-e IGU VT66	33.45	6.83	7.93	2.98	51.19	$0.74

Table AC65. COMFEN site energy, generic NORTH façade case, NO daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	60.54	7.89	10.52	10.73	89.68	$1.25
B	1, clear	absorbing	62.78	6.98	9.82	10.73	90.32	$1.21
C	1, clear	low-e VT35	47.85	5.89	8.07	10.73	72.54	$1.03
D	1, clear	low-e VT50	47.47	6.37	8.40	10.73	72.96	$1.05
E	1, clear	low-e VT70	46.27	7.00	8.82	10.73	72.82	$1.07
F	1, clear	spec. sel. VT40	66.69	5.78	8.89	10.73	92.09	$1.18
G	1, clear	spec. sel. VT70	58.36	6.50	8.92	10.73	84.51	$1.14
H	1, bronze	none	63.24	6.81	9.68	10.73	90.46	$1.21
I	1, bronze	low-e VT35	48.28	5.67	7.91	10.73	72.59	$1.02
J	1, bronze	low-e VT50	48.36	5.95	8.12	10.73	73.16	$1.04
K	1, bronze	low-e VT70	47.81	6.31	8.36	10.73	73.21	$1.05
L	1, bronze	spec. sel. VT40	67.07	5.65	8.79	10.73	92.23	$1.18
M	1, bronze	spec. sel. VT70	59.43	6.08	8.62	10.73	84.85	$1.13
N	2, clear	none	43.27	7.48	8.98	10.73	70.46	$1.07
O	2, clear	low-e VT35	41.23	6.15	7.99	10.73	66.09	$0.99
P	2, clear	low-e VT50	40.83	6.51	8.21	10.73	66.28	$1.01
Q	2, clear	low-e VT70	39.97	6.97	8.47	10.73	66.15	$1.02
R	2, clear	spec. sel. VT40	49.76	6.18	8.35	10.73	75.03	$1.06
S	2, clear	spec. sel. VT70	46.10	6.54	8.46	10.73	71.83	$1.05
T	2, bronze	none	49.33	6.32	8.40	10.73	74.78	$1.06
U	2, bronze	low-e VT35	42.09	5.79	7.78	10.73	66.39	$0.98
V	2, bronze	low-e VT50	42.07	6.00	7.90	10.73	66.71	$0.99
W	2, bronze	low-e VT70	41.67	6.25	8.05	10.73	66.70	$1.00
X	2, bronze	spec. sel. VT40	51.14	5.70	8.02	10.73	75.60	$1.05
Y	2, bronze	spec. sel. VT70	47.70	5.93	8.07	10.73	72.43	$1.03
Z	2, clear	factory low-e IGU VT66	41.77	5.98	7.86	10.73	66.34	$0.99

Table AC66. COMFEN site energy, generic NORTH façade case, daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	66.24	6.47	8.80	3.02	84.53	$0.97
B	1, clear	absorbing	67.33	5.70	8.37	4.15	85.55	$0.98
C	1, clear	low-e VT35	50.97	4.77	7.07	5.82	68.63	$0.85
D	1, clear	low-e VT50	51.77	4.98	7.08	4.30	68.13	$0.82
E	1, clear	low-e VT70	51.34	5.55	7.45	3.42	67.76	$0.82
F	1, clear	spec. sel. VT40	70.02	4.53	8.47	4.88	87.90	$0.99
G	1, clear	spec. sel. VT70	63.62	4.84	7.56	3.46	79.48	$0.88
H	1, bronze	none	67.71	5.57	8.37	4.13	85.78	$0.98
I	1, bronze	low-e VT35	50.15	5.01	7.31	7.80	70.26	$0.92
J	1, bronze	low-e VT50	51.05	4.98	7.25	6.45	69.74	$0.88
K	1, bronze	low-e VT70	51.55	5.01	7.12	4.93	68.60	$0.84
L	1, bronze	spec. sel. VT40	69.13	5.01	8.47	7.11	89.72	$1.06
M	1, bronze	spec. sel. VT70	63.11	4.62	7.56	5.03	80.33	$0.92
N	2, clear	none	48.38	6.06	7.64	3.21	65.29	$0.81
O	2, clear	low-e VT35	43.89	5.13	7.13	6.37	62.53	$0.83
P	2, clear	low-e VT50	44.63	5.15	6.97	4.75	61.50	$0.79
Q	2, clear	low-e VT70	44.64	5.50	7.13	3.74	61.01	$0.77
R	2, clear	spec. sel. VT40	52.98	5.09	7.35	5.52	70.93	$0.87
S	2, clear	spec. sel. VT70	50.83	5.16	7.12	3.78	66.90	$0.80
T	2, bronze	none	53.32	5.06	7.14	4.59	70.11	$0.84
U	2, bronze	low-e VT35	43.62	5.22	7.30	8.25	64.39	$0.89
V	2, bronze	low-e VT50	44.25	5.18	7.22	7.17	63.82	$0.86
W	2, bronze	low-e VT70	44.69	5.11	7.09	5.73	62.63	$0.82
X	2, bronze	spec. sel. VT40	52.99	5.08	7.46	7.76	73.29	$0.94
Y	2, bronze	spec. sel. VT70	50.73	4.88	7.14	5.85	68.59	$0.86
Z	2, clear	factory low-e IGU VT66	46.70	4.57	6.50	3.67	61.44	$0.74

Table AC67. COMFEN site energy, generic WEST façade case, NO daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	41.42	15.67	25.00	10.73	92.82	$1.76
B	1, clear	absorbing	46.46	12.73	21.24	10.73	91.16	$1.60
C	1, clear	low-e VT35	40.70	8.68	12.35	10.73	72.47	$1.19
D	1, clear	low-e VT50	38.13	10.23	14.51	10.73	73.60	$1.28
E	1, clear	low-e VT70	34.54	12.31	17.18	10.73	74.76	$1.39
F	1, clear	spec. sel. VT40	55.63	9.07	16.02	10.73	91.45	$1.40
G	1, clear	spec. sel. VT70	46.13	10.64	17.13	10.73	84.63	$1.42
H	1, bronze	none	47.48	12.22	20.56	10.73	91.00	$1.57
I	1, bronze	low-e VT35	41.63	8.21	12.04	10.73	72.61	$1.17
J	1, bronze	low-e VT50	40.28	9.11	13.31	10.73	73.44	$1.22
K	1, bronze	low-e VT70	38.22	10.23	14.80	10.73	73.98	$1.28
L	1, bronze	spec. sel. VT40	56.54	8.73	15.62	10.73	91.62	$1.39
M	1, bronze	spec. sel. VT70	48.75	9.49	15.67	10.73	84.64	$1.36
N	2, clear	none	28.32	15.07	20.92	10.73	75.03	$1.53
O	2, clear	low-e VT35	33.45	9.52	13.31	10.73	67.01	$1.19
P	2, clear	low-e VT50	31.54	10.75	14.90	10.73	67.92	$1.26
Q	2, clear	low-e VT70	29.09	12.32	16.80	10.73	68.94	$1.34
R	2, clear	spec. sel. VT40	37.62	11.03	16.88	10.73	76.27	$1.36
S	2, clear	spec. sel. VT70	34.09	11.73	17.17	10.73	73.71	$1.37
T	2, bronze	none	36.98	11.38	17.03	10.73	76.12	$1.37
U	2, bronze	low-e VT35	35.70	8.47	11.98	10.73	66.88	$1.14
V	2, bronze	low-e VT50	34.69	9.14	12.89	10.73	67.46	$1.18
W	2, bronze	low-e VT70	33.21	9.96	13.93	10.73	67.84	$1.22
X	2, bronze	spec. sel. VT40	41.20	9.40	14.62	10.73	75.95	$1.28
Y	2, bronze	spec. sel. VT70	38.12	9.72	14.53	10.73	73.10	$1.26
Z	2, clear	factory low-e IGU VT66	33.78	9.31	12.60	10.73	66.42	$1.17

Table AC68. COMFEN site energy, generic WEST façade case, daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	46.09	13.78	23.10	2.72	85.69	$1.45
B	1, clear	absorbing	51.17	11.09	19.42	3.42	85.10	$1.32
C	1, clear	low-e VT35	44.97	7.17	10.67	4.43	67.23	$0.94
D	1, clear	low-e VT50	42.75	8.52	12.73	3.51	67.50	$1.00
E	1, clear	low-e VT70	39.33	10.43	15.37	2.98	68.10	$1.09
F	1, clear	spec. sel. VT40	60.40	7.64	14.22	3.87	86.13	$1.15
G	1, clear	spec. sel. VT70	51.38	8.99	15.29	3.00	78.67	$1.13
H	1, bronze	none	52.36	10.61	18.75	3.40	85.11	$1.29
I	1, bronze	low-e VT35	44.97	6.99	10.51	5.90	68.38	$0.98
J	1, bronze	low-e VT50	44.23	7.66	11.66	4.82	68.37	$0.99
K	1, bronze	low-e VT70	42.56	8.58	13.06	3.90	68.10	$1.02
L	1, bronze	spec. sel. VT40	60.32	7.54	13.96	5.30	87.12	$1.18
M	1, bronze	spec. sel. VT70	53.31	8.00	13.91	3.97	79.19	$1.10
N	2, clear	none	32.53	13.09	19.13	2.85	67.60	$1.23
O	2, clear	low-e VT35	37.23	8.00	11.67	4.77	61.68	$0.95
P	2, clear	low-e VT50	35.75	9.00	13.15	3.79	61.70	$0.99
Q	2, clear	low-e VT70	33.51	10.41	15.04	3.16	62.12	$1.05
R	2, clear	spec. sel. VT40	41.65	9.47	15.15	4.25	70.52	$1.11
S	2, clear	spec. sel. VT70	38.72	9.96	15.39	3.19	67.26	$1.08
T	2, bronze	none	41.31	9.71	15.26	3.69	69.97	$1.10
U	2, bronze	low-e VT35	38.65	7.30	10.51	6.38	62.84	$0.96
V	2, bronze	low-e VT50	38.17	7.76	11.31	5.36	62.60	$0.96
W	2, bronze	low-e VT70	37.14	8.38	12.26	4.38	62.16	$0.97
X	2, bronze	spec. sel. VT40	44.37	8.21	13.06	5.89	71.52	$1.08
Y	2, bronze	spec. sel. VT70	42.14	8.23	12.86	4.44	67.67	$1.02
Z	2, clear	factory low-e IGU VT66	38.82	7.61	10.85	3.13	60.41	$0.88

Table AC69. COMFEN site energy, generic EAST façade case, NO daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	42.21	15.05	23.74	10.73	91.73	$1.71
B	1, clear	absorbing	47.31	12.22	20.01	10.73	90.27	$1.55
C	1, clear	low-e VT35	40.83	8.37	12.15	10.73	72.08	$1.17
D	1, clear	low-e VT50	38.37	9.89	14.24	10.73	73.23	$1.26
E	1, clear	low-e VT70	34.92	11.95	16.80	10.73	74.40	$1.37
F	1, clear	spec. sel. VT40	56.31	8.62	14.88	10.73	90.53	$1.36
G	1, clear	spec. sel. VT70	46.74	10.22	16.28	10.73	83.97	$1.38
H	1, bronze	none	48.45	11.73	19.36	10.73	90.27	$1.53
I	1, bronze	low-e VT35	41.71	7.89	11.81	10.73	72.14	$1.16
J	1, bronze	low-e VT50	40.40	8.75	13.02	10.73	72.90	$1.21
K	1, bronze	low-e VT70	38.45	9.88	14.49	10.73	73.54	$1.27
L	1, bronze	spec. sel. VT40	57.16	8.29	14.46	10.73	90.64	$1.35
M	1, bronze	spec. sel. VT70	49.27	9.08	14.83	10.73	83.91	$1.33
N	2, clear	none	28.78	14.69	20.44	10.73	74.63	$1.51
O	2, clear	low-e VT35	33.50	9.17	13.25	10.73	66.64	$1.18
P	2, clear	low-e VT50	31.67	10.41	14.80	10.73	67.60	$1.25
Q	2, clear	low-e VT70	29.30	12.00	16.69	10.73	68.72	$1.33
R	2, clear	spec. sel. VT40	38.10	10.62	16.26	10.73	75.72	$1.34
S	2, clear	spec. sel. VT70	34.50	11.34	16.70	10.73	73.27	$1.35
T	2, bronze	none	37.43	10.99	16.48	10.73	75.63	$1.35
U	2, bronze	low-e VT35	35.67	8.13	11.92	10.73	66.45	$1.12
V	2, bronze	low-e VT50	34.72	8.80	12.82	10.73	67.08	$1.16
W	2, bronze	low-e VT70	33.31	9.64	13.86	10.73	67.54	$1.21
X	2, bronze	spec. sel. VT40	41.55	9.03	14.01	10.73	75.33	$1.25
Y	2, bronze	spec. sel. VT70	38.41	9.36	14.13	10.73	72.63	$1.24
Z	2, clear	factory low-e IGU VT66	33.98	9.02	12.51	10.73	66.24	$1.16

Table AC70. COMFEN site energy, generic EAST façade case, daylight controls, Minn., MN

ID	# layers, glass substrate	Applied film	Heating kBtu/ ft2-yr	Cooling kBtu/ ft2-yr	Fan kBtu/ ft2-yr	Lighting kBtu/ ft2-yr	Total Energy kBtu/ ft2-yr	Total Cost $/ft^2-yr
A	1, clear	none	46.66	13.35	22.20	2.94	85.15	$1.42
B	1, clear	absorbing	51.81	10.72	18.49	3.75	84.77	$1.30
C	1, clear	low-e VT35	44.89	7.02	10.76	4.78	67.45	$0.95
D	1, clear	low-e VT50	42.73	8.31	12.78	3.85	67.67	$1.00
E	1, clear	low-e VT70	39.40	10.18	15.32	3.25	68.16	$1.09
F	1, clear	spec. sel. VT40	60.79	7.34	13.38	4.22	85.72	$1.13
G	1, clear	spec. sel. VT70	51.68	8.69	14.76	3.28	78.42	$1.12
H	1, bronze	none	52.91	10.24	17.84	3.73	84.72	$1.27
I	1, bronze	low-e VT35	44.88	6.81	10.48	6.26	68.43	$0.98
J	1, bronze	low-e VT50	44.15	7.46	11.64	5.17	68.41	$0.99
K	1, bronze	low-e VT70	42.52	8.37	13.05	4.25	68.19	$1.02
L	1, bronze	spec. sel. VT40	60.76	7.24	13.01	5.65	86.66	$1.15
M	1, bronze	spec. sel. VT70	53.55	7.72	13.34	4.32	78.93	$1.09
N	2, clear	none	32.83	12.82	18.95	3.09	67.69	$1.22
O	2, clear	low-e VT35	37.11	7.80	11.88	5.12	61.91	$0.96
P	2, clear	low-e VT50	35.66	8.81	13.38	4.14	61.98	$1.00
Q	2, clear	low-e VT70	33.46	10.20	15.21	3.47	62.34	$1.06
R	2, clear	spec. sel. VT40	41.91	9.21	14.81	4.60	70.54	$1.10
S	2, clear	spec. sel. VT70	38.87	9.68	15.21	3.50	67.26	$1.08
T	2, bronze	none	41.52	9.47	15.02	4.04	70.06	$1.10
U	2, bronze	low-e VT35	38.50	7.11	10.64	6.74	62.99	$0.96
V	2, bronze	low-e VT50	38.03	7.58	11.48	5.72	62.80	$0.97
W	2, bronze	low-e VT70	37.04	8.18	12.46	4.73	62.42	$0.98
X	2, bronze	spec. sel. VT40	44.63	7.97	12.63	6.24	71.48	$1.07
Y	2, bronze	spec. sel. VT70	42.24	8.00	12.70	4.80	67.74	$1.02
Z	2, clear	factory low-e IGU VT66	38.68	7.44	11.05	3.43	60.61	$0.89

D. ENERGY PRICES

Table AD1. Commercial retail electricity and gas prices, by state, used to calculate energy cost savings and payback. Source EIA, 2015/2016

	Electricity $/kWh	Gas $/1000cu.ft.	Gas $/therm
Arizona (Phoenix)	$0.106	$9.41	$0.912
DC (Washington)	$0.117	$10.52	$1.019
Florida (Miami)	$0.091	$10.67	$1.034
Illinois (Chicago)	$0.087	$8.65	$0.839
Minnesota (Minneapolis)	$0.098	$6.97	$0.675
Texas (Dallas)	$0.076	$6.84	$0.663
Utah (Ogden)	$0.089	$7.31	$0.708

Electricity prices based on an average of monthly values for Jan 2016 – Aug 2016
Gas prices based on an average of monthly prices for Aug 2015 – July 2016

Note: the cost structure of electrical power for a particular facility can vary significantly from this state average for commercial buildings. Fixed costs may mean the incremental kWh charge is smaller. Reducing peak demand may bring down the capacity charge portion of the bill.

E. OCCUPANT SURVEYS

Table AE1. Survey results for Dallas site after winter with retrofit only (collected March 2015)

1. How close to a window do you sit to perform the majority of your work?		
less than 15 feet	67%	14
15 - 30 feet	14%	3
greater than 30 feet	19%	4
Total		21

2. In which locations have you experienced discomfort associated with windows? (you may select more than one)		
enclosed office	31%	5
open plan office	63%	10
common areas	25%	4
total		19/16

3. How often were you thermally uncomfortable in your work spaces before/after the window retrofit? (you may select more than one answer in each row)							
	frequently too cold	occasionally too cold	never too cold	never too hot	occasionally too hot	frequently too hot	Total
before retrofit winter	12%	35%	41%	24%	12%	0%	
	2	6	7	4	2	0	17
before retrofit summer	0%	12%	41%	35%	24%	6%	
	0	2	7	6	4	1	17
after retrofit winter	0%	31%	56%	13%	13%	6%	
	0	5	9	2	2	1	16

4. How often did windows cause visual discomfort (glare) before and after the window retrofit?				
	frequently too bright (glare)	occasionally too bright (glare)	never too bright (no glare)	Total
before retrofit winter	5%	28%	67%	
	1	5	12	18
before retrofit summer	12%	18%	70%	
	2	3	12	17
after retrofit winter	18%	0%	82%	
	3	0	14	17

5. What is your preferred position for the window blinds in your work space? (you may select more than one answer)		
up, clear window view	50%	10
down, slats horizontal (open)	5%	1
down, slats tilted (partially open)	10%	2
down, slats vertical (closed)	5%	1
no preference	10%	2
don't have a window or window blinds in my work space	20%	4
total		20

6. How often do you adjust the position of the window blinds in your work space?		
frequently adjust blinds	10%	2
occasionally adjust blinds	20%	4
never adjust blinds	45%	9
don't have a window or window	25%	5
total		20

7. What factors motivate your adjustment of the window blinds in your work space? (you may select more than one answer)		
adjusting light level (glare control)	41%	7
thermal management	24%	4
privacy	0%	0
don't have a window or window blinds in my work space	24%	4
other (please specify)	35%	6
total		17

Received 6 open responses below:
Don't adjust the blinds
Do not adjust
I don't move them
Security
I don't adjust
The dismal view.

8. How much do you value the view and visible light provided by the windows in your workspaces?		
high value	70%	14
moderate value	15%	3
low value	5%	1
no value	10%	2
total		20

9. How would you characterize the visual appearance of the window retrofit?						
	Excellent	Good	Fair	Poor	No opinion	Total
before retrofit	30%	35%	20%	0%	15%	
	6	7	4	4	3	20
after retrofit	10%	32%	26%	16%	16%	
	2	6	5	3	3	19

10. Please offer any other comments or feedback regarding issues associated with the windows, and the window film retrofit, that this survey did not capture. (received 10 open responses)
These survey questions were very leading. Please re-issue this survey with better questions. Question 2 does not allow for the option of "I have no discomfort." Not everyone has a problem with windows.
I cannot tell that the window film has made any difference in the fluctuation of temperatures. The cold draft that I feel comes from underneath the HVAC unit.
The test has not gone on too long so it is hard to come up with any firm conclusion. In Dallas the winters are generally short and not too cold. The biggest issue that we have with temperature fluctuations during the summer. We have not experienced a summer yet with the new film.
There are multiple bubbles in the tint which creates a distorted view. The tint also creates a yellowish tint when looking outside. I have not noticed any difference in the temperature but I didn't have any issues with the temperature prior to the tint.
I have no way of knowing if the window film affects the temperature in my office. The problem has always been with the heater during the winter months.
After the installation of the new film it has been necessary to keep the blinds down due to excessive glare. The difference between the old film and the new film has caused me to have to re-position my computer location to put my back to the window to avoid headaches from excessive light. Even with the blinds down the light pierces through the string gaps.
Before the retrofit, I keep my blinds rolled up to enjoy my window view. Now, I have them partially rolled up, due to the morning glare and the dismal/dreary/dark view. Maybe, it's the color. I don't know, but my window view is not as bright and cheery, since the retrofit.
I do not care for the amber glow created by the film application. It has been noted by visitors to our office as well.
I sit in a cubicle 10 ft away from a window. The cubicle partition height prevents any direct glaze or thermal discomfort in my space.
The glare has been ridiculous after the installation of the film. It has also been extremely hot after the installation of the film and I have had to turn off the blower on the heater as even my co-workers who are further away have been complaining.

Table AE2. Survey results for Ogden site after summer with retrofit only (collected Sept. 2015)

1. How close to a window do you sit to perform the majority of your work?		
less than 15 feet	94%	33
15 - 30 feet	6%	2
greater than 30 feet	0%	0
Total		35

2. In which locations did you experience windows with the retrofitted low-e solar control window film? (you may select more than one)		
enclosed office	23%	8
open plan office	57%	20
common area	11%	4
north side	54%	19
south side	29%	10
east side	17%	6
west side	23%	8
total		75/35

3. How often did you have the following comfort experiences in retrofitted work spaces before and after the window film retrofit? (you may select more than one answer in each row)							
	frequently too cold	occasionally too cold	never too cold	never too hot	occasionally too hot	frequently too hot	Total
before retrofit winter	25%	54%	11%	7%	21%	7%	
	7	15	3	2	6	2	28
before retrofit summer	9%	22%	6%	13%	34%	38%	
	3	7	2	4	11	12	32
after retrofit summer	10%	19%	16%	45%	26%	0%	
	3	6	5	14	8	0	31

4. What was your experience with visual comfort and glare before and after the window film retrofit?				
	frequently too bright (glare)	occasionally too bright (glare)	never too bright (no glare)	Total
before retrofit winter	32%	35%	32%	
	10	11	10	31
before retrofit summer	32%	50%	18%	
	11	17	6	34
after retrofit summer	0%	15%	85%	
	0	5	29	34

5. What is your preferred position for the window blinds in your work space? (you may select more than one answer)		
up, clear window view	60%	21
down, slats horizontal (open)	20%	7
down, slats tilted (partially open)	23%	8
down, slats vertical (closed)	6%	2
no preference	0%	0
don't have a window or window blinds in my work space	6%	2
total		35

6. How often do you adjust the position of the window blinds in your work space?		
frequently adjust blinds	14%	5
occasionally adjust blinds	43%	15
never adjust blinds	37%	13
don't have a window or window blinds in my work space	6%	2
total		35

7. What factors motivate your adjustment of the window blinds in your work space? (you may select more than one answer)		
adjusting light level (glare control)	62%	21
thermal management	24%	8
privacy	3%	1
don't have a window or window blinds in my work space	6%	2
other (please specify)	38%	13
total		34

Received 13 open responses below:
I don't adjust them
Desire to look out window
Love having the view outside, never close the blinds.
reducing visuals/concentration, or wanting to see outside
I leave blinds full open, north side no direct sun
I never adjust the blinds
none
It's not really glare it's just gets too bright when the sun comes up on my monitor.
view
time of year and day. blinds usual halfway down to provide shade and still see outside
Early morning when the sun is rising in the east close blinds partially to avoid glare on computer screen
I just want to be able to work and see outside at the same time, without fuzziness
having a view and sense of space creates a preferred work environment for me

8. Based on your experience with the window film retrofit in your building, would you recommend similar retrofits in other office buildings?		
strongly recommend	49%	17
recommend	29%	10
no opinion	11%	4
don't recommend	11%	4
total		35

9. How would you characterize the visual appearance of the windows, before/after the window film retrofit?						
	Excellent	Good	Fair	Poor	No opinion	Total
before retrofit	6%	17%	29%	49%	0%	
	2	6	10	17	0	35
after retrofit	51%	37%	6%	6%	0%	
	18	13	2	2	0	35

10. Did the window film retrofit change your experience or behavior related to windows in your work space? Please offer any other comments or feedback regarding the window film retrofit that this survey did not capture. (received 24 open responses)
Before the retrofit, we were able to turn the lights off in our section for the vast majority of the day during the summer and much of the day during the winter. Since the retrofit, we have been unable to turn our lights off at all throughout the day. So does the cost savings in A/C during the summer (and heating during the winter) offset the increase in electricity cost for lighting?
I have been able to leave the blinds up and look out the window more (a big plus!) The temperature in my workspace has also been more comfortable.
The new film provides excellent clarity for the view outside. The old film was fairly "fuzzy". To get a good look outside, I had to go to another cubicle window. I haven't been in the office much since the new film was installed to notice a difference in thermal properties.

10. Did the window film retrofit change your experience or behavior related to windows in your work space? Please offer any other comments or feedback regarding the window film retrofit that this survey did not capture. (received 24 open responses)
yes, significantly
YES. Retrofit window does reduce glare and provides an altered view thru the film. However, before the retrofit, we did not use the overheads lighting on sunny days. Now, the lights must always be on. So, additional cost for lighting most every day now. Are we saving money??
Yes. The windows in this building are old. The covering fixed a lot of the problem. But it can't stop the cold air coming through the out dated window frames that allow hot and cold in the building. That said, having the coverings installed has been a major and noticeable improvement.
it's nice to have a clear view and it helps with the heating and cooling
The window tint film has limited the quality of natural light coming through the windows. It's created an amber, smokey, dim lit ambiance in the interior work spaces. The natural light before the window tint treatment was more appealing. The window tint makes the interior work spaces feel like you're in a cave.
The film has created a very depressing, yellowish level of light in the office - like a smog-filled winter day or an atmosphere blanketed with wildfire smoke. It's surprising how much this affects one's well being. Gloomy.
I think the window retrofit was fantastic. The new film made a significant difference in the temperature in my office especially during the summer months. I would hope that the entire building gets retrofitted. Also the folks that were installing the new film did an outstanding job. They worked quickly, were very careful around people's work spaces and were extremely professional.
I was informed the retrofit was mainly for keeping in winter heat since I'm on the north side of the building, and I haven't been through winter yet with the retrofit, so those results won't show up in my survey.
Given the temp changes I have noticed on the North side I think addition of the film to all South and West facing windows could be beneficial in providing increased customer comfort.
Question 4 does not address all concerns. Before retrofit we did not have a clear view of the outside. After retrofit the view is clear and crisp. Good change.
No.
The best benefit is actually being able to see out the window now.
I've only worked here since March 2015, so I don't have much experience with winter issues. The positive aspect of the retrofit is being able to see out of the windows, the view is clear now.

10. Did the window film retrofit change your experience or behavior related to windows in your work space? Please offer any other comments or feedback regarding the window film retrofit that this survey did not capture. (received 24 open responses)
My windows had no film before the retro fit. While glare has been reduce, so has the natural light color. Now everything has a brown or copper tint to it. I hate it really. It is a depressing color temp. I contemplate removing it from at least one of my two windows on a daily basis. The best thing is it is visually clear, unlike the old silver stuff. Being on the north side I never ever, ever get direct sunlight in the windows.
the retrofit made it nice to look out the window because you can actually see through them. They are also great for maintaining a more consistent temperature. I love them.
It's now dark and gloomy in my work space. I work on the north side of the building. Window films are not necessary on north facing elevations. I REALLY dislike the film.
I like the new film. The old film had bubbled and clouded, and the replacement film is very clear. Not perfect, but definitely 100% better than the film that was replaced.
the film blocks too much sun on north side so the office receive less natural light and feels gloomy
All I can say is that I sit next to windows that have old film and that FILM is gross and horrible. They make me sick to look outside. ANY tenting will protect the building from the hot intense glare as the sun goes into the western skis, it is a NO BRAINER... We need to be able to see out of them with making use dizzy or making us get a headache. The tenting no matter what needs to happen in the building. IT ONLY MAKES SENSE!
Many of the windows before the retro fit were so bubbly or cloudy, you couldn't see out. I don't think the old film gave us any energy benefits. It was a poor morale enhancer. The new film seems to keep the temperature lower on certain sides of the building. The new film is clear and you can actually see out a window. The HVAC system however needs to be managed better. There are days it's too cool in this office. Thanks for allowing us to give you some tips!
We moved into our offices just a week or two before the retrofit, and therefore I cannot comment on the temperatures experienced beforehand. However, the quality of the view out the entire east side of our office space was blurry at best before the retrofit, and the new film has allowed for very clear views. I particularly appreciate this change in our conference room.

Table AE3. Survey results for Dallas site after winter and summer with retrofit (collected Sept. 2015)

1. How close to a window do you sit to perform the majority of your work?		
less than 15 feet	67%	2
15 - 30 feet	33%	1
greater than 30 feet	0%	0
Total		3

2. In which locations did you experience windows with the retrofitted low-e solar control window film? (you may select more than one)		
enclosed office	33%	1
open plan office	3%	1
common area	33%	1
north side	33%	1
south side	33%	1
total		5/3

3. How often did you have the following comfort experiences in retrofitted work spaces before and after the window film retrofit?? (you may select more than one answer in each row)							
	frequently too cold	occasionally too cold	never too cold	never too hot	occasionally too hot	frequently too hot	Total
before retrofit winter	0%	67%	33%	0%	0%	0%	
	0	2	1	0	0	0	3
before retrofit summer	0%	0%	0%	67%	33%	0%	
	0	0	0	2	1	0	3
after retrofit winter	0%	33%	67%	0%	0%	0%	
	0	1	2	0	0	0	3
after retrofit summer	0%	0%	0%	100%	0%	0%	
	0	0	0	3	0	0	3

4. What was your experience with visual comfort and glare before and after the window film retrofit?				
	frequently too bright (glare)	occasionally too bright (glare)	never too bright (no glare)	Total
before retrofit winter	0%	0%	100%	
	0	0	2	2
before retrofit summer	0%	67%	33%	
	0	2	1	3
after retrofit winter	0%	0%	100%	
	0	0	2	2
after retrofit summer	0%	0%	100%	
	0	0	3	3

5. What is your preferred position for the window blinds in your work space? (you may select more than one answer)		
up, clear window view	100%	3
down, slats horizontal (open)	0%	0
down, slats tilted (partially open)	0%	0
down, slats vertical (closed)	0%	0
no preference	0%	0
don't have a window or window blinds in my work space	0%	0
total		3

6. How often do you adjust the position of the window blinds in your work space?		
frequently adjust blinds	0%	0
occasionally adjust blinds	0%	0
never adjust blinds	100%	3
don't have a window or window blinds in my work space	0%	0
total		3

7. What factors motivate your adjustment of the window blinds in your work space? (you may select more than one answer)		
adjusting light level (glare control)	50%	1
thermal management	0%	0
privacy	0%	0
don't have a window or window blinds in my work space	0%	0
other (please specify)	50%	1
total		2
Received 1 open response below:		
none		

8. Based on your experience with the window film retrofit in your building, would you recommend similar retrofits in other office buildings?		
strongly recommend	0%	0
recommend	67%	2
no opinion	33%	1
don't recommend	0%	0
total		3

9. How would you characterize the visual appearance of the windows, before/after the window film retrofit?						
	Excellent	Good	Fair	Poor	No opinion	Total
before retrofit	33%	33%	33%	0%	0%	
	1	1	1	0	0	3
after retrofit	33%	67%	0%	0%	0%	
	1	2	0	0	0	3

10. Did the window film retrofit change your experience or behavior related to windows in your work space? Please offer any other comments or feedback regarding the window film retrofit that this survey did not capture. (received 2 open responses)
The film has helped somewhat with the glare and temperature fluctuations.
Haven't noticed much of a difference.

Table AE4. Survey results for Ogden site after summer and winter with retrofit (collected March 2016)

1. How close to a window do you sit to perform the majority of your work?		
less than 15 feet	78%	29
15 - 30 feet	19%	7
greater than 30 feet	3%	1
Total		37

2. In which locations did you experience windows with the retrofitted low-e solar control window film? (you may select more than one)		
enclosed office	24%	9
open plan office	38%	14
common area	14%	5
north side	41%	15
south side	30%	11
east side	16	6
west side	22	8
total		68/37

3. How often did you have the following comfort experiences in retrofitted work spaces before and after the window film retrofit? (you may select more than one answer in each row)							
	frequently too cold	occasionally too cold	never too cold	never too hot	occasionally too hot	frequently too hot	Total
before retrofit winter	38%	41%	12%	12%	0%	6%	
	13	14	4	4	0	2	34
after retrofit winter	6%	56%	29%	18%	0%	3%	
	2	19	10	6	0	1	34
before retrofit summer	3%	0%	10%	21%	41%	34%	
	1	0	3	6	12	10	29
after retrofit summer	10%	3%	7%	52%	31%	3%	
	3	1	2	15	9	1	29

4. What was your experience with visual comfort and glare before and after the window film retrofit?				
	frequently too bright (glare)	occasionally too bright (glare)	never too bright (no glare)	Total
before retrofit winter	15%	44%	41%	
	5	15	14	34
after retrofit winter	3%	27%	70%	
	1	9	23	33
before retrofit summer	17%	55%	28%	
	5	16	8	29
after retrofit summer	3%	31%	66%	
	1	9	19	29

5. What is your preferred position for the window blinds in your work space? (you may select more than one answer)		
up, clear window view	59%	22
down, slats horizontal (open)	22%	8
down, slats tilted (partially open)	27%	10
down, slats vertical (closed)	5%	2
no preference	5%	2
don't have a window or window blinds in my work space	8%	3
total		37

6. How often do you adjust the position of the window blinds in your work space?		
frequently adjust blinds	8%	3
occasionally adjust blinds	46%	17
never adjust blinds	38%	14
don't have a window or window blinds in my work space	8%	3
total		37

7. What factors motivate your adjustment of the window blinds in your work space? (you may select more than one answer)		
adjusting light level (glare control)	69%	24
thermal management	17%	6
privacy	11%	4
don't have a window or window blinds in my work space	9%	3
other (please specify)	17%	6
total		35
Received 6 open responses below:		
I enjoy seeing the mountains and clouds outside regardless of sun or glare in the windows.		
look at view		
Morning Sun level trying to keep the blinds to block direct light		
what others who are affected by the windows in my space prefer		
do not adjust		
Like to see daylight		

8. Based on your experience with the window film retrofit in your building, would you recommend similar retrofits in other office buildings?		
strongly recommend	35%	13
recommend	19%	7
no opinion	32%	12
don't recommend	14%	5
total		37

9. How would you characterize the visual appearance of the windows, before/after the window film retrofit?						
	Excellent	Good	Fair	Poor	No opinion	Total
before retrofit	5%	24%	35%	35%	0%	
	2	9	13	13	0	37
after retrofit	39%	39%	11%	11%	0%	
	14	14	4	4	0	36

10. Did the window film retrofit change your experience or behavior related to windows in your work space? Please offer any other comments or feedback regarding the window film retrofit that this survey did not capture. (received 22 open responses)
The only thing I really notice was a little temperature change. Glare wise the film I feel did nothing, the blinds have always been most effective.
The new window film is great!!! It made an amazing difference regarding the temperature in my office, and the visibility was significantly improved. The whole building should get the new film, Mark
We didn't get the retrofit on our floor. We have a film that has been here as long as I have.....11 years. The clarity is terrible when looking out the window.
Yes, it's amazing to be able to clearly see the clouds and mountains outside my window. What a great, beautiful view we have from the office. With the previous film, everything looked blurry. Now everything looks beautiful and clear. Thanks so much for changing it out!
The primary benefit of the new film has been an ability to actually see outdoors clearly. The old film was restricted us from seeing outdoors.
no
No comment.
The old film was foggy and murky-looking on most windows. The new film is much clearer, and I have really enjoyed the views as I move throughout my office space.
I think it was a good to have done. Very old building and windows are the original from 1958.
It is unfair to compare the old film that needed replacement with a top of the line film. I do like the new film, but does it offer payback for the expense over a typical new film? This seems to be the best film I have experienced.

10. Did the window film retrofit change your experience or behavior related to windows in your work space? Please offer any other comments or feedback regarding the window film retrofit that this survey did not capture. (received 22 open responses)
I think it was a waste of taxpayer money and they should have let us keep our damn heaters. I still have to use a fan in the summer time. The money could have been better spent by updating the ventilation systems in the building, or making it earthquake proof.
The film creates a yellow-ish, gloomy quality of light - as if it's a very smoggy or smoky day. It's a little depressing and it feels so much better to step outside into the whiter, natural light.
current window film is awful, new window film is needed
The retrofit makes the office too dark and affects the mood of myself and others in the office. The office used to be bright and sunny on nice days and now the office always has an overcast feel to it. I notice it now negatively affecting my mood. Would prefer it to be taken down- especially on the North facing side of the building.
It's much easier to keep the blinds open now and the glare is not as bad. During full sun we still close the blinds, generally between 12:00 - 3:00 pm when the sun hits straight on. We haven't had the blinds for a full summer yet so cannot comment on that. In past years the south side of the building generally gets extremely hot so the blinds were always closed.
And kind of new film would benefit the building greatly being that the film in there right now has to be really really really old. possibly more than 25 years old.
no
Not really, hardly notice the difference
The retrofit created a dark, gloomy work space. The retrofit was installed about the same time as the HVAC system was replaced. The women in my office are now FREEZING all summer long. I am not a fan.
The windows films before were cracked, bubbling and blue. They were very old and created a gloomy feeling. The new films are very nice. They have a yellow hint but make the view much nicer and clean. We feel the difference slightly in temperature as well. Very satisfied.
Less adjusting of the blinds and better temp control in our space. Thank you.
As a person who receives the majority of requests for temperature adjustments on 2.5 floors of the building I have had far less comments this year. I am not sure if that was all the window film or also the duct work and chiller replacement that contributed. I feel the film is much better though and should be on all windows.

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G. GLOSSARY

Term	Definition
Low-emittance, or low-emissivity (Low-E) coating	Microscopically thin, virtually invisible, metal or metallic oxide layers deposited on a window or skylight glazing surface primarily to reduce the U-factor by suppressing radiative heat flow. A low-e coating can be highly transparent in the solar spectrum (visible light and short-wave infrared radiation) and reflective of long-wave infrared radiation. Low-e coatings are often combined with solar heat gain control features that maintain high visible transmission, while reflecting most of the short-wave infrared in the solar spectrum.
U-factor (U-value)	A measure of the rate of non-solar heat loss or gain through a material or assembly. It is expressed in units of BTU/hr-ft^{2}-°F (US) or W/m^{2}-°K (metric). Values are normally given for NFRC/ASHRAE winter conditions of 0° F (-18° C) outdoor temperature, 70° F (21° C) indoor temperature, 15 mph wind, and no solar load. The U-factor may be expressed for the glass alone or the entire window, which includes the effect of the frame and the spacer materials. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value.
Solar heat gain coefficient (SHGC)	The fraction of solar radiation admitted through a window or skylight, both directly transmitted and absorbed and subsequently released inward. The SHGC has replaced the shading coefficient as the standard indicator of a window's shading ability. It is expressed as a number between 0 and 1. The lower a window's SHGC, the less solar heat it transmits, and the greater its shading ability. SHGC can be expressed in terms of the glass alone or can refer to the entire window assembly.
Visible transmission (Tvis, or VT)	The fraction of incident light that passes through a window or skylight. Only the portion of the solar spectrum that is visible to the human eye.
Solar transmission (Tsol)	The fraction of incident solar radiation that passes through a window or skylight. The entire solar spectrum (UV, visible and near infrared) are included in this transmission. Represent the total fraction of incident solar energy that enters the rooms by direct transmission.
Insulating Glass (IG) Insulating Glass Unit (IGU)	A combination of two or more panes of glass with a hermetically sealed air space between the panes of glass, separated by a spacer. This space may or may not be filled with an inert gas, such as argon.
Conduction	Thermal heat transfer through a solid material. Heat flows from high temperature portions of the solid toward the cooler temperature portions.

Term	Definition
Convection	Thermal heat transfer in a fluid (including gases) resulting from bulk motion of the fluid resulting from a temperature difference in the fluid inducing buoyancy driven flows (warmer portions of the fluid have a different density than cooler portions of the fluid).
Radiation	Thermal heat transfer propagated by electromagnetic radiation (light waves) across an air/gas gap or vacuum. Warmer objects radiate more energy than cooler objects, resulting in a net heat flow between warm/cool surfaces. Surface material properties can change the amount of radiation emitted (see low-emittance surface above).
Infrared	The portion of the electromagnetic spectrum (light waves) with longer wavelengths than visible light. Infrared includes parts of the solar spectrum (near infrared or solar infrared), as well as longer wavelengths emitted by room temperature objects (long-wave infrared).
Thermogram	An image of surface temperatures (each pixel is a numerical surface temperature), collected with a thermal camera. Typically, the surface temperature data is presented using a false color temperature scale (red on the hot end and blue on the cool end), although the color scale is arbitrary.
Variable Air Volume (VAV) system	A variable air volume heating and cooling system has a central conditioning system providing relatively constant supply air temperature to a series of distributed variable air volume boxes the serve smaller zones of the building, modulating the locally required heating and cooling demands by adjusting the volume of air supplies to the space rather that the temperature of the air.
Quad	One-quadrillion (10^{15}) BTUs, a very large unit of energy commonly used to express national annual energy consumption. U.S. annual energy consumption is roughly 100 quads.
Applied window film	Fenestration attachment products that consist of a flexible adhesive-backed polymer film, which may be applied to the interior or exterior surface of an existing glazing system.
Solar reflectance	The ratio of the reflected solar radiation to the incident solar radiation.
Solar absorption	The ratio of the absorbed solar radiation to the incident solar radiation.
Center of Glass (COG)	Indicates that the properties being reported are associated with the glass area of the window only. The edge and frame window properties are not included. Values reported as “whole window” properties include the entire center of glass, edge and frame areas.
Double glazed	Glazing system in a window, consisting of two glass panes.

Term	Definition
Bronze tint	Bronze colored glazing, manufactured by incorporation of additives in the molten glass.
HVAC	An acronym for heating, ventilation and air-conditioning equipment and design, referring to all the building mechanical systems that produce and deliver temperature and humidity conditioned air and fresh air supply within a building.