New Rating Opening Windows to a World of Comfort, Opportunity, and Cost-Effective Savings

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ABSTRACT

Window attachments offer a huge, cost-effective energy-saving opportunity that remains largely untapped. The newly launched window attachment energy rating and certification program, through the Attachments Energy Rating Council (AERC), is altering the way people think about residential and commercial window attachments by providing reliable, easy-to-understand energy performance information to consumers.

Window attachments, such as blinds, shades, shutters, awnings, and low-emissivity (low-e) storm windows, represent an enormous existing market. With 64% of U.S. homes having single- or double-pane clear (non-low-e) less-efficient windows, the savings opportunity is significant. Studies of model homes show energy savings of 10% or more after installing more efficient storm window and cellular shades technologies (AERC 2016). In a study conducted by Efficiency Vermont, 68% of respondents had concerns with their existing windows and could benefit from an upgrade (Efficiency Vermont 2016).

Through AERC, window attachment products are rated based on their Energy Performance (EP). The EP metric is an easy-to-understand comparative metric created for consumers. This rating not only allows consumers to make more informed decisions when buying attachments products, but also creates a new energy savings measure for utilities and efficiency programs to incentivize energy efficient window attachment products.

This paper will outline the savings potential of window attachments, introduce the AERC rating program, detail the methodology behind the Energy Performance ratings, and explain the AERCalc tool that generates the ratings.

Introduction

Window attachments are interior or exterior products that are installed over windows in residential or commercial buildings. Interior products are often referred to as window coverings, window treatments, or window fashions. Examples of interior window attachments include blinds, shades, drapes, shutters, window quilts, and films. Exterior window attachments include roller shades, storm windows, roller shutters, and awnings. Window attachments, particularly interior products, are traditionally thought of as decorative or aesthetic items and are not viewed by most consumers as an energy-saving measure.

There is a significant opportunity to improve the energy performance of U.S. homes by upgrading the performance of existing windows. Windows contribute to 29% of a residential home's HVAC consumption and 34% of commercial building's HVAC consumption, a substantial contribution to energy use (Apte and Aratech 2006). HVAC energy consumption accounts for 48% of a household's overall energy use, meaning windows contribute around 14% of total household energy consumption (EIA 2009). Studies conducted by EIA and Pacific

Northwest National Laboratory (PNNL) found that 47.2 million (42%) of U.S. homes have single pane windows and an additional 46 million (41%) homes have double pane clear glass windows (EIA 2009; PNNL 2013). In total, approximately 64% of U.S. homes currently have inefficient windows, and with only about 2% of homes replacing their windows per year it will take a long time to replace all inefficient windows. Window attachments can offer a more cost-effective and immediate option for improving the energy performance of windows and the building envelope, particularly for consumers who may not be in a position to replace all of their windows.

The Attachments Energy Rating Council

Despite the fact that window attachments offer a cost-effective option to reduce the energy use of windows, until very recently there was not a standardized way of assessing their energy performance and no way for consumers to make apples-to-apples comparisons between products. The formation of AERC has bridged this gap. AERC is an independent, U.S. Department of Energy (DOE) funded, public interest organization whose mission is to provide consumers with credible, relevant, and comparable information about the energy performance of window attachments. AERC was formed because DOE, public interest groups, and the window attachments industry wanted to provide consumers with a way to make direct comparisons of different window attachment products and raise awareness of window attachments as an energy-saving measure. The window attachments industry was also interested in an ENERGY STAR® program for window attachments, which was unlikely to be established without an existing rating and certification program.

AERC was formed in October 2014 with a 4-year, $1.6 million matching grant from DOE to the Window Coverings Manufacturers Association (WCMA). AERC is a membership-based organization formed under the WCMA umbrella and made up of a variety of stakeholder groups including manufacturers of window attachment products and components, public interest groups, trade associations, federal research and commercial labs, and utilities. The majority of the AERC Board of Directors comes from public interest groups.

Since its formation, AERC primarily has focused on developing and launching the residential product rating and certification program. Lawrence Berkeley National Laboratory (LBNL) developed the modeling software used by the program and AERC developed the rating and certification procedures. The residential rating and certification program launched in March 2018 for cellular shades, storm windows, blinds, solar screens, pleated shades, and roller shades. Once a sufficient number of products have been certified, AERC will launch its consumer-facing website, AERCEnergyRating.org, likely in the third quarter of 2018, as a resource for consumers to access rated product performance information and to learn more about window attachments.

With the launch of the residential rating and certification program, the organization is shifting gears to focus on outreach and education around the residential program and developing a certification and rating program for commercial window attachments. Throughout the next year, AERC will be opening up certification to additional residential window attachment types and will expand its rating and certification program to the commercial sector.

Energy Performance Metric and AERCalc Software Tool

AERC elected early on in its formation that in addition to rating and certifying the metrics closely associated with fenestration performance – U-Factor, Solar Heat Gain

Coefficient (SHGC), Visual Transmittance (VT), and Air Leakage (AL) – the organization wanted to create a unified energy performance metric that would encapsulate the effects of these other metrics and how people operate their window attachments in a home. A consumer survey reinforced this decision, revealing that consumers had very limited knowledge of the existing metrics and found them confusing. To address this concern and simplify the message, AERC decided to create one overarching energy performance metric consumers could use to compare product performance and make purchasing decisions while still making the other metrics available to consumers or others who wanted to dig deeper. This Energy Performance (EP) metric is the centerpiece of the AERC program and the residential consumer label, which will appear on the packaging of certified products in retail locations.

EP Metric Overview

Developed by LBNL, the EP metric, at its basic level, is a ratio that represents the annual HVAC energy savings generated by adding a window attachment to a standardized baseline window. In more formal terms, the EP index is defined as the ratio of energy savings of a window with a window attachment over a standardized baseline window divided by the energy use of the standardized baseline window. The higher the EP, the greater the energy savings and performance of the window attachment.

To understand the energy impact of adding a window attachment to a baseline window, LBNL modeled the total energy use of the house and analyzed the change that occurred when adding a window attachment. The EP metric is built on a number of assumptions including the house type and size, heating and cooling systems, and geographic location, as well as the window area and distribution, and the window attachment product and its operation. The AERC Technical Committee and LBNL partnered to generate the assumptions used to calculate EP.

Climate Assumptions

The AERC Technical Committee opted to divide the United States into two climate zones, with one metric representing product performance in cooler climates and another representing performance in warmer climates. The selection of two climates allows the rating to account for the diverse climate zones within the United States while avoiding an overly complex decision-making process for consumers. This decision was also made since the EP metric is a ratio and meant to be a comparative metric for consumers based on a typical house, and not as a means to determine the exact dollar or energy savings they will experience by purchasing that product.

The two resulting EP ratings are referred to as EP_H (heating) and EP_C (cooling). EP_H characterizes a product's performance in a heating-dominated (cooler weather) climate, and EP_C characterizes a product's performance in a cooling-dominated (warmer weather) climate. The committee decided to select a "representative" city for each climate zone. LBNL conducted analysis of weather, energy consumption, housing stock, and the installed base of windows across the country. Based on this analysis, the committee selected Minneapolis, MN, and Houston, TX, as the representative cities for cool and warm climates respectively.

In addition, due to the difficulty of combining heating and cooling energy into one metric, the committee decided to incorporate HVAC heating season-only and HVAC cooling season-only energy use, respectively, into EP calculations because home energy use in those cities is dominated by those seasons and therefore the primary benefit consumers will see for window attachments will occur during those periods. As a result, EP_H is based on the HVAC heating load in Minneapolis, MN, and EP_C is based on the HVAC cooling load in Houston, TX.

House and Baseline Window Assumptions

Because of the different housing stock in each city and climate zone, the committee created a house with characteristics typical to that climate for each of the representative cities. To develop model home assumptions, the Technical Committee reviewed previous versions of the International Energy Conservation Code (IECC). At the time of analysis, most states were still operating under IECC 2006, but the majority of existing housing stock was much older. With those considerations in mind, the committee decided to model the homes based primarily on IECC 1998 because the 1998 code was considered to be more widely representative of the U.S. housing stock. AERC expects to alter these assumptions over time to ensure that they remain representative of U.S. housing stock.

The simulations require a baseline house model for use in the software tools, and LBNL presented multiple existing residential building models for review, including ones employed by PNNL, DOE, the Environmental Protection Agency, the National Fenestration Rating Council, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers. The Committee moved forward with PNNL model houses because they developed residential house models for cities in each IECC climate zone and AERC had already decided to develop ratings for Minneapolis and Houston – cities covered by the PNNL models. Each residential building model developed by PNNL combined several building vintages into a single "typical" house for the representative city used for that climate zone.

From there, the committee reviewed all of the parameters used in IECC 1998 and the PNNL residential building models and evaluated them for use in simulations for the AERC program – to balance the need for accounting for differences in housing stock based on climate zone while also standardizing parameters such as square footage to be representative of the entire U.S. housing stock. Table 1 lists some of the key assumptions the committee decided upon based on analysis of the housing stock of Minneapolis and Houston, and the country as a whole.

Table 1. Key housing assumptions

Assumption	Minneapolis	Houston
Floor area	2400 ft^2: 34.64ft (W) x 34.64ft (L) x 8.5ft (H)	
House type	2-story: 1 small core zone and 4 big perimeter zones for each floor	
Wall framing system	Wood	
Bedrooms/ bathrooms	3/ 3	
Foundation	Unheated basement	Slab-on-grade without insulation
Insulation R-values	Ceiling: R-49 Wall: R-21 Floor: R-21 Basement: R-11	Ceiling: R-30 Wall: R-13 Floor: R-11 Slab: R-0
Infiltration	ACH50= 7	ACH50= 10
HVAC system and efficiency (1 zone)	Gas furnace (78% AFUE) and A/C (10 SEER)	Electric heat pump (6.8 HSPF and 10 SEER)
Thermostat setting	70° F	75° F
Baseline window type and performance	Double clear wood frame: VT= 0.639, SHGC= 0.601, U-factor= 0.472 Btu/hr.ft2.F, AL= 2 cfm/ft2 Adiabatic window: VT= 0, SHGC= 0, U-factor= 0, AL= 0	

Window distribution	8 windows per floor, distributed evenly and centered on the external walls. Each big window was split into two sections.
Calculation engine	EnergyPlus version 8.5 customized to include window attachment models

Source: Peng and Curcija 2017.

The committee made adjustments to the assumptions with a focus on parameters that would affect the HVAC energy use of the modeled home and the baseline windows. The committee elected to use the same single baseline window type in both climates to maximize the ability to make apples-to-apples comparisons with the EP metric and minimize the simulation and calculation time. Other assumptions that were altered from the IECC 1998 code were the air infiltration levels and temperature set-point. The committee considered the characteristics of older housing stock and decided to use slightly higher air infiltration levels (DOE 2015; Culp, Drumheller, and Wiehagen 2013; Drumheller, Kohler, and Minen 2007). In addition, the committee decided to allow products submitting for AERC certification to undergo air infiltration physical testing and report those infiltration values. The committee also reviewed temperature set-points for a variety of reference houses and settled on a middle-ground approach.

All AERC certified products must be rated for EP over the baseline window[1] identified in Table 1. In the future, manufacturers will be able to rate products over additional baseline window types.

EP Calculation

As previously mentioned, EP represents the simulated annual HVAC energy savings generated by a window attachment in relation to a baseline window in a model house. It is generated using a suite of software tools that calculate the difference between the home's energy use with the window attachment installed compared to the energy performance of the home if the window did not have an energy impact. The no-energy-impact window condition is called an adiabatic window, where the window allows no heat to transfer through its surface.

The assumptions for performance of the adiabatic window are detailed in Table 1. Figures 1 and 2 explain the basis of and the formulas used to calculate EP ratings:

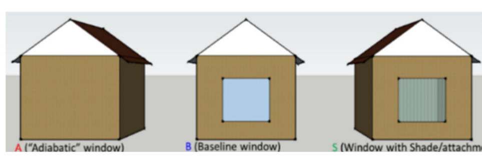

Figure 1. Images of window configurations used to calculate EP.

$$EP_C = \frac{(E_B - E_S)_{Houston}}{(E_B - E_A)_{Houston}} \qquad EP_H = \frac{(E_B - E_S)_{Minneapolis}}{(E_B - E_A)_{Minneapolis}}$$

Where:

E_A: Annual HVAC cooling or heating energy use of the house with "adiabatic" window (A)

E_B: Annual HVAC cooling or heating energy use of the house with baseline window only (B)

E_S: Annual HVAC cooling or heating energy use of the house with window attachment (S)

Figure 2. Formulas for EP_C and EP_H.

[1] Referred to as "Baseline Window B" in AERC 1.

The resulting EP is a decimal ratio that is multiplied by 100 to create a whole number rating that provides a comparison of the relative performance of a window attachment to other window attachments within and outside of its product category. Table 2 explains how to interpret EP.

Table 2. Interpreting EP ratings

EP value	Signifies
<0	The window attachment installed over the baseline window causes the house to use more energy on an annual basis than if it had no attachment at all.
0	The window attachment installed over the baseline window has no net impact on the energy performance of the home on an annual basis.
>0 and <100	The window attachment installed over the baseline window improves the net annual energy performance of the home compared to if it had no attachment at all, but not as much as if there was an adiabatic surface.
100	The window attachment installed over the baseline window improves the net annual energy performance of the home, rendering its performance equivalent in energy performance to an adiabatic window.
>100	The window attachment installed over the baseline window improves the energy performance of the home so much that it is a net annual energy producer compared to an adiabatic window.

EP ratings for a window attachment are generated using a set of software tools developed by LBNL. The Berkeley Lab WINDOW and THERM programs could model a number of window attachment types, but LBNL made further updates to those software tools and created a new software tool, AERCalc, to generate EP ratings for the AERC program.

AERCalc Overview

To generate an EP rating, an AERC Accepted Simulator models the fenestration with the window attachment. The Simulator first models the frame components with the glazing components in THERM, imports the THERM file, and, finally, models the performance properties of the entire glazing system including the window attachment in Berkley Lab WINDOW (AERC 2017). LBNL developed the AERCalc software tool as an adaptation of RESFEN and COMFEN to manage the energy simulations and EP calculations.

AERCalc enables simulators to import a window and window attachment modeled using THERM and Berkeley Lab WINDOW and initiate simulation runs using EnergyPlus to simulate annual energy use based on the AERC climate, house, and operation assumptions built into the system. The number of EnergyPlus runs depends on the product type being rated and its functionality (i.e., adjusts up and down and/or tilts). Each product type requires a different number of EnergyPlus simulations – ranging from one to seven.

Since product operation can affect the energy performance, AERC based the operation schedule for each type of operable window attachment on a representative survey of 2,100 U.S. households conducted by D+R International. The survey resulted in a weighted operation schedule that identified the proportion of window attachments in a certain position (open, half-open, or closed) based on the time of day, day of the week, and season (Bickel, Phan-Gruber, and Christie 2013). AERCalc integrates the operation schedule with the EnergyPlus runs of each position of operation, and then weights the overall EP number by the frequency of window attachment operation to calculate EP ratings (Peng and Curcija 2017). LBNL will further develop the AERCalc tool to enable rating of automated products (using a different operation schedule) in addition to rating products over other baseline window types. Automated products can help to maximize energy performance and savings.

Savings Opportunity

Window attachments represent a significant energy savings opportunity in the United States because of their potential to optimize HVAC energy use (Curcija et al. 2013). Understanding the impact of different types of window attachments across different climate zones and under different operation schedules is key to capturing their energy-saving potential.

To develop estimated energy savings for window attachments across the United States, AERC worked with LBNL to identify major cities in each of the IECC Climate Zones (see Table 3). The city selections were primarily based off of the representative cities used for DOE's commercial reference buildings, while also taking into consideration population centers and overall geographic representativeness.

Table 3. IECC Climate Zones and representative U.S. cities analyzed

Zone	Climate	Representative city	State
1	A	Miami*	Florida
2	A	Houston*	Texas
2	B	Phoenix*	Arizona
3	A	Atlanta*	Georgia
3	B	Los Angeles*	California
3	C	San Francisco*	California
4	A	Washington	District of Columbia
4	B	Albuquerque*	New Mexico
4	C	Seattle*	Washington
5	A	Chicago*	Illinois
5	A	Boston	Massachusetts
5	B	Denver	Colorado
6	A	Minneapolis*	Minnesota
6	B	Helena*	Montana
7	A	Duluth*	Minnesota
8	A	Fairbanks*	Alaska

* indicates cities from DOE commercial reference buildings

LBNL ran energy simulations for a "typical house" in each city to calculate annualized energy and dollar savings from the installation of window attachments compared to baseline energy use of the home without attachments installed. These simulations used the AERC operation schedule for each window attachment product type (AERC 2017). The energy-saving potential of window attachments varies by location as does the potential cost savings because of differences in local energy prices (see Figure 3).

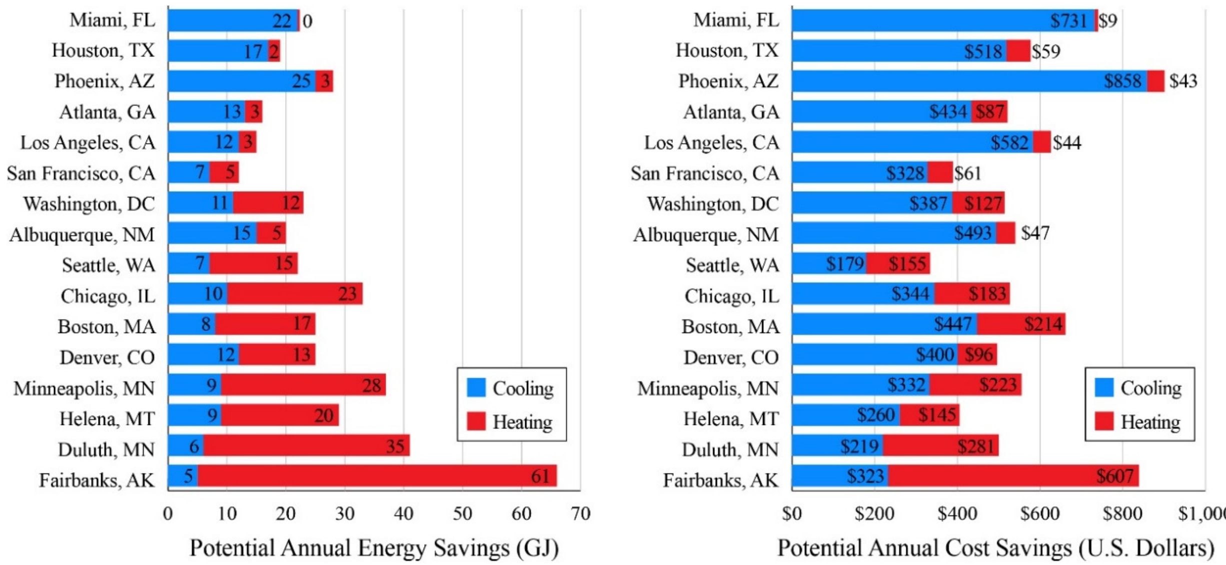

Figure 3. Potential window attachment annual cooling and heating energy and cost savings per house (18 windows).

The graphs in Figure 3 demonstrate the significant savings potential that consumers can achieve through the installation of window attachments in their home. However, window attachment products vary in performance by climate. As Figure 4 demonstrates, some product types are better designed to save energy and money in cooling climates (e.g., solar screens), whereas others will perform best in heating climates (e.g., low-e storm windows).

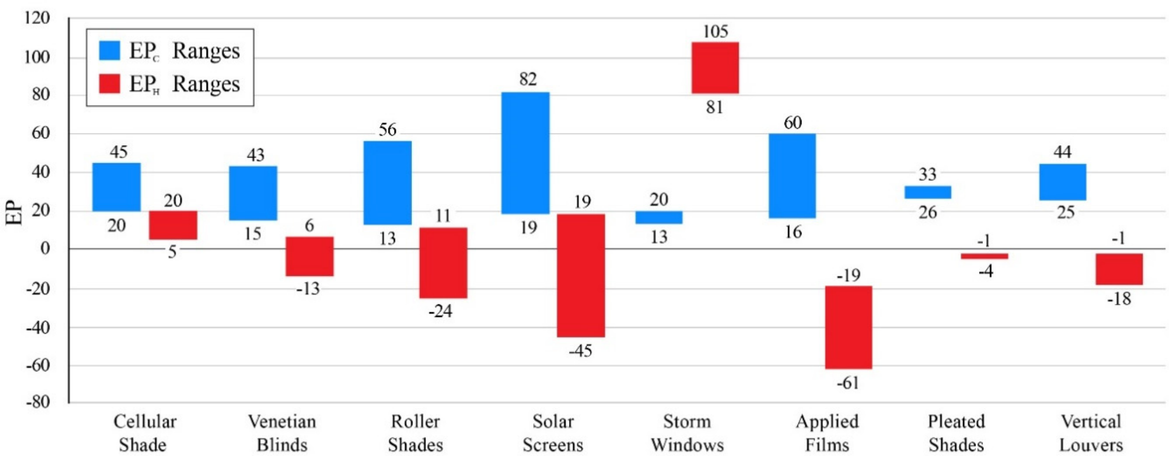

Figure 4. EP_C and EP_H ranges by product type.

In addition, some products have the potential to have a negative impact on home energy performance if installed in a certain climate, and particularly, if their use is not optimized Consequently, consumers should consider whether they are located in a climate zone that is cooling or heating dominated (or consider both equally) and take into consideration the EP_C and/or EP_H of a product.

The best performing product types for each city included in the analysis were exterior solar screens (for cooling-dominated climates like Phoenix, Miami, and Los Angeles) and interior low-e storm windows (for heating-dominated climates, with the exception of Seattle and

Denver). Figure 5 shows the relationship between those high-performing products and potential annual dollar savings in Houston (solar screen) and Minneapolis (low-e storm window).

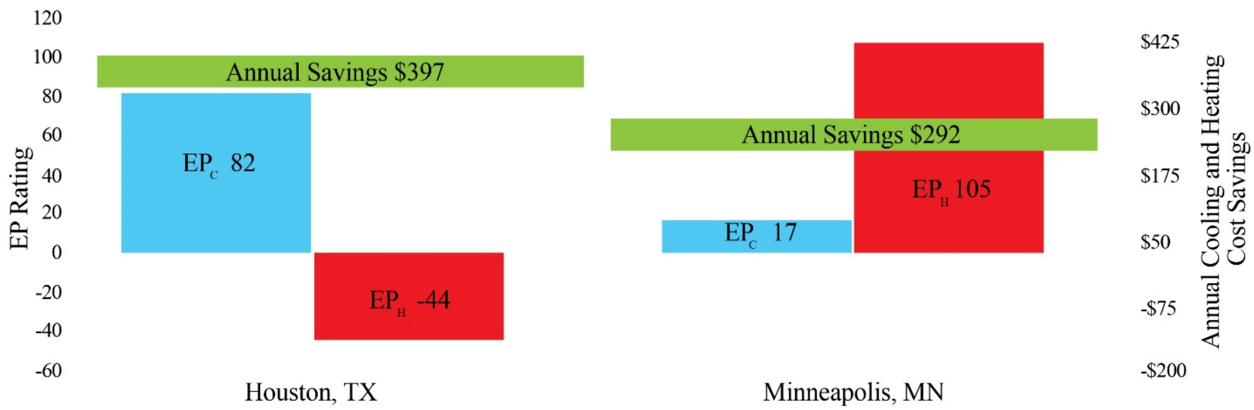

Figure 5. EP ratings and annual cost savings for highest-performing product types in Houston and Minneapolis.

Although solar screens can result in higher cost savings in cooling climates, the products with the highest energy-saving capability (in terms of $EP_{C\text{ or }H}$) of any product currently available in the market are interior low-e storm windows. Due to their unique ability to reduce air infiltration through the window, these products can achieve an EP_H of over 100. Low-e storm windows can save the most energy in heating-dominated climates such as Fairbanks, Duluth, and Boston. In all three cities, they have the potential to save more than $300 per year if installed in every window of the home (equivalent to at least $16 annually per window installed).[2]

Multiple field studies have reinforced the simulated energy-saving potential of low-e storm windows and of other window attachment types like cellular shades. Table 4 summarizes findings from three field studies of window attachment products.

Table 4. Estimated energy savings from window attachment field studies

Product type	Location (year)	Baseline window/ house type	Estimated energy savings
Low-e storm windows	Chicago, IL	Single pane, clear glass Single-family detached	19-27% annual heating energy savings ($145-$600)
Low-e storm windows	Richland, WA	Double-pane, clear glass, aluminum frame PNNL Model House	10.5% heating season energy savings 8.0% cooling season energy savings
Cellular shades (triple cell) on optimum operation schedule	Richland, WA	Double-pane, clear glass, aluminum frame PNNL Model house	10.5 ±3.0% heating season and 16.6 ±2.9% for the cooling season compared to vinyl blinds employing the same operation schedule

Sources: Drumheller, Kohler, and Minen 2007; Knox and Widder 2014; Peterson et al. 2016.

The window attachment field studies summarized in Table 4 validate the simulated energy savings. LBNL simulations resulted in estimated annual household savings from low-e storm windows at $253 for Chicago and $194 for Seattle. These savings estimates confirm that

[2] Total estimated savings take into account both heating and cooling performance.

window attachments offer a significant opportunity for consumers to save money and energy in their homes. With that opportunity in mind, window attachment industry stakeholders developed the AERC certification program to provide consumers with energy performance information.

Consumer Use of the Ratings

EP ratings will help consumers make comparisons about the energy impact of window attachment products. Certified products will display the AERC Energy Improvement label, which will have the product's EP_H and EP_C ratings directly on the packaging, enabling consumers to quickly understand that product's energy performance in both climates.

A consumer can determine how an AERC certified window attachment is likely to perform in their home using the EP ratings on the AERC label. The simplest approach is for the consumer to evaluate whether they live in a relatively cool climate or warm climate. Most consumers will inherently know their climate. If they are in a cool climate, consumers should look at the cool climate rating on the AERC label and vice versa for a warm climate. Generally, the higher the rating for their climate, the better performance that product can offer.

The AERC label also shows the range of performance for products within that window attachment product type so a consumer can understand a product's energy performance compared to others of the same type. In addition, a consumer may compare EP ratings of different options within a product type (e.g., cellular shades) as well as across product types (e.g., cellular shades vs. solar screens). The AERC label will also reference the AERC Certified Products Website, where consumers can access educational resources and search the entire list of AERC certified window attachments along with their ratings and performance metrics.

Utility Program Opportunity

Window attachments represent a new opportunity for utility and efficiency programs from energy savings and demand response perspectives, and can offer a cost-effective solution for fenestration and the building envelope for their customers. Utility programs have largely avoided offering incentives on fenestration since full-scale window replacement can be expensive and not cost effective. In addition, due to the significant window replacement costs, the rebate a utility can offer is often not enough to influence purchasing decisions.

Now that the AERC rating and certification program exists, utilities and efficiency programs can look to AERC Energy Performance ratings to identify and offer incentives on energy efficient window attachments. Utilities could use the AERC rating and certification program in a number of ways. At a minimum, utilities can require AERC certification on any products they offer an incentive. Requiring AERC certifications will give utilities confidence that products have been independently assessed. ENERGY STAR is also working on a specification for storm windows. Once that specification is released, utilities, as in many other cases, can point to ENERGY STAR certification as their criteria as well.

Utilities can also set a minimum EP heating or EP cooling value that they would incentivize. For example, a southern-based utility may only incent certified products with an $EP_C \geq 25$. To determine the minimum EP value that they would incent, they would calculate the kW or kWh savings that would pass their cost effectiveness test and then use an AERC-provided calculator to determine the corresponding minimum EP value.

Pilot Projects

Two low-e storm windows retail markdown pilots have been conducted by Efficiency Vermont and Focus on Energy in Wisconsin. In both pilots, the price of low-e storm windows were marked down to the price of clear glass storm windows, a 20-30% discount on low-e storm windows at big-box retailers. In Vermont, The Home Depot and Lowe's participated, and in Wisconsin, Menards and The Home Depot participated. Both pilots ran for approximately eight weeks in September and October during the major storm window sales season.

The pilots relied on different combinations of in-store marketing materials including cut sheets, pocket cards for sales associates, sticker clings for storm window displays, sell sheets, and stack outs in retail store aisles. In addition, there were social media and radio promotions in Vermont, and a website landing page and digital marketing in Wisconsin.

Results from both pilots were impressive, generating an overall sales lift and a shift from clear glass storm windows to low-e, demonstrating the effectiveness of the markdown and marketing strategies, as demonstrated in Table 5. Efficiency Vermont is evaluating how to incorporate low-e storm windows into its programs, and Focus on Energy is planning to launch a statewide program in fall 2018.

Table 5. Low-e storm window pilot results

Pilot (year)	Overall storm window sales increase	Low-e sales increase	Low-e market share
Efficiency Vermont (2015)	37%	337%	2014 – 22% 2015 – 70%
Focus on Energy (2017)	9.6%	125%	2016 – 30% 2017 – 62%

Sales increases are in comparison to the same period of time the prior year.

Conclusion

Until now, there was no cost-effective solution to the problem of increased HVAC energy use caused by inefficient windows, as the cost of full window replacement is a deterring factor. Previous field studies and energy analyses indicated the savings potential of some window attachment products, but there was no reliable performance data available for consumers to reference for purchasing decisions. AERC launched a rating and certification program in March 2018 to help identify the energy performance of specific products, and further modeling and analysis validates the significant energy saving potential of window attachments across the U.S. As manufacturers certify their window attachment products, consumers and utilities will have the opportunity to understand and tap into the energy-saving potential of window attachments.

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