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Results from Low-e Storm Window Work in the Northwest

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Consortium for Energy Efficiency

Window Attachments Call, June 30, 2016

U.S. DEPARTMENT OF ENERGY

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

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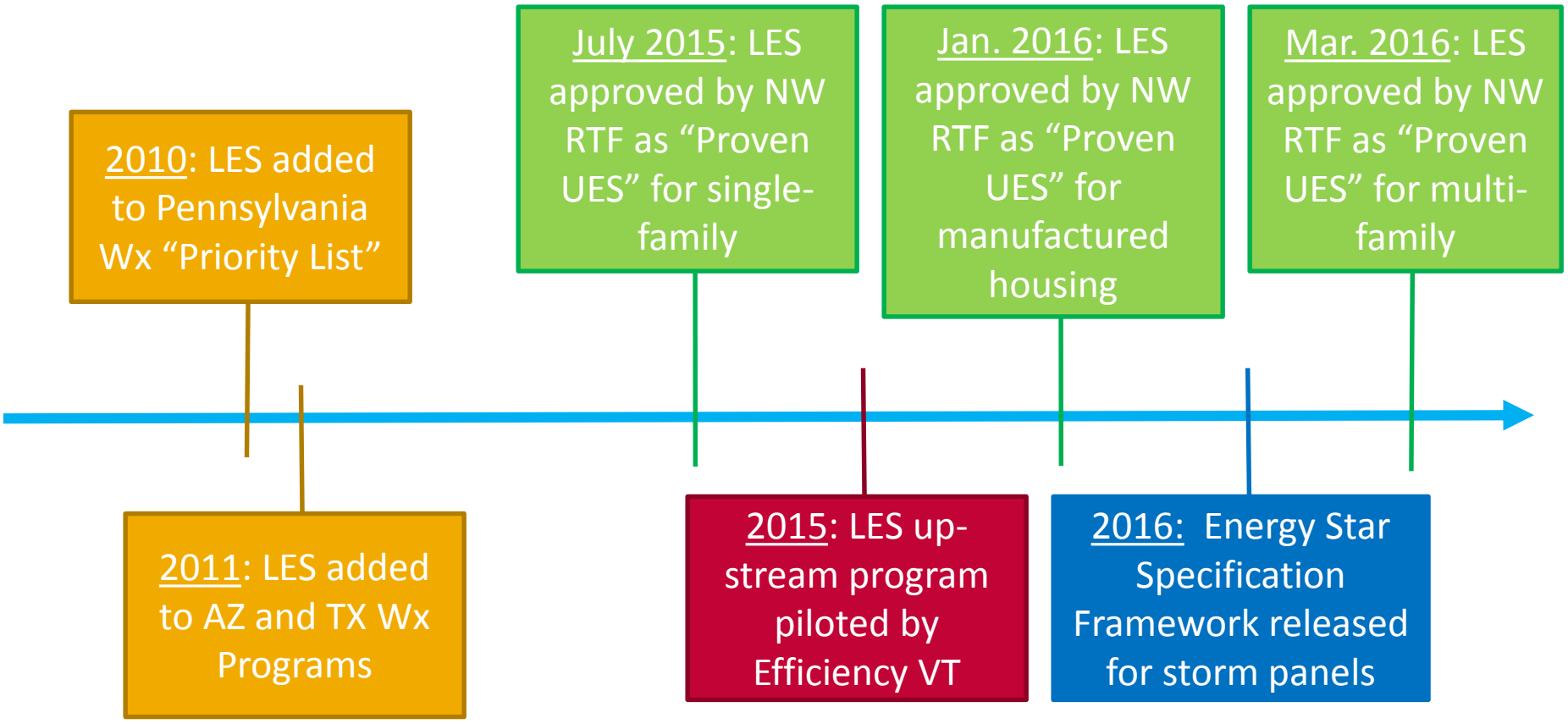

Energy Star for Exterior and Interior Storm Panels

- Energy Star program issued it's "Specification Framework Document" related to storm panels in January 2016. Determines whether or not:
  - Significant energy savings can be realized on national basis from the application of storm panels.
  - Product energy performance can be measured and verified with testing.
  - Purchasers will recover their investment in energy-efficient storm panels within reasonable period of time.
  - Labeling would effectively differentiate products and be visible to purchasers.

Activity	Timeframe
Specification Framework Released For Comment	January 14, 2016
Deadline for written comments on framework document	February 12, 2016
Draft 1 Specification Issued	Summer 2016
Final Specification Issued and Effective	2017

LES Measure Analysis Inputs

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Key Analysis Inputs	Value	Source
Savings Estimate	4-18 kWh/yr/ft^2 of window (depending on baseline window, heating zone, and HVAC type)	SEEM model, validated based on field data
Installed Cost	\$10.71/ft^2 of window	PNNL cost memo
Measure Life & Persistence	20 year product life & 96% persistence	Product warranty & field data

Underlying data available at http://rtf.nwcouncil.org/meetings/2015/07/

Savings Estimate Basis

- 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]

Window Type		Baseline U-Factor	U-Factor With Low-e Storm	Baseline SHGC	SHGC with Low-e Storm
Glazing	Frame Type				
Single	Metal	1.09	0.41	0.66	0.52
	Wood	0.88	0.35	0.61	0.50
Double	Metal	0.69	0.33	0.63	0.48
	Wood	0.49[3]	0.27	0.59	0.46
NFRC-rated u-0.30		0.30	0.18[4]	0.30	0.24[4]

  - 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
[2]Cort, KA; SH Widder, TD Culp. 2015. "Thermal and Optical Properties of Low-E Storm Windows and Panels." PNNL-24444.
[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.

Energy Savings from SEEM Compared to Field Studies

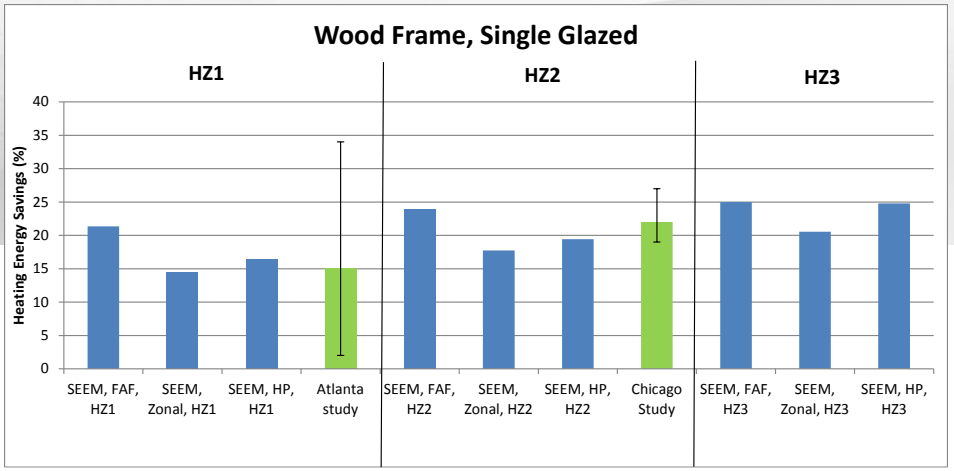
- Recent SEEM modeling generally consistent with results from field studies for window types studied

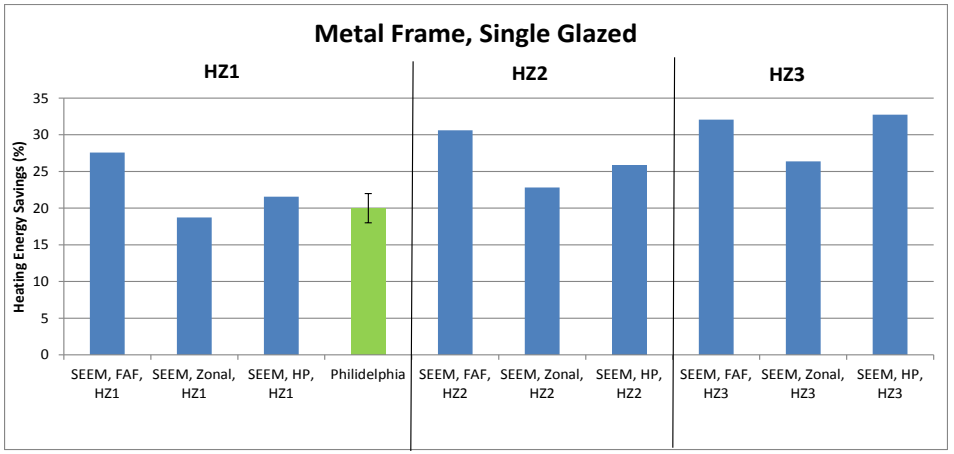
Study	N	Heating System	Air Leakage Reduction
Atlanta	10	Gas furnace (9), FAF (1)	17%
Chicago	4 (1)	Gas furnace (2) or boiler (2)	7%
Philadelphia	2 (2)	Central gas	10%
PNNL Lab Homes	1	FAF	0%

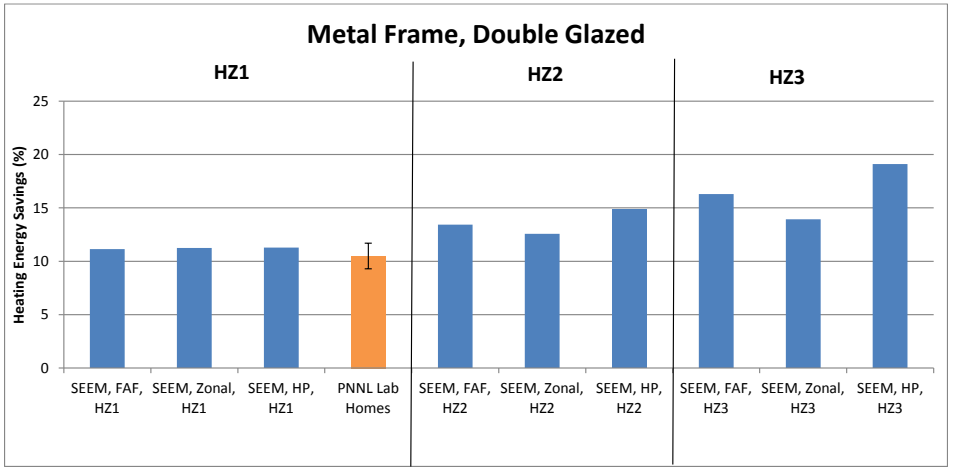
(1) Six homes in study, but 2 had clear storms

(2) Featured 2 multifamily buildings with a total of 101 units

Source: RTF. 2015. Low-E Storm Window Measure Proposal.







Installed Cost and Lifetime Info

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Installed Cost

- Not a lot of data available for installation costs
  - RTF Information (PNNL Memo) Available at: http://rtf.nwcouncil.org/meetings/2015/07/LES_Cost_Lifetime_Memo_July_2015.docx

Low-e Storm Window Costs	Value (2014$'s)	Source
Material Costs (per sq.ft.)	**$7.50**	**PNNL (see memo)**
Professional Installation Costs (per window)	$60	PNNL (Wx installer informal survey)
DIY Installation Rate	80%	PNNL (via manufacturer interview)
DIY Instllation Cost (per window)	$30	Assumed as 1/2 professional install
Average window size (sq.ft.)	13.5	Analyst assumption (3 x 4.5)
Average installation cost (per sq.ft.)	**$2.67**	**Calculated**
Total Installed Cost (per sq.ft.)	**$10.17**	**Calculated**

Lifetime

- **20 year measure life** based on product warranty
- **96% measure persistence/implementation**
  - Based on evaluation in Chicago field study participants (after 10 years) found that 3 of 96 storm windows (that were still present and in good condition) were not fully closed in the middle of winter.[1]

[1] Culp, TD. "Low-E storm windows persistence in Chicago case study homes." Birch Point Consulting. See: http://rtf.nwcouncil.org/meetings/2015/07/Low-e%20storm%20window%20persistence%2027Jan15.pdf

RTF Measure Specifications

- Define measure specification to match measure performance assumptions and ensure delivery of savings

Measure Specification	Purpose
Storm windows must use glazing materials with an **emissivity less than or equal to 0.22** and **a solar transmittance greater than 0.55**, as listed in the International Glazing Database (IGDB) managed by Lawrence Berkeley National Laboratory and measured in accordance with NFRC 300-14,NFRC 301-14 and NFRC 302-10.	Verify tested glazing performance via third party database
Storm windows must be of the same opening type as the existing prime window.	Maximize persistence by maintaining window operability
Storm window shall be permanently installed.	Maximize persistence by ensuring permanent installation
Storm windows shall be oriented with the low-e coating facing toward the interior of the house.	Ensure performance via proper installation
For installations with metal framed prime windows the storm window's frame shall not be in direct contact with the prime window frame.	Ensure performance via proper installation

Expanding to Different Climates

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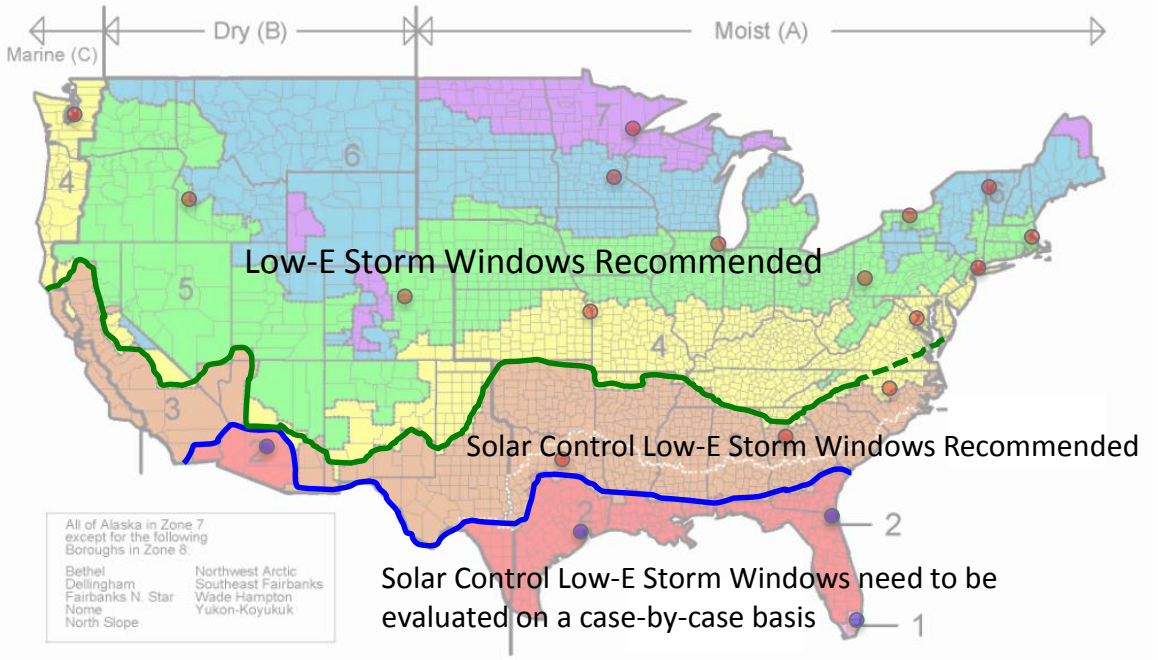
- Analysis is available to expand savings estimates to different climates
  - Energy Savings of Low-E Storm Windows and Panels across the US Climate Zones.[1]
  - NEAT analysis to 22 cities across all 8 climate zones.[2]



Cost effective in climate zones 3-8 with SIR 1.2 – 3.2 over all single pane windows and double-pane metal-framed windows

[1] Culp, TD and Cort, KA. 2015. Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24826.pdf
[2] Culp, et. al. 2014. Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf

Expanding to Additional Window Attachments

- Analysis is available regarding energy savings for other window attachments

Study	Participants	Baseline description	Findings
Energy savings from window shades (2015)	Hunter Douglas and Rocky Mountain Institute	EnergyPlus modeling of DOE residential buildings	Thermal properties tested in LBNL and HD testing facility and RMI modeled savings showed: Denver Max Cooling Savings – 25% Denver Max Heating Savings – 10% Peak electrical demand reduction of 9% for new homes
PNNL Lab Homes: High Efficiency Cellular Shades (2015-present)	High Efficiency Cellular Shades: Static Operation (Hunter Douglas)	Blinds remain closed for the duration of experiment. Compared to standard vinyl blinds remaining closed for full experiment.	• Cooling: 10.4 ±6.5% to 14.4 ±2.0% • Heating: 10.5 ±3.0% to 16.6 ±5.3% (depending on operating schedule of blinds in base-case and efficient case)

Thank You!

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Questions?

Window Attachments Program at PNNL

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Lab-Home Study and Results

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EXTRA SLIDES

Pacific Northwest Regional Technical Forum

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- The Regional Technical Forum (RTF) is an advisory committee established in 1999 to develop standards to verify and evaluate conservation savings.
  - Voting members are appointed by the Council and include individuals experienced in conservation program planning, implementation and evaluation.
  - See charter and bylaws and Policy Advisory Committee charter.
- The RTF is also responsible for developing a conservation and renewable resources rate discount (C&RD) for the Bonneville Power Administration.
  - The C&RD program awards rate discounts to customers who have implemented effective energy conservation measures.
- http://rtf.nwcouncil.org/

Low-E Storm Window Field and Lab Studies

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Study	Participants	Baseline description	Findings
Chicago case study (2007)	DOE, HUD, NAHB Research Center, LBNL	6 low-income homes; single-pane wood-framed windows	Low-e storm windows showed: • 21% reduction in overall home heating load • 7% reduction in overall home air infiltration • Simple payback of 4 to 5 years
Atlanta case study, 2-year study (2014)	DOE, Quanta,[(a)] Larson,[(b)]	10 occupied homes; single-pane wood-framed windows	High variability, but low-e storm windows showed approximately: • ~15% heating energy reduction • ~2 to 30% cooling reduction (highly variable) • 17% reduction in overall home air infiltration
Pennsylvania weatherization technical support (2010)	DOE, Birch Point Consulting	37 model homes with range of window types	Modeled window retrofit technology showing results for 7 climate zones: • 12%–33% overall HVAC savings
PNNL Lab Homes: Exterior low-e storm windows (2013)	DOE, Larson Manufacturing, PNNL	Double-pane aluminum frame clear glass windows	Average Annual Savings: 10.1 ±1.4%
PNNL Lab Homes: Interior low-e storm windows (2015)	DOE, Quanta Technologies	Covering 74% of window area over double-pane aluminum frame clear glass windows	Average Annual Savings: 7.8 ±1.5%

RTF Approved Measures*

Existing Window Type	Single Family	Manufactured Housing	Multi-Family
Single Pane Metal Frame	All heating zones and system types	All heating zones and system types	All heating zones and system types (except heat pump in HZ 1**)
Single Pane Wood Frame	All heating zones and system types (except heat pump in HZ 1)	All heating zones and system types (except HZ 1)	All heating zones and system types (except heat pump in HZ 1&2)
Double Pane Wood Frame	Only electric resistance FAF for HZ 2&3 and zonal/DHP for HZ 3	Only HZ 3 (electric resistance and heat pump)	All HZ for electric resistance FAF, HZ 2&3 for zonal and DHP

* Based on Measure Workbooks available at http://rtf.nwcouncil.org/measures/Default.asp as of March 29, 2016; currently under QA review

** HZ = Heating Zone