Low-E Storm Windows Gain Acceptance as a Home Weatherization Measure

by Theresa Gilbride and Katherine Cort

One recent addition to the cost-effective efficiency measures available for home retrofits is low-e storm windows. These high-performing window attachments are up to 25% more efficient than single-pane or double-pane windows. Recent validation studies by DOE have now made it possible for utilities to add these low-e storm windows to their energy efficiency and weatherization programs.

The energy performance of storm windows has greatly improved over the last 20 years. Forget about the clunky old galvanized aluminum-framed storm windows that had to be removed and stored every spring and hauled out and reinstalled every fall. Modern storm windows have a variety of configurations, including sleek, custom-sized, openable units with coated frames in colors that match the house trim. Some exterior storm windows permanently attach to the existing window frame to block out summer heat and winter cold and drafts, while others are removable. These tight-fitting storm windows improve air sealing, while the extra layer of glass and air space increases insulation to reduce heating and cooling costs by as much as 25% over the home's original single-pane or double-pane windows (Petersen et al., 2015).

PACIFIC NORTHWEST NATIONAL LABORATORY

Pacific Northwest National Laboratory's Lab Homes are two identical homes located on the PNNL campus in Richland, Washington. The low-e storm windows were performance tested in the homes under conditions carefully controlled to replicate heating and cooling in a typical home.

The addition of low-e coatings is one of the recent improvements to storm windows. These coatings consist of silver metal applied during the glass-manufacturing process in a layer so microscopically thin (1/500 of a human hair) that the coating is transparent and virtually invisible. The coating reduces the emissivity of the glass—its ability to transmit heat—so heat from inside is reflected back into the home in the winter and heat from outside is reflected back outside in the summer (see Figure 1). DOE-sponsored studies found that the low-e coating can improve overall energy savings by 10–15% over standard storm windows without the low-e coating. Low-e storm windows cost about 10% more than clear-glass storm windows, but DOE research has confirmed that this additional expense is cost-effective in all climate zones and with all types of window (Culp and Cort, 2014). See Table 1.

In addition to saving energy, storm windows can reduce drafts, improve comfort, and reduce the transmission of outside noise. Storm windows can also protect delicate antique stained-glass or leaded-glass windows, or original single-pane windows, while preserving the historic appearance of the home.

While homeowners can appreciate all of these benefits, the biggest benefit may be the cost savings. Storm windows can be a less expensive way to improve a home's energy efficiency when a total window replacement isn't in the homeowner's bud-

get. Although windows account for more than 30% of a typical home's heating losses, the high up-front cost of a total window replacement (at $200–500 per window or $8,000–15,000 for a typical home) prevents many homeowners and businesses from replacing their drafty, inefficient old windows. Storm windows can be a less expensive option, at $80–150 per storm window plus DIY installation, when a total window replacement isn't in the homeowner's budget.

In the late 1990s, researchers at DOE's Lawrence Berkeley National Laboratory (LBNL) identified a potentially cost-effective solution: storm windows made with durable low-e coatings as a cost-effective solution that could help insulate and air seal existing windows. In the following years, with support from the DOE Building Technologies Office, low-e storm windows were further researched, further developed, and field-tested—with positive results. (For a short history of the development of storm windows, and of DOE's market transformation activities as described below, see "Low-E Storm Window Development Time Line.")

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Left, interior low-e panel, operable as a slider. *Right,* exterior low-e storm window, operable as a single-hung with screen.

Overcoming Market Barriers

To help overcome the market barriers and further validate the energy savings data, DOE's Building America initiative funded additional research and market transformation efforts by the Pacific Northwest National Laboratory (PNNL). Between 2013 and 2015, PNNL and its project partners conducted studies in PNNL's Lab Homes, two side-by-side, identical manufactured homes located at PNNL's Richland, Washington, campus, where conditions could be closely controlled to replicate a normal home environment in both homes while the performance of one home's windows with low-e storm window attachments could be compared to the performance of the other home's windows without attachments. Results were reported in various studies conducted by PNNL (see Knox and Widder, 2014, and Petersen et al., 2015, for example). In addition to these performance validation studies, researchers at PNNL carried out a market assessment and education and outreach efforts for low-e storm windows through the Consortium for Energy Efficiency and the Home

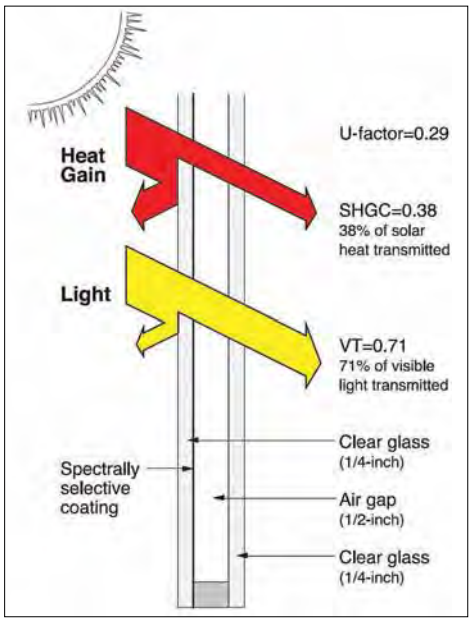
Table 1. Cost and Performance Data

	SINGLE-PANE WINDOW	DOUBLE-PANE REPLACEMENT WINDOW	CLEAR STORM WINDOW	PRELIMINARY LOW-E STORM WINDOW DATA
Cost range of window	–	$200–500	$70–125	$80–150
Installation cost	–	$100–500 per window	$2 (DIY) to $60 per window	$2 (DIY) to $60 per window
SIR compared to single pane	–	<1 (not qualified for WX program)	<1 to 1.2 (usually not qualified for WX program)	1.3–3.2 in central and northern climates—qualifies for WX)
Average HVAC energy cost savings compared to single pane	–	11–35%	5–20%	12–33%
U-factor (Btu/hr ft² F)	0.88	0.30–0.35	0.50	0.34–0.36
SHGC	0.63	0.25–0.30	0.56	0.45–0.52
Air leakage (cfm/ft²)	1–4	0.1–0.3	0.3	0.1–0.3

Note: *Low-e storm window estimates based on case studies and preliminary findings from NEAT/RESFEN regional analysis. All other ranges and estimates based on Consortium for Energy Efficiency (CEE) windows working group consensus estimates (Hefty and Cort 2013).*

DIY = do it yourself; HVAC = heating, ventilation, and air-conditioning; PA = Pennsylvania; SHGC = solar heat gain coefficient; SIR = savings to investment ratio; WX = weatherization

Conventional Storm Windows



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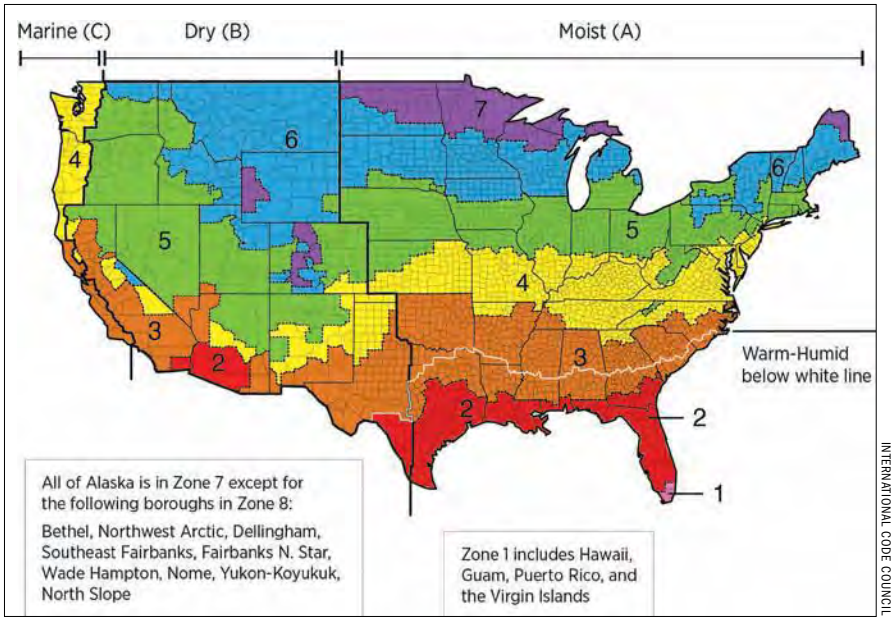

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Figure 1 *(left)*. Conventional storm windows improve efficiency by providing additional air-sealing and insulation. Low-e storm windows further improve performance by providing a spectrally selective coating that blocks most of the long-wave solar heat radiating from the sun while allowing light to come through. Figure 2 *(right)*. DOE research confirmed that low-e storm windows are a cost-effective retrofit over single-pane windows in climate zones 3 through 8 and over double-pane metal-framed windows in climate zones 4 through 8. Climate zones shown in this map are taken from the International Energy Conservation Code.

Performance Coalition, among other channels. PNNL produced several reports (Cort 2013b) and brochures (Cort 2013a) dealing with low-e storms. PNNL also produced two information guides for the Building America Solution Center (*Low-E Exterior Storm Windows* and *Low-E Interior Permanent Storm Windows*) and a video on low-e storm window installation.

PNNL's research results were reviewed by the Pacific Northwest Regional Technical Forum (RTF), which serves as the advisory board to the Pacific Northwest Electric Power Planning Council and the Bonneville Power Administration. In late July 2015, the RTF approved the results of PNNL's research (EERE, 2015). The RTF's approval is the first and essential step in integrating weatherization measures into energy-efficiency planning and utility programs in the Pacific Northwest. As a result of RTF approval, PNNL expects that low-e storm windows will be included as a cost-effective energy-saving measure in a growing number of weatherization and utility incentive programs nationwide. PNNL estimates that more than 90 million U.S. homes with single-pane or low-performing double-pane windows would benefit from this technology. Low-e storm windows are suitable not only for private homes but also for small commercial buildings, historic properties, and facilities that house residents, such as nursing homes, dormitories, and inpatient facilities.

To increase market acceptance of low-e storm windows and other high-efficiency window attachments, DOE helped found the Attachment Energy Rating Council (AERC) in 2015. AERC is an independent, public-interest, nonprofit organization whose mission is to rate, label, and certify the performance of window attachments. During the next two years, AERC will create a comprehensive rating, labeling, and certification program for window attachments that will provide accurate and credible information about the energy performance of window attachments to help consumers make informed decisions about these products.

"Today's storm window not only offers a new, modern design, it brings a tremendous opportunity to cost-effectively improve performance in windows," says Tom Culp of Birch Point Consulting, a member of the PNNL team. "Low-e storm windows today cost about a quarter of what full window replacement would cost but bring similar energy savings," Culp adds. "They're operable, add comfort, and have a modern aesthetic."

Payback Analysis

PNNL assessed the cost-effectiveness of low-e storm windows using two software platforms (Culp and Cort 2014): the National Energy Audit Tool (NEAT) used by weatherization programs and the RESFEN software used to compare the annual energy performance of different window options in single-family homes. Exterior and interior low-e storm windows and panels installed in conjunction with three different primary window types were evaluated in 22 different cities across all eight International Energy Conservation Code climate zones (see Figure 2).

Both regular low-e glass and solar-control low-e glass, which decreases solar heat gain in addition to decreasing heat transfer through the glass, were included in the analyses. The NEAT analysis

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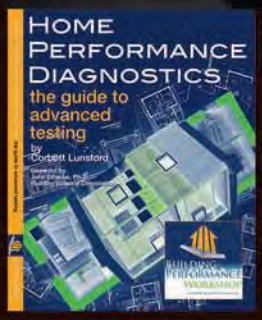

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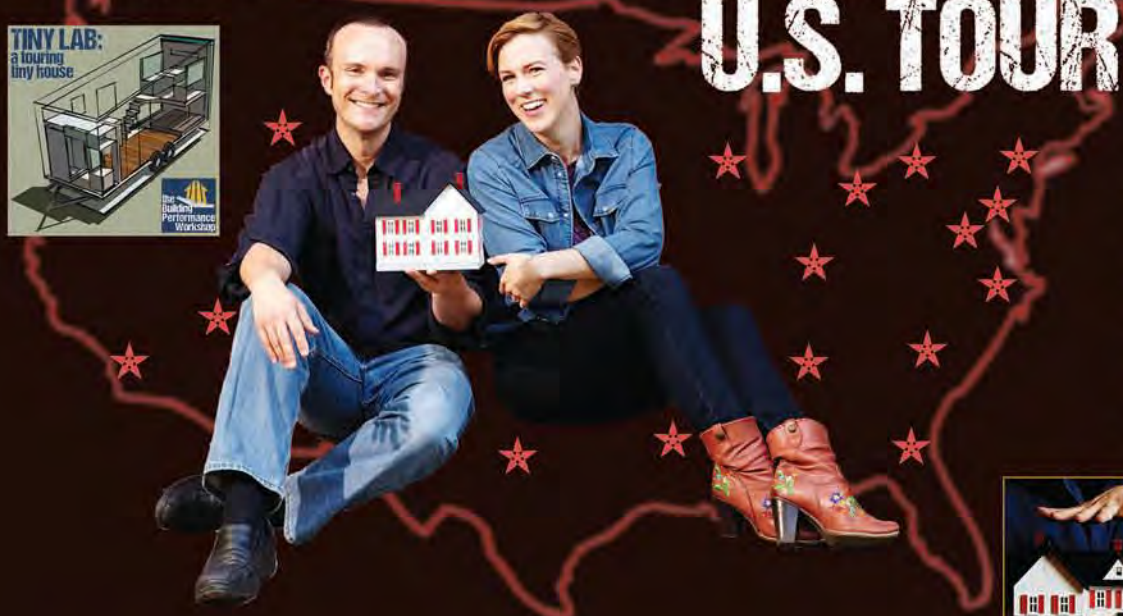

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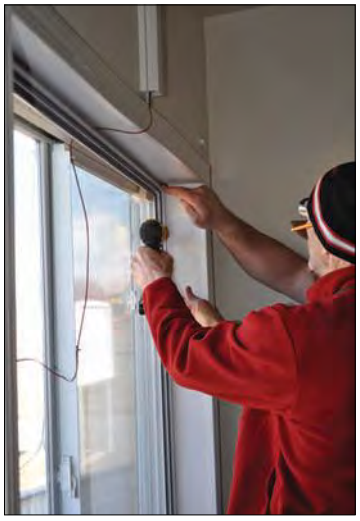
Low-E Storm Window Development Time Line

Here is a brief history of low-e storm windows:

- **Late 1990s.** Researchers at DOE's Lawrence Berkeley National Laboratory propose adding low-e coatings to storm windows for cost-effective insulating and air sealing of existing windows.
- **2000–02.** DOE supports lab testing at LBNL's Mobile Window Thermal Test Facility.
- **2003–13.** DOE funds field testing in Chicago **(2003–06)**, Pennsylvania **(2009–11)**, and Atlanta and Philadelphia **(2011–13)**.
- **2009.** Low-e storm windows become commercially available.
- **2013–15.** DOE sponsors low-e storm window market transformation activities under its Building America program. Through Building America, DOE's Pacific Northwest National Laboratory (PNNL) has:
  - Completed a market assessment, identifying barriers to market uptake and pathways to market transformation for low-e storm windows (Cort 2013b).
  - Conducted climate-based energy simulation analyses for representative climates throughout the United States.
  - Validated heating and cooling energy savings of low-e storm windows by performing controlled whole-home testing of both exterior and interior low-e storm windows at PNNL's Lab Homes in Richland, Washington.
  - Collaborated with the Federal Energy Management Program and the U.S. Department of Defense modeling support team to integrate low-e storm windows into building energy simulation programs, including the FEDS model used for energy auditing at military bases.
  - Developed outreach and education material related to low-e storm windows disseminated with the support of the Consortium for Energy Efficiency, the Home Performance Coalition, the Building America Solution Center, and Energy.gov administrators.
  - Worked with Pacific Northwest utilities and the Bonneville Power Administration through the Regional Technical Forum. Supported by PNNL's performance validation results, in **July 2015**, low-e storm windows were approved as a proven energy efficiency measure for use in all electric utility programs in the Pacific Northwest.
  - Served on the board of the newly developed AERC, which plans to develop ratings for storm windows.

included 39 model homes and the RESFEN analysis included 2 model homes.



PNNL

Installation of an interior low-e panel in the PNNL Lab Homes.

PNNL found that low-e storm windows were cost-effective when installed over single-pane windows in climate zones 3 through 8, and over double-pane, metal-framed windows in climate zones 4 through 8. The savings-investment ratio ranged from 1.2 to 3.2 across the different locations analyzed. The average source energy savings ranged from 24% to 36% with a simple payback period of 4.7 to 12.9 years across climate zones 4 through 8. The use of solar-control low-e storm windows, which have a lower solar heat gain coefficient, is recommended in climate zone 3, and may also be considered in warmer parts of zone 4 where cooling degree-days exceed heating degree-days. The use of regular low-e storm windows is recommended in zones 4 through 8.

PNNL also found that low-e storm windows qualified as cost-effective weatherization measures (based on a savings-investment ratio greater than 1) and would therefore be recommended for installation over double-pane wood or vinyl-framed windows in climate zones 6 through 8 and in eastern parts of zone 5 where heating-fuel costs are higher. The savings-investment ratio ranged from 1.1 to 1.9 across the different locations analyzed. The average source energy savings ranged from 16% to 19% with a simple payback period of 11 to 14 years. In comparison, the payback for full window replacement with new windows is about 25 years.

PNNL also examined how different attachment methods affect payback. The paybacks given above assume that there is no metal-to-metal contact; that is, that the exterior storm windows are attached to a wood frame or wood blocking. However, if the metal storm windows attach directly to metal framing, potential energy savings will decrease by about one-third, and the payback period will increase by three to five years. Therefore, PNNL recommends that installers provide thermally broken mounting with no metal-to-metal contact wherever possible.

In addition, payback times are reduced if the cost savings attributable to the reduction in air infiltration from the storm windows is also included.

The addition of low-e storm windows—that are up to 25% more efficient than single-pane or even double-pane windows—to the energy efficiency tool kits of utility and weatherization programs provides a relatively simple cost-effective measure that saves consumers energy and makes homes more comfortable to live in.

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Katherine Cort *is an economist with the Pacific Northwest National Laboratory and the team lead for the DOE Building America window attachment program.*

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>> learn more

For a video about storm window installation, go to www.youtube.com/watch?v=DeU6wn0psrU.

For the Building America Solutions Center guides mentioned in this article, and for lots more useful information, go to https://basc.pnnl.gov/resource-guides.

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