Residential Window Coverings: Saving Energy or Just Nice Looking?

Katherine Cort
Pacific Northwest National Laboratory

Emerging Technologies Showcase
September 20, 2017
GoToWebinar Logistics

- Minimize or maximize control panel
- Phone lines are muted
- Please use question pane to ask questions at any time, or if you have any technical issues

NOTE: Today’s presentation is being recorded and will be available at http://e3tnw.org/Webinars
Residential Window Coverings: Saving Energy or Just Nice Looking?

Emerging Technologies Showcase Webinar

Katherine Cort
Pacific Northwest National Laboratory
September 20, 2017
Webinar Objectives

- What are Window Attachments?
- Why are Window Attachments important?
  - What is the problem we are trying to solve?
  - How can window attachments help address this problem?
- Who is doing work in this area?
- What kind of research is being done and what are the findings?
- What are some of the emerging technologies we should be keeping an eye on?
The Problem: Minding the Gap

80% of U.S. homes have non-low-e single or double pane windows.

30% of a typical home’s heating and cooling energy.

Energy losses through the window.

Most household heat is lost through the windows and roof.

Only 2% of homes replace their windows each year.

93 million homes have inefficient windows.
What are Window Attachments?

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<td>Insulated Cellular Shades</td>
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<td>Surface-Applied Films</td>
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<td>Solar Screens</td>
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</table>

1 The benefits of this technology for the given attribute are not generalized and should be examined on a case-by-case basis.
Window Attachments Value Proposition

Large market opportunity:
- Applicable to new and existing homes
- 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 blinds (horizontal slatted)

Energy Savings Potential:
- Reduces home’s HVAC consumption by 3-30%
- Can also reduce infiltration, glare, and noise

- Comfort
- Aesthetics
- Minimize Glare
- Daylighting
- Noise Control

Energy Savings
Who is doing work with Window Attachments?

- **DOE**
  - Emerging Technologies windows research
  - Attachment Energy Rating Council (AERC)
  - **Building America** research, testing, and technical assistance
  - ENERGY STAR program for storm windows

- **Utilities**
  - Consortium for Energy Efficiency
  - BPA and NEEA
  - Silicon Valley Power (with assistance from the American Public Power Association)
  - Efficiency Vermont
  - Focus on Energy Wisconsin
Energy Modeling

- Comprehensive energy-modeling study that examined 11 different typical residential window attachments including:
  - shades
  - blinds
  - storm window panels
  - surface-applied films
- Baseline with 4 types of houses, 3 types of windows, in 12 climate zones
- Operation assumptions based on empirical study
- For most attachments examined, energy savings significant, but results depend on type of attachment, season, climate, and operation.
- In heating-dominated climates in north/central zones, low-e insulating storm panels (both interior and exterior) and insulating cellular shades are the most effective at reducing HVAC.
What is the AERC?

AERC is an independent, public interest organization whose mission is to rate, label, and certify the energy performance of window attachments.

- Founded in 2014 with support from DOE
- AERC members include
  - Public Interest Groups
  - National Labs
  - Commercial Labs
  - Product Manufacturers
  - Component Manufacturers
  - Utilities
- Board is majority public interest
  - AERC member available at: http://aercnet.org/membership/current-members/
Why is AERC Necessary?

- Window attachments can save energy
  - However, many consumers are unaware of their energy-saving capability
- Consumers have no way to compare the energy performance of attachments
  - Unverified energy savings claims by manufacturers are prevalent
- Energy Efficiency program managers also benefit from ratings and energy performance information

The AERC rating allows consumers and program managers to make more informed decisions.
AERC 2017 Goals

- **Energy Performance Ratings** for residential window attachments

<table>
<thead>
<tr>
<th>PHASE 1 2017</th>
<th>Blinds</th>
<th>Cellular Shades</th>
<th>Roller Shades</th>
<th>Storm Windows</th>
<th>Solar Screens</th>
<th>Pleated Shades</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE 2 2018</td>
<td>Awnings</td>
<td>Window Quilts</td>
<td>Roller Shutters</td>
<td></td>
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<tr>
<td>PHASE 3 2018</td>
<td>Drapes</td>
<td>Interior Shutters</td>
<td>Roman Shades</td>
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</tr>
</tbody>
</table>

- **Product Label** for the residential market

- **Website** that will allow consumers to access certified product performance information

- **Public outreach and education**
  - Go to [www.aercnet.org](http://www.aercnet.org)
  - Or e-mail [info@aerc.org](mailto:info@aerc.org)

Label Prototype (not final)

Disclaimer: The Attachments Energy Rating Council ratings are based on a standard set of assumptions including attachment installation over a double pane clear glass window. AERC does not guarantee that the consumer will experience energy savings. See website for additional details about the assumptions for the ratings.
ENERGY STAR for Exterior and Interior Storm Panels

ENERGY STAR program issued its “Specification Framework Document” related to storm panels in January 2016. Determines whether or not:

- Significant energy savings can be realized on a national basis from the application of storm windows/panels.
- Product energy performance can be measured and verified with testing.
- Purchasers will recover their investment in energy-efficient storm windows/panels within a reasonable period of time.
- Labeling would effectively differentiate products and be visible to purchasers.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Timeframe</th>
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<tbody>
<tr>
<td>Specification Framework Released For Comment</td>
<td>January 14, 2016</td>
</tr>
<tr>
<td>Deadline for written comments on framework document</td>
<td>February 12, 2016</td>
</tr>
<tr>
<td>Draft 1 Specification Issued</td>
<td>Summer 2016</td>
</tr>
<tr>
<td>Final Specification Issued and Effective</td>
<td>2017</td>
</tr>
</tbody>
</table>
PNNL Lab Homes Field Testing: Sited within the Tri-Cities Research District in Richland, WA
Side-by-side simulated field environment provides a unique platform for efficiently and cost-effectively demonstrating new energy-efficient and grid-responsive technologies.
Lab Homes Characteristics

- Specified to represent existing manufactured and stick-built housing
  - 3 BR/2BA, 1493 ft², double-wide factory-built to HUD code.
  - All-electric with 13 SEER/7.7 HSPF heat pump central HVAC + alternate Cadet fan wall heaters throughout
  - R-22 floors, R-11 walls & R-22 ceiling with composition roof
  - 195.7 ft² (13% of floor) window area
  - Wood (Smartpanel) siding
  - Incandescent lighting
  - Bath, kitchen, whole house exhaust fans
  - Carpet + vinyl flooring
  - Refrigerator/range/washer/dryer/dishwasher
  - All electric

- Modifications include extensive metering and 3 EV charging stations
Low-e Storm Windows

Low-e Storm Windows (both interior and exterior)

- Aesthetically pleasing
- Adds comfort year-round
- Permanent installation
- Operable
- Energy savings similar to full replacement of non low-e windows with low-e double-pane windows
- About 1/3 the cost of full window replacement
- Low cost installation (80% installed as do-it-yourself measure)
- Simple payback of 4 to 14 years*

In late 90’s, LBNL suggested that low-e storm windows could be a cost-effective insulating and air sealing measure for existing windows:

- **Air Sealing of Prime Window**
  - Case studies show 10% reduction in overall home air leakage

- **Creation of “Dead Air Space”**
  - Reduce conduction and convective losses across prime window

- **Reflection of Radiant Heat: Low-E Glass**
  - 35% increased performance over clear glass

**Fixed wood window, single glazed**

**With exterior storm, clear glass**

**With exterior storm, low-E glass**
Lab Homes – Low-E Storm Windows

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Description</th>
<th>Picture</th>
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<tbody>
<tr>
<td><strong>Exterior Low-E Storms</strong></td>
<td>Operable low-e metal-frame exterior storm window</td>
<td></td>
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<tr>
<td>(Larson Manufacturing)</td>
<td>U-factor = 52% reduction</td>
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<td>SHGC = 24% reduction</td>
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<td></td>
<td>Compared to clear double-pane primary windows</td>
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<tr>
<td><strong>Interior Low-E Storms</strong></td>
<td>Operable low-e metal-frame interior storm window</td>
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<tr>
<td>(Quanta Technologies)</td>
<td>U-factor = 53% reduction</td>
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<td>SHGC = 19% reduction</td>
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<td></td>
<td>Compared to clear double-pane primary windows</td>
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See PNNL youtube video that includes installation instructions: [https://www.youtube.com/watch?v=DeU6wn0psrU](https://www.youtube.com/watch?v=DeU6wn0psrU)
### Lab Homes – Low-E Storm Windows Impact on Energy Savings

<table>
<thead>
<tr>
<th>Technology (experiment)</th>
<th>Baseline and Experiment Description</th>
<th>Energy Savings (%)</th>
</tr>
</thead>
</table>
| **Exterior low-e storm windows, 2014** (Larson Manufacturing) | Double-pane metal-frame clear glass windows (no window coverings)                                      | Average Annual Savings: 10.1 ±1.4%  
Simple Payback = 5-7 yrs                                                     |
| **Interior low-e storm windows, 2015** (Quanta Technologies) | Covering 74% of window area over double-pane metal-frame clear glass windows                        | Average Annual Savings: 7.8 ±1.5%                                                  |

#### Infrared Images – Interior Storm Windows

**Baseline Home**

**Experimental Home**
Recent Interest in Low-e Storm (LES) Window Incentives

- **2010**: LES added to Pennsylvania Wx “Priority List”
- **2011**: LES added to AZ and TX Wx Programs
- **July 2015**: LES approved by NW RTF as “Proven UES” for single-family
- **Jan. 2016**: LES approved by NW RTF as “Proven UES” for manufactured housing
- **Mar. 2016**: LES approved by NW RTF as “Proven UES” for multi-family
- **2015**: LES upstream program piloted by Efficiency VT
- **2016**: ENERGY STAR Specification Framework released for storm panels
- **2017**: Focus on Energy (Wisconsin) launches pilot
## Regional Technical Forum (Northwest) LES Measure Analysis Inputs

<table>
<thead>
<tr>
<th>Key Analysis Inputs</th>
<th>Value</th>
<th>Source</th>
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<tbody>
<tr>
<td>Savings Estimate</td>
<td>4-18 kWh/yr/ft² of window (depending on baseline window, heating zone, and HVAC type)</td>
<td>SEEM model, validated based on field data</td>
</tr>
<tr>
<td>Product Cost</td>
<td>$70-160/window (~$7/ft² average)</td>
<td>Based on 2017 Big Box product availability</td>
</tr>
<tr>
<td>RTF Installed Cost</td>
<td>$10.17/ft² of window</td>
<td>Estimated $60/window for installation</td>
</tr>
<tr>
<td>Measure Life &amp; Persistence</td>
<td>20 year product life &amp; 96% persistence</td>
<td>Product warranty &amp; field data</td>
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</table>

Underlying data available at [http://rtf.nwcouncil.org/meetings/2015/07/](http://rtf.nwcouncil.org/meetings/2015/07/)
First Low-E Storm Incentive Pilot (August-October 2015)

Full markdown of Low-e storm window incremental cost to clear glass storm window

Partnering with Larson Manufacturing, D+R International, Home Depot, and Lowes

Successfully demonstrated market impact and lift

Utility outreach & marketing activities had impact

Opportunity to engage DIY, low-to moderate-income groups

Engage trade allies
Over all single-pane windows or double-pane metal-framed windows:

NEAT and RESFEN analysis expanded to 22 cities across all 8 climate zones.¹

Cost effective in climate zones 3-8 with Savings to Investment Ratio = 1.2 – 3.2

¹ Culp et al. 2014 and 2015. PNNL-22864 rev2 and PNNL-24826
Cellular Shades

- Aesthetically pleasing
- Operable
- Automation commercially available
- Adds comfort and privacy year-round
- Significant heating and cooling energy savings
- Costs range -- Median price of $70/window

Heating Savings: Can reduce heat loss through windows by 40% or more.

Cooling Savings: Reduces unwanted solar heat through windows by up to 80%
### Lab Homes – Cellular Shades Testing (2015-2016)

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<tr>
<th>Technologies</th>
<th>Description</th>
<th>Picture</th>
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</table>
### Lab Homes – Cellular Shades Impact on Energy Savings (2015-2016 Testing)

<table>
<thead>
<tr>
<th>Technology (experiment)</th>
<th>Baseline and Experiment Description</th>
<th>Energy Savings (%)</th>
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<tbody>
<tr>
<td><strong>High Efficiency Cellular Shades:</strong> Static Operation – always down (Hunter Douglas)</td>
<td>Blinds remain closed for the duration of experiment. Compared to standard vinyl blinds remaining closed for full experiment.</td>
<td>Cooling: 13.3 ±2.8%</td>
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<td>Heating: 10.5 ±3.0%</td>
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<tr>
<td><strong>High Efficiency Cellular Shades:</strong> Optimum Operation Comparison (Hunter Douglas)</td>
<td>Blinds operated per the Hunter Douglas recommended energy-saving schedule. Compared to standard vinyl blinds operated with same schedule.</td>
<td>Cooling: 10.4 ±6.5%</td>
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<td>Heating: 16.6 ±5.3%</td>
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<tr>
<td><strong>High Efficiency Cellular Shades:</strong> Optimum Operation (Hunter Douglas)</td>
<td>Blinds operated per the Hunter Douglas recommended energy-saving schedule. Compared to no blinds in baseline home (double-pane clear glass windows)</td>
<td>Cooling: 14.8 ±2.1%</td>
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<tr>
<td></td>
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<td>Heating: 14.4 ±2.0%</td>
</tr>
</tbody>
</table>
Lab Homes Testing of Cellular Shades: Heating Season

Energy Savings on a Winter Day (cellular shades testing, December 2015)

- Baseline HVAC
- Experimental HVAC
- Baseline Interior Temp
- Experimental Interior Temp
- OAT
Lab Homes Testing of Cellular Shades: Cooling Season Savings

Energy Savings on a Summer Day
(cellular shades testing, July 2016)
Goals of Research

- **Cost-effective materials** (examining lower cost cellular shade products)

- **Persistence of Savings through Automation**
  - Utilize Hunter Douglas Powerview Motorization to control shades
  - Characterizing “typical use”\(^1\) performance versus automated and optimal control

- **Advanced and Integrated Controls**
  - Integration of multiple controls (thermostat and window shade controls)
  - Program controls on transactive platform (VOLTTRON)
  - Demand response
  - Dynamic “smart” control

\(^1\) Based on D&R 2014 empirical research
Cellular Shades Typical Use

- **Summer Typical Use**
  - Shades remain closed in bedrooms
  - West-facing window shades closed halfway
  - All other window shades remain open
  - No operation throughout the day
## Cellular Shades - Lab Homes PRELIMINARY
### 2017 Cooling Season Results

<table>
<thead>
<tr>
<th>Cooling Test Protocol – Dynamic Control of Cellular Shades Lab Homes Testing</th>
<th>Duration</th>
<th>HVAC Savings % Compared to Control Home (PRELIMINARY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular Shade Comparison – Static Operation (always down) of Cellular Shades Compared to No Window Coverings</td>
<td>11 days</td>
<td>26%</td>
</tr>
<tr>
<td>Cellular Shade Comparison – Static Operation (always down) of Cellular Shades Compared to “typical” blinds (horizontal slatted vinyl)</td>
<td>6 days</td>
<td>14%</td>
</tr>
<tr>
<td>Typical Use with Cellular Shades (compared to no shades in baseline)</td>
<td>4 days</td>
<td>5%</td>
</tr>
<tr>
<td>Cellular Shade Comparison – Typical Operation (compared to typical blinds and typical use in baseline)</td>
<td>8 days</td>
<td>6%</td>
</tr>
</tbody>
</table>

### Optimal and Integrated Control Strategies

| Optimal Control – HD Green Mode (compared to typical blinds and typical use) | 6 days | 15% |
| Typical Use with Occupancy Override 9AM-5PM (compared to typical blinds and typical use) | 8 days | 15% |

### Integrated Control and Demand Response

| Part 1: 4 degree setback 3pm-7pm and cellular shades closed during this peak period (compared to LHA typical blinds and typical use) | 10 days | 16% |
| Part 2: LHB 4 degree setback 3pm-7pm and cellular shades closed during this peak period (compared to LHA 4 degree setback, typical blinds and typical use) | 10 days | 17% |

### “Smart” Dynamic Control

| Enhanced and Responsive Control Features – Weather Underground Application Testing | 25 days | TBD |
Connected Homes: Don’t Forget the Automated Window Coverings

Connected + Smart + Efficient Windows!
Emerging Technologies and Opportunities

- **Low-emissivity (low-e) 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.

- **Surface-Applied Window films** now have the potential to yield more heating benefits by providing greater thermal resistance in the same manner as the low-e storm windows.

- **Automated controls** also present opportunities for expanding the market and energy savings from window attachments:
  - Dynamically controlled shading devices will be tested in the PNNL Lab Homes in 2017-2018.

Photos courtesy of QUANTAPANEL
Key Takeaways

► Window Attachments Save Energy!
  ■ High efficiency products available
  ■ Added comfort
  ■ Aesthetic appeal (= market appeal)
  ■ Privacy and noise reduction benefits

► High Market Potential

► Relatively Affordable Retrofit Measure
  ■ Median cost of $100/attachment
  ■ Installation can often be done as do-it-yourself measure
  ■ Low-e storm windows meet most cost-effectiveness requirements (e.g., weatherization programs SIR>1)

► More Education and Outreach needed

► More Field Demonstrations and Pilots needed

► Operable, Automated Shading devices have place in the Connected Homes discussion

- FIELD DEMONSTRATED ENERGY SAVINGS: 3%-30%
- LOWER COST MEASURE: $100 median price per window
- YEAR ROUND BENEFITS:
  ■ Heating: 20 - 500 therms/year
  ■ Cooling: 700 - 5,200 kwh/year
- HIGH MARKET POTENTIAL:
  ■ 150 million+ attachments shipped annually
  ■ 4-16 year lifetimes
Other Resources

Low-e Storm Windows

Adam Hadley
Regional Technical Forum
July 21, 2015

Evaluation of Cellular Shades in the PNNL Lab Homes

November 2016

Window Attachment Opportunity Assessment for the Pacific Northwest

Prepared For NEEA: Rob Currie, Sr. Product Manager
Prepared by: Katie Cort, Erica Johnson
Prepared by Pacific Northwest National Laboratory: 902 Battelle Blvd, Richland, WA 99354, 509.375.2121
Northwest Energy Efficiency Alliance (NEEA) 503.688.5430
info@neea.org

CEE Product Overviews
Residential Energy Efficient Penetration Options

Energy Savings of Low-E Storm Windows and Panels across US Climate Zones

Windows
Skylights
Doors
Storm Panels
Window Films
Coverings
Attachments

October 2015

Low-E Storm Windows: Market Assessment and Pathways to Market Transformation

KA Cort
June 2013
References


Time for Q & A

Katie Cort
Katherine.cort@pnnl.gov

Pacific Northwest National Laboratory
- Cheryn Metzger
- Joshua McIntosh
- Travis Ashley
- Eric Wilcox Freeburg
- Rick Pratt

Partners
- Thomas Culp, Birch Point Consulting
- Greg Sullivan, Efficiency Solutions
- Larson Manufacturing Company
- Quanta Technology
- Hunter Douglas
Next ET Showcase Webinars

Demystifying Alternative Refrigerants       Sept 28

Join our email list at subscribe-e3tnw@listserv.energy.wsu.edu
Webinar information and registration at www.e3tnw.org/webinars

More information about emerging technologies:
• ET Program: www.bpa.gov/EE/Technology/EE-emerging-technologies/

Thank you for attending!
Modeled Using PNW’s standard SEEM model\(^1\)
- U-factors and SHGC's generated using NFRC WINDOWS/THERM modeling software
  - Validated based on testing in LBNL’s MoWiTT thermal test chamber \(^2\)

<table>
<thead>
<tr>
<th>Glazing</th>
<th>Frame Type</th>
<th>Baseline U-Factor</th>
<th>U-Factor With Low-e Storm</th>
<th>Baseline SHGC</th>
<th>SHGC with Low-e Storm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>Metal</td>
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<td>0.41</td>
<td>0.66</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td>0.88</td>
<td>0.35</td>
<td>0.61</td>
<td>0.50</td>
</tr>
<tr>
<td>Double</td>
<td>Metal</td>
<td>0.69</td>
<td>0.33</td>
<td>0.63</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td>0.49(^3)</td>
<td>0.27</td>
<td>0.59</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>NFRC-rated u-0.30</td>
<td>0.30</td>
<td>0.18(^4)</td>
<td>0.30</td>
<td>0.24(^4)</td>
</tr>
</tbody>
</table>

10% reduction in air leakage based on average of field study data

\(^1\)For more info, see [http://rtf.nwcouncil.org/measures/support/SEEM/Default.asp](http://rtf.nwcouncil.org/measures/support/SEEM/Default.asp)
\(^3\)Assumes no low-e coating, but in practice, there would be windows by this definition with low-e coating.
\(^4\)U-Factor and SHGC for low-e storm window + NFRC-rated U-0.30 window based on a regression of the other data in the table.