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# Window Attachment Opportunity Assessment for the Pacific Northwest

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# Window Attachment Opportunity Assessment for the Pacific Northwest

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# Executive Summary

Laboratory and field studies sponsored by the U.S. Department of Energy, Bonneville Power Administration, and others demonstrate that the use of window attachments can lead to significant heating and cooling building energy savings. This report provides a summary of commercially available window attachments in the market and characterizes these attachments in terms of energy efficiency, savings potential, and other functional attributes applicable to the northwestern states of Washington, Oregon, Idaho, and Montana. A summary of the research findings related to window attachments and energy savings is provided. This report also examines the barriers to market and utility program acceptance of high efficiency window attachments and identifies opportunities to transform the market for window attachments in the northwest.

Based on a review of various studies featuring laboratory testing, field research, and climate-based energy simulation modeling, the installation of a high efficiency window attachment is estimated to reduce heating and cooling consumption by an average of 5-30% in residential single-family and multi-family homes as well as small commercial buildings. Although individual building savings would depend on the type of window attachment installed, structural and orientation characteristics of the home or building, the overall condition of existing windows, climate conditions and the behavior of the occupants (see Table 3 of this report), it is reasonable to assume that the typical home or small building in the northwest could save an average of 10% on annual heating and cooling bills based on the studies summarized in this report, which include studies focused on the northwestern region.

Market transformation programs could implement a number of targeted outreach, education, and technical assistance programs to have a measurable impact on reducing residential and small commercial building energy consumption over time. From a northwestern regional utility program perspective, four window attachments stand out as promising technologies in terms of persistent year-round energy savings potential, durability, cost, and commercial availability. These include both interior and exterior low-e storm windows , high-efficiency cellular shades, and advanced surface-applied window films. Although surface-applied window films have traditionally been favored in cooling-dominated climates, some emerging low-e films show promise in the heating season as well,

**Target Market**
- Both *new and existing* buildings.
- High benefit for existing *residential households* (both single- and multi-family) with low-performing windows.
- Includes *selected commercial buildings* (e.g., nursing homes, dormitories, and small commercial buildings) with low-performing (i.e., single-pane or non-low-e double-pane) windows.

**Energy Savings**
5-30% heating and cooling building energy savings (estimated an average of 10% savings for a typical home).

**Potential Regional Impact**
- Over 80% of homes and small commercial buildings have some form of window attachment.
- Over 80% of window attachments that are in place are relatively low-performing vinyl slatted shades.
- Large opportunity to transform the market to higher efficiency products.

**Emerging Technologies and Opportunities**
- *Low-emissivity (low-e) coatings* are being effectively applied to window attachments to provide additional year-round savings.
- Although window attachments that are operated (e.g. opened and closed) can present challenges to ensure persistent savings, *automated controls* also present opportunities for expanding the market and energy savings from window attachments.

which makes it a more favorable technology in the heating-dominant climates of the northwest. In addition, once a film is applied, it provides a persistent form of savings with broad commercial and residential applications, which makes it a good candidate for a utility-incentive measure. A qualitative assessment of the attributes for these four technologies is presented in Table 1, below, and described in further detail in Table 7 of this report.

**Table 1.** Qualitative Ratings of Attributes for Low-e Exterior and Interior Storm Windows, Insulated Cellular Shades, and Surface-Applied Films

● "Greatest Benefit"
◐ "Moderate Benefit"
○ "Neutral or Average"
◍ "Emerging products – Unverified benefits"

| | Wide Application | Year-Round Savings | Persistence | Lifetime | Cost | Product Variance | Availability |
|---|---|---|---|---|---|---|---|
| Low-e Exterior Storm Windows | ◐ | ● | ● | ● | ◐ | ● | ● |
| Low-e Interior Window Panels | ● | ● | ● | ● | ◐ | ● | ◐ |
| Insulated Cellular Shades | ◐ | ● | ○ | ◐ | ◐ | ◐ | ● |
| Surface-Applied Films* | ● | ◍ | ● | ◍ | ◍ | ○ | ◐ |

*Recent improvements to the thermal performance of films suggest benefits during the heating season, but the savings of the technology have not been verified in the northwest.

# Acronyms and Abbreviations

| | |
|---|---|
| AERC | Attachment Energy Rating Council |
| API | application programming interface |
| BPA | Bonneville Power Administration |
| Btu | British thermal units |
| CBECS | Commercial Buildings Energy Consumption Survey |
| CEE | Consortium for Energy Efficiency |
| DOE | U.S. Department of Energy |
| EIA | Energy Information Administration |
| EPA | Environmental Protection Agency |
| HUD | U.S. Department of Housing and Urban Development |
| HVAC | heating, ventilation, and air-conditioning |
| IFTTT | If This Then That |
| LBNL | Lawrence Berkeley National Laboratory |
| Low-e | low emissivity |
| NAHB | National Association of Home Builders |
| NEEA | Northwest Energy Efficiency Alliance |
| PNNL | Pacific Northwest National Laboratory |
| RTF | Pacific Northwest Regional Technical Forum |
| RECS | Residential Energy Consumption Survey |
| SEEM | Simplified Energy Enthalpy Model |
| TBD | To be determined |
| UV | ultraviolet |

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# 1.0 Introduction

Energy-efficient window attachments (also known as window coverings) appear to hold promise for effectively reducing heating, ventilation, and air-conditioning (HVAC) consumption in new and existing buildings. Because of the relative affordability of window attachments and the large numbers of existing homes and small commercial buildings that have low-performing, single-pane or double-pane clear windows, a significant opportunity exists to provide energy savings by promoting the appropriate use of energy-efficient window attachments throughout the United States, including the northwestern regional states of Oregon, Washington, Idaho, and Montana.

The report was written with support from the Northwest Energy Efficiency Alliance (NEEA). NEEA is an alliance of more than 140 northwest regional utilities and energy-efficiency organizations working on behalf of more than 13 million energy consumers.[1] NEEA's mission is to accelerate both electric and gas energy efficiency, leveraging regional partnerships to advance the adoption of energy-efficient products. This report provides a summary of the types of commercially available window attachments currently available in the market and characterizes these attachments in terms of energy efficiency, savings potential, and other functional attributes applicable to the northwestern regional states. The report includes a summary of previous research on window attachments, recent technological breakthroughs, and emerging technologies. Finally, the report describes some of the energy-efficiency program efforts that are focused on window attachments both at the national and regional levels, including the newly formed Attachment Energy Rating Council (AERC).

[1] See http://neea.org/about-neea for more information (accessed September 2015).

# 2.0 Background

Window attachments (e.g., window shades and blinds) have been used for privacy and comfort for centuries. Only recently, however, has attention been drawn to the energy savings potential achieved through increasing the insulating values of window attachments, while optimizing the solar gain added to the space. The type and selection of window attachment technologies has greatly expanded in recent years. However, limited information exists regarding the energy-saving characteristics of these products, and no comprehensive rating system currently exists to help distinguish energy-saving features among window attachments (Curcija et al. 2013).

Utilities and energy efficiency organizations have shown some interest in the energy savings potential of window attachments, but with limited comprehensive field data, those savings cannot be easily quantified or captured across different regions and building types. To address this problem, the DOE has funded several research and market transformation activities focused window attachments, including energy simulation studies, field research, whole home experiments, and the recent launch of an independent rating council. NEEA and BPA have also supported research related to window attachments using PNNL's Lab Homes experimental platform. Section 2.1 of this report describes the various categories of window attachments and how they work. Section 2.2 of this report summarizes the research related to window attachment energy savings.

## 2.1 Window Attachments

Window attachments are interior and exterior products that are installed over windows, doors, or skylights in both residential and commercial buildings. Interior products often are referred to as window treatments, window attachments, or window fashions, and include blinds, shades, drapes, shutters, and films. Exterior products include roller shades, roller shutters, window quilts, and awnings. Attachments also include both interior and exterior storm windows. Window attachment products, particularly interior attachments, have traditionally been thought of as decorative features; however, these products offer a variety of benefits to homeowners, including energy savings.

A summary of commercially available window attachments is provided in Table 2, organized by mounting location and range of operability. Operable window attachments provide the occupant some flexibility in how often the attachment is used based on time of day or season. In addition, the location of the window attachment differentiates how the attachment manages heat loss in the winter and heat gain in the summer. A short description of each window attachment listed in Table 2 is provided in Appendix A.

**Table 2**. Commercially Available Window Attachments Organized by Mounting Location and Operability

| | Interior Window Attachments | Exterior Window Attachments |
|---|---|---|
| Fixed Attachments | Applied Films<br>Interior Fixed Storm Panels<br>Interior Solar Screens | Exterior Fixed Storm Panels<br>Exterior Solar Screens<br>Fixed Awnings<br>Surface-Applied Films |
| Operable Attachments | Cellular Shades<br>Drapes/Curtains<br>Interior Louvered Shutters<br>Interior Roller Shades<br>Interior Operable Storm Panels<br>Louvered Blinds<br>Pleated Shades<br>Roman Shades<br>Sheer Shades<br>Window Quilts | Drop-Arm/Retractable Awnings<br>Exterior Louvered Shutters<br>Exterior Roller Shades<br>Exterior Operable Storm Panels<br>Roller Shutters |

## 2.2 Previous Research

A number of research efforts, field studies, and experiments have demonstrated the energy-saving capabilities of various window attachments. Window attachments can save energy across product types, window types, and climate zones. Table 3 shows the range of energy savings from field demonstrations and modeled estimates of energy savings for various attachment types over single-pane and double-pane clear windows in a variety of climate zones.

In addition to DOE research focused on window attachments, a number of research institutions, energy-efficiency programs, and utilities have completed characterization and meta-analyses[2] (Ariosto et al. 2013) and energy simulation analyses (CEE 2014; Garber-Slaght and Craven 2011; Zirnhelt et al. 2015) that validate energy savings from cellular shades and other window attachments (Table 3).

In 2013, DOE sponsored a comprehensive energy modeling study led by LBNL that focused on a range of window attachments, including products such as shades, blinds, storm window panels, and surface-applied films simulated in four types of "typical" houses located in 12 characteristic climate zones. The simulations captured the optical and thermal complexities of these products (Curcija et al. 2013) and also considered typical operation and usage patterns based on a separate study that focused on user behavior with respect to operable window attachments (Bickel et al. 2013). The study found that many of the window attachments examined can yield significant energy savings when installed over windows; however, the degree of savings depends on the attachment type, baseline window conditions, seasonal and climate factors, and when applicable, how the attachment is operated. Nevertheless, the study concluded that in heating-dominated climates, particularly in the north-central climate zones, low-e storm windows and insulated cellular shades are two of the most effective window attachments at reducing HVAC usage.

[2] See, for example, the websites at http://www.efficientwindowcoverings.org/, which was sponsored and developed by DOE, Building Green, and LBNL, and http://energy.gov/energysaver/articles/energy-efficient-window-treatments.

**Table 3.** Summary of Case Studies Focused on Window Attachments

| Study | Sponsor | Baseline description | Findings |
|---|---|---|---|
| Field Studies | | | |
| Chicago case study (Drumheller et al. 2007) | DOE, HUD,[a] NAHB[b] Research Center, LBNL[c] | Six low-income homes; single-pane wood-framed windows | Low-e storm windows showed:<br>• 21% reduction in overall home heating load<br>• 7% reduction in overall home air infiltration<br>• Simple payback of 4 to 5 years |
| Atlanta case study (2-year study) (Quanta 2013) | DOE,[d] Quanta Technologies (Quanta), Larson Manufacturing (Larson) | Ten occupied homes; single-pane wood-framed windows | High variability, but low-emissivity (low-e) storm windows showed approximately:<br>• ~15% heating energy reduction<br>• ~2 to 30% cooling reduction (highly variable)<br>• 17% reduction in overall home air infiltration |
| Modeling Studies and Meta-Analyses | | | |
| Pennsylvania weatherization technical support (2010) | DOE, Birch Point Consulting | Thirty-seven model homes with range of window types | Modeled window retrofit technology showing results for seven climate zones:<br>• 12% to 33% overall HVAC savings |
| LBNL Modeled Estimates (Curcija et al. 2013) | DOE | Five product types over single-pane and double-pane windows in 12 climate zones | Modeled energy savings varied by product types, climate zone, and baseline, but annual energy dollar savings ranged from $280 to $470 for cellular shades and $370 to $910 for storm windows. |
| Modeling Studies and Meta-Analyses (continued) | | | |
| Energy savings from window shades (Zirnhelt et al. 2015) | Hunter Douglas and Rocky Mountain Institute | EnergyPlus modeling of DOE residential buildings | Modeling of cellular shades showed:<br>• Denver Max Cooling Savings – 25%<br>• Denver Max Heating Savings – 10%<br>Peak electrical demand reduction of 9% for new homes |
| Evaluation of Residential Window Retrofit Solutions for Energy Efficiency (Aristo et al 2013) | Pennsylvania Housing Research Center | Modeled cellular shades | • Reduction in U-factor[e] of 38%<br>• Reduction in solar heat gain coefficient of 39% |
| Evaluating Window Insulation for Cold Climates (Garber-Slaght and Craven 2011) | Cold Climate Housing Research Center | Double cell cellular shades over double-pane clear window | • Modeled reduction in U-factor of 15%<br>• Actual increase in R-value of 60% |

**Table 3.** (continued)

| Study | Sponsor | Baseline description | Findings |
|---|---|---|---|
| Whole House Laboratory Experiments | | | |
| PNNL[f] Lab Homes: Exterior Low-e Storm Panels (Knox and Widder 2014) | DOE, Larson | Double-pane aluminum-frame clear glass | Annual average savings percentage of 10.1 ±1.4 |
| PNNL Lab Homes: Interior Low-e Storm Panels (Petersen et al 2015) | DOE, NEEA, Quanta | Covering 74% of window area double-pane aluminum-frame clear glass | Annual average savings percentage of 7.8±1.5 |
| PNNL Lab Homes: Cellular Shades (Petersen et al 2016) | DOE, BPA,[g] Hunter Douglas | Double-pane aluminum-frame clear glass (no window attachments) | Under "Optimal" operation conditions.<br>• Cooling savings 14.8 ±2.1%<br>• Heating savings 14.4% ±2.0% |
| PNNL Lab Homes: Static Operation Cellular Shades (Petersen et al 2016) | DOE, BPA, Hunter Douglas | Double-pane aluminum-frame clear glass (compared to venetian blind attachments) | • Cooling savings 16.6±2.9%<br>• Heating savings 10.5±3.0% |

[a] HUD is the U.S. Department of Housing and Urban Development.
[b] NAHB is the National Association of Home Builders.
[c] LBNL is the Lawrence Berkeley National Laboratory.
[d] DOE is the U.S. Department of Energy.
[e] The rate of heat loss is indicated in terms of the U-factor (U-value) of a window assembly. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating properties.
[f] PNNL is Pacific Northwest National Laboratory.
[g] BPA is the Bonneville Power Administration.

PNNL conducted whole-home experiments for both cellular shades and low-e storm panels using its two side-by-side Lab Homes located on the PNNL campus in Richland, Washington (Petersen et al 2016; Petersen et al 2015; Knox and Widder 2014) These experiments measured the potential energy savings of window attachment products within different operational schedules in an experimental home compared to a baseline home equipped with standard double-pane, clear-glass windows with aluminum frames and sliding clear-glass patio doors. The windows in the baseline home are representative those installed in many existing homes in the northwest regional states and much of the United States. Different operational schedules were tested to help understand the effect of the window attachment technology on the HVAC energy use. The results of the experiments are provided in Table 3.

# 3.0 Technology Breakthroughs and Emerging Technologies

Over the past 15 years, new window replacement and retrofit technologies, including low-emissivity (low-e) storm windows, insulating blinds, and window films, have been developed that increase energy savings and the options available to homeowners and utilities when considering energy-efficient window upgrades in existing buildings.

## 3.1 Low-e Storm Windows

Traditional storm windows consisted of a single piece of clear glass (or plastic) mounted in a wood or aluminum frame that were installed on the outside of an existing window. This window retrofit design focused on reducing thermal conduction and, to a limited extent, convection. However, modern storm windows feature new designs that can be operable or fixed in place, and they can significantly reduce air leakage much more than previous storm window designs (see Figure 1). For example, as modern storm windows are intended to be permanently mounted, they typically feature tighter seals and gasketed or caulked window frames that further reduce conductive heat transfer as compared to older storm window designs (Cort 2014).


(a) (b) (c)

**Figure 1**. Evolution of Storm Window Design and Construction: (a) Traditional seasonal storm panels. (b) Aluminum-framed, self-storing storm window and screen. (c) High-performance, low-e storm windows.

In addition to conduction and convection, radiation is an important mechanism for heat gain and heat loss through windows. All materials radiate heat in the form of long-wave infrared energy depending on the emissivity and temperature of their surfaces, which contributes to heat loss from buildings in addition to conductive and convective heat loss. Typical low-e storm windows include a low-e pyrolytic coating that lowers the emissivity of glass for certain wavelengths, effectively reducing heat transmission through the storm window (see Figure 2). Specifically, low-e coatings are microscopic coatings of a very thin, electrically-conductive material that is transparent in the visible light region and reflective in the infrared region (Culp et al. 2015).

Uncoated glass typically has an emissivity of around 0.84, while low-e coated glass can have an emissivity of 0.16 or lower. When interior heat energy tries to escape to the colder exterior during the winter, the low-e coating reflects the radiative heat back to the inside, reducing the overall heat loss through the glass. The reverse transfer of heat occurs during the summer (Culp et al. 2015).

## 3.2 Window Films

Window films have been available since 1965 with high-performance window films being available since the energy crisis in the 1970s. Today's films include an adhesive layer, a film layer (containing dyes or other solar-absorbing materials, or metal or metal-oxide coatings), and a scratch resistant hard coating that provides improved adhesion to the glass and scratch resistance for the exposed layer. Window films quickly and easily provide modest-to-significant thermal performance improvement at a reasonable cost. Other benefits include improved occupant comfort, glare control, and protection from ultraviolet radiation. Some window films significantly reduce the transmission of visible light (with a potential for increased use of electric lighting). In addition, films do not improve the air tightness of windows, which may be a performance issue for the existing window units (CEE 2013).

Surface-applied window films improve window performance by reducing solar heat gain and, for some films, increasing thermal resistance. A range of film types and products are available and are useful in different climates and window applications.

- Standard or reflective window films offer the highest performance in reducing solar heat gain, and are reflective in nature. Hybrid films are a type of reflective film that contains both metals and dyes to offer an aesthetic improvement over standard reflective films. They provide significant solar heat gain reduction with improved night time visibility at comparable visible light levels.
- Spectrally-selective films offer higher visible light transmission while significantly reducing solar heat gain. Many of these films offer the additional benefit of very low reflectivity for improved day and night visibility.
- Low-e films are able to improve window insulating performance by reducing the window U-factor. This is accomplished by suppressing radiative heat flow. These films also reduce solar heat gain and can best be thought of as year-round products for a variety of climates.

Films are appropriate for windows of any building type (single-family, multi-family, or commercial) as well as construction type (new or retrofit). The solar and thermal properties can be chosen depending on specific needs or requirements. Most film products are applied on the interior surface of windows; however, current film technology includes films that can be installed on the exterior of windows although these are rarely used in residential applications. A building owner or homeowner typically would not be able to remove the product as window films are designed for removal by a professional once they have reached their end of life. Care must be taken to match the performance properties of the window and the film. Manufacturers provide clear guidance for both technical and field determination of compatible window and window film technologies (CEE 2013).

Window films have traditionally reduced HVAC energy use by reducing solar heat gains; thus, the energy-saving benefits have primarily been realized during the cooling season. However, some emerging low-e surface film technologies have the potential to yield more heating benefits by providing greater thermal resistance in the same manner as the low-e storm windows (see Figure 2). EnerLogic, the manufacturer of a low-e film, claims that low-e films reflect 92% of a room's radiant warmth back into the home.[3] In addition to low-e coatings, thermo-chromic films change solar control properties as the ambient and surface temperatures change, thus enabling beneficial heat gains and thermal resistance when the building needs it. Because these films can be applied to existing windows in existing buildings with relatively low installation costs, the potential for wide scale adoption and energy savings is significant.

[3] "Low-E Technology Makes a New Luxury Home Even More Comfortable. Durham, North Carolina Case Study featured at www.enerlogicfilm.com.

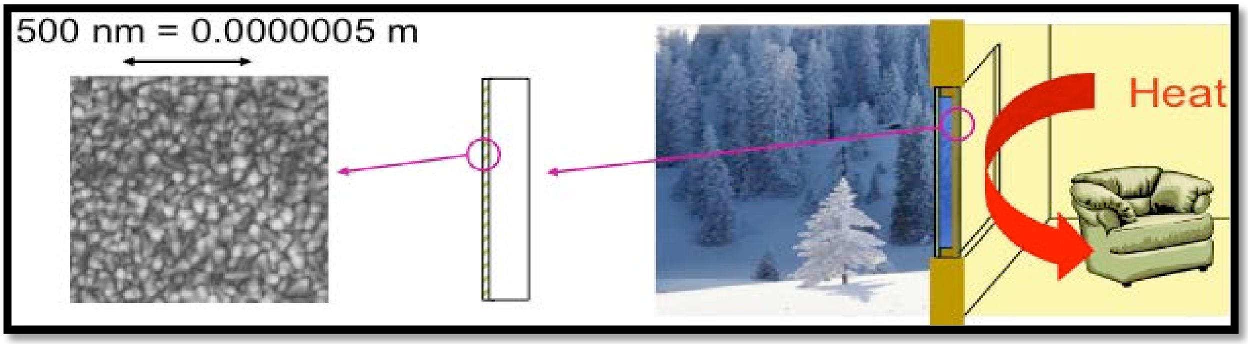


**Figure 2**. Low-e Coating Reflects Infrared Heat Back into the Home, thus Reducing Heating Losses

## 3.3 Controls and Automated Window Attachment Systems

Almost any window attachment that is operable may be controlled and automated, including drapes, shades, screens, shutters, or awnings (see Table 2 for other operable window attachments). Window attachments can be controlled by timers, sensors, remote controls, and applications on portable devices, or they can be integrated into a home automation system. Programmable operation can be based on light intensity, outdoor ambient temperature, thermostat temperature reading, or a variety of other sensed parameters. Exterior window attachments (like awnings or shutters) can be programmed to respond to wind sensors, which will then automatically retract when high winds threaten the attachments.[4] Several studies have shown significant improvement in both the thermal performance of adjustable window attachment operation and reduced lighting energy consumption when automation is employed.[5]

Window attachments can be motorized using power from batteries, electrical outlets (i.e., plug-in), or hard wiring. A battery-operated window attachment has the advantage of being a wireless system and does not involve installation from an electrician, but is suited for smaller or lighter window attachments. A plug-in window attachment control also does not require an electrician, but outlets and cords can be unsightly if not designed into the construction of the building. An outlet-powered window attachment control typically uses a direct current motor and is best suited to power low- to medium-weight window attachments. Hard wired motorized window attachments require direct connection to the building electrical system, which is best accomplished during construction or a major renovation. Hard wired systems use alternating current motors that are well-suited for heavier window attachments or systems of multiple window attachments.[5]

There are several companies that offer window attachment controls or automation systems, including Hunter Douglas PowerView®, Lutron Caséta®, Nest Learning Thermostat™, and the If This Then That (IFTTT) application. Hunter Douglas markets PowerView® Motorization as a way to move a window treatment to an opportune position and be able to control the operation through the use of a remote control.[5] Hunter Douglas PowerView Motorization uses wireless radio-frequency communication to control the raising, lowering, tilting, or traversing of window attachments. The PowerView system also can work on a schedule of operation of the window attachments using an intuitive application from a

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4 Window Coverings & Attachments. https://www.efficientwindowcoverings.org/understanding-window-coverings/attachment-automation

5 Hunter Douglas PowerView® Motorization. https://www.hunterdouglas.com/operating-systems/powerview-motorization

portable device. PowerView automation schedules are able to operate each attachment independently, allowing a schedule to be set based on any number of variables, and it can operate multiple attachments simultaneously to fit the mood or activity. The PowerView system also integrates with other sophisticated whole-home automation systems.

The Lutron Caséta Wireless system uses a combination of controls for lighting, window attachments, and thermostats.[6] The Caséta Wireless system consists of dimmers, Pico® remote controls, the Smart Bridge, and an online application. The Caséta Wireless system includes the Lutron Serena® battery-powered, remote control window attachments to add privacy and convenience. The system also works with a variety of Nest products including the Nest Learning Thermostat, Nest Protect, and Nest Home/Away Assist. The Nest Learning Thermostat™ is an internet-connected thermostat that continuously learns about usage patterns in the home to optimize comfort and save energy.[7] The Nest Learning Thermostat can be controlled through an online application from a portable device. It is based on a wide range of algorithms (Early On, True Radiant, or Airwave™) with a Nest application programming interface (API) designed to allow products to control the HVAC system without disrupting these algorithms.

IFTTT defines a clear and concise protocol to be implemented by a separate service's API.[8] Each trigger and action maps to an API endpoint built specifically for IFTTT. These trigger endpoints are the event streams that IFTTT uses for new data. Conversely, action endpoints will be writable endpoints for data sent by IFTTT. IFTTT is compatible with a number of services common to home automation systems, including a variety of smart thermostats, lighting strategies, and motorized window attachments. When connected with weather applications, IFTTT can be programmed to use weather signals to control certain aspects of the home. For example, lights can be automatically turned off at sunrise or your thermostat adjusted when the outside temperature rises. Other controlled features include humidity, air quality through the use of air purifiers, or rain delays. Notably, the IFTTT applet can close blinds on a bright day when the ultraviolet index exceeds 11.

In 2017, BPA teamed with PNNL, Hunter Douglas, DOE, and NEEA as part of its 2016 Technology Innovation program to support research related to savings potential of dynamically controlled shading devices using the PNNL Lab Homes as the experimental platform. As part of the experiment, integrated control strategies will be developed to control high-efficiency cellular shades to assess the net benefits of automated controls in single-family homes. To address concerns related to savings persistence, the experiments will be conducted to examine operable shading devices under varied operational schedules. The intent is to determine the extent to which varied schedules impact HVAC load and recommend operating strategies and control algorithms that take input signals from sensors to adjust dynamic components of shading devices. These advanced control strategies are done in coordination with Hunter Douglas's PowerView automated system. The algorithms will be developed on the open transactive platform, VOLTTRON™[9]to better assess integrated control strategies and responses to external (grid) signals for potential application in utility demand response programs. Results of these experiments will be available in 2018.

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[6] Lutron Caséta® Wireless https://workswith.nest.com/company/lutron-electronics/lutron-caseta

[7] "Thermostat: Everything you need to know about thermostats in the data model", Nest Learning Thermostat™. https://developers.nest.com/documentation/cloud/thermostat-guide

[8] "8 ways to control your home with Weather Underground", If This Then That. https://ifttt.com/blog/2017/02/8-ways-to-control-your-home-with-weather-underground

[9] The VOLTTRON™ platform is a distributed control and sensing software platform designed to manage a wide range of applications within the grid and buildings environment.

# 4.0 Regional Market Overview

Residential buildings currently require approximately 5.3 quadrillion Btus of energy for heating and cooling, which accounts for just under 50% of the primary energy consumed by homes.[10] Small commercial buildings (i.e., 25,000 $ft^2$ or less) consume slightly less than 900 trillion Btus of energy for the HVAC needs of the building, accounting for about 40% of the delivered energy consumed by these buildings.[11] Windows are a major source of heating losses and gains in residential and small commercial buildings. Before installation of double-pane windows became common practice in northern climates in the 1970s and 1980s, single-pane windows were the standard. Many homes and small businesses with single-pane windows use window attachments to provide thermal comfort, air-infiltration barriers, privacy, or aesthetic benefits.

An assortment of different attachments can be used to save energy in all types of buildings. These savings are particularly accessible and applicable in all residential homes including single-family, multi-family, and manufactured homes; smaller commercial buildings such as smaller office, assembly, and retail buildings; and commercial buildings with overnight occupants and/or residential uses such as nursing homes and dormitories. This section describes the installed base of window characteristics and window attachments in the northwest regional states and identifies potential opportunities for energy savings with this technology.

## 4.1 Window Characteristics in Homes and Small Commercial Buildings

The 2011 Residential Building Stock Assessment study by Ecotope (Baylon et al. 2012) estimates that approximately 87% of residential single-family homes in the study representing approximately 4 million of the residential single-family customers in the northwest regional states[12] have double-pane windows; however, many of these double-pane windows are low-performing clear-glass windows. The total number of residential single-family customers with these low-performing (i.e., not low-e) windows is estimated to be approximately 44% of the total. Of the approximately 1.8 million households with low-performing windows, few (~11%) have installed energy-saving fenestration attachments in the form of storm windows. Although no information was available for other shading devices, a recent study conducted by D& R International (Bickel et al. 2013) estimates that 82% of windows in the northern climate zones have some sort of window covering.

Window performance in the same region for multi-family homes follows a similar pattern, where 82% of all housing units have double-pane windows; however, it is estimated that approximately 44% of the window area in multi-family homes is made up of relatively low-performing (i.e., not low-e) windows. Survey results show that identified approximately 540,000 multi-family customers in the northwest regional states.

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[10] "Heating and cooling no longer majority of U.S. home energy use", U.S. Energy Information Administration (EIA), published March 7, 2013, https://www.eia.gov/todayinenergy/detail.php?id=10271&src=%E2%80%B9%20Consumption%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-b1.

[11] "2012 Commercial Buildings Energy Consumption Survey: Energy Usage Summary", EIA, published March 18, 2016, https://www.eia.gov/consumption/commercial/reports/2012/energyusage/.

[12] The northwestern region includes the BPA region of Oregon, Washington, Idaho and the western portion f Montana.

In addition, according to data from the 2014 Commercial Building Stock Assessment study (NEEA 2014), approximately 3200 commercial buildings with residential uses (i.e., dormitories, assisted living buildings, or in-patient rehabilitation centers) are located in the northwest regional states. Approximately 88% of the windows in these small commercial buildings with residential uses are double-pane, 56% are double-pane windows with clear glass, and 32% are double-pane windows with a low-e coating with various glazing materials (clear, tinted, and reflective). In contrast, commercial buildings with floor areas less than 20,000 $ft^2$ (i.e., small commercial buildings such as offices, places of assembly, or retail shops) had a higher prevalence of single-pane windows. Just over 67% of small commercial buildings have double-pane windows, 54% have double-pane windows with clear or tinted glass, and 13% have double-pane windows with a low-e coating and various glazing materials (i.e., clear, tinted, and reflective).

A recent study conducted by D&R International (Bickel et al. 2013) estimates that 82% of windows in the northern climate zone have some sort of window covering. Based on the data associated with NEEA's commercial buildings study, the northwest regional states have approximately 2175 commercial buildings with residential uses (e.g., nursing homes) and with low-performing windows, and approximately 92% of these buildings have operable window attachments (i.e., blinds or curtains). Presuming that current market shares for various window attachments roughly reflect the window attachments installed in the 82 to 92% of buildings in the northwest regional states that have window attachments, it is likely that the predominant window attachments are the relatively low-performing vinyl venetian-style blinds (see Figure 3).[13] This would suggest that there is a large market opportunity to shift consumers from less efficient products toward higher efficiency products such as low-e storm windows and/or high-efficiency cellular shades.

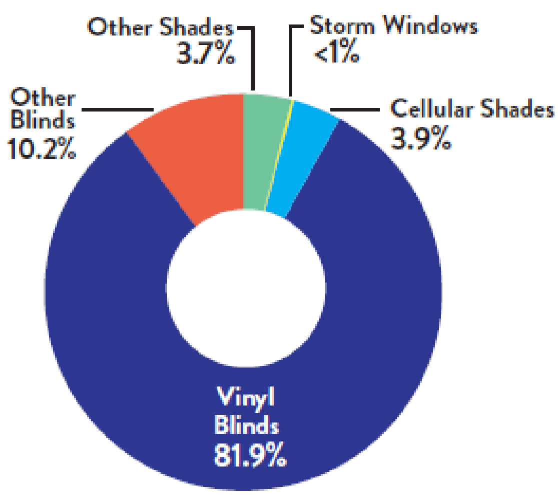



**Figure 3**. Estimated 2015 Market Share for Interior Window Coverings (Bickel, et al. 2013)

## 4.2 Energy Savings Potential

There are several studies that estimate the energy savings potential of various window attachments based on laboratory testing, case studies, and climate-based modeled energy savings (see Table 3 in this report). As previously discussed, in its 2013 analysis, *Energy Savings from Window Attachments*, LBNL modeled the energy savings potential for a typical home for a range of window attachments (Curcija et al. 2013). Across all window attachments in the study, most energy savings come from reduced heating loads, but

[13] These data points are derived from data provided by LBNL in support of AERC 2016 publication, "Window Attachments: Call to Action."

some savings do come from reduced cooling loads. For example, louvered blinds with reflective materials and vertical blinds provide some savings in cooling loads. However, heating loads were higher with these window attachments, making the overall savings lower than the baseline window. Low-e coatings, offered on many attachments, increase insulation and lower the solar heat gain coefficient, thus decreasing the passive solar heating effect that increases cooling loads. A summary of the performance characteristics of each window attachment from the Efficient Windows Collaborative[14] is presented in Table 4. Various energy-efficiency organizations may be interested in these performance characteristics to help inform energy-efficiency programs for the various interior and exterior window attachments in both residential and small commercial applications.

**Table 4.** Window Attachment Attributes of Interest to Energy Efficiency Organizations

Legend:
- ● "Greatest Benefit"
- ◑ "Moderate Benefit"
- ○ "Neutral or Average"
- ▨ "Undetermined[15]"
- ◪ "Emerging products – Unverified benefits"

| | Insulation | Airtightness | Solar Heat Control | Winter Comfort | Summer Comfort | Condensation Resistance | Ventilation | Low Product Cost | Low Installation Cost | Durability/Service Life |
|---|---|---|---|---|---|---|---|---|---|---|
| **Exterior Attachments** | | | | | | | | | | |
| Storm Windows (including low-e) | ● | ● | ◑ | ● | ◑ | ◑ | ● | ○ | ○ | ● |
| Awnings | ○ | ○ | ● | ○ | ● | ○ | ● | ○ | ▨ | ◑ |
| Roller Shades | ○ | ○ | ● | ○ | ● | ○ | ◑ | ◑ | ◑ | ○ |
| Roller Shutters | ◑ | ○ | ● | ○ | ● | ○ | ○ | ▨ | ▨ | ● |
| **Interior Attachments** | | | | | | | | | | |
| Conventional Roller Shades | ○ | ○ | ◑ | ◑ | ◑ | ○ | ○ | ● | ● | ○ |
| Conventional Drapes | ○ | ○ | ◑ | ◑ | ◑ | ○ | ○ | ● | ● | ○ |
| Louvered Blinds | ○ | ○ | ◑ | ○ | ◑ | ○ | ◑ | ● | ● | ○ |
| Window Panels (including low-e) | ● | ● | ◑ | ● | ◑ | ◑ | ▨ | ◑ | ● | ○ |
| Insulated Cellular Shades | ● | ◑ | ◑ | ● | ◑ | ▨ | ○ | ○ | ◑ | ◑ |
| Window Quilts | ● | ◑ | ◑ | ● | ◑ | ▨ | ▨ | ○ | ▨ | ○ |
| Surface-Applied Films | ◪ | ○ | ◑ | ◪ | ◑ | ○ | ○ | ◑ | ◑ | ○ |
| **Other** | | | | | | | | | | |
| Solar Screens | ○ | ○ | ● | ○ | ◑ | ○ | ◑ | ◑ | ● | ◑ |

Although all window attachments can impact the energy performance of windows, the energy savings may vary based on occupant behavior and the climate where the building is located. According to a study

[14] Conclusions regarding attributes are based on information presented in the Efficient Window Collaborative website (http://www.efficientwindows.org/index.php), which is currently being updated as part of the Attachment Energy Rating Council's outreach and education efforts (2017). Conclusions also are based on findings from Curcija et al. (2013) and other studies presented in Table 2.

[15] The benefits of this technology for the given attribute are not generalized should be examined on a case-by-case basis.

conducted by D&R International on window attachment behavior (Bickel et al. 2013), 75 to 84% of window attachments remain in the same position throughout the day, depending on the season and day of the week. Further, about half of all window attachments are always closed, and many homeowners do not adjust any of the attachments in their home on a daily basis. The study showed that the proportion of window attachments open during winter days is larger than the proportion of attachments open during summer days. In the evening, some window attachments are closed during both the winter and the summer (Bickel et al. 2013). This indicates that households may open window attachments during the day in the winter to allow for passive heating in the home, and may close the attachments at night to keep the heat in or provide privacy. These behavioral impacts also demonstrate that some energy savings can be achieved through occupant behavior, but maximum energy savings may not be fully guaranteed if solely dependent on occupant behavior.

## 4.3 Regional Impact

Based on laboratory testing, case studies, and climate-based modeled energy savings, installation of a typical window attachment could reduce the average heating and cooling consumption by 10% for residential homes and small commercial buildings. Individual savings for single-family residences or small commercial buildings depend on the overall condition of existing windows, the behavior of the occupants, and climate conditions. Window attachments would potentially have the ability to reduce energy in combination with all types of windows, but particularly with some of these lower performing windows in the region.

As previously mentioned, there are approximately 1.8 million homes in the northwestern regional states with low-performing windows. This large number of households with low performing windows persists despite the fact that there are over 70 utility incentive programs in place in this same region that provide incentives for window replacements.[16] In comparison to the utility incentives programs that target window replacement, DSIRE listed only one utility efficiency program in the region that directly addresses energy-efficient window attachments in 2015.[17]

Of the approximately 1.8 million households with low-performing windows, approximately 324,000 do not have any form of window attachments. It could further be assumed that 82% of the estimated 1.48 million that do have window attachments are using relatively low-efficiency attachments for the climate zone.[18] Thus, just over 1.5 million households, consuming over 125 trillion Btu of electricity and natural gas each year, could greatly benefit from high-efficiency window attachment applications. Since the window performance in multi-family homes and small commercial follows a similar pattern to single-family homes in the region, an additional 450,000 multi-family homes and 2660 small commercial buildings would greatly benefit from high efficiency window attachments.

## 4.4 Climate Variation

In addition to the energy savings variation based on behavior and baseline window characteristics, the energy savings potential for each type of window attachment also varies based on the climate associated with the building location. The International Energy Conservation Code's (IECC) climate zones map of the United States is shown in Figure 4. This map places western Washington and western Oregon in the Mixed/Marine climate zone, but splits parts of eastern Washington, eastern Oregon, and western Idaho

[16] Based on DSIRE database search available online at: http://www.dsireusa.org/.
[17] Note that since the adoption of low-e storm windows in the BPA portfolio of "proven measures" in 2015, a number of utilities in the northwest are starting to offer incentives for this measure; however, these programs were not explicitly reflected in the 2016 DSIRE database.
[18] Based on assumption that 82% have window attachments in northern climate zones (Bickel et al. 2013).

into the Cool/Dry climate. The rest of eastern Washington, eastern Idaho, and all of Montana is classified as Cold/Dry.

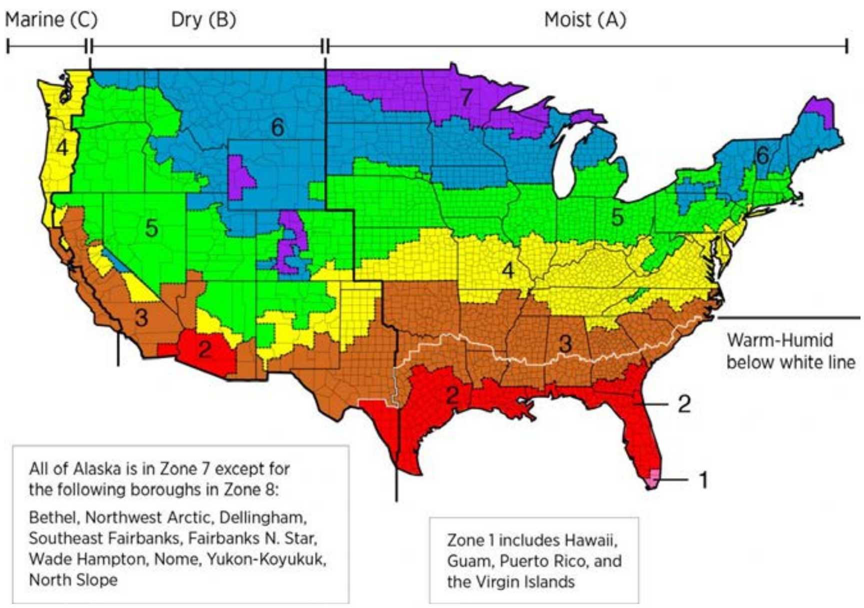



**Figure 4**. The 2012 IECC Climate Zone Map

The northwest regional states are in the heating-dominant northern climate zone, meaning that the heating energy requirement is higher than the cooling energy requirement on an annual basis. Thus, an effective window attachment in the region would have a combination of insulating properties and balanced solar control. Based on the general attributes[19] of various products (listed in Table 1), several window attachments would provide negligible energy savings benefits in certain heating-dominated climates while others may provide substantial savings. The 2013 LBNL window attachment study (Curcija et al. 2013) found that interior window panels, exterior storm panels, and cellular shades provided the most consistent energy savings in the northern climate zone. This was also confirmed with PNNL's Lab Home experimental results on these same technologies (see Table 2 summary of results). The interior panels and exterior low-e storm panels performed well for both heating and cooling energy use. Cellular shades also provide significant energy savings for both heating and cooling, but rely on some user operation to ensure that savings persist. When comparing the performance of cellular shades to vinyl blinds in an always-closed position during both seasons, the cellular shades had a heating savings of 10.5% and cooling savings of 16.6%.

Other insulating window attachments, such as window quilts and insulating roller shutters are estimated to provide similar level of energy savings, although they were not included in the LBNL or PNNL studies. Based on modeled energy savings, the characteristics of some of the window attachments would imply negligible energy savings on a year-round basis in the northwest regional states; thus, the application of these attachments would be best evaluated on a case-by-case basis. Examples of such window attachments are vertical louvered blinds, awnings, and exterior films (Curcija et al. 2013), which are particularly effective at shading and reducing the cooling load; however, these same attributes may contribute to a higher heating load in the winter, which could negate the overall annual energy savings.

[19] Conclusions regarding attributes are based on information presented in the Efficient Window Collaborative website (http://www.efficientwindows.org/index.php), which is currently being updated as part of the Attachment Energy Rating Council's outreach and education efforts (2017). Conclusions are also based on findings from Curcija et al. (2013) and other studies presented in Table 2.

In addition to the Lab Homes experiments conducted by PNNL, a modeling study focusing on low-e storm window energy savings and cost-effectiveness found that low-e storm windows were a cost-effective[20] method to save energy in single-family residences in most of the United States, including the northwest regional states (Culp and Cort 2015). Figure 5 depicts the areas of the United States where the application of low-e storm windows over single-pane or double-pane (clear-glass) metal-framed windows yields a savings-to-investment ratio greater than 1. These findings were further confirmed by the Pacific Northwest Regional Technical Forum (RTF),[21] which conducted a modeling study based on its Simplified Energy Enthalpy Model (SEEM)[22] and the RTF Operating Guidelines (RTF 2015) to evaluate the cost-effectiveness of low-e storm windows in the region. Supported by the existing field and experimental data discussed above, results from SEEM modeling demonstrated that low-e storm windows met the total resource cost criteria to be considered a "proven" and cost-effective energy-saving measure for most applications in the BPA region (i.e., Oregon, Washington, Idaho, and part of Montana), which led to approval by the RTF board for the measure in the northwest regional states. In 2016, the RTF expanded the study to include manufactured and multi-family homes, and the board's approval followed.[23]

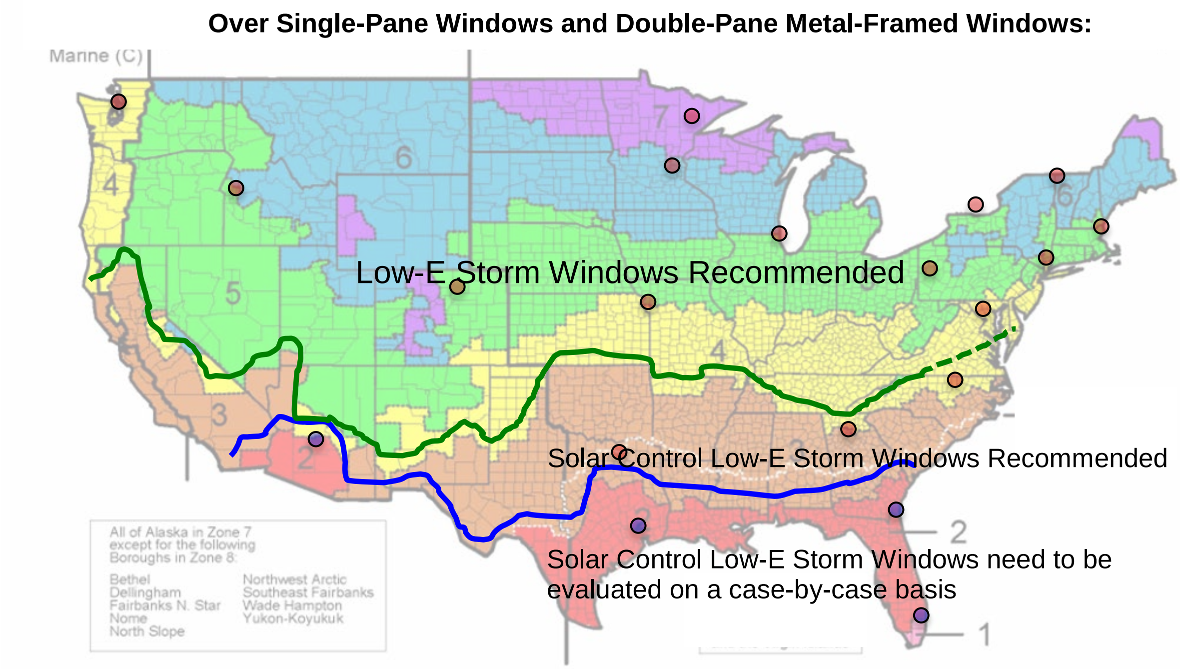



**Figure 5**. Overall Recommended Regions for the Use of Low-e Storm Windows Installed Over Single-Pane Windows and Double-Pane Metal-Framed Windows and the Location of Cities included in this Analysis (Culp and Cort 2015)

An assessment effectiveness of the various interior and exterior window attachments when installed in the northwest regional states is presented in Table 5, based on the energy performance characteristics provided in Table 4 with regional variability discussed in this section. Table 5 provides a breakdown of

[20] A method is considered to be cost effective if the savings-to-investment ratio greater than 1.

[21] The RTF is an advisory committee for the Northwest Power and Conservation Council established to develop standards to verify and evaluate energy savings from technologies, approaches, systems, and measures for BPA.

[22] The SEEM program is designed to model energy use in small-scale residential building. It performs hourly thermal and humidity simulations that interact with duct specifications, equipment, and water parameters to calculate the annual heating and cooling energy requirements of the home.

[23] See meeting agenda and minutes online: http://rtf.nwcouncil.org/meetings/2016/03/.

the window attachment energy performance when installed in western Washington, western Oregon, eastern Washington, eastern Oregon, Idaho, and Montana.

## 4.5 Marketability

Often there are non-energy metrics that homeowners typically consider when installing window attachments. The Efficient Windows Collaborative provides a summary the non-energy characteristics of each window attachment that are typically taken into consideration by the homeowners when purchasing window attachments (see Table 6 of this report).[24] Attributes such as privacy and noise control may influence purchasing decisions and are important to consider as an energy efficiency organization when evaluating the effectiveness of an incentive program.

**Table 5**. Estimated Effectiveness of Installed Window Attachment in the Washington, Oregon, Idaho, and Montana

● "Greatest Benefit"
◐ "Moderate Benefit"
○ "Neutral or Average"
▨ "Undetermined" [a]

| | Effectiveness in the PNW | Western Washington | Western Oregon | Eastern Washington | Eastern Oregon | Idaho | Montana |
|---|---|---|---|---|---|---|---|
| **Exterior Attachments** | | | | | | | |
| Low-e Storm Windows | ● | ● | ● | ● | ● | ● | ● |
| Awnings | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ |
| Roller Shades | ○ | ○ | ○ | ◐ | ◐ | ○ | ○ |
| Roller Shutters | ◐ | ○ | ○ | ◐ | ◐ | ◐ | ◐ |
| **Interior Attachments** | | | | | | | |
| Conventional Roller Shades | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Conventional Drapes | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Louvered Blinds | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Low-e Window Panels | ● | ● | ● | ● | ● | ● | ● |
| Insulated Cellular Shades | ● | ● | ● | ● | ● | ● | ● |
| Window Quilts | ● | ◐ | ◐ | ● | ● | ● | ● |
| Surface-applied Films | ◐ | ○ | ◐ | ◐ | ◐ | ◐ | ◐ |
| **Other** | | | | | | | |
| Solar Screens | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

[a] The benefits of this technology for the given attribute are not generalized and should be examined on a case-by-case basis.

[24] Conclusions regarding attributes are based on information presented in the Efficient Window Collaborative website (http://www.efficientwindows.org/index.php) as well as findings from LBNL (2013) and other studies identified in Table 2.

## 4.6 Utility Appeal

From a utility program perspective, there are several attributes of a given technology or measure that make it well-suited for energy-efficiency programs. One attribute is broad applicability rather than narrow or niche applicability. Because the northwest regional states generally have a heating-dominated climate, energy savings realized during the heating season are beneficial; however, considering that there are several climate zones within the region that also experience hot summers, a technology that enables both heating and cooling savings (i.e., year-round savings) also has appeal. Persistence in savings that is not unduly influenced by behavior or seasonal activities is also an important attribute of utility-supported energy-efficiency measures. Durability, low cost, and consistent performance are also beneficial attributes. Finally, it is important that the measure be commercially available and easy to acquire. Table 7 lists the qualitative rating of these attributes for three technologies that rate favorably in the northwest regional states as noted in Table 5.

**Table 6**. Non-Energy Window Attachment Attributes of Interest to Homeowners

● "Greatest Benefit"
◑ "Moderate Benefit"
○ "Neutral or Average"
◍ "Undetermined"[a]

| | Maintains View | Daylighting | Glare Control | Privacy | Adjustability | Protection for Window | Noise Control | Egress | Security |
|---|---|---|---|---|---|---|---|---|---|
| **Exterior Attachments** | | | | | | | | | |
| Low-e Storm Windows | ● | ◑ | ○ | ○ | ◑ | ● | ◑ | ○ | ◑ |
| Awnings | ◑ | ◑ | ● | ○ | ◑ | ◑ | ○ | ● | ○ |
| Roller Shades | ○ | ○ | ◑ | ● | ◑ | ◑ | ○ | ○ | ○ |
| Roller Shutters | ◍ | ◍ | ● | ● | ◑ | ● | ◑ | ○ | ● |
| **Interior Attachments** | | | | | | | | | |
| Conventional Roller Shades | ○ | ◑ | ◑ | ● | ◑ | ○ | ○ | ○ | ○ |
| Conventional Drapes | ○ | ○ | ◑ | ● | ◑ | ○ | ○ | ○ | ○ |
| Louvered Blinds | ◑ | ● | ● | ● | ◑ | ○ | ○ | ○ | ○ |
| Low-e Window Panels | ● | ◑ | ○ | ○ | ◍ | ○ | ◑ | ◍ | ◑ |
| Insulated Cellular Shades | ○ | ◑ | ◑ | ● | ● | ○ | ◑ | ○ | ○ |
| Window Quilts | ◍ | ◍ | ○ | ● | ◑ | ○ | ◑ | ○ | ○ |
| Surface-applied Films | ◑ | ◑ | ◑ | ◑ | ○ | ○ | ◑ | ● | ◑ |
| **Other** | | | | | | | | | |
| Solar Screens | ◍ | ◍ | ◑ | ○ | ◍ | ○ | ○ | ○ | ○ |

[a] The benefits of this technology for the given attribute are not generalized and should be examined on a case-by-case basis.

The three technologies (low-e storm windows, insulated cellular shades, and surface-applied films) listed in Table 7 show promise for applications in the northwest regional states. Low-e storm windows/panels have been extensively tested in the PNNL Lab Homes (controlled experimental homes), and in the field. Low-e storm windows receive high marks for persistent year-round savings in that they are permanently installed, operable in a manner that is similar to the primary window, and save energy during the summer and winter by reducing infiltration and adding an insulating layer to the window. Low-e storm windows can be installed as an existing building retrofit measure in both residential and small commercial applications. Low-e storm windows also are readily available at a relatively low cost and they have proven to be durable, with extended guarantee times and product consistency. Interior storm panels are rated slightly higher than exterior storm panels in terms of "wide application," as they have some installation advantages in high-rise multi-family buildings and commercial applications.

**Table 7.** Qualitative Ratings of Attributes for Low-e Exterior and Interior Storm Windows, Insulated Cellular Shades, and Surface-Applied Films

Legend: ● "Greatest Benefit"; ◑ "Moderate Benefit"; ○ "Neutral or Average"; ◈ "Emerging products – Unverified benefits"

| | Wide Application[a] | Year-Round Savings[b] | Persistence[c] | Lifetime[d] | Cost[e] | Product Variance[f] | Availability[g] |
|---|---|---|---|---|---|---|---|
| Low-e Exterior Storm Windows | ◑ | ● | ● | ● | ◑ | ● | ● |
| Low-e Interior Windows/Panels | ● | ● | ● | ● | ◑ | ● | ◑ |
| Insulated Cellular Shades | ◑ | ● | ○ | ◑ | ◑ | ◑ | ● |
| Surface-Applied Films[h] | ● | ◈ | ● | ◈ | ◈ | ○ | ◑ |

[a] Wide Application: The widespread application the window attachments are typically implemented. The 'greatest benefit' indicates that the attachment is implemented both in the residential and commercial space, 'moderate benefit' indicates that the attachment is widely implemented in either the residential space or the commercial space, and 'neutral or average' indicates that the window attachment is not widely implemented in either the residential or commercial space.

[b] Year-Round Savings: Summarizes the energy-saving impact of the window attachments across both the heating season and the cooling season. The 'unverified moderate benefit' indicates that significant improvements have been made in that technology, but the savings have not been verified through studies.

[c] Persistence: This indicates whether the savings from the window attachment are achieved solely through the proper installation of the attachment or whether any user behavior is required to achieve the savings.

[d] Lifetime: Indicates the duration of savings achievable through the window attachment. Also reflective of the durability of the product. The 'unverified moderate benefit' indicates that significant improvements have been made in that technology, but have not been verified through studies.

[e] Cost: Indicative of the average cost of purchasing and installing the window attachment. The 'unverified moderate benefit' indicates that significant improvements have been made in that technology, but the added costs of the improved technology have not been verified.

[f] Product Variance: This category describes the variability in the product offerings based on potential savings, costs, or other factors. The 'greatest benefit' indicates that the attachment has a low variability in product offerings, 'moderate benefit' indicates that the attachment has a moderate variability, and 'neutral or average' indicates that the window attachment has a wide range of variability in its offerings.

[g] Availability: This describes the commercial availability of the window attachment. The 'greatest benefit' indicates that the attachment is offered from a wide range of manufacturers or has high shipment volumes, 'moderate benefit' indicates that the attachment has some manufacturers involved and moderate shipments, and 'neutral or average' indicates that there are some opportunities to increase the number of manufacturers or shipments in that window attachment.

[h] There have been considerable improvements in surface-applied films, but the savings and other new characteristics of the technology have not been verified.

Insulating window coverings, such as cellular shades or quilts, also can provide significant energy savings in the northwest regional states. As a utility-sponsored product, cellular shades have verified heating and cooling saving ratings and have been proven to provide significant year-round savings (see Table 2). This product has some variability in cost, product durability, and performance, but high-performing products are readily available. This product is rated slightly lower in terms of its application in the market because it is primarily used in the residential sector; however, it has broad appeal in both new and existing homes, and benefits of this product can be realized when attached over either high efficiency or low efficiency windows. Cellular shades have been tested in PNNL's Lab Homes over double-pane clear glass, aluminum frame windows. The PNNL Lab Homes are located in eastern Washington State (see Table 3 of this report). Perhaps from a utility program perspective, the biggest drawback of this product is the fact that they are typically operated by the building occupant, thus their savings is dependent on a behavioral component that could affect persistent savings. Nevertheless, a study by D&R International (Bickel et al. 2013) indicates that, on average, these shading devices would be operated in a manner to save energy. In addition, automated control features could be added to ensure more consistent and persistent savings.

Surface-applied window films have traditionally saved energy during the cooling season, which does not necessarily make them good candidates as energy-efficient measures in the northwest regional states, particularly in the marine climate zone. However, some emerging low-e films show promise in the heating season as well, and once a film is applied, it provides a persistent form of savings with broad commercial and residential applications. Thus, these products were included on this list as a potential measure for the northwest regional states. More focused testing and demonstrations of this product may be necessary to ensure savings in the regional climate zones.

# 5.0 Market Barriers

Although wide-scale adoption of window attachments and relative cost and performance attributes of energy-efficient window attachments set the stage for broad market success, some significant barriers to deployment have been noted based on early experience in the market. One primary concern is that operable attachments would be limited in energy-saving potential depending on use or operation by the homeowner. One market barrier to achieving more widespread penetration of energy-efficient window attachment programs and utility incentives is the lack of standardized ratings for such products. The following section outlines some of the barriers faced for widespread market adoption of these products.

## 5.1 Potential Market and Utility Program Barriers

Based on market research and input from industry representatives and researchers who have participated in case studies and pilot programs, the following potential barriers to market adoption have been identified:

1. *Consumer Awareness*: Although over 80% of households have some form of attachment installed, relatively few consumers are familiar with the various product categories for this product or realize that window attachments can be energy-savers.
2. *Identity Crisis*: End users and energy-efficiency program administrators often do not have a category or classification for window attachments as an energy-efficiency measure. Window attachments often fall between the cracks of being windows and insulation (e.g., they have no ratings from the National Fenestration Rating Council, which rates the performance of windows and no rating as an insulation measure). Weatherization program administrators often categorize window attachments in the same category as window replacements. Because window replacements are usually too costly to qualify as weatherization measures, by association, window attachments also are dismissed as qualified measures. Furthermore, end users and energy efficiency program managers often do not realize how much energy can be saved with the appropriate use of window attachments.
3. *Energy Savings Persistence*: The operability of many window attachments (e.g., blinds, shades, etc.) allows control by the user. However, this feature also leaves the measure vulnerable to sub-optimal use. For example, although a shading device could theoretically save 20% on heating or cooling bills, these savings will only be realized if the building occupant operates the technology in an energy-optimal manner. This is significant barrier for utility energy-efficiency program managers who often are required to ensure persistence of savings of any measure promoted or incentivized by their programs.
4. *Stigma*: Some window attachments, such as storm windows, suffer from an image problem that results, in part, from some of the more unattractive, inoperable storm windows from the past. Further, previous generations of storm windows were typically only installed during the winter and taken down for the remainder of the year, making their installation a tedious annual chore. Previous generations of storm windows were not always well sealed, became dirty easily, and were subject to condensation buildup. Despite improvements in the sealing, framing, aesthetics, and operability of storm windows, the stigma persists and potentially hampers market uptake.
5. *Non-Recognition by Rating Systems*: Despite the proven energy savings, no standard rating system or energy-efficiency label exists for window attachments. This impacts other areas, such as building energy standards and codes, federal tax energy-efficiency rebates, and various energy-efficiency programs that reference the product ratings of the National Fenestration Rating Council or other reputed organizations as criteria for meeting requirements or qualifying for funding and programs. Although Energy Star has labels for windows, there is no Energy Star label for any window

attachments. One industry representative mentioned that one of the most frequently asked questions by potential low-e storm window customers was whether or not the product has an Energy Star label. Consumers have come to rely on the Energy Star label to guide their decision-making process related to energy-efficient products. The absence of this label and rating potentially hamper the market uptake of this product. Likewise, although it is a newer rating system, DOE’s Home Energy Score does not take into account the influence of window attachments on energy consumption, and it does not include window attachments in its list of recommended improvements.

6. *Do-It-Yourself (or not)*: One manufacturer noted that 80% of storm window installations are do-it-yourself projects. Likewise, many interior window attachments are purchased at big-box stores and installed by the homeowner. In some marketability respects, this is good news as it implies low-cost and easy installation. However, this indicates that third-party installation contractors and installers are not common and that this potential “sales force” has not been well developed. Further, many do-it-yourself projects are put off for another day or simply never happen. If window attachments reside in the do-it-yourself category, they may fall victim to procrastination and installation of window attachments will only occur after the homeowner gets around to fixing the hole in the fence, programming the thermostat, cleaning out the closets, etc.
7. *High First Costs*: Despite the fact that window attachments, in general, have a much lower price point than replacement windows, there are many products and product categories that have high first costs that inhibit and prevent some home and commercial building owners from considering these energy-saving measures.

## 5.2 Efforts to Address Barriers and Alignment with Other Programs

Although many barriers persist in the market for energy-efficiency window attachments, there are a number of programs that are addressing these barriers with targeted research, outreach and education, and the development of a process to provide energy ratings for window attachments.

DOE’s work and interest with window attachments initially came about through its research into low-e coatings in the 1990s (Klems 2003). Early field testing demonstrated that these low-e storm windows provided the same performance improvement as new low-e replacement windows. This research has been applied to window films and other window attachment material as well. Much of the demonstration and field research that has been sponsored by DOE is described in Table 2 of this report. More recently, the DOE Building America program has supported the demonstration and testing of high-efficiency window attachments in the Lab Homes at PNNL. Through partnership with the Consortium for Energy Efficiency, BPA, NEEA, Window Coverings Manufacturers Association, and others, various program efforts supporting market transformation of energy-efficient window attachments have been implemented, including utility-sponsored education and outreach and energy-efficiency labeling efforts.

### 5.2.1 Attachment Energy Rating Council and Labeling Efforts

Standards and ratings can help inform consumers and drive the market for energy-efficient products. Because no energy-related rating or standards existed for window attachments, in 2014 DOE helped establish the AERC, which is a voluntary rating council for energy-efficient window attachments. The purpose of the AERC is to develop a comprehensive energy-rating, labeling, and certification program for window attachments. The council is run as an independent, non-profit organization that serves the public interest by providing accurate and credible information about the energy performance of window attachments. The objective is to develop a third-party program that creates a consistent set of energy performance-based rating and certification standards and develop and maintain a publicly available, searchable electronic database of fenestration attachment product performance. The council's initial goals include establishing a rating for storm windows and cellular shades by the end of 2017.

In addition to the AERC labeling effort, the Environmental Protection Agency (EPA) is in the process of developing a specification for low-e storm windows as part of the ENERGY STAR Program. In January 2016, EPA released a framework document outlining its preliminary research and discussion questions for comment. EPA expects to release a first draft of the specification sometime in 2017.

### 5.2.2 Utilities and Energy Efficiency Organizations

For the BPA utility region, the RTF approved low-e storm windows as a deemed unit energy savings measure. BPA is offering an incentive for installing low-e storm windows for single-family, multi-family, and manufactured housing. In the northeast, Efficiency Vermont ran a pilot program in 2015 to test a markdown of low-e storm windows to the price of non-low-e storm windows across different marketing platforms. The pilot showed more than a 300% increase in low-e sales and an overall increase in storm panel sales of 37%. Efficiency Vermont currently is going through the review process to add low-e storm windows as an energy-efficiency measure (Bonn et al. 2015). Focus on Energy, Wisconsin's statewide energy-efficiency and renewable-resource program, also has initiated program plans to launch an education and marketing campaign, similar to Efficiency Vermont's program, to support market transformation for low-e storm windows. Most recently, Silicon Valley Power, with support from the American Public Power Association, has funded research to examine the energy-savings potential of cellular shades throughout California to help inform program planning for energy-efficiency measures.

# 6.0 Conclusions

Improving the insulation and solar heat gain characteristics of windows in a home has the potential to significantly improve overall thermal performance by reducing heat loss (in the winter) and cooling loss and solar heat gain (in the summer) through windows. A high-quality window retrofit can provide this added insulation and can also minimize or reduce air leakage through the building envelope, thus decreasing infiltration. These improvements all contribute to decreasing a building's overall energy use.

Over the past 15 years, new window replacement and retrofit technologies have been developed that significantly increase the options available to homeowners and utilities when considering upgrading existing windows, including low-e storm windows, insulating blinds, and other window attachments. Both window replacement and energy-efficient window attachments, such as high-efficiency shades, blinds, storm windows, or other window attachments, can significantly improve the thermal performance of a window. From a northwestern regional utility program perspective, four window attachments stand out as promising technologies in terms of persistent year-round energy savings potential, durability, cost, and commercial availability. These include low-e storm windows (both interior and exterior), high-efficiency cellular shades, and advanced surface-applied window films. Both cellular shades and low-e storm windows (both interior and exterior) have been tested in the northwest, in PNNL's Lab Homes, and have demonstrated savings from 10-17% in both the heating and cooling seasons. Although surface-applied window films have traditionally been favored in cooling-dominated climates, some emerging low-e films show promise in the heating season as well, which makes it a more favorable technology in the heating-dominant climates of the northwest. In addition, once a film is applied, it provides a persistent form of savings with broad commercial and residential applications, which makes it a good candidate for a utility-incentive measure; however, more focused testing and demonstrations of this product may be necessary to ensure savings in the northwest regional climate zones.

In addition to these emerging window attachment materials, many window attachment manufacturers currently offer motorized attachments or attachments that can be operated through a control system, making it easier for consumers to optimally operate their window attachments and generate higher energy savings. The advancement of controls and automation in the window attachments field can potentially be integrated with home automation systems and other sensors to become even more dynamic and respond to weather conditions and the needs of the building occupant, potentially achieving further energy savings and comfort benefits.

Many residential homes and residential use commercial buildings in the northwest regional states are consuming large amounts of electricity and natural gas each year by wasting a considerable amount of heat through inefficient windows. These losses could be reduced by choosing and installing appropriately designed window attachments. Window attachments have the potential to reduce energy in combination with all types of windows, but particularly with the lower performing windows still in use in this region. The continuation of targeted research, outreach, and education efforts focused on optimizing the energy savings potential of window attachments in the northwestern residential and small commercial buildings could benefit the NEEA region.

# 7.0 References


Attachment Energy Rating Council (AERC). 2016. "Window Attachments: Call to Action." AERC Utility Outreach Committee. Available online at: http://aercnet.org/wp-content/uploads/2016/10/UtilityInfo.pdf.

Ariosto T and A Memari. 2013. *Evaluation of Residential Window Retrofit Solutions for Energy Efficiency*. No. 111, Pennsylvania Housing Research Center (PHRC), University Park, Pennsylvania.

Baylon D, P Storm, K Geraghty, and B Davis. 2012. *2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use*. Prepared by Ecotope, Inc. for the Northwest Energy Efficiency Alliance, Portland, Oregon.

Bickel S, E Phan-Gruber, and S Christie. 2013. *Residential Windows and Window Coverings: A Detailed View of the Installed Base and User Behavior*. Prepared by D&R International for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, Washington, D.C. Available online at: http://energy.gov/sites/prod/files/2013/11/f5/residential_windows_coverings.pdf.

Bonn, L, J Rivest, E Phan-Gruber, J Winer, S Bickel, T Stratmoen, and D Bailey. 2015. "Lo(w-e) and Behold: Low-e Storm Windows Provide a New Way to Solve the Window Conundrum." Efficiency Vermont, D+R International, and Larson Manufacturing. Available online: https://www.efficiencyvermont.com/Media/Default/docs/white-papers/efficiency-vermont-low-e-and-behold-white-paper.pdf

Consortium for Energy Efficiency (CEE). 2013. *CEE Window Product Overviews: Energy Efficient Fenestration Options.* Residential Windows Working Group (Alice Rosenberg, Program Manager), Boston, Massachusetts.

Cort, KA. 2013. *Low-e Storm Windows: Market Assessment and Pathways to Market Transformation.* PNNL-22565. June 2013. Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22565.pdf

Culp, T.D. and K.A. Cort. 2015. *Energy Savings of Low-e Storm Windows and Panels across U.S. Climate Zones.* PNNL-24826, Pacific Northwest National Laboratory, Richland, WA.

Culp, T.D., S.H. Widder, and K.A. Cort. 2015. *Thermal and Optical Properties of Low-e Storm Windows and Panels.* PNNL-24444, Pacific Northwest National Laboratory, Richland, WA.

Curcija DC, M Yazdanian, C Kohler, R Hart, R Mitchell, and S Vidanovic. 2013. *Energy Savings from Window Attachments*. Prepared for U.S. Department of Energy under DOE EERE award #DE-FOA-0001000. October 2013. Lawrence Berkeley National Laboratory, Berkeley, California. Available at: http://energy.gov/sites/prod/files/2013/11/f5/energy_savings_from_windows_attachments.pdf.

DOE. 2011. *Buildings Energy Data Book*. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Washington, D.C. Available at: http://buildingsdatabook.eren.doe.gov/DataBooks.aspx.

DOE-EIA. 2009. *2009 Residential Energy Consumption Survey: Housing Characteristics*. U.S. Department of Energy-Energy Information Administration, Washington, D.C.

DOE-EIA. 2012. *2012 Commercial Building Energy Consumption Survey*. U.S. Department of Energy-Energy Information Administration, Washington, D.C.

DOE-EERE. 2013. *Building America Technical Innovations Leading to 50% Savings – A Critical Path*. Developed by NREL, Building America (BA) Standing Technical Committee Chairs and BA Team Technical Leads. April 17, 2013 (interim update).

Drumheller SC, C Kohler, and S Minen. 2007. *Field Evaluation of Low-e Storm Windows*. LBNL-1940E, Lawrence Berkley National Laboratory, Berkeley, California.

Huang J, J Hanford, and F Yang. 1999. *Residential Heating and Cooling Loads Component Analysis.* LBNL-44636, Building Technologies Department, Lawrence Berkeley National Laboratory, Berkeley, CA.

Klems JH. 2003. "Measured Winter Performance of Storm Windows," *ASHRAE Transactions* 109(2), Paper KC-03-12-1, Lawrence Berkeley National Laboratory, Berkeley, California.

Knox JR and SH Widder. 2014. *Evaluation of Low-e Storm Windows in the PNNL Lab Homes*. PNNL-23355, Pacific Northwest National Laboratory, Richland, Washington.

Krigger J and B Van der Meer (Principal Authors). 2011. *Weatherization Standards and Field Guide for Pennsylvania*. Published for the Department of Energy Weatherization Assistance Program and the Pennsylvania Department of Community, Economic Development, and Office of Energy Conservation and Weatherization. February 2011 Edition.

Northwest Energy Efficiency Alliance (NEEA). 2014. *2014 Commercial Building Stock Assessment: Final Report.* Prepared by Navigant Consulting, Boulder, Colorado.

Petersen JM, KA Cort, MB Merzouk, and G Sullivan. 2016. *Evaluation of Cellular Shades in the PNNL Lab Homes*. PNNL-24857 Rev 2, Pacific Northwest National Laboratory, Richland, Washington.

Petersen, JM, KA Cort, MB Merzouk, G Sullivan, and V Srivastava. 2015b. *Evaluation of Interior Low-e Storm Windows in the PNNL Lab Homes*. PNNL-24827, Pacific Northwest National Laboratory, Richland, Washington.

Quanta Technologies. 2013. "2012-13 Quarterly Reports" prepared for U.S. Department of Energy under DOE EERE award #DE-EE0004015.

Regional Technical Forum (RTF). 2015. *Roadmap for the Assessment of Energy Efficiency Measures.* Regional Technical Forum, Portland, Oregon. Available at http://rtf.nwcouncil.org/subcommittees/Guidelines/Complete%20Operative%20Guidelines%20(Released%202015-12-08).pdf.

Zalis W et al. 2010. *Evaluation of Low-E Storm and R-5 Windows for Inclusion in Pennsylvania's Weatherization Priority List*. Prepared by W Zalis, Energetics; T Culp, Birch Point Consulting; C Kohler, LBNL; and PM LaFrance, U.S. Department of Energy; for the Pennsylvania Department of Community and Economic Development, May 2010, Columbia, Maryland.

Zirnhelt H, B Bridgeland, and P Keuhn. 2015. "Energy Savings from Window Shades." Prepared for Hunter Douglas by Rocky Mountain Institute, Boulder, Colorado.

Appendix A

# Description of Window Attachments

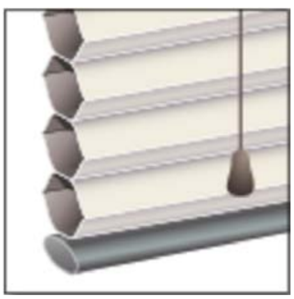
# Appendix A

# Description of Window Attachments

Each window attachment in Table 1 of this document is presented in this appendix, organized by mounting location (interior or exterior) and operability (fixed or operable). These graphics and descriptions are presented on the Lawrence Berkeley National Laboratory and Building Green's Efficient Window Coverings website. For more information regarding the window attachments listed in this appendix, visit the Efficient Window Coverings website at http://www.efficientwindowcoverings.org/.

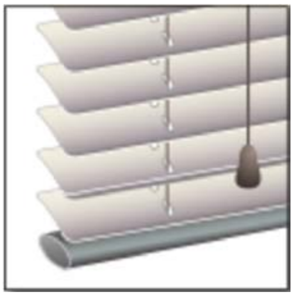
## Interior Window Attachments

**Applied Films**
Applied films primarily reduce summer solar gains and block ultraviolet (UV) light effectively. They require little maintenance. Many variations exist for additional desired performance including: glare reduction, privacy, security, and winter thermal performance. Window films typically cannot be adjusted or readily removed. Because of the range of film types, there are products that are useful in almost every climate and for every window application.



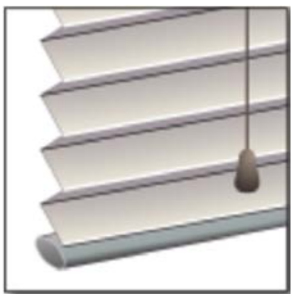
**Cellular Shades**
Insulated cellular shades are made of a pleated material and designed to fold up, accordion-like, usually at the top of the window but sometimes at either top or bottom, which provides maximum adjustability for daylight control, view, and privacy. Some insulated shades contain multiple air layers in a honeycomb cross-section. Insulated cellular shades are typically installed inside the window opening.

**Drapes/Curtains**
Curtains and drapes are the simplest, most common window treatments and are most associated with interior aesthetics. They are fabric interior attachments that are either sized to fit the window (curtains) or to reach all the way to the floor (drapes). Curtains and drapes usually are installed for privacy, but also offer some energy and comfort benefits.



**Louvered Blinds**
Louvered blinds enable a greater degree of light and view control than any other conventional interior window treatment. Their main benefits are reduced glare and solar heat gain. Horizontal slats or louvers are typically connected with cloth tape or cord running through a slot near the end of each slat; these are commonly called venetian blinds. Another control allows the slats on the fully or partially extended blind to be tilted so that more or less light comes through.

**Louvered Shutters**
Louvered shutters enable a greater degree of light and view control than any other conventional interior window treatment. Their main benefits are reduced glare and solar heat gain. Horizontal slats or louvers are typically connected with cloth tape or cord running through a slot near the end of each slat; these are commonly called venetian blinds. Another control allows the slats on the fully or partially extended blind to be tilted so that more or less light comes through.



**Pleated Shades**
Roman, pleated, and sheer shades offer unique combinations of aesthetics and function. Each can be selected for a huge range of configurations, colors, fabric type, and weight. Pleated shades are simpler and more economical versions of cellular shades with an extensive range of fabric selections.

**Roller Shades**
Roll-down shades (also called roller shades or roller blinds) fit inside the window casing next to the window sash and are available in a wide variety of fabrics and weaves. The least expensive and simplest are typically opaque and are usually installed to darken rooms and provide full privacy. Roller shades offer modest energy benefits by providing a small amount of insulation (less than fabric curtains), trapping air, and blocking sunlight.

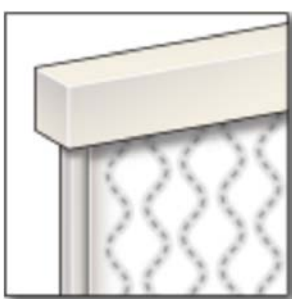
**Roman Shades**
Roman, pleated, and sheer shades offer unique combinations of aesthetics and function. Each can be selected for a large range of configurations, colors, fabric type, and weight. Roman shades are often made of heavier fabric to feature privacy and thermal performance.

**Sheer Shades**
Roman, pleated, and sheer shades offer unique combinations of aesthetics and function. Each can be selected for a huge range of configurations, colors, fabric type, and weight. Sheer shades offer a wide range of aesthetics with a focus on softened view and glare control.

**Solar Screens**
Residential solar screens are either roller shade or fixed panels, which can be installed on either the exterior or interior of a window. Solar screens reduce solar heat gain, UV damage, and glare while permitting significant view and light transmission. Interior roller solar screens function much like any interior adjustable window covering combining solar heat gain reduction with glare control and visibility.

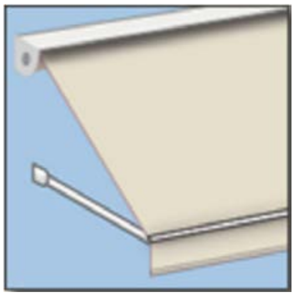
**Storm Panels (Fixed)**
Interior window panels function much like traditional exterior storm windows, adding an insulating layer to prevent heat loss from windows in cold weather, improving energy and comfort performance. The most common interior window panels are inexpensive, lightweight, clear plastic panels mounted in a frame sized to face-mount on the interior window casing or inset to mount on cleats installed in the window jamb. Low-e glass interior panels also are available.

**Storm Panels (Operable)**
Interior window panels function much like traditional exterior storm windows, adding an insulating layer to prevent heat loss from windows in cold weather, improving energy and comfort performance. Tracked interior window panels are just like exterior storms, but permanently installed on the inside of the window. With integral screens, they adjust for ventilation. Made of glass, they are durable, easy to clean, and are available with low-emissivity (low-e) coatings.

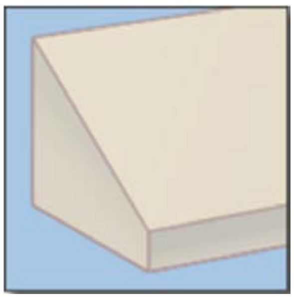


**Window Quilts**
Quilted blinds are typically face mounted and either roll up at the top of the window—with the roll exposed or hidden by a valance—or pull up so that the fabric is folded at the top of the window. The vertical edges of quilted roller blinds fit into edge channels, the bottom edge has foam or felt gasketing, and the top of the blind fits snugly against a compression bar. Less expensive (and less adjustable) quilted window blinds are available that use continuous Velcro or snaps to attach the blind to the window trim.

## Exterior Window Attachments

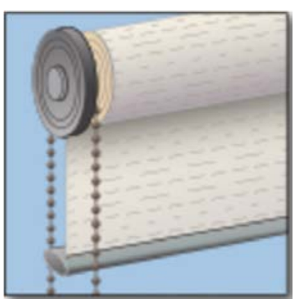


**Drop-arm/Retractable Awnings**
Awnings are roof-like shelters installed on a home's exterior to shade windows from the sun's heat, glare, and damaging UV rays. By blocking the sun's radiation outside of the home, before it reaches windows, awnings can be far more effective than interior blinds and shades at reducing indoor temperature increases from sunlight (solar heat gain). Retractable awning frames typically have hinged arms that allow for extension. Many retractable models are fully adjustable, providing tremendous flexibility in how much shade they provide.



**Fixed Awnings**
Awnings are roof-like shelters installed on a home's exterior to shade windows from the sun's heat, glare, and damaging UV rays. By blocking the sun's radiation outside of the home, before it reaches windows, awnings can be far more effective than interior blinds and shades at reducing indoor temperature increases from sunlight (solar heat gain). Stationary awnings are typically made of a durable fabric but can also be made of metal or fiberglass. They usually have a fixed aluminum frame and are designed for seasonal removal.

**Louvered Shutters**
Exterior shades and shutters are window attachments deployed on the outside of a building to dramatically reduce unwanted heat from the sun (solar heat gain). This is a high priority in hot climates or in any home where solar heat gain contributes to discomfort or significant air-conditioning costs. Exterior shades and shutters also provide a high degree of privacy; shutters may offer the added benefits of security and storm protection.



**Roller Shades**
Exterior window shades are typically a fabric screening—usually polyvinyl chloride-coated polyester or fiberglass—that rolls up into a protected valance at the top of the window (or terrace door). Solar heat gain through exterior roller shades depends on the openness (the larger the openness factor, the larger the solar gain) but also on the transparency of the fabric itself. Roller shades are most commonly lowered or raised by hand; some are operated from the outside, and others can be operated from inside using a through-the-wall crank.

**Roller Shutters**
Exterior roller shutters have hollow or foam-filled interlocking aluminum or plastic slats that form a fairly rigid protective barrier over a window when deployed and roll up neatly into a valance at the top of the window (or terrace door) when not in use. The slats typically fit into edge tracks and provide full privacy and security against break-ins and storms. Common in some areas of Europe, exterior roller shutters are less common in the United States, although they are used in the southwest and hurricane-prone areas.

**Solar Screens**
Residential solar screens are either roller shade or fixed panels that can be installed on either the exterior or interior of a window. Solar screens reduce solar heat gain, UV damage, and glare while permitting significant view and light transmission. Exterior solar screens are often fixed panels face mounted with clips, not that much different than an insect screen except with much better solar heat gain control.

**Storm Panels (Fixed)**
Storm windows are exterior windows added to cover and protect existing windows from weather and improve energy performance. High-performance, low-e exterior storm windows often have better seals, smoother long-term operation, and significantly better energy performance. Fixed panels are the most airtight, and double-tracks are more airtight than triple-tracks. Fixed-panel exterior storms may need to be removed seasonally to get full benefit when employed on operable windows.

**Storm Panels (Operable)**
Storm windows are exterior windows added to cover and protect existing windows from weather and improve energy performance. High-performance, low-e exterior storm windows often have better seals, smoother long-term operation, and significantly better energy performance. There are three basic types of exterior storm windows: 1) triple-track (two operable glass panels and an operable screen), 2) double-track (an operable lower panel and an operable screen), and 3) fixed (one non-operable glass panel).

**Surface-Applied Films**
Applied films primarily reduce summer solar gains and block UV light effectively. They require little maintenance. Many variations exist for additional desired performance including glare reduction, privacy, security, and winter thermal performance. Window films typically cannot be adjusted or readily removed. Because of the range of film types, there are products that are useful in almost every climate and for every window application.

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