ENERGY STAR® for Internal and External Storm Windows

Version 1.0 Criteria Analysis Report

July 2017

Contents

Note: D+R International provided the technical support for the development of this report on behalf of the U.S. Environmental Protection Agency.

Introduction

The U.S Environmental Protection Agency (EPA) is pleased to share the Draft 1 Criteria and Analysis Report for the ENERGY STAR Exterior and Interior Storm Windows program.[1] After careful consideration of research, analysis, and stakeholder comments, EPA believes that an ENERGY STAR specification for low-emissivity (low-e) storm windows will help consumers identify energy efficient products and reduce their energy costs. An ENERGY STAR label would also help identify an affordable option for homes where full window replacement may not be possible, such as the following:

- Lower-income households
- Low-rise multi-family households
- Households working with HUD or Weatherization programs
- Households in historic preservation districts

Consumers purchase approximately 8 million storm windows every year, but only about 10% of those products currently use low-e glass. EPA estimates that the Draft 1 Criteria for storm windows have the potential to increase the market share for low-e storm windows up to 50%, saving up to 1.2 trillion Btu (tBtu) per year nationwide.

This report outlines the research and analyses that EPA performed to determine an appropriate set of criteria for this program. EPA appreciates stakeholder feedback it received on the Framework Document and welcomes additional comments on this Criteria Analysis Report. Please submit your comments to windows@energystar.gov by August 31, 2017.

Version 1.0 Draft 1 Criteria for Storm Windows

Overview of Process

A proposed timeline for the specification development process is provided in Table 1. Please note that these are a tentative dates and may change.

Table 1: Tentative Timeline for Specification Development

Timeline	
Draft 1 Specification & Criteria and Analysis Report	July 2017
Stakeholder Webinar	August 3, 2017
Comments Due	August 31, 2017
EPA Response to Draft 1 Comments	October 2017
Final Draft Specifications	November 2017
EPA Response to Final Draft Comments	November – December 2017
Publish Version 1.0 Requirements	December 2017 – January 2018
Criteria Take Effect	Immediately following publication

[1] EPA initially used the term "Storm Panels" in the Framework Document. However, EPA received several comments that exterior and interior storm panels are known as "Storm Windows" within the industry. Therefore, EPA will be using the term "Storm Windows" in this report and going forward.

Overview of Version 1.0 Criteria

The Draft 1 criteria for exterior and interior storm windows are provided in Table 2 and Table 3. Note that EPA has not set criteria for interior storm windows in the Southern/South-Central zone, as research suggests that interior storm windows are not an appropriate application in those Climate Zones. The full Draft 1 specification for Storm Windows is available at http://www.energystar.gov/products/spec/exterior_and_interior_storm_panels_version_1_0_pd.

Table 2: Draft 1 Criteria for Exterior Storm Windows

ENERGY STAR Climate Zone	Emissivity	Solar Transmission	Air Leakage (cfm/ft^2)
Northern	≤ 0.22	> 0.55	≤ 1.5
North-Central	≤ 0.22	≤ 0.55 or > 0.55	≤ 1.5
South-Central	≤ 0.22	≤ 0.55	≤ 1.5
Southern	≤ 0.22	≤ 0.55	≤ 1.5

Table 3: Draft 1 Criteria for Interior Storm Windows

ENERGY STAR Climate Zone	Emissivity	Solar Transmission	Air Leakage (cfm/ft^2)
Northern	≤ 0.22	> 0.55	≤ 0.5
North-Central	≤ 0.22	> 0.55	≤ 0.5
South-Central	ENERGY STAR certification not available for Interior Storm Windows in these zones.		
Southern			

Guiding Principles

EPA employs six key principles when establishing or revising an ENERGY STAR product performance specification. See the *ENERGY STAR Products Program Strategic Vision and Guiding Principles* at https://www.energystar.gov/ia/partners/prod_development/downloads/ENERGY_STAR_Strategic_Vision_and_Guiding_Principles.pdf.

These principles include:

1. Significant energy savings can be realized on a national basis.
2. Energy efficiency can be achieved through one or more technologies such that qualifying products are broadly available and offered by more than one manufacturer.
3. Product performance can be maintained or enhanced with increased energy efficiency.
4. Product energy consumption and performance can be measured and verified with testing.
5. Purchasers will recover their investment in increased energy efficiency within a reasonable period of time.
6. Labeling would effectively differentiate products and be visible for purchasers.

Based on EPA's research and the papers referenced in the Framework Document, the Agency believes that ENERGY STAR certified storm windows would satisfy all of these principles and therefore should be considered for addition to the ENERGY STAR program.

a) Significant energy savings can be realized on a national basis

EPA estimates that ENERGY STAR certification for storm windows could save up to 1.2 tBtu per year. EPA developed this estimate based on market assessments and energy savings analyses conducted by Pacific Northwest National Laboratories (PNNL) and a review of the historical adoption of low-e technology in primary windows.[2]

Per-Unit Performance

Low-e storm windows save energy by improving the thermal performance of the existing window system in a home. The extent of the performance improvement depends on the properties of the base window, type of storm window (interior or exterior), and the glass properties of the storm window (i.e., solar transmittance and emissivity). PNNL research shows that low-e storm windows can improve the U-factor by 47% to 61% for non-metal primary windows and 53% to 63% for metal primary windows.[3] See Appendix B for the typical U-factor and solar heat gain coefficient (SHGC) ratings for different types of base windows and details about how clear and low-e storm windows affect the U-factor and SHGC rating.

Household Energy Savings

The household energy savings presented in this report were modeled by PNNL using RESFEN software. RESFEN, which was developed by Lawrence Berkeley National Laboratory (LBNL), is the standard software used for calculating the impact of fenestration products on heating and cooling costs for new and existing residential buildings.

The major inputs and assumptions that PNNL used for its RESFEN modeling can be found in PNNL-24826, "Energy Savings of Low-E Storm Windows and Panels across US Climate Zones," August 2015. PNNL assumed the following glass properties in its analysis:

Product type	IECC Climate Zone	Emissivity	Solar Transmittance
Clear glass storm window (baseline)	All	0.84	0.86
Low-e storm window	1, 2, and 3	0.15	0.50
Low-e storm window	4, 5, 6, 7, and 8	0.15	0.69

Based on PNNL's energy savings estimates, EPA calculated the annual site heating and cooling cost savings in each Climate Zone for low-e storm windows when installed over single-pane wood frame, double-pane wood frame, and double-pane metal frame window.[4] Figure 1 shows the annual base energy savings (the impact of installing a low-e storm window over the base window) and air leakage energy savings (additional savings for reducing air leakage) for low-e storm windows in each Climate Zone. The savings range from 10 kBtu/yr/ft^2 to 250 kBtu/yr/ft^2. Figure 2 shows the annual energy savings per square foot for low-e storm windows compared to clear glass storm windows in each Climate Zone.

[2] PNNL-22565, "Low-E Storm Windows: Market Assessment and Pathways to Market Transformation," June 2013 and PNNL-24826, "Energy Savings of Low-E Storm Windows and Panels across US Climate Zones," August 2015.
[3] PNNL-24444, "Thermal and Optical Properties of Low-E Storm Windows and Panels," July 2015.
[4] PNNL-24826, "Energy Savings of Low-E Storm Windows and Panels across US Climate Zones," August 2015.

Figure 1 Annual Energy Savings (kBtu/yr/ft²) for Low-E Storm Windows[5]

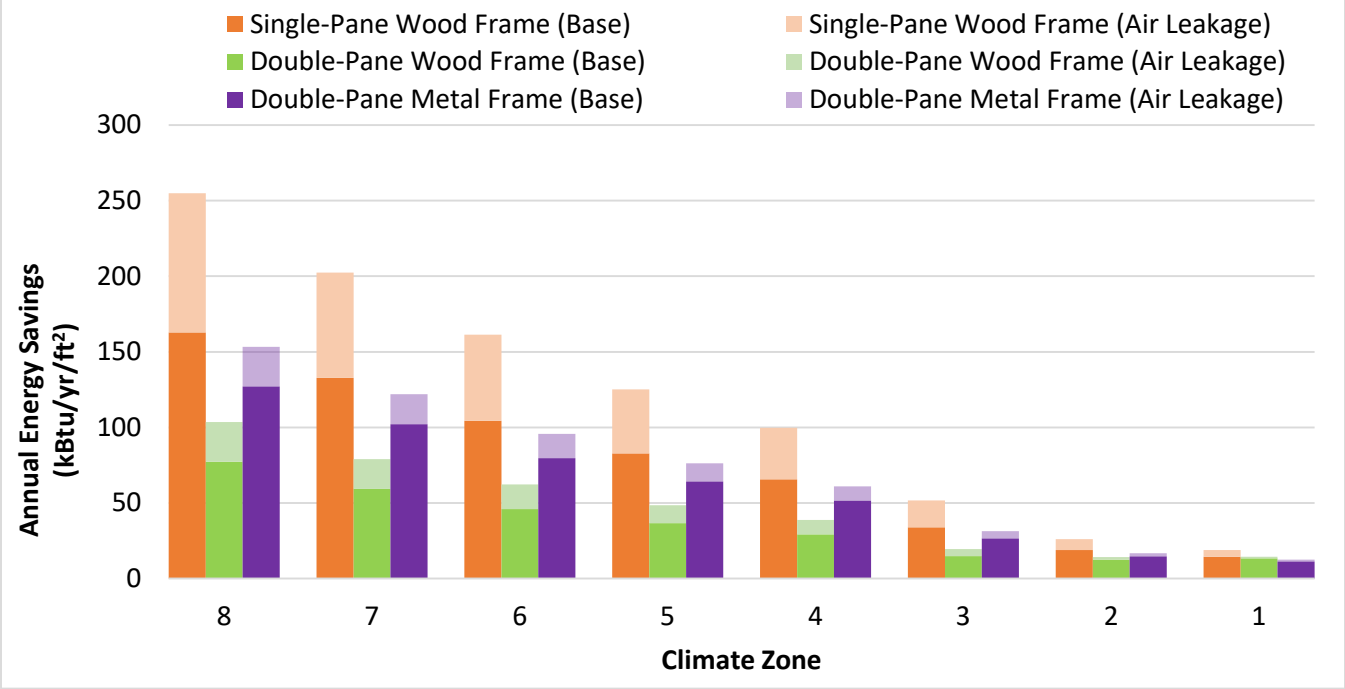


Figure 2 Annual Energy Savings (kBtu/yr/ft²) for Low-e Storm Windows vs Clear Glass Storm Windows[6]

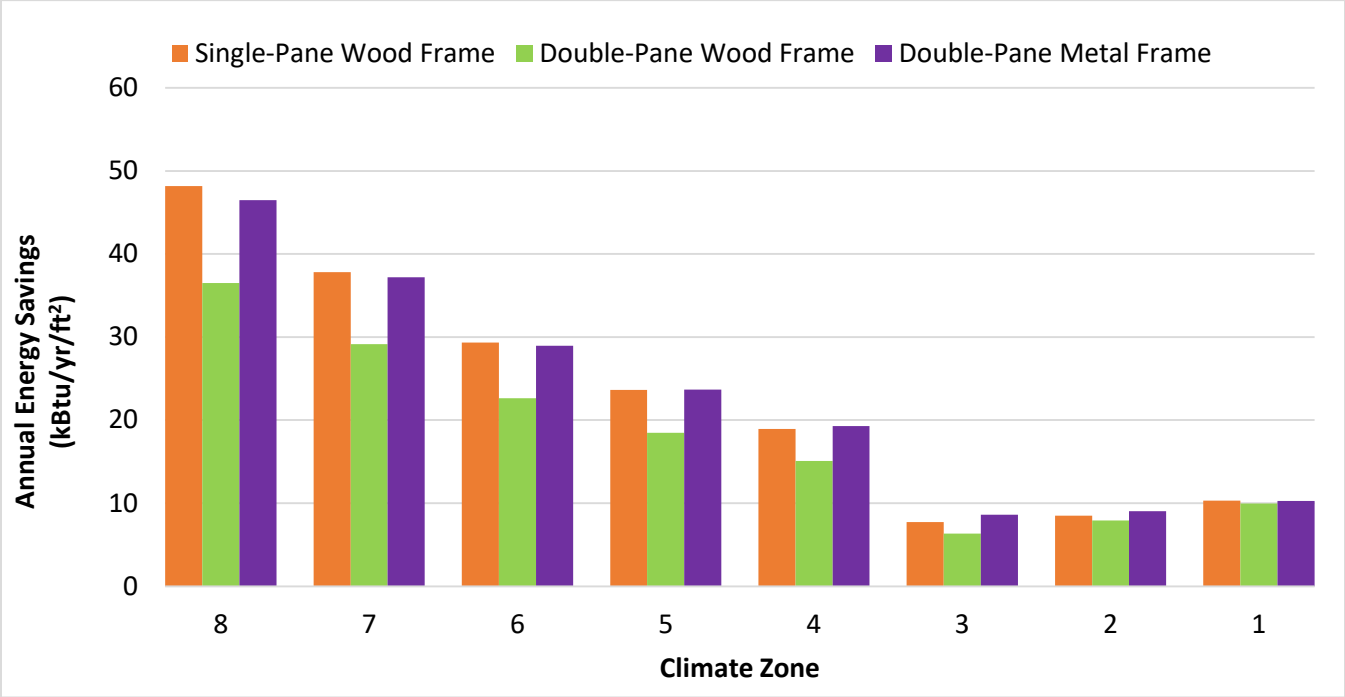
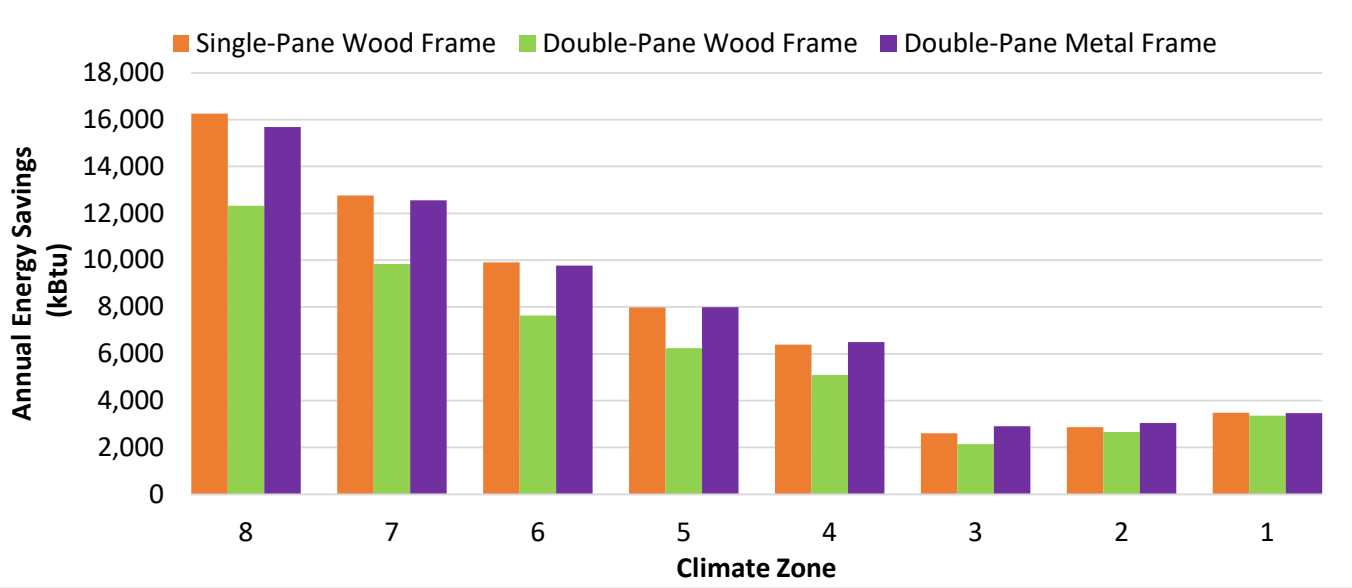


Figure 3 shows that, compared to clear glass storm windows, low-e storm windows can save up to 16,000 kBtu annually per household when installed over single-pane wood windows, up to 12,000 kBtu annually per

[5] Ibid.
[6] Ibid.

household when installed over double-pane wood window, and up to 15,700 kBtu annually per household when installed over double-pane metal windows. EPA calculated the incremental annual household savings based on the difference in the site heating and cooling cost savings between low-e storm windows and clear glass storm windows from PNNL's energy savings estimate. These savings represent the average for new and existing single story (255 ft^2 of glazing area) and two story homes (420 ft^2 of glazing area).

Figure 3 Annual Household Site Energy Savings for Low-E Storm Windows vs Clear Glass Storm Windows



National Energy Savings

To calculate the national energy savings for low-e storm windows, EPA used PNNL's estimates that approximately 8 million storm windows are sold in the United States every year (to about 500,000 households), and the current market share for low-e storm windows is approximately 10%. Then, using PNNL's estimate of the distribution of single- and double-pane windows by census division, EPA estimated the number of households that install storm windows every year in each Climate Zone, as shown in Table 4.[7]

Table 4 Estimated Number of Households that Install Single Pane and Double Pane Storm Windows

Estimated Number of Households that Install Storm Windows		
Climate Zone	**Single Pane Households**	**Double Pane Households**
8	17	14
7	3,371	4,977
6	23,849	36,521
5	75,099	117,296
4	70,944	65,829
3	45,120	15,548
2	27,572	9,180
1	3,577	1,084

[7] PNNL-22565, "Low-E Storm Windows: Market Assessment and Pathways to Market Transformation," June 2013.

Low-e storm windows can potentially save up to 1.2 tBtu per year if the market share for low-e storm windows increases from the current 10% baseline to 50%.[8]According to Ducker International, the market share for primary windows with low-e glass increased following the introduction of an ENERGY STAR specification (from 30% to 80% within 10 years). EPA believes that the market for low-e glass in storm windows may follow a similar trend with the introduction of an ENERGY STAR specification. Figure 4 shows the potential energy savings annually for each Climate Zone based on 50% market share.

Figure 4: Potential Savings from Low-E Storm Windows[9]

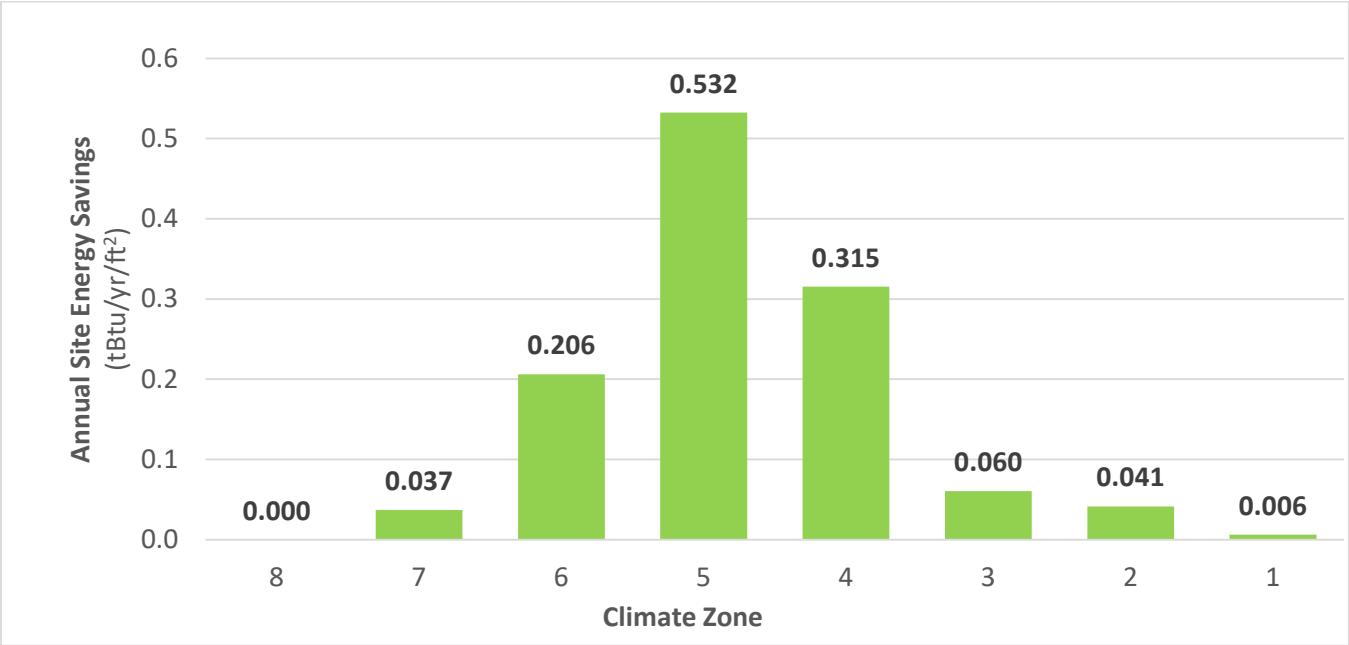


Table 5 shows the annual site energy savings for low-e storm windows at 10%, 25%, and 50% market share.

Table 5 Annual Site Energy Savings, by Low-E Market Share

Low-E Storm Windows Market Share	Annual Site Energy Savings (tBtu)	Savings over Baseline (tBtu)
10% (Baseline)	0.299	-
25%	0.749	0.450
50%	1.499	1.200

[8] Value based on savings over clear glass storm windows.

[9] Figure based on savings over clear glass storm windows, assuming 50% low-e market share minus baseline savings. Savings for Climate Zones 1 – 3 based on low solar transmittance glass.

b) Energy efficiency can be achieved through one or more technologies

EPA conducted online retail research, evaluated regional energy efficiency programs, and analyzed the International Glazing Database (IGDB) to determine whether the proposed ENERGY STAR criteria can be met through one or more technologies, that qualifying products are broadly available in different parts of the United States, and that the criteria will not favor any one manufacturer over others. The following factors were considered and evaluated in this research:

- Number of manufacturers that make low-e glass with pyrolytic coatings that meet the criteria
- Availability, variety, and cost-competitiveness of storm windows in the market
- Proprietary or exclusive nature of any technologies in use
- Influence of regional energy efficiency programs

Retail Research

To determine the availability of storm windows in the U.S. market, EPA researched the price and availability of aluminum frame, double-hung interior and exterior storm windows sold online by "big-box" home improvement chains (The Home Depot, Lowe's Home Improvement, and Menards). To assess regional availability, EPA searched for products using ZIP codes from 6 major U.S. cities: Boston, MA; Miami, FL; Madison, WI; San Francisco, CA; Fort Collins, CO; and St. Louis, MO.

EPA found 121 different storm window products, 88 of which were identified as low-e storm windows. Product variations included different brands, operator types, and sizes. Both clear glass and low-e storm windows were available in each location. Most low-e storm windows were advertised as having both interior and exterior options available. EPA concluded from the retail research that low-e storm windows are widely available in the market for consumers to purchase.

Regional Energy Efficiency Programs

When evaluating potential ENERGY STAR specifications, EPA often considers the market influence of criteria from other energy efficiency programs. The Regional Technical Forum (RTF), an administrative body serving the Northwest states of Idaho, Montana, Oregon, and Washington, determines criteria that utilities and other programs may use for a variety of energy efficiency measures, including low-e storm windows. The current RTF criteria for low-e storm windows are:

- Emissivity ≤ 0.22
- Solar transmittance > 0.55
- Opening type same as existing prime window
- Storm window is permanently installed
- Low-e coating facing toward the interior of the house
- If metal frame prime window, storm window frame is not in direct contact with the prime window frame[10]

By proposing criteria for emissivity and solar transmittance that match the RTF criteria, EPA believes that ENERGY STAR will help to reinforce existing market signals and ensure that qualifying products are broadly available. ENERGY STAR certification will help to promote these better-performing products and create an easier way to identify products that are eligible for incentives.

[10] Regional Technical Forum. Residential, Single Family Weatherization, Version 3.6. https://rtf.nwcouncil.org/measure/single-family

EPA also considered the design and installation requirements specified by the RTF. The RTF requires permanent installation because weatherization programs confirm installations on-site, but such a requirement does not apply to the ENERGY STAR program. Similarly, the requirement that the low-e coating face the interior of the house would not apply for interior storm windows. Instead, EPA has proposed requiring installation instructions that provide guidance on operator type and thermal breaks. This approach is similar to the installation instructions successfully used in the ENERGY STAR Windows, Doors, and Skylights program.

The IGDB Analysis

The IGDB is a collection of optical data for glazing products that is maintained by LBNL, with support from the U.S. Department of Energy (DOE). EPA analyzed the IGDB database V52.0 to understand the different glass options available in the market at different performance levels.

Using the RTF as guidance, EPA confirmed that an emissivity of 0.22 and below encompasses better-performing low-e glass options used in storm window applications. Clear glass has an average emissivity of 0.84, and the small number of specialty glazing types with emissivity between 0.84 and 0.22 are not intended for storm window applications. EPA analyzed the number of distinct glass options available at 0.22 emissivity and below, but excluded low-e coatings that cannot be used with exposed surfaces and laminated coatings, as such products are not typically used for storm windows. EPA also excluded variations of the same glass product, such as different thicknesses and tints. See Table 6 for results of this analysis.

Table 6: IGDB Analysis

	Solar Transmittance > 0.55 Northern Zone		**Solar Transmittance ≤ 0.55 Southern Zone**	
Emissivity	**Number of glass options**	**Number of manufacturers**	**Number of glass options**	**Number of manufacturers**
≤ 0.22	12	5	17	4
≤ 0.21	12	5	17	4
≤ 0.20	11	5	16	4
≤ 0.19	8	4	16	4
≤ 0.18	7	4	16	4
≤ 0.17	7	4	16	4
≤ 0.16	7	4	13	4
≤ 0.15	5	2	11	3
≤ 0.14	0	0	0	0

EPA found that there are at least 12 glass options available from 5 manufacturers that would qualify for the proposed Northern Zone criteria, and 17 glass options from 4 manufacturers that would qualify for the proposed Southern Zone criteria. Based on these results, EPA concluded that the proposed criteria for storm windows are technologically feasible. In addition, EPA concluded that an emissivity of 0.15 (as assumed in the energy modeling) would eliminate otherwise viable low-e options that are currently available in the market. See Appendix A for the full list of glass options that meet the proposed criteria.

Note that EPA is providing this information to confirm that there are glass options available in the market from more than one manufacturer that can meet the proposed criteria. Storm windows manufacturers may use any glass option that is listed in the IGDB, and EPA does not promote the use of any one of these glass options over others that also meet the proposed criteria.

c) Product performance can be maintained or enhanced with increased energy efficiency

When creating specifications for a new product category, EPA determines whether increased energy efficiency will maintain or enhance the performance of the product beyond simply energy performance. In response to stakeholder comments on the Framework Document, EPA has investigated three issues related to product performance in greater depth – product safety, condensation, and visual transmittance.

Safety and Structural Certification

One commenter suggested that ENERGY STAR storm windows should be certified and labeled according to the North American Fenestration Standard (NAFS) to do the following:

- Ensure consistent, quality products
- Ensure proper glass strength in accordance with ASTM E1300
- Establish maximum air leakage criteria that align with NAFS for both interior and exterior windows

In this product category, EPA is reluctant to assign product design requirements that do not directly affect the energy performance of the product, are not widely used, and may increase product cost. However, EPA is proposing air leakage requirements in Draft 1 because air leakage performance is directly related to energy performance. As discussed below, EPA is proposing the Attachments Energy Rating Council's AERC 1.2 as the test procedure for air leakage. EPA will accept NAFS certification (as well as other third-party certifications) for compliance with the air leakage requirement provided such certification uses the AERC 1.2 test procedure or a demonstrated equivalent.

Another commenter raised concerns regarding consumer safety and provided EPA with injury data showing 56 injuries over a 10-year period related to storm window breakage in the Consumer Product Safety Commission (CPSC) – National Electronic Injury Surveillance System's (NEISS) sample of 100 hospitals. After carefully analyzing the injury data, EPA found that 55 of the 56 cited injuries related to storm windows had a disposition of '1' (the lowest possible severity) on a scale of 1-9, which indicates that the patient was examined and released with or without treatment. The remaining case had a disposition of '2', which indicated that the patient was treated and transferred to another hospital. There was also no indication that the injuries were related specifically to low-e glass. Thus, EPA concludes that storm windows in general pose a very minimal safety risk to consumers, and there is little evidence to suggest that low-e storm windows pose any greater risk.

An important distinction is when storm windows are installed in regions where local building codes require safety glazing or other measures, such as in storm-prone regions. To address this issue, the Draft 1 proposal requires that manufacturers include a reference in their installation instructions to following safety requirements in local building codes.

Condensation

EPA also received comments on the Framework Document indicating that storm windows can create condensation problems as a function of the air tightness of the storm window and primary window. To mitigate the potential for condensation issues, EPA is proposing that weep holes or other moisture management technologies be required for exterior storm windows. The proposed air leakage requirement for exterior storm windows will allow a limited amount of air leakage through weep holes.

Visual Transmittance

Some commenters noted that there may be a negative impact on visual transmittance if a consumer adds low-SHGC storm windows to low-SHGC windows. While EPA agrees that consumers may not be aware of the

potential impact on visual transmittance, this does not necessarily indicate that requirements related to visual transmittance should be included in the specification. In fact, some consumers may prefer products with a lower visible transmittance to reduce glare. To address potential issues related to visual transmittance, EPA will provide information on the ENERGY STAR website about low visual transmittance from two layers of low-e glass to educate consumers.

d) Product energy consumption and performance can be measured and verified with testing.

EPA has proposed a specification based on emissivity, solar transmittance, and air leakage. Emissivity and solar transmittance are glass-only properties, and these metrics would directly distinguish higher-performing storm windows from conventional storm windows. Air leakage for storm windows can be assessed through a modification to the ASTM E283 test procedure described below.

Certification Requirements

EPA will use its standard process to solicit eligible organizations to test and certify ENERGY STAR storm windows. Interested organizations will be asked to submit certification and verification procedures to EPA, and EPA will review the submissions and approve organizations to act as certification bodies. More information on this process will be forthcoming.

Storm window manufacturers will be required to submit applications to approved certification bodies for each model that they wish to have certified as ENERGY STAR. The certification body may confirm that the product meets requirements for emissivity, solar transmittance, and air leakage either through direct testing or review of test results from an accredited third party. The certification body will then submit certified products to EPA to be listed on the ENERGY STAR website. Once approved, these products are considered to be ENERGY STAR certified and can be labeled according to the program requirements.

Air Leakage Test Procedure

EPA is proposing that air leakage be measured in accordance with AERC 1.2 test procedure "Physical Test Methods for Measuring Energy Performance Properties of Fenestration Attachments." AERC 1.2 specifies testing the storm window product installed over a calibrated test panel in accordance with ASTM E283 at a design pressure of 75 Pa (1.57 psf) applied to the exterior side of the test assembly. The test panel is calibrated to a baseline window air leakage of 2.0 cfm/ft^2 to represent an old existing window. AERC 1.2 also requires that the storm window be installed according to manufacturer instructions, with no special sealing that would not be part of a normal product installation. The test procedure allows the use of retaining clips or brackets while under pressure for storm windows that are not permanently attached to the baseline window frame, as long as they do not affect the air leakage.

AERC found that testing storm window products with this method yielded an air leakage of approximately 1.3 cfm/ft^2 for exterior operable products and 0.4 cfm/ft^2 for interior operable products. EPA is proposing air leakage requirements of ≤ 1.5 and ≤ 0.5 cfm/ft^2, respectively, to allow for reasonable variability in product performance.[11]

[11] See "AERC - Air Leakage Charts – May 2017" at https://www.energystar.gov/products/spec/exterior_and_interior_storm_panels_version_1_0_pd

Frame Performance and Alternative Certification

EPA is not proposing the use of U-factor and SHGC for the storm window criteria, as these metrics account for the thermal performance of frame material in addition to glazing materials. Additional analysis provided to EPA shows that the frame of exterior and interior storm windows has a negligible impact on product performance. Specifically, the effect of storm window frame material on overall U-factor is 1.9-2.6%, while the effect of glazing type (low-e vs. clear) has 10 times more impact than the frame material, reducing the U-factor of these windows by 21-24%.[12]

One application where frame material can affect performance is when an aluminum frame storm window is mounted over a metal frame primary window. To address this issue, EPA is proposing that manufacturers include a reference in their installation instructions regarding the need for thermal breaks. When an aluminum frame storm window is mounted over a wood or other non-metal frame primary window, the aluminum frame does not adversely affect product performance because there is no continuous thermal bridge between the storm window frame and the primary window frame.

AERC is currently developing procedures to certify fenestration attachments, including storm windows, for U-factor, SHCG, and Annual Energy Performance (AEP). AERC expects to publish technical documents on product certification by Fall 2017. Once available, EPA will evaluate these procedures for possible inclusion as an alternative path for ENERGY STAR certification for products with equivalent energy performance via other metrics.

e) Investment in increased energy efficiency can be recovered within reasonable period of time.

While developing specification criteria for a new product category, EPA evaluates the cost-effectiveness of the proposed criteria, including:

- Additional cost of energy-saving technologies for the manufacturer
- Incremental cost and payback of increased efficiency products to consumers
- Price of energy

Price Premium

In its research on product prices from big-box home improvement chains, EPA found the range of product costs to be $34 to $59 for clear glass storm windows and $45 to $131 for low-e storm windows. The range in prices resulted mainly from a wide range of available sizes. EPA noted that some low-e storm windows were marketed as premium models with extra features, such as double weather stripping or better frame design. As discussed in Section D, these improvements have a negligible impact on energy performance compared to the improvement of low-e glass. When evaluating cost effectiveness and payback, EPA uses basic and lower-priced products to isolate the cost of the improved technology; therefore, EPA excluded price quotes for the high-end models from its analysis. One retailer's prices were consistently $20-$30 higher than other retailers' for the same storm windows. Therefore, EPA also excluded those price quotes from its analysis.

The final dataset used for the evaluation included prices from 41 clear and low-e storm windows. From the dataset, the average price per square foot was found to be $4.58 for clear storm windows and $6.16 for low-e

[12] See "Birch Point Consulting - Additional Comments on Storm Window Frames - March 2017" at https://www.energystar.gov/products/spec/exterior_and_interior_storm_panels_version_1_0_pd

storm windows. These prices are slightly lower than the values used by PNNL in the paper that EPA cited in the Framework Document, but the price premium is slightly higher. Table 7 describes the values used in the PNNL paper and the values EPA calculated from its online research.

Table 7: Cost Data for Clear and Low-E Storm Windows

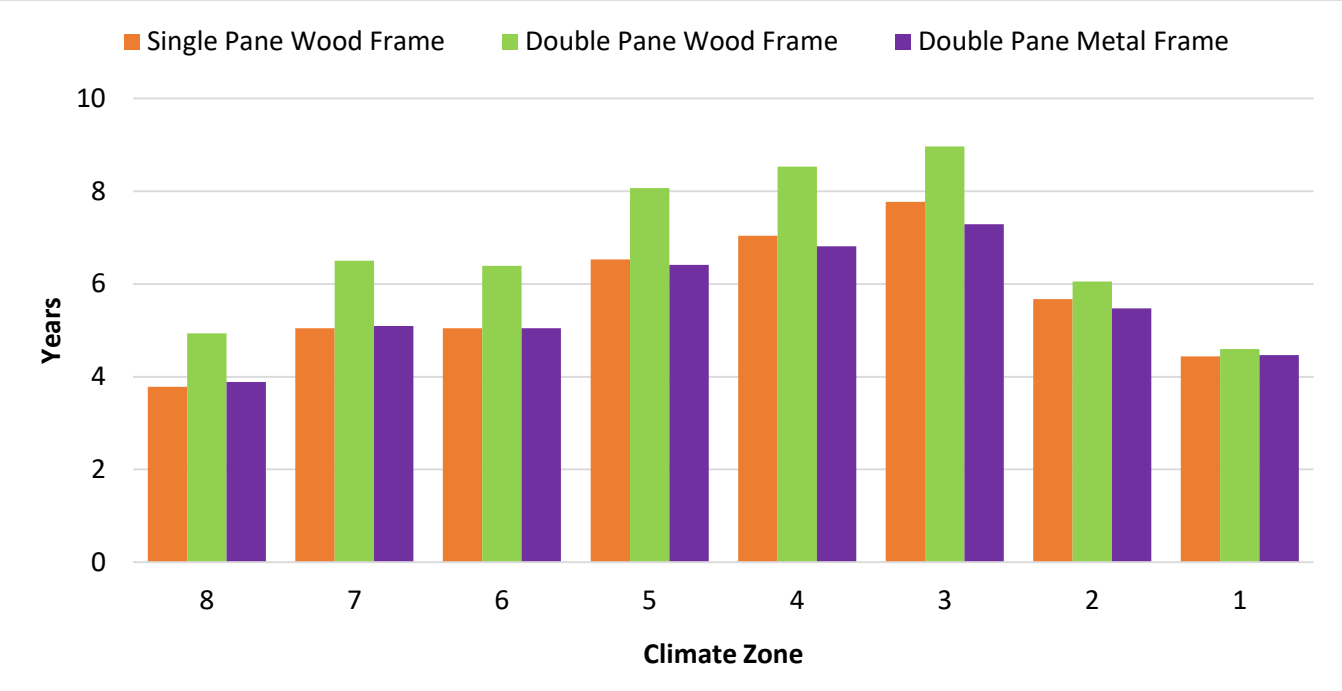
Product Type	Price Range		Price per Square Foot	
	PNNL[13]	EPA	PNNL[14]	EPA
Internal Clear Storm Window	$70-$125	$34 - $59	$6.00	$4.58
External Clear Storm Window	$70-$125	$34 - $59	$7.00	$4.58
Internal Low-E Storm Window	$80-$150	$45 - $131	$7.00	$6.16
External Low-E Storm Window	$80-$150	$45 - $131	$8.00	$6.16

Payback Calculations by Climate Zone

To understand how the updated price per square foot affects payback, EPA updated PNNL's RESFEN analysis with the revised information. Figure 5 presents incremental payback for low-e storm windows with the updated pricing information. Note that all other variables were kept unchanged from the original PNNL analysis.

Figure 5: Incremental Payback for Low-E Storm Windows

PNNL's research showed the payback for low-e storm windows to be in the range of 2.4 to 5.7 years, while EPA's research with updated costs shows the payback to be in the range of 3.8 to 8.5 years across all Climate Zones. These paybacks show a reasonable return on the consumer's investment in increased energy efficiency, well within the lifetime of the product.



[13]PNNL-22565 "Low-E Windows: Market Assessment and Pathways to Market Transformation." June 2013.
[14]PNNL-24826, "Energy Savings of Low-E Storm Windows and Panels across US Climate Zones," August 2015.

f) Labeling would effectively differentiate products and be visible for purchasers

Storm windows have been a reliable choice for consumers for many decades. Storm windows that use glass with low-e coatings have been available to consumers since 2009. When combined with other features that reduce air leakage, low-e storm windows can provide better thermal performance than traditional storm windows.

It can be very difficult to differentiate low-e glass from clear glass through visual inspection alone, and consumers can find it challenging to understand and trust marketing material about the technology. An ENERGY STAR label will help consumers identify better-performing low-e storm windows from conventional storm windows and should improve their trust in the technology. In addition, having an ENERGY STAR certification program for storm windows will help utilities and weatherization programs promote the option of low-e storm windows or offer rebates/incentives to homeowners for installing low-e storm windows. In jurisdictions with historical preservation codes that prohibit window replacements, low-e storm windows can help make the whole window assembly more energy efficient without affecting the look of the windows.

Conclusion

Based on EPA's research and the research papers cited in the Framework Document, the Agency believes that ENERGY STAR certified storm windows would satisfy all of the ENERGY STAR Guiding Principles and therefore are a good candidate for addition to the ENERGY STAR program.

- The proposed Version 1.0 criteria could save a significant amount of energy, up to 1.2 trillion Btu on a national basis at a 50% market share.
- Qualifying products would be broadly available from more than one manufacturer, and manufacturers would be able to use a variety of different glazing options to meet the proposed criteria.
- Storm windows with low-e glass are of equal or better quality than conventional storm windows and therefore maintain or enhance product performance.
- The proposed criteria of emissivity, solar transmittance, and air leakage can all be measured and verified with testing.
- Low-e storm windows have a payback period of 2.4 to 8.5 years.
- Labeling with ENERGY STAR would help differentiate low-e storm windows from conventional storm windows.

Next Steps

EPA requests that stakeholders provide comments on the proposed Draft 1 Specification and Criteria Analysis Report. During the comment period, EPA will hold a webinar to review the proposal. EPA will provide a response to comment document on all feedback received from stakeholders and expects to release the final draft specification in the fall of 2017, followed by another comment period. Please submit all comments and supporting information to windows@energystar.gov by August 31, 2017.

Appendix A: U-factor, SHGC, and VT of Storm Windows over Different Primary Windows

Primary Window	Storm Window[15] Type	U-factor (Btu/hr ft^{2}F)	SHGC	VT
Wood Double Hung, Single Glazed	-	0.88	0.61	0.66
	Clear, Exterior	0.47	0.54	0.57
	Clear, Interior	0.46	0.54	0.59
	Low-e, Exterior	0.36	0.46	0.52
	Low-e, Interior	0.34	0.50	0.54
Wood Double Hung, Double Glazed	-	0.51	0.57	0.61
	Clear, Exterior	0.34	0.49	0.53
	Clear, Interior	0.32	0.51	0.55
	Low-e, Exterior	0.28	0.42	0.48
	Low-e, Interior	0.26	0.47	0.50
Wood Fixed, Single Glazed	-	0.87	0.64	0.69
	Clear, Exterior	0.46	0.58	0.62
	Clear, Interior	0.45	0.56	0.62
	Low-e, Exterior	0.34	0.50	0.56
	Low-e, Interior	0.34	0.52	0.57
Wood Fixed, Double Glazed	-	0.47	0.60	0.64
	Clear, Exterior	0.32	0.53	0.57
	Clear, Interior	0.32	0.54	0.58
	Low-e, Exterior	0.27	0.46	0.52
	Low-e, Interior	0.25	0.50	0.53

Source: PNNL-24444. "Thermal and Optical Properties of Low-E Storm Windows and Panels," July 2015.

[15] Low-e storm window: Storm window with standard pyrolytic low-e glass with an emissivity of 0.15 was modeled. For Climate Zones 1, 2, and 3, a solar transmittance of 0.50 was modeled. For Climate Zones 4, 5, 6, 7, and 8, a solar transmittance of 0.69 was modeled.
Clear glass storm window: Emissivity of 0.84 and solar transmission of 0.86 were modeled.

Primary Window	Storm Window Type	U-factor (Btu/hr ft^{2}F)	SHGC	VT
Aluminum Double Hung, Single Glazed	-	1.12	0.61	0.65
Worst-case mounting	Clear, Exterior	0.67	0.56	0.58
Thermally broken mounting (recommended)	Clear, Exterior	0.58	0.56	0.59
	Clear, Interior	0.53	0.53	0.59
Worst-case mounting	Low-e, Exterior	0.57	0.47	0.53
Thermally broken mounting (recommended)	Low-e, Exterior	0.44	0.48	0.54
	Low-e, Interior	0.41	0.50	0.54
Aluminum Double Hung, Double Glazed	-	0.75	0.58	0.60
Worst-case mounting	Clear, Exterior	0.55	0.51	0.54
Thermally broken mounting (recommended)	Clear, Exterior	0.45	0.52	0.55
	Clear, Interior	0.41	0.51	0.55
Worst-case mounting	Low-e, Exterior	0.49	0.44	0.49
Thermally broken mounting (recommended)	Low-e, Exterior	0.36	0.44	0.50
	Low-e, Interior	0.32	0.47	0.50
Aluminum Fixed, Single Glazed	-	1.06	0.72	0.77
Worst-case mounting	Clear, Exterior	0.62	0.59	0.62
Thermally broken mounting (recommended)	Clear, Exterior	0.55	0.61	0.65
	Clear, Interior	0.51	0.60	0.66
Worst-case mounting	Low-e, Exterior	0.51	0.50	0.57
Thermally broken mounting (recommended)	Low-e, Exterior	0.42	0.52	0.59
	Low-e, Interior	0.38	0.56	0.60
Aluminum Fixed, Double Glazed	-	0.62	0.67	0.71
Worst-case mounting	Clear, Exterior	0.47	0.54	0.58
Thermally broken mounting (recommended)	Clear, Exterior	0.40	0.56	0.60
	Clear, Interior	0.36	0.57	0.61
Worst-case mounting	Low-e, Exterior	0.42	0.47	0.52
Thermally broken mounting (recommended)	Low-e, Exterior	0.33	0.48	0.55
	Low-e, Interior	0.29	0.53	0.56

Source: PNNL-24444. "Thermal and Optical Properties of Low-E Storm Windows and Panels," July 2015.

Appendix B: List of Glass Options that Meet the Proposed Criteria

Manufacturer	Product Name	Emissivity	Range of Tsol	Zone
AGC Glass Co. N.A.	Comfort E²	0.20	0.66 - 0.71	Northern
AGC Glass Co. N.A.	Comfort Select 73 Laminated	0.15	0.62	Northern
AGC Glass Co. N.A.	Comfort Select 73	0.15	0.68 - 0.73	Northern
AGC Glass Co. N.A.	Comfort Select 73 Defender	0.15	0.61	Northern
AGC Glass Co. N.A.	Energy Select 73	0.15	0.67	Northern
Cardinal Glass Industries	E340/ Tinted PVB / i89	0.15	0.07	Southern
Cardinal Glass Industries	E366/ Tinted PVB / i89	0.15	0.11	Southern
Cardinal Glass Industries	E366 / PVB / i89	0.15	0.23 - 0.24	Southern
Cardinal Glass Industries	E340 / PVB / i89	0.15	0.13 - 0.14	Southern
Cardinal Glass Industries	E366 / SGP / i89	0.15	0.23	Southern
Cardinal Glass Industries	E340 / SGP / i89	0.15	0.13 - 0.14	Southern
Cardinal Glass Industries	i89	0.15	0.68 - 0.75	Northern
Cardinal Glass Industries	x89	0.19	0.71 - 0.77	Northern
Eastman Chemical Company	XIR®7241	0.16	0.21 - 0.30	Southern
Eastman Chemical Company	XIR®7247	0.16	0.22 - 0.33	Southern
Guardian	ClimaGuard IS-20	0.20	0.59 - 0.73	Northern
Guardian	SunGuard® IS 20	0.20	0.67 - 0.77	Northern
Guardian	SunGuard® Neutral 40	0.15	0.28 - 0.30	Southern
Guardian	SunGuard® Neutral 40 Tinted	0.15	0.18	Southern
Guardian	SunGuard® Neutral 50	0.15	0.36 - 0.38	Southern
Guardian	SunGuard® Neutral 50 Tinted	0.15	0.23	Southern
Pilkington North America	Eclipse Advantage Tinted	0.21	0.23 - 0.35	Southern
Pilkington North America	Eclipse Advantage Clear	0.21	0.58	Northern
Pilkington North America	Energy Advantage Low-E	0.16	0.56 - 0.75	Northern
Pilkington North America	Solar E	0.17	0.40 - 0.46	Southern
Pilkington North America	Solar E Laminated	0.15	0.41	Southern
Pilkington North America	Solar-E Tinted	0.17	0.15 - 0.19	Southern
Pilkington North America	Solar-E Plus Tinted	0.17	0.14 - 0.28	Southern
Viracon	PyroLowE Laminated	0.16	0.63	Northern