ENERGY STAR® Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report

July 2021

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Introduction

The U.S. Environmental Protection Agency (EPA) is pleased to share with stakeholders the Criteria Analysis Report for Draft 1 of the ENERGY STAR® Version 7.0 Windows, Doors, and Skylights (WDS) specification criteria revision. EPA is providing this document for stakeholders to review and consider prior to providing comments on the Draft 1 Version 7.0 specification revision proposal.

EPA reviews all ENERGY STAR specifications regularly to determine whether a revision would help consumers identify units that will further reduce energy use in a cost-effective manner. EPA has gathered and analyzed data that support proposing changes to the current ENERGY STAR window, door, and skylight criteria to save consumers additional energy and money. This report was developed to document key data, analysis, and the proposed criteria revisions to the current criteria for consideration.

EPA is committed to transparency and has provided publicly available background data and analytical results in the report, in the appendix of this document, and on the specification revision web page.

Stakeholder engagement is a vital aspect of the success of the ENERGY STAR program, and EPA looks forward to considering comments submitted by interested parties as part of this collaborative process. Please submit any formal comments on the Draft 1 Version 7.0 specification revision to windows@energystar.gov by **August 20, 2021**.

Background and Process

EPA published the current (Version 6.0) WDS specification in January 2014. That specification had a two-part effective date, with most of the criteria taking effect in January 2015 and the Northern Climate Zone prescriptive and equivalent energy performance criteria for windows taking effect in January 2016.[1]

In September 2019, EPA published a Discussion Guide, laying out many topics and issues leading up to a possible proposed Version 7.0 criteria revision. EPA raised certain topics and issues in an effort to get feedback from stakeholders as part of the collaborative process. EPA received feedback on several topics including, but not limited to:

- Market share data
- Current codes
- Approach to product availability
- Product cost data collection
- Approach to energy analysis
- Changing or combining certain ENERGY STAR Climate Zones
- Sunsetting door and/or skylight criteria
- Setting a minimum solar heat gain coefficient (SHGC) in the Northern Climate Zone
- Applying the ENERGY STAR Windows Specification to Full-Lite Sliding Patio Doors

EPA reviewed and considered all comments received from the Discussion Guide and has drafted responses. Part 1 of the responses were released in September 2020. Part 2 is being released concurrently with this document. Both sets of responses are available on the ENERGY STAR Partner web page.

Guiding Principles and the Specification Revision Process

In establishing or revising an ENERGY STAR product performance specification, EPA employs a set of six key principles:

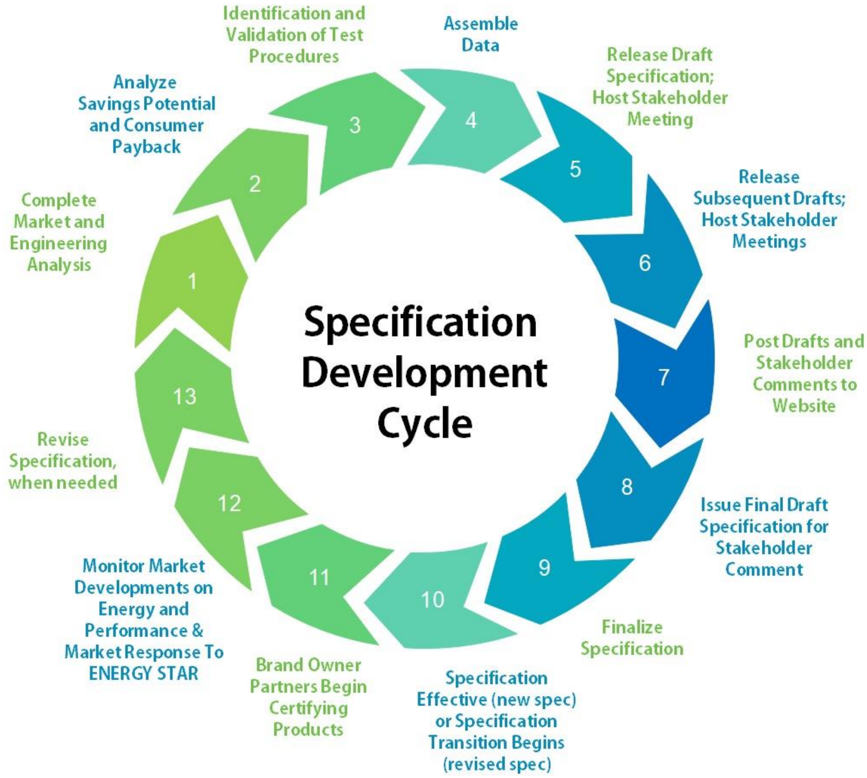
[1] EPA provides background documents on previous specification revisions and specifications currently in development at https://www.energystar.gov/products/building_products/residential_windows_doors_and_skylights/partners.

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

It is important to note that these principles are not applied as a strict checklist. The ultimate viability and environmental impact of an ENERGY STAR specification in the marketplace depends on many factors. The principles are used as guidance during an iterative process to achieve the desired balance among the principles, using the best available market information. The success of a specification can be more reasonably ensured through the application of these principles.

Figure 1 illustrates the general process that EPA uses to monitor the market, begin potential specification revision efforts, and make decisions.

Figure 1. Specification Revision Process



Current Market Assessment

EPA has continued to monitor developments in the market since the implementation of Version 6.0. Specifically, EPA has been following market share changes and advances in energy codes. These data sources are preliminary indicators that help determine whether EPA should consider a new specification revision process. Here are the results of EPA's review.

Market Share

EPA found that market share remained high since the implementation of Version 6.0. Table 1shows that the market share for ENERGY STAR certified WDS was high even before Version 6.0 was implemented in 2014, and did not decrease substantially following implementation of Version 6.0 in 2015 and 2016. Market share in all categories remained high or increased a small amount leading up to 2019. See Market Share by Climate Zone in the appendix for more details.

Table 1. ENERGY STAR Market Share by Year

Product Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Residential Windows	81%	79%	77%	80%	83%	84%	83%	84%	85%	86%
Hinged Entry Doors	71%	73%	74%	76%	77%	79%	78%	80%	79%	80%
All Patio Doors							81%	82%	83%	84%
Skylights	70%	68%	62%	60%	62%	65%	64%	68%	68%	72%

Source: DuckerFrontier, 2020.

A persistently high market share for ENERGY STAR certified products generally suggests that the current specification represents a widely achievable level of performance in the market. Furthermore, the high market share indicates a criteria revision may identify better performing energy-efficient products that deliver cost-effective savings to consumers. EPA has performed that analysis and is providing those results in this report.

Developments in Energy Codes

As part of its monitoring of the fenestration market, EPA noted a trend in WDS performance improvements for some building energy codes. It is important for the ENERGY STAR specification to keep pace with code improvements to align with the ENERGY STAR program's Guiding Principles for effectively differentiating energy-efficient products and contributing significant energy savings nationwide. Since the issuance of the Version 7 Discussion Guide, a key change has been the final issuance of the 2021 International Energy Conservation Code (IECC). The 2021 IECC did make a few changes to the requirements for fenestration. Specifically, the requirements for IECC Climate Zones 3 and 4 were revised from a U-factor of 0.32 down to 0.30. The IECC Climate Zones 3 and 4 fenestration requirements now match the ENERGY STAR South-Central and North-Central Climate Zones, respectively.

The California Title 24 lower SHGC requirement of 0.23 in some California climate zones continues to be more stringent than the current ENERGY STAR South-Central Climate Zone requirement.

Finally, the Natural Resources Canada ENERGY STAR Version 5.0 specification for WDS became effective in January 2020. The specification set a maximum U-factor for windows and doors at 0.21, with an alternate minimum energy rating of 34. The maximum U-factor for Canadian skylights is 0.40, without an energy rating equivalent.

Windows

EPA's analysis indicates that the proposed windows criteria (see Table 2) can save a significant amount of energy at the national level and provide cost-effective savings for consumers, paying back incremental price premiums in a reasonable amount of time. The criteria can be met through multiple technical pathways, do not require proprietary technology, and do not negatively impact the non-energy performance of the product. Products meeting the criteria are available for sale and provide a clear differentiation over standard products in the market.

EPA developed its proposal based on a detailed analysis of technical feasibility, product availability, consumer costs, component costs, energy and cost savings, and cost-effectiveness. EPA has laid out the key results of its analysis in the following section.

Table 2. Proposed ENERGY STAR Criteria for Windows

Version 6

Climate Zone	U-Factor	SHGC	
Northern	≤ 0.27	Any	Prescriptive
	= 0.28	≥ 0.32	Equivalent Energy Performance
	= 0.29	≥ 0.37	
	= 0.30	≥ 0.42	
North-Central	≤ 0.30	≤ 0.40	
South-Central	≤ 0.30	≤ 0.25	
Southern	≤ 0.40	≤ 0.25	

Version 7

Climate Zone	U-Factor	SHGC	
Northern	≤ 0.22	≥ 0.17	Prescriptive
	= 0.23	≥ 0.35	Equivalent Energy Performance
	= 0.24	≥ 0.40	
	= 0.25	≥ 0.45	
	= 0.26	≥ 0.50	
North-Central	≤ 0.24	≤ 0.40	
South-Central	≤ 0.28	≤ 0.23	
Southern	≤ 0.32	≤ 0.23	

Product Availability and Technical Feasibility

EPA concluded that the proposed criteria for windows are technologically feasible and can be met through a variety of technical pathways, and products are currently available for sale that can meet these criteria. To reach this conclusion, EPA analyzed performance and component data from ENERGY STAR certified product lines listed in the National Fenestration Rating Council (NFRC) Certified Products Directory (CPD),[2] evaluated product shipment data published by the Fenestration and Glazing Industry Alliance (FGIA)/DuckerFrontier, and conducted mystery shopping. EPA has published the CPD analysis data in the Supplemental Data Package.

EPA focused its analysis on vertical slider windows (single-hung and double-hung) because this operator type is popular in the U.S. market and performs worse than other operator types for the same set of components. EPA also focused primarily on vinyl-framed windows as these products make up 73% of U.S. window sales (FGIA/DuckerFrontier). Through this research and analysis, EPA developed a model of the technical pathways that are commonly used to meet different performance levels. EPA defines a *technical pathway* as a combination of frame options, glazing configurations, coating options, spacers, and gas fills.

[2] NFRC's FenStar certification program is a requirement for ENERGY STAR certification. ENERGY STAR product brand owners must designate each line that they plan to label and market as ENERGY STAR for the year. EPA assumes that product lines designated for FenStar are a reasonable proxy for product availability.

Table 3. Common Technical Pathways by Performance Tier for Vinyl Vertical Slider Windows

U-Factor	Most Common Technical Pathways	Alternative Technical Pathways
0.32–0.35	1 Low-emissivity (low-e) coating, air-filled insulating glass unit (IGU) and basic frames	–
0.28–0.31	1 Low-e coating with argon-filled IGU	Better performing products in this range have improved frames or non-metal spacers
0.27	1 Low-e coating with argon-filled IGU and improved frames and spacers	2 Low-e coatings (room-side low-e) with basic frames
0.24–0.26	2 Low-e coatings (room-side low-e) with argon-filled IGU	Double-pane with 1 low-e coating, argon-filled IGU and foamed frames Triple-pane with 2 low-e coatings and air-filled IGU
0.22–0.23	Triple-pane with 2 low-e coatings and argon-filled IGU	Double-pane with room-side low-e surface and foamed frames
0.21 and Below	Triple-pane with room-side low-e, argon-filled IGU, non-metal spacers, and improved and/or foamed frames	Krypton-filled IGUs are more common below 0.20

Frame Material

Frame performance can vary widely and have a significant impact on the U-factor. For vinyl frame windows, manufacturers engineer frames with hollow cavities to improve thermal insulation, and performance is impacted by operator type and other design decisions.

EPA found that a vinyl vertical slider with one triple-silver low-emissivity (low-e), one room-side low-e, a non-metal spacer, and argon gas (referred to as VS_Vinyl_A_25_ARG) can have a U-factor ranging from 0.22 to 0.32. The NFRC CPD does not contain data on frame performance; however, EPA assumes that better performing products within a given pathway use “improved” vinyl frames with multiple interior chambers.

Some manufacturers also use die-cut or spray-in foam for additional insulation. Figure 2 shows the higher prevalence of foamed frames at lower U-factors among double-pane vinyl windows.

Figure 2. Percentage of Double-Pane, Vinyl, Vertical Slider Options with Foamed Frames

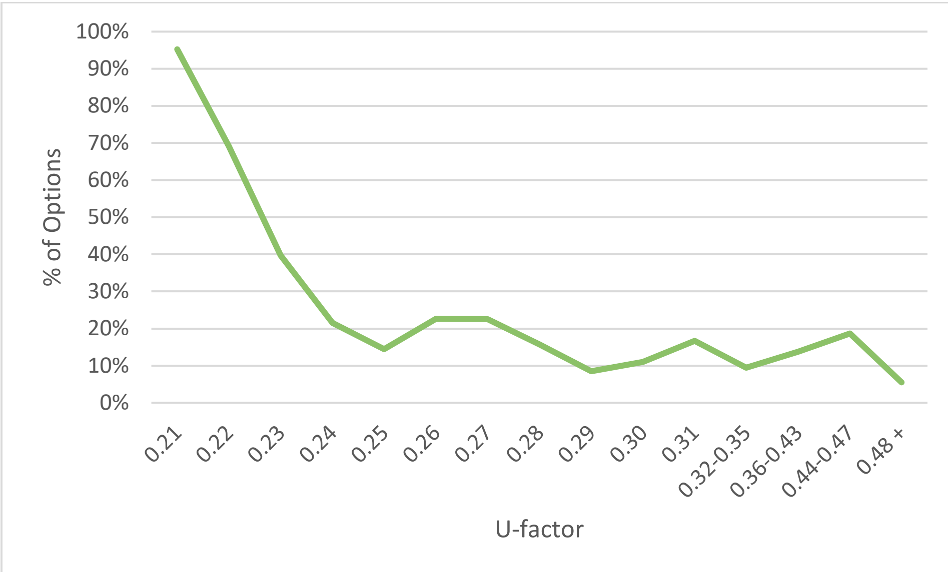
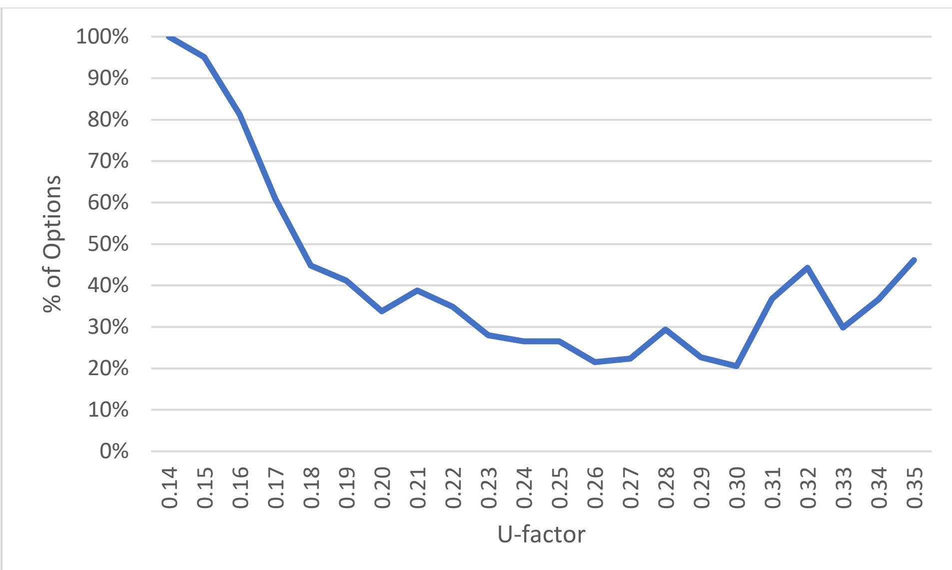


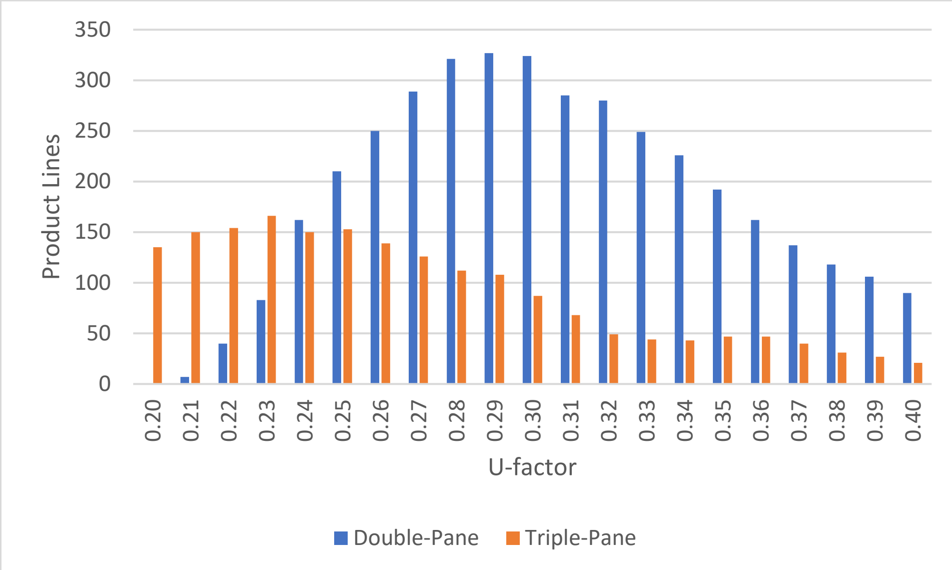
Figure 3. Percentage of Vinyl, Vertical Slider, Triple-Pane Options with Foamed Frames



Glazing Configuration and Coatings

The number of glazing layers and types of low-e coatings are the most significant driver of product performance. The choice between a double-pane or triple-pane window determines other design choices for the manufacturer, including the width and weight of the frame. EPA found that a vinyl double-pane product can achieve U-factors as low as 0.21 with argon, room-side low-e, foamed frames, and non-metal spacers. Some composite frame products can also achieve a 0.21 U-factor with a double-pane. However, the majority of certified product lines currently use a triple-pane configuration to reach U-factors below 0.24. Figure 4 illustrates the number of unique product lines that have a double-pane option at each U-factor compared with those that only have a triple-pane option at that level.

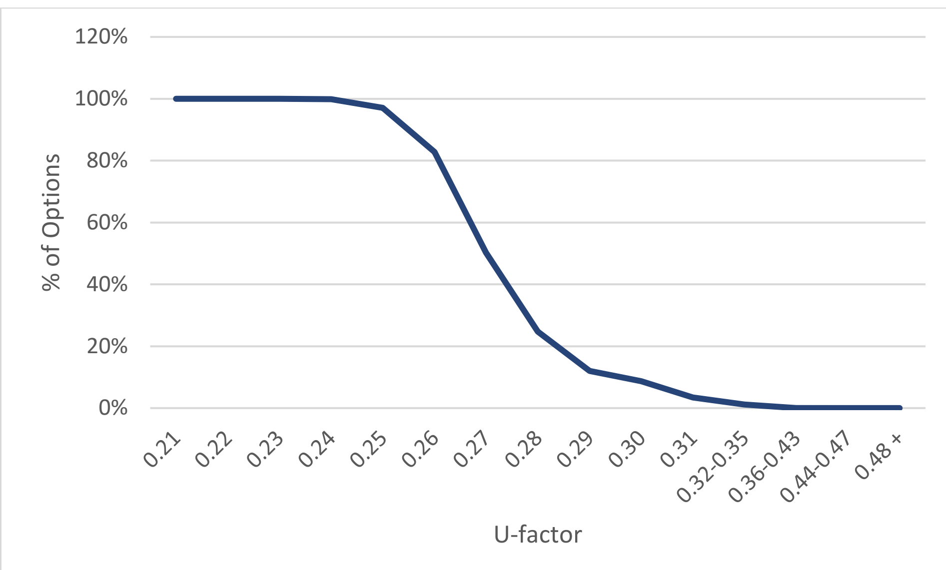
Figure 4. Vinyl Vertical Slider Product Lines by U-Factor and Glazing Layers



Room-Side Low-e

EPA evaluated using room-side (or fourth surface) low-e coatings to improve performance. EPA found that about 50% of double-pane vinyl products certified to meet the Version 6.0 Northern Climate Zone criteria of 0.27 use a room-side low-e (Figure 5). Among double-pane vertical sliders with a U-factor below 0.25, 100% of certified options used room-side low-e.

Figure 5. Percentage of Double-Pane, Vinyl, Vertical Sliders with Room-Side Low-e



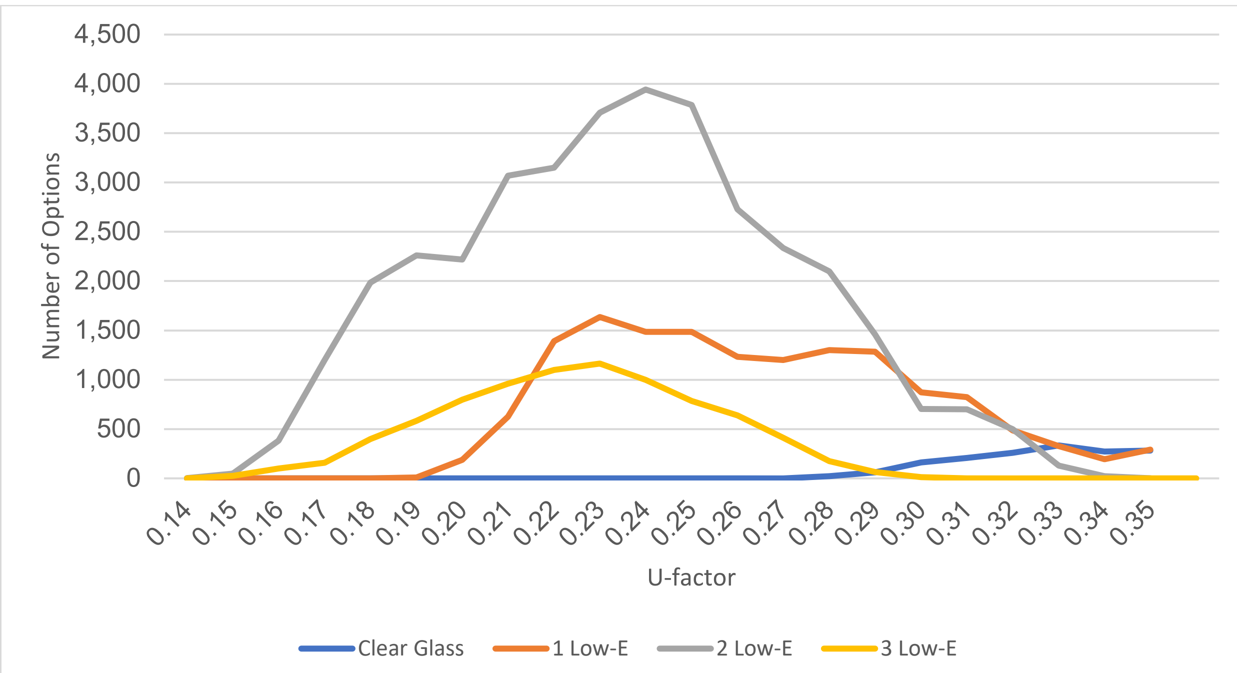
There are two different room-side low-e technologies on the market offered by multiple glazing suppliers—these pyrolytic and sputtered options have comparable thermal performance. In its mystery shopping research, EPA also found that this technology was widely available from windows dealers, with a variety of product lines offering a room-side low-e option.

EPA received anecdotal reports of non-energy performance issues related to room-side low-e, including more susceptibility to condensation in cold climates. Comfort for the occupants of a space and condensation build-up on the glazing are features of windows that can be subjective or difficult to quantify because they are highly dependent upon other characteristics of the home. Discomfort can come from excess solar heat gain or from a cold glass surface. The Efficient Windows Collaborative has attempted to characterize comfort and condensation, taking into account the number of panes of glass, the frame type, the U-factor, and the SHGC of various window offerings in cities across the United States. This information shows that products with room-side low-e do not inherently have poorer comfort or condensation performance compared with other configurations with similar thermal performance.[3] EPA found that choosing the appropriate SHGC for a particular climate zone is the most important factor for its effects on comfort.[4] EPA concluded that room-side low-e is a viable technology that does not adversely affect consumer preferences.

Triple-Pane Glazing

EPA looked more closely at the glazing configuration of triple-pane products. Manufacturers used dozens of different combinations of coatings on different surfaces, and EPA believes that many of the certified triple-pane options in the CPD are not commonly built and sold. Nevertheless, the performance distribution of certified options provides a useful understanding of how different triple-pane configurations perform and which are most common. The most common type of configurations at a 0.22 U-factor use two low-e surfaces, with around 25% of certified options using one low-e surface and 20% using three low-e surfaces (see Figure 6). EPA concluded that a triple-pane product with two low-e surfaces is the representative configuration for the proposed Northern Climate Zone criteria.

Figure 6. Triple-Pane, Vinyl, Vertical Slider Options by Number of Low-e Surfaces



Solar Heat Gain and Visual Transmittance

EPA also explored the impact of the type of low-e coatings on solar heat gain and visual transmittance. The industry differentiates among sputtered low-e coatings by the number of layers of coating that are deposited on the surface of the glass—single-silver, double-silver, and triple-silver. Some glass companies alternatively offer low-e pyrolytic coatings. EPA found that triple-silver coatings are generally needed to reach low levels of SHGC (0.25 and below), and single-silver coatings are used to reach higher

[3] https://www.efficientwindows.org/existing-selection1/
[4] Ibid.

SHGCs (above 0.47) (see Figures 23, 24, and 25 in the appendix). Products with double-silver coatings are able to reach lower U-factors and meet a range of low to high SHGCs.

EPA wanted to ensure that ENERGY STAR certified products in the South-Central and Southern Climate Zones with SHGCs at 0.23 and below are not excessively dark. EPA found that products with low SHGCs generally have lower visual transmittance (VT); however, the largest share of product options with triple-silver coatings have an SHGC between 0.20 and 0.23 and a VT of 0.40 or higher (see Table 4), meaning most triple-silver coatings are not too dark.

Table 4. Triple-Silver Options by SHGC and Visual Transmittance

	Visual Transmittance				
SHGC	**0–0.194**	**0.195–0.294**	**0.295–0.394**	**0.395–0.499**	**0.500+**
< 0.175	80	3,980	4,265		
0.175–0.194	4		119	693	
0.195–0.224	28	36	1,676	22,393	3,309
0.225–0.254	14	18	2	2,752	2,410
0.255–0.284		67	26	1,401	578
0.285–0.314		851	207	4,858	1,899
0.315–0.344		413	1,643	1,556	798
0.345–0.374			222	224	757
0.375–0.404					105

Note: Colored shading indicates higher and lower counts of products. Red shading indicates low counts, light shading indicates medium counts, and blue shading indicates higher counts.

Spacer

EPA identified four categories of spacer technology that could be grouped by material and thermal performance. As defined in the Window Technology Pathways Methodology paper,[5] these categories are shown in Table 5.

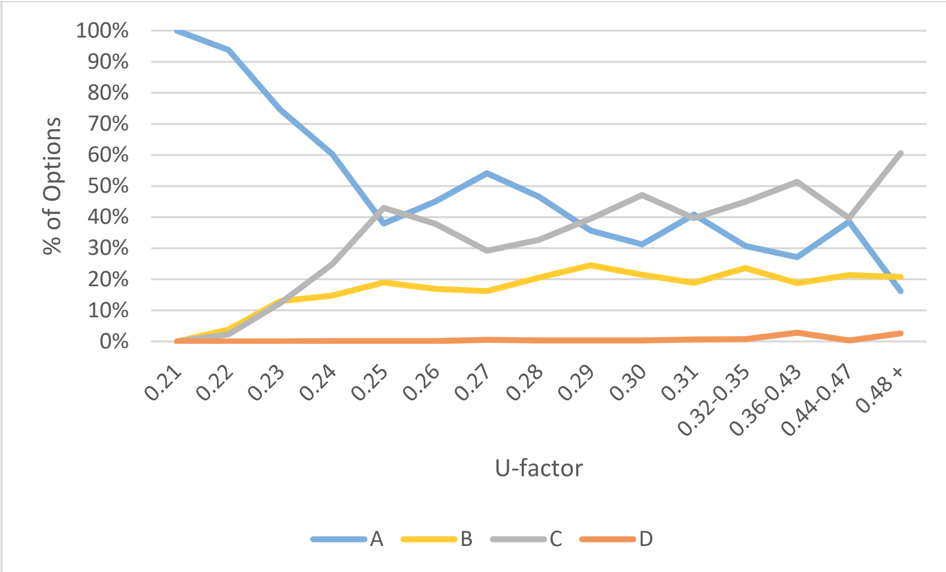
Table 5. Spacer Category Description and Performance

Category	Material/Description	Thermal Conductivity (K_{eff})
A	Non-metal spacers of different materials	Less than 0.2
B	U-shaped stainless steel spacers and thermoplastic spacers	0.2–0.4
C	Metal spacers, including U-shaped coated steel	0.4–1.0
D	Basic metal spacers	Greater than 1.0

EPA found that the highest tier non-metal spacers begin to dominate certified double-pane options below a 0.25 U-factor. Before that, spacers appear to be a secondary design decision, helping manufacturers reach the lower bound of performance possible with other frame, glazing, and gas fill choices.

[5] EPA. January 2017. Available for download on the ENERGY STAR website at https://www.energystar.gov/sites/default/files/asset/document/Window%20Technology%20Pathways%20Methodology%20White%20Paper.pdf.

Figure 7. Percentage of Double-Pane, Vinyl, Vertical Slider Options by Spacer Type



Among triple-pane windows, A-tier spacers are the most common choice for nearly all U-factors; however, they are not a requirement. There are more options with B and C spacers at a 0.22 U-factor than for those with A spacers.

Gas Fill

Manufacturers use different gases to improve the thermal performance of the sealed insulating glazing unit (IGU). Typically, these options are air, argon, krypton, or a combination of the three. Argon is the most common gas fill on the market. Interestingly, there is an increase in the share of air-filled options at the current Northern Climate Zone criteria of 0.27, which may reflect manufacturers' attempts to hit the criteria while minimizing complexity and reducing the possibility of seal failure. EPA understands that krypton gas is more costly and also requires a narrower glazing cavity to optimize performance, which may require changes to the frame design. At the proposed Northern Climate Zone criteria, 51% of double-pane and 55% of triple-pane options use argon.

Figure 8. Double-Pane, Vinyl, Vertical Slider Options by Gas Fill

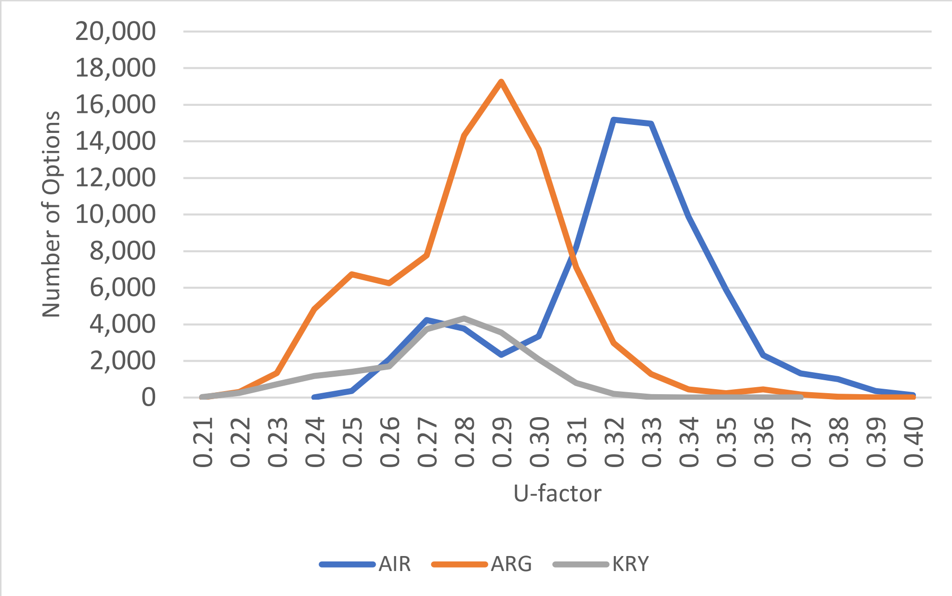
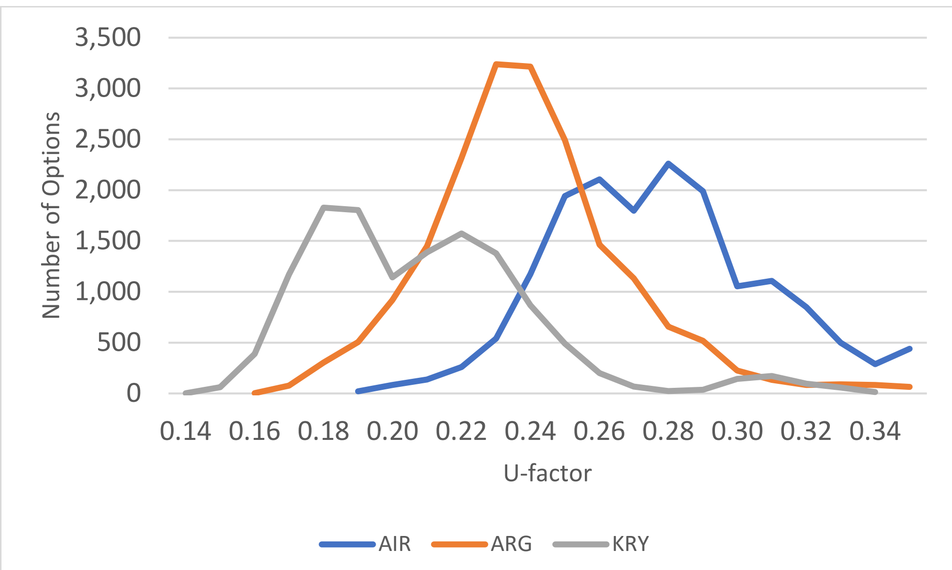


Figure 9. Triple-Pane, Vinyl, Vertical Slider Options by Gas Fill



Baseline Performance

EPA evaluated energy savings and cost-effectiveness against two different performance baselines.

Table 6. Baseline Performance Levels

Baseline	U-Factor	SHGC
Market Baseline	0.35	0.30
Code Baseline	0.30	0.30

The market baseline represents the worst-case performance that a typical consumer will encounter when purchasing a replacement window. This product typically has one double-silver low-e coating with air fill and a basic (i.e., simpler, with fewer cavities) frame. The U.S. Department of Energy's Energy Code Field Studies[6] found that the worst-case products installed are a 0.35 U-factor, even in southern climates. This also represents the worst-case product sold at big-box retailers.

The building code baseline represents the prescriptive performance required in the latest 2021 IECC for the Northern, North-Central, and South-Central Climate Zones. The 2021 code is not universally adopted, so this baseline reflects a conservative assumption about products that would otherwise be installed in the absence of the ENERGY STAR label.

EPA used a 0.30 SHGC for both baselines, reflecting that double-silver low-e is the most common type of low-e at both performance levels.

Cost Research and Incremental Cost Model

EPA collected cost data from mystery shopping at retailers, installers, and distributors, and costs voluntarily shared by manufacturers. Through this research, EPA established a model of the incremental cost to the consumer of an improved window compared with the baseline performance levels. EPA found that window prices vary widely, and thermal performance was not the primary driver of consumer prices. When evaluating cost-effectiveness, EPA focuses on the lowest cost options for improving performance.

Table 7. Incremental Consumer Costs Over the Market Baseline

U-Factor	Most Common Technical Pathways	Incremental Consumer ('Retail') Cost Over the Market Baseline	
		SHGC > 0.25	SHGC ≤ 0.25
0.32–0.35	1 Low-e coating, air-filled IGU and basic frames	Market Baseline	$7.50
0.28–0.31	1 Low-e coating with argon-filled IGU	$6	$13.50
0.27	1 Low-e coating with argon-filled IGU and improved frames and spacers	$18	$25.50
0.24–0.26	2 Low-e coatings (room-side low-e) with argon-filled IGU	$29	$36.50
0.22–0.23	Triple-pane with 2 low-e coatings and argon-filled IGU	$54	$61.50

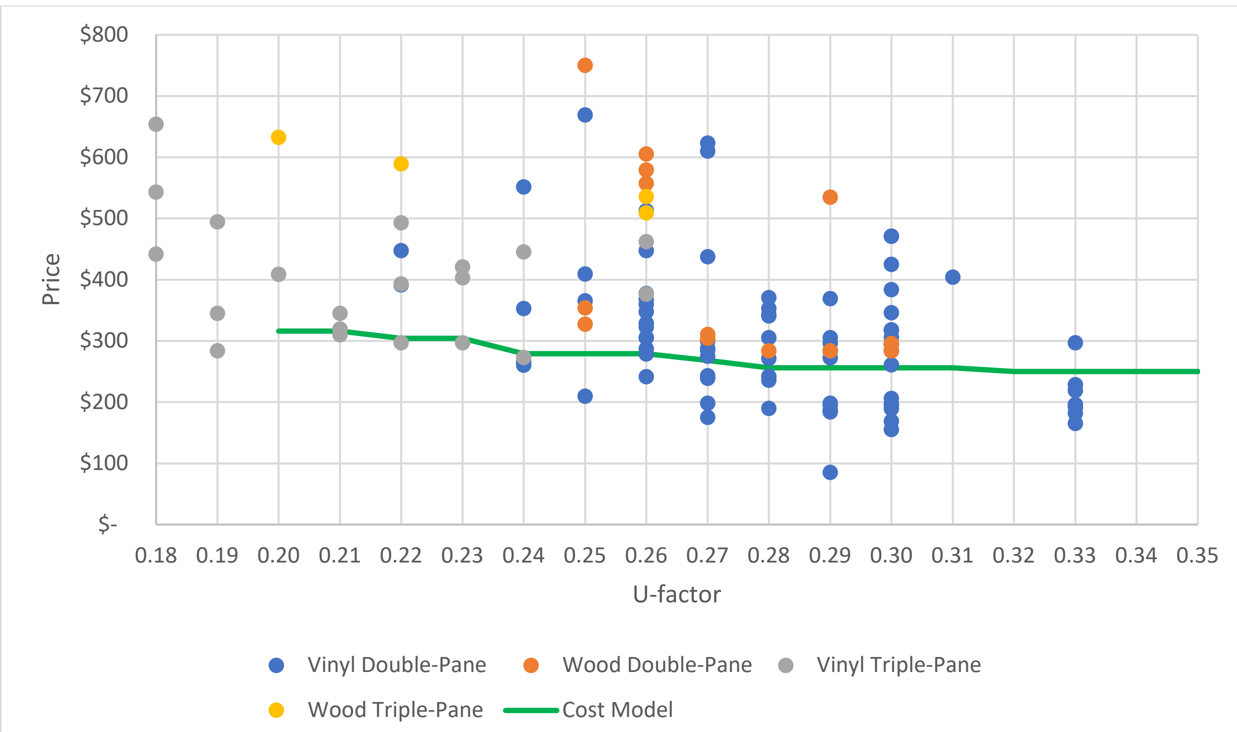
[6] U.S. Department of Energy, Building Energy Codes Program. Energy Efficiency Field Studies. Accessed at https://www.energycodes.gov/compliance/energy-code-field-studies.

0.21 and Below	Triple-pane with room-side low-e, argon-filled IGU, non-metal spacers, and improved and/or foamed frames	$66	$73.50

Consumer Prices

EPA collected consumer price data on 138 different windows from 60 product lines and 39 manufacturers. Over summer 2020, researchers contacted window installers and wholesalers, and asked for price quotes for a window replacement project involving 12 windows without installation. Researchers attempted to get quotes on multiple levels of performance and specified certain technologies, including room-side low-e, triple-pane, and foam-filled frames. EPA has published these anonymized prices and product characteristics in the Supplemental Data Package. Figure 10 shows a scatterplot of all prices, broken out by frame material and number of panes, along with the trend line for EPA's cost model.

Figure 10. Plot of Consumer Cost Research and Cost Model



EPA found a wide range of prices within each performance level. Windows were more expensive at lower U-factors; however, thermal performance was not the primary driver of cost. Other factors, such as quality of materials, hardware choices, company mark-up, and local market dynamics, likely all contribute to the final consumer cost. The consumer prices that EPA observed were particularly flat from the baseline level to the current Northern Climate Zone criteria of a 0.27 U-factor. EPA understands that technology improvements to reach this mid-range of performance include the addition of argon gas fill and improved frames and spacers. To characterize these costs and establish a cost model for improvements across the performance range, EPA analyzed the manufacturers' costs of the component technologies.

Component Costs

EPA interviewed manufacturers and established a range of costs for a variety of components, including glazing options, spacers, gases, and vinyl frames. EPA provided a preliminary release of these estimates in the Part 1 Response to Comments document. Table 8 shows a selection of key component cost assumptions and the full tables are available in appendices B and C of EPA's Response to Comments (Part 1).

Table 8. Component Cost Range and Modeled Consumer Premium

Component	Component Cost Range for 15-ft^2 Window	Modeled Consumer Premium Over Market Baseline
Single- or double-silver low-e	$3–$6	Baseline
Triple-silver low-e	$5.25–$11.25	$7.50
Argon	~$2	$6
Improved spacer	$4–$6.40	$6
Improved vinyl frame[7]	$1.50–$6	$6
Foamed frame	$8–$12	$23
Room-side low-e	$3–$15	$23
Triple-pane (including extra glass, coating, spacer, and heavier frame)	$15–$38	$48

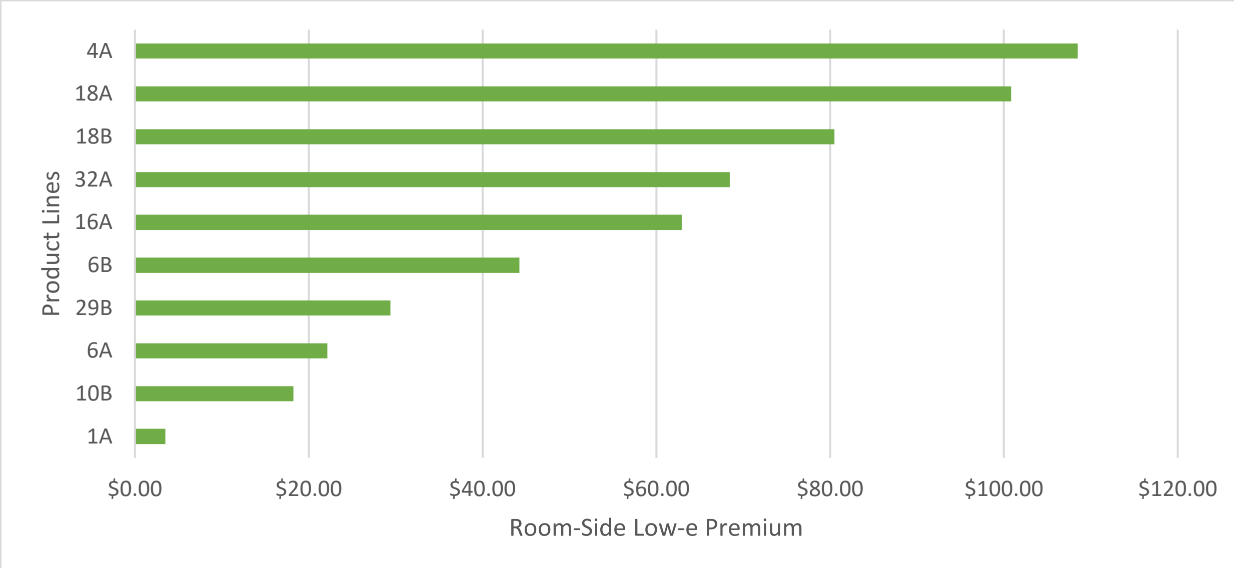
EPA used component cost estimates to understand the extent to which higher consumer costs reflected technology improvements compared with other mark-ups. After completing mystery shopping research, EPA identified product lines that offered options at different performance levels and isolated the performance improvement, component differences, and cost premiums among those options. EPA specifically looked at the addition of room-side low-e, triple-silver low-SHGC glazing, and a third pane of glass.

Room-Side Low-e

EPA found 13 product lines that offered a room-side low-e option with a wide range of price premiums (see Figure 11). Three product lines had a premium of less than $25 for room-side low-e, demonstrating that this technology is accessible to consumers at a lower cost. On average, room-side low-e products had a U-factor that was 0.04 lower than the standard option, meaning that a product with a U-factor of 0.28 could improve to 0.24 with the addition of room-side low-e. The component costs to manufacturers for a 15-ft^2 window range from $3 to $15 to add an indium tin oxide sputtered coating or a pyrolytic coating. Based on the data, EPA assumed a cost of $23 to add room-side low-e, for a total premium of $29 over the market baseline to reach a U-factor between 0.26 and 0.24.

[7] Cost for improved vinyl frame reflects the additional weight of vinyl at commodity prices.

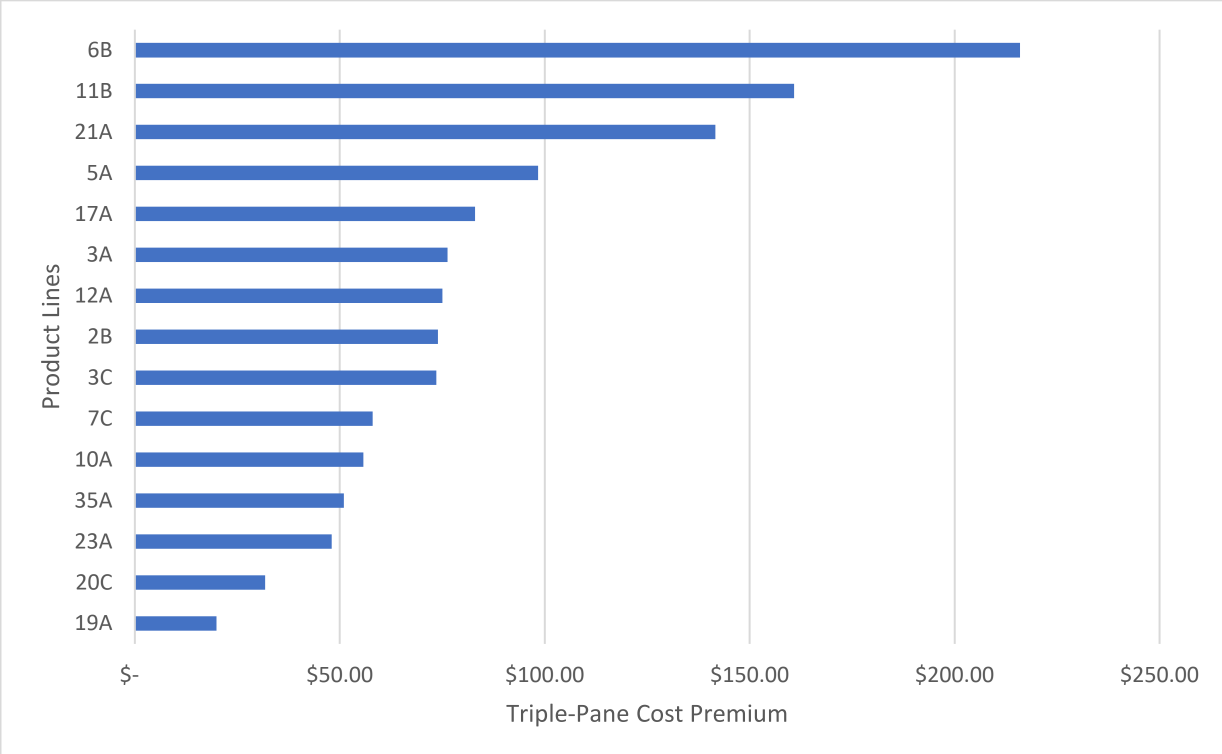
Figure 11. Cost Premium for Adding Room-Side Low-e Within a Product Line



Triple-Pane

EPA found 17 product lines that offered a triple-pane option with a wide range of price premiums (see Figure 12). While some triple-pane windows had a premium of more than $120, five product lines had a premium of less than $60 to add a third pane. EPA understands that adding a third pane generally also involves an improved vinyl frame to provide additional support and insulation, with a second low-e coating and spacer. Together, these technologies can reduce the U-factor by 0.06 or more to reach U-factors of 0.23 and below. EPA calculated that the cost of these components adds up to between $15 and $38 for a 15-ft^2 window. Additional improvements to the frame and spacer, and the addition of room-side low-e are needed to reach even lower U-factors. Based on the data, EPA assumed a premium of $54 over the market baseline to reach 0.22 and 0.23, and $66 to reach 0.20 and 0.21.

Figure 12. Cost Premium for Adding Triple-Pane within a Product Line



Low SHGC

EPA found 43 products with a low-SHGC performance at 0.23 or below. Manufacturers generally use triple-silver low-e coatings to reach this level of performance, and EPA estimated that such coatings cost between $2.25 and $5.25 more than double-silver coatings per 15 ft^2. Based on the data, EPA estimated that consumers can purchase products with low solar gain triple-silver low-e for an additional $7.50 above other improvements. EPA assumed that this price premium applies to all products with a 0.25 SHGC and below.

Savings and Payback

EPA considers savings and payback calculations as part of its analysis to consider improved criteria.

Energy Model

EPA's analysis relied on the Lawrence Berkeley National Laboratory's (LBNL) energy use and cost model based on the EnergyPlus model. LBNL modeled 264 U-factor and SHGC performance pairs in 132 cities. The full analysis inputs and results are included in the Supplemental Data Package. EPA calculated the population-weighted average of energy savings and cost savings for each IECC and ENERGY STAR Climate Zone. LBNL's model assumed a standard house size of 2,380 ft^2, with 357 ft^2 of glazing (15% of the floor area). Assuming a standard size of 3 ft x 5 ft per window, this resulted in 23.8 windows per home.

Energy Prices

ENERGY STAR typically uses a single set of national energy prices for gas and electric rates to calculate energy costs and savings. However, since the WDS program is divided up into four regions across the United States, EPA calculated utility rates for each zone based on a population-weighted average of rates in the cities and states included in the analysis.

Table 9. Energy Price Assumptions

Climate Zone	Electricity ($/kWh)	Gas ($/MMBtu)
Northern	0.1385	12.007
North-Central	0.1301	12.998
South-Central	0.1428	13.500
Southern	0.1197	17.866

Reasonable Payback

In the Discussion Guide, EPA stated that for a product like windows, it has considered a potential specification to offer reasonable payback if payback of the incremental cost is expected to occur within the lifetime of the product. Products such as WDS have relatively long lifetimes compared with other ENERGY STAR products and can have warranties of 20 years or more. In previous specification revisions, some stakeholders noted that many homeowners do not stay in their homes for the entire life of the home and asked to consider payback within the length of time a typical homeowner stays in a home. EPA considered several studies to understand the length of time that homeowners remain in their home, and the findings are summarized in Table 10.

Table 10. Summary of Documented Home Ownership Studies

Date	Organization	Title	Data Source	Years of Home Ownership
2011	National Association of Home Builders (NAHB)	Response to Request for Information from the U.S. Department of Energy (76 Federal Register 56413) on the methodology for assessing the cost-effectiveness of changes to residential building energy codes	American Housing Survey NAHB Analysis	12 years for typical owner 11 year for first-time buyer Payback of 10 years suggested
2013	NAHB	Latest Calculations Show Average Buyer Expected to Stay in a Home 13 Years	American Housing Survey	15 years for typical owner 11.4 years for first-time buyer
2020	National Association of Realtors	Realtor Blog: How long do homeowners stay in their homes?	American Community Survey	13 years is the median duration of home ownership

Based on the Discussion Guide comments from stakeholders and additional research that EPA conducted to find more recent studies, EPA concludes that the length of time a typical homeowner stays in a home is between 10 and 13 years. This range was used to consider the payback period for criteria options in the Draft 1 proposal.

It should also be noted that replacing windows and doors in a home with energy-efficient options also can add to the value of that home in addition to providing energy savings. EPA reviewed Remodeling magazine's Cost vs. Value Report, which has been published annually for nearly 20 years. The report indicated that over the past 10 years, window replacement projects typically had a resale value of between 64% and 77%. Over the past 10 years, doors had a replacement project resale value of between 65% and 100%. Therefore, even if a homeowner made a window or door improvement and sold their home before the typical home ownership range of 13 years, they would receive energy savings over the period they owned the home and would likely recoup a significant portion of the original investment value.

EPA considered this additional benefit as an alternate scenario in its payback analysis, which effectively shortens the payback period for some consumers.

Energy Cost Savings and Payback Results

Northern Climate Zone

EPA found that the proposed Northern Climate Zone criteria would save, on average, $113.99 per year, with a payback of 11.3 years. Savings and payback were even better in cities in Climate Zones 6, 7, and 8.

Table 11. Annual Cost Savings and Payback for the Northern Climate Zone (Proposed Criteria Highlighted)

U-factor	SHGC	Savings ($/year)	Payback (years)
0.20	**0.30**	$131.97	11.9
0.21	**0.30**	$122.98	12.8
0.22	**0.30**	**$113.99**	**11.3**
0.23	**0.30**	$105.13	12.2
0.24	**0.30**	$96.25	7.2
0.25	**0.30**	$87.40	7.9
0.26	**0.30**	$79.29	8.7
0.27	**0.30**	$70.86	6.0

Equivalent Energy Performance and Trade-offs

The Version 6.0 criteria for windows introduced a set of trade-off options for the Northern Climate Zone as alternatives to the prescriptive criteria. These options reflect the fact that windows with a higher solar heat gain and slightly higher U-factor would save an equivalent amount of energy in heating-dominant climates compared with a product that has a lower U-factor.

For Version 7.0, EPA evaluated what levels would have an equivalent energy performance to the proposed Northern Climate Zone criteria of 0.22. The heat map in Table 12 for Zone 5 shows that for every increase of 0.05 SHGC, a 0.01 increase in U-factor results in equivalent energy savings. EPA provides a chart of Zone 5 energy savings since that zone has the lowest energy savings and therefore the highest payback of all the IECC zones included in the ENERGY STAR Northern Zone. EPA found that this incremental equivalent energy effect is true regardless of the assumed window orientation by running a sensitivity analysis with different distributions of windows on the sides of a modeled home (equal orientation on four sides, as well as windows only on the north and south or east and west sides). A full set of energy savings data tables by zone can be found in the data package on Modeling Inputs and Energy Modeling released with this analysis.

Table 12. Energy Savings (GJ) for IECC Climate Zone 5 over the Market Baseline for Various U-Factor and SHGC Combinations

	SHGC															
U-factor	**0.17**	**0.19**	**0.2**	**0.21**	**0.23**	**0.25**	**0.27**	**0.30**	**0.32**	**0.35**	**0.37**	**0.40**	**0.42**	**0.45**	**0.47**	**0.50**
0.20	8.1	8.7	8.9	9.2	9.8	10.3	10.8	11.5	11.9	12.5	12.6	12.8	13.1	13.4	13.8	14.3
0.21	7.3	7.9	8.2	8.5	9.0	9.5	10.0	10.7	11.2	11.8	11.9	12.1	12.3	12.7	13.1	13.6
0.22	6.6	7.2	7.5	7.8	8.3	8.8	9.3	10.0	10.5	11.1	11.2	11.4	11.6	12.0	12.4	12.9
0.23	5.9	6.5	6.7	7.0	7.6	8.1	8.6	9.3	9.7	10.4	10.5	10.7	10.9	11.3	11.7	12.2
0.24	5.2	5.7	6.0	6.3	6.9	7.4	7.9	8.6	9.0	9.7	9.8	10.0	10.2	10.6	11.0	11.5
0.25	4.4	5.0	5.3	5.6	6.1	6.7	7.2	7.9	8.3	9.0	9.1	9.3	9.5	9.9	10.2	10.8
0.26	3.7	4.3	4.6	4.9	5.4	5.9	6.3	6.9	7.4	8.1	8.3	8.6	8.8	9.2	9.6	10.2
0.27	3.0	3.6	3.9	4.2	4.7	5.2	5.5	6.0	6.5	7.2	7.4	7.9	8.2	8.6	9.0	9.5
0.28	2.3	2.9	3.2	3.4	4.0	4.5	4.7	5.1	5.6	6.3	6.6	7.2	7.5	8.0	8.4	8.9
0.29	1.5	2.2	2.5	2.7	3.3	3.8	3.9	4.3	4.7	5.5	5.9	6.5	6.8	N/A	7.8	N/A
0.30	0.8	1.5	1.7	2.0	2.6	3.1	3.1	3.4	3.9	4.7	5.1	5.8	6.2	6.8	7.2	7.8

Providing these trade-offs gives consumers an option to use high solar gain products and save the same amount of energy; however, EPA found that the cost savings would be lower for higher SHGC products because EPA assumed higher cooling costs relative to heating costs. Nevertheless, consumers may enjoy a shorter payback period with high solar gain products that use less costly technologies (see Table 13).

Table 13. Cost Savings and Payback for Equivalent Energy Trade-Offs

Equivalent Energy Levels		**IECC Climate Zone 5**		**IECC Climate Zone 6**	
U-Factor	**SHGC**	**Savings ($/year)**	**Payback (years)**	**Savings ($/year)**	**Payback (years)**
0.22	0.30	$110.27	11.7	$137.03	9.4
0.23	0.35	$99.42	12.9	$131.20	9.8
0.24	0.40	$94.81	7.3	$126.52	5.5
0.25	0.45	$83.07	8.3	$117.05	5.9
0.26	0.50	$70.44	9.8	$108.73	6.4

North-Central Climate Zone

EPA found that the proposed North-Central Climate Zone criteria would save, on average, $80.75 per year, with a payback of 8.5 years. EPA found that a lower SHGC did not significantly improve cost savings in this climate zone, and higher SHGCs slightly reduced savings. Therefore, EPA proposes to maintain the current SHGC criteria of ≤ 0.40 to avoid excessively high solar gain products.

Table 14. Annual Cost Savings and Payback for the North-Central Climate Zone (Proposed Criteria Highlighted)

U-Factor	SHGC	Savings ($/year)	Payback (years)
0.22	**0.23**	$99.30	14.7
0.23	**0.23**	$91.35	16.0

0.24	**0.23**	$83.42	10.4
0.25	**0.23**	$75.55	11.5
0.26	**0.23**	$67.75	12.8
0.27	**0.23**	$59.98	10.1
0.28	**0.23**	$52.28	6.1
0.30	**0.23**	$36.85	8.7
0.22	**0.30**	$96.27	13.4
0.23	**0.30**	$88.48	14.5
0.24	**0.30**	**$80.75**	**8.5**
0.25	**0.30**	$73.12	9.4
0.26	**0.30**	$66.82	10.3
0.27	**0.30**	$60.18	7.1
0.28	**0.30**	$52.86	2.7
0.30	**0.30**	$37.30	3.8
0.22	**0.40**	$95.53	13.5
0.23	**0.40**	$87.98	14.6
0.24	**0.40**	$80.45	8.6
0.25	**0.40**	$72.94	9.5
0.26	**0.40**	$65.32	10.6
0.27	**0.40**	$57.65	7.4
0.28	**0.40**	$50.09	2.9
0.30	**0.40**	$34.99	4.1

South-Central Climate Zone

EPA found that the proposed South-Central Climate Zone criteria would save, on average, $35.85 per year, with a payback of 9.0 years. EPA found that additional cost-effective savings were possible with a lower SHGC; however, EPA balanced this consideration with its analysis of visual transmittance at SHGCs below 0.23 (see Table 4).

Table 15. Annual Cost Savings and Payback for South-Central Climate Zone (Proposed Criteria Highlighted)

U-Factor	SHGC	Savings ($/year)	Payback (years)
0.24	**0.20**	$63.05	13.8
0.25	**0.20**	$59.22	14.7
0.26	**0.20**	$55.52	15.6
0.27	**0.20**	$51.77	11.7
0.28	**0.20**	$48.03	6.7
0.30	**0.20**	$40.57	7.9
0.24	**0.23**	$50.68	17.1
0.25	**0.23**	$46.93	18.5
0.26	**0.23**	$43.23	20.1

0.27	**0.23**	$39.56	15.3
0.28	**0.23**	$35.85	9.0
0.30	**0.23**	$28.51	11.3
0.24	**0.25**	$41.93	20.7
0.25	**0.25**	$38.29	22.7
0.26	**0.25**	$34.60	25.1
0.27	**0.25**	$30.95	19.6
0.28	**0.25**	$27.29	11.8
0.30	**0.25**	$20.02	16.0

Southern Climate Zone

EPA found that the proposed Southern Climate Zone criteria would save, on average, $20.14 per year, with a payback of 8.9 years. A lower SHGC of 0.20 could save significantly more energy in the Southern Climate Zone; however, EPA balanced this consideration with the impact on visual transmittance. Very low SHGC products are available for sale and consumers can choose those products based on their preferences regarding darker glass.

Table 16. Annual Cost Savings and Payback for Southern Climate Zone (Proposed Criteria Highlighted)

U-Factor	SHGC	Savings ($/year)	Payback (years)
0.28	**0.20**	$46.71	6.9
0.30	**0.20**	$40.70	7.9
0.32	**0.20**	$34.45	5.2
0.35	**0.20**	$25.27	7.1
0.28	**0.23**	$32.26	10.0
0.30	**0.23**	$26.28	12.2
0.32	**0.23**	**$20.14**	**8.9**
0.35	**0.23**	$11.26	15.9
0.28	**0.25**	$22.52	14.3
0.30	**0.25**	$16.63	19.3
0.32	**0.25**	$10.58	16.9
0.35	**0.25**	$1.82	98.1

Windows Summary and Conclusion

As stated above, EPA concluded that the proposed windows criteria can provide meaningful savings for consumers, paying back incremental price premiums in a reasonable period of time. The criteria can be met through multiple technical pathways, do not require proprietary technology, and do not negatively impact the non-energy performance of the product. Products meeting the criteria are available for sale and provide a clear differentiation over standard products in the market.

Product Availability

EPA's analysis indicated that the proposed criteria for the Northern Climate Zone can already be met by more than 50% of the product lines. Based on the market response to the Version 6.0 criteria, EPA believes that manufacturers may introduce new product lines and options in response to this criteria change, and the number of product lines with a qualifying option will increase by the effective date. EPA believes that there will remain a wide variety of available products and manufacturers that can meet the proposed criteria.

Table 17. Counts of Unique Product Lines for Various Criteria Levels and Frame Materials

Product Type	All ENERGY STAR Products	Version 6 Northern Climate Zone	Proposed Northern Climate Zone
All Operators and Frames	2,342	2,165	1,502
All Vertical Sliders	542	474	268
Vinyl Vertical Sliders	398	348	226
Wood Vertical Sliders	103	94	35

Table 18. Counts of Unique Manufacturers for Various Criteria Levels and Frame Materials

Product Type	All ENERGY STAR Products	Version 6 Northern Climate Zone	Proposed Northern Climate Zone
All Operators and Frames	166	163	138
All Vertical Sliders	144	132	96
Vinyl Vertical Sliders	131	119	89
Wood Vertical Sliders	26	25	13

Household Savings and Payback

The proposed criteria will save consumers a significant amount of energy at the household level, and consumers can expect to recoup the incremental cost of their investment in a reasonable amount of time. The payback for the proposed Northern Zone Criteria is longer when compared to the code baseline; however, this is a conservative assumption that only applies to a smaller number of jurisdictions. In many areas that have adopted the IECC for 2018 and later years, such as the Pacific Northwest, additional utility incentives are available that can improve cost-effectiveness.

Table 19. Annual Cost Savings and Payback for Proposed Criteria by Climate Zone

Climate Zone	Cost Savings ($/year)	Simple Payback	Payback With $200 Incentive	Payback With 64% Recouped Cost
Northern (Market Baseline)	$113.35	11.3	9.5	4.1
Northern (Code Baseline)	$70.26	16.2	15.4	6.5
North-Central	$80.75	8.5	6.1	3.1
South-Central	$35.85	9.0	3.4	3.2
Southern	$20.14	8.9	0.0	3.2

Table 20. Annual Cost Savings and Paybacks for Proposed Northern Zone Tradeoff Criteria (Market Baseline)

U-factor	SHGC	Cost Savings ($/year)	Simple Payback	Payback with $200 Incentive	Payback With 64% Recouped Cost
0.23	0.35	$104.18	12.3	10.4	4.4
0.24	0.40	$99.71	6.9	4.9	2.5
0.25	0.45	$88.56	7.8	5.5	2.8
0.26	0.50	$76.69	9.0	6.4	3.2

Table 21. Annual Cost Savings and Paybacks for Proposed Northern Zone Tradeoff Criteria (Code Baseline)

U-factor	SHGC	Cost Savings ($/year)	Simple Payback	Payback with $200 Incentive	Payback With 64% Recouped Cost
0.23	0.35	$60.88	18.8	17.8	7.6
0.24	0.40	$56.41	9.7	8.7	4.4
0.25	0.45	$45.27	12.1	10.8	5.5
0.26	0.50	$33.39	16.4	14.7	7.4

National Savings Impact

On a national level, the proposed criteria would save 9.7 trillion Btu per year over the baseline products if shipments of ENERGY STAR windows remain equal to 2019 shipments. EPA recognizes that shipments of ENERGY STAR windows may decline in the near term as manufacturers and consumers adjust to the new criteria; therefore, EPA also estimated the total annual energy savings assuming 50% shipments. EPA has seen the market rebound relatively quickly, however, in the past.

Table 22. Total Annual Energy Savings of All Windows Sold in the United States

Climate Zone	Energy Savings (MMBtu)	2019 Shipments	Total Energy Savings (TBtu)
Northern (Replacement)	0.40	11,084,395	4.420
Northern (New Construction)	0.26	6,576,665	1.726
North-Central	0.26	9,370,708	2.451
South-Central	0.08	12,387,796	0.946
Southern	0.03	4,815,650	0.132
	National Total (2019 Shipments)		**9.675**
	National Total (50% Shipments)		**4.838**

Sliding Glass Doors

In the Version 7 Discussion Guide, EPA indicated that it was considering creating a new product category for sliding glass doors and aligning the performance criteria with those of windows. Sliding glass doors, also referred to as full-lite sliding patio doors and classified by NFRC product code DDSG, share many glazing package characteristics with windows. EPA has proceeded with this proposed change, which will result in a new criteria table for sliding glass doors (see Figure 13).

Figure 13. Proposed Version 7.0 Criteria for Sliding Glass Doors

Version 6

Glazing Level	U-Factor	SHGC	
Opaque	≤ 0.17	No Rating	
≤ ½-Lite	≤ 0.25	≤ 0.25	
> ½-Lite	≤ 0.30	Northern North-Central	≤ 0.40
		Southern South-Central	≤ 0.25

Version 7

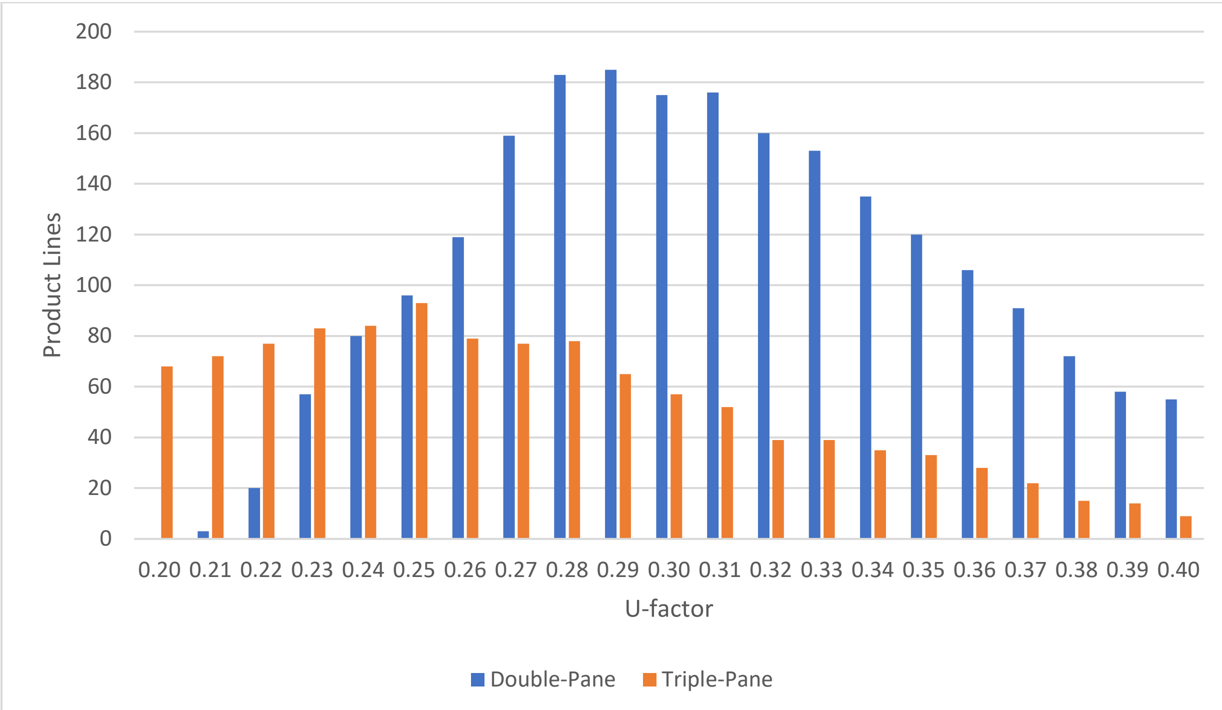
Climate Zone	U-Factor	SHGC	
Northern*	≤ 0.22	≥ 0.17	Prescriptive
	= 0.23	≥ 0.35	Equivalent Energy Performance
	= 0.24	≥ 0.40	
	= 0.25	≥ 0.45	
	= 0.26	≥ 0.50	
North-Central	≤ 0.24	≤ 0.40	
South-Central	≤ 0.28	≤ 0.23	
Southern	≤ 0.32	≤ 0.23	

Currently, sliding glass doors are considered > ½-lite doors for the purposes of the ENERGY STAR specification, so aligning these criteria would boost the performance criteria in the Northern Climate Zone significantly. In addition, aligning criteria would make it easier to specify visually consistent glass packages for windows and sliding glass doors. Manufacturers informed EPA that many consumers request similar-looking glass for doors and windows, and EPA has already extended the ENERGY STAR Most Efficient recognition criteria for windows to sliding glass doors based on earlier requests from manufacturers.

Product Availability and Technical Feasibility

EPA contacted several sliding patio door manufacturers and confirmed that glass packages used in windows also can be used in sliding patio doors (with the required tempered glass). In comments on the Discussion Guide, EPA received feedback from stakeholders supporting the concept of criteria alignment. Stakeholders cautioned that differences in design to increase durability for foot-traffic may make it harder to meet more stringent criteria. To evaluate this impact, EPA reviewed the performance distribution of certified sliding glass doors and found that there is a similar distribution for window performance (see Figure 14). EPA found at least 70 vinyl product lines and 26 wood product lines currently have an option that can meet the proposed Northern Climate Zone criteria.

Figure 14. Performance Distribution of Vinyl Sliding Patio Door Product Lines by Glazing Layers



Sliding Glass Doors Conclusion

EPA is proposing to match the criteria for sliding glass doors and windows based on the better performance, comfort improvement, and consistent glazing look that the change will provide. EPA did not calculate energy savings for sliding patio doors individually; however, EPA concluded that the technical and performance similarities between sliding glass doors and windows suggest that the windows cost and payback analysis also applies to patio doors. While creating a new category for these products will require a change in labeling practices, EPA believes that this new approach will be easier for consumers to understand and create a more seamless buying experience for whole-home window purchases.

Swinging Doors

In the Version 7 Discussion Guide, EPA proposed either sunsetting the ENERGY STAR criteria for swinging doors or advancing the criteria if additional savings were possible. After considering comments from stakeholders on the Discussion Guide and conducting analysis, EPA concluded that additional performance improvements are possible for ≤ ½-lite and > ½-lite doors (see Figure 15). EPA is not proposing any changes to the opaque door criteria.

Figure 15. Proposed Version 7.0 ENERGY STAR Criteria for Swinging Doors

Version 6

Glazing Level	U-Factor	SHGC	
Opaque	≤ 0.17	No Rating	
≤ ½-Lite	≤ 0.25	≤ 0.25	
> ½-Lite	≤ 0.30	Northern North-Central	≤ 0.40
		Southern South-Central	≤ 0.25

Version 7

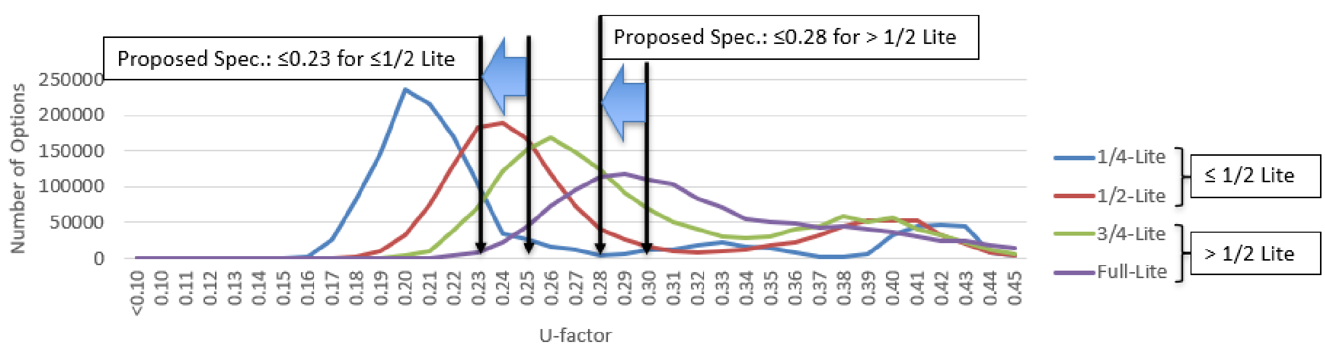
Glazing Level	U-Factor	SHGC	
Opaque	≤ 0.17	No Rating	
≤ ½-Lite	≤ 0.23	≤ 0.23	
> ½-Lite	≤ 0.28	Northern North-Central	≤ 0.40
		Southern South-Central	≤ 0.23

Product Availability and Technical Feasibility

It is difficult to analyze swinging doors because there are many unique glazing design and frame options available, including different shapes that are not clearly differentiated in the CPD. Therefore, EPA focused its analysis on broad performance distributions to evaluate product availability.

The ENERGY STAR swinging door criteria groups ¾-lite and full-lite doors together into > ½-lite, and groups ¼-lite and ½-lite doors together into ≤ ½-lite to simplify the specification. Figure 16 indicates that the peaks of the certified door performance distribution for any of the four NFRC classifications have lower U-factors than the current ENERGY STAR criteria. Therefore, EPA believes that the proposed criteria can be met with products that are currently available for sale, and the better performance would more clearly differentiate energy-efficient products for consumers.

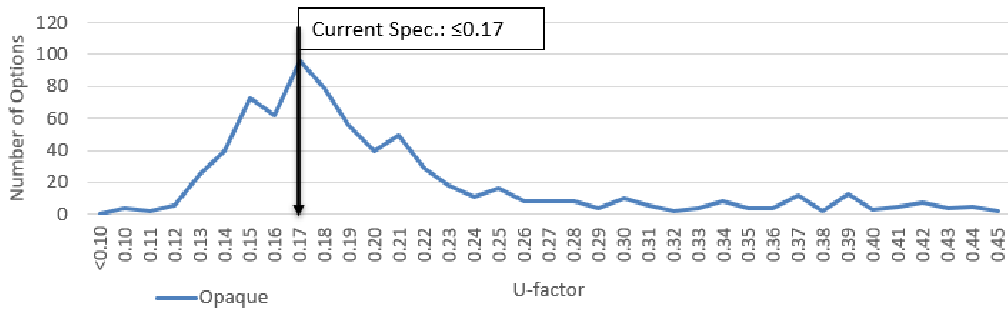
Figure 16. Performance by Lite Level for Double-Pane Swinging Doors of All Materials



EPA believes that the opaque door criteria already represent an appropriate level for ENERGY STAR and is not proposing to revise the criteria for that category. NFRC does not have a designated category for opaque doors, so EPA summed the number of door options with flush and embossed type codes. Figure

17 shows that some products are certified below the current level; however, there are only a smaller number of certified products in these categories so EPA did not believe that there were sufficient data to conclude that products are available below the current criteria level.

Figure 17. Performance Distribution of Opaque Swinging Doors



Energy Savings

Doors represent a much smaller amount of surface area of a house compared to windows, and therefore have a lesser impact on household energy use. EPA attempted a simplified analysis of door energy and cost savings using U-factor and SHGC analysis data from its window analysis. EPA assumed that if two doors were replaced in a home, it would account for approximately 42 ft^2 of the house's glazing area (21 ft^2 per door). EPA used the following baseline performance levels.

Table 23. Swinging Door Baseline Assumptions

Door Category	U-Factor	SHGC
≤ ½-Lite	0.30	0.17
> ½-Lite Northern and North-Central	0.35	0.30
> ½-Lite South-Central and Southern	0.35	0.25

Although the proposed maximum SHGC criterion for > ½-lite doors is 0.40, EPA found that higher SHGCs are a very small share of certified products. EPA assumed an SHGC of 0.30 for both the baseline and modeled criteria levels to isolate the impact of the U-factor improvement. Among certified > ½-lite products at the proposed U-factor, 60% had an SHGC ≤ 0.17 and 87% had an SHGC ≤ 0.25.

The energy savings and cost savings are listed below in Table 24 and Table 25, showing improved energy and monetary savings in all climate zones.

Table 24. Energy and Cost Savings for Proposed ≤ ½-Lite Door Criteria

Climate Zone	Door Type	U-Factor	SHGC	Energy Savings (GJ)	Savings ($/year)
Northern	≤ ½ Lite	0.23	0.17	0.59	$7.54
North-Central	≤ ½ Lite	0.23	0.17	0.46	$6.51
South-Central	≤ ½ Lite	0.23	0.17	0.26	$3.17
Southern	≤ ½ Lite	0.23	0.17	0.15	$2.55

Table 25. Energy and Cost Savings for Proposed > ½-Lite Door Criteria

Climate Zone	Door Type	U-Factor	SHGC	Energy Savings (GJ)	Savings ($/year)
Northern	> ½ Lite	0.28	0.30	0.60	$7.28
North-Central	> ½ Lite	0.28	0.30	0.46	$6.22
South-Central	> ½ Lite	0.28	0.23	0.24	$3.97
Southern	> ½ Lite	0.28	0.23	0.16	$3.58

Swinging Doors Conclusion

EPA concluded that the proposed criteria for doors would reduce energy costs for consumers in all climate zones. While the household energy savings are small, these savings would add up to 1.16 trillion Btu on a national level. Products are currently available for sale at the proposed levels, and these criteria would differentiate higher performing products more effectively than the Version 6.0 criteria.

Table 26. National Energy Savings for Swinging Doors

Door Type	Unit Energy Savings (MMBtu)	2019 Shipments	Total Energy Savings (TBtu)
> ½ Lite	0.19	3,398,611	0.64
< ½ Lite	0.19	2,729,966	0.52
		National Total (2019 Shipments)	1.16
		National Total (50% Shipments)	0.58

Skylights and Tubular Daylighting Devices (TDDs)

In the Discussion Guide, EPA proposed several different options for skylights and TDDs, including possibly sunsetting the criteria. After completing its analysis, EPA has found that additional opportunity for improvement is possible, and EPA is proposing to advance the specification instead of sunsetting it (see Figure 18).

Figure 18. Proposed Version 7.0 Criteria for Skylights and TDDs

Version 6

Climate Zone	U-Factor	SHGC
Northern	≤ 0.50	Any
North-Central	≤ 0.53	≤ 0.35
South-Central	≤ 0.53	≤ 0.28
Southern	≤ 0.60	≤ 0.28

Version 7

Climate Zone	U-Factor	SHGC
Northern	≤ 0.45	Any
North-Central	≤ 0.50	≤ 0.25
South-Central		
Southern		

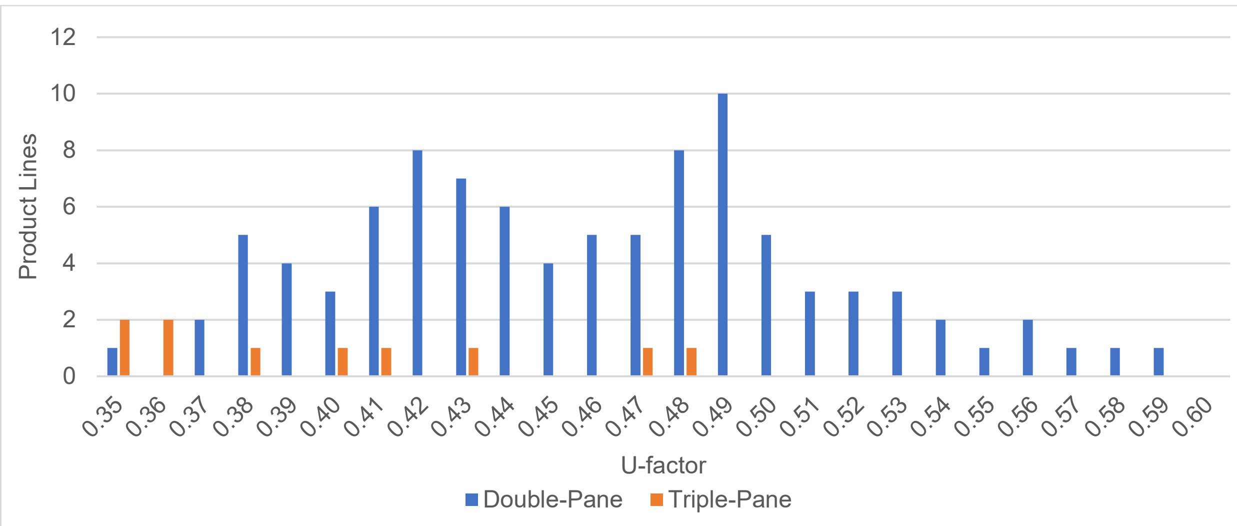
Product Availability and Technical Feasibility

EPA reviewed the certified product distribution and found that a reasonable improvement in criteria could be made without the need for more costly technologies, such as triple pane. The proposed improvement is less stringent than the current Canadian ENERGY STAR criteria for skylights set at a U-factor of 0.40.

In the Discussion Guide, EPA presented analysis using WINDOW modeling software to determine what the performance of a skylight would be with different components, including room-side low-e. EPA compared the performance of a projection type product at a 90° angle and a 20° angle. The results of the analysis showed inconsistent differences among products with varying component types but did show that ENERGY STAR windows with the same or similar components perform much better than skylights at the proposed criteria level.

EPA also evaluated the distribution of performance by the number of glazing layers and found that a high number of product options are certified at lower U-factors. EPA understands that the mounting type for skylights—curb-mounted versus deck-mounted—has a significant impact on performance. This variable is not clearly distinguished in the CPD; however, EPA reviewed a selection of products for different manufacturers and confirmed that several curb-mounted skylights can still meet the proposed criteria, although they may need additional performance improvements to overcome heat loss through the mounting block.

Figure 19. Performance Distribution of Certified Skylights by Number of Panes



Skylights and TDDs Conclusion

EPA concluded that additional performance improvements are available in the market without the need for triple-pane products or other costly components, and therefore proposed to advance the criteria to better differentiate energy-efficient products. EPA did not analyze energy savings or cost-effectiveness for skylights because LBNL's model was not configured to model skylight energy. EPA found in its windows analysis that performance improvements with the same or similar components used to meet the skylights criteria were cost-effective, and therefore believes that this conclusion applies to skylights as well.

EPA understands that TDDs have a different form than skylights; however, they meet similar needs for providing daylight in a space through a roof and should be subject to the same ENERGY STAR requirements. Further, EPA found TDDs available for sale that could meet the criteria with simple insulating kits.

Along with the proposal to improve the criteria, EPA also proposes to simplify the skylight and TDD criteria to two sets of criteria across the United States—one set of criteria for the Northern Climate Zone and another set for the North-Central, South-Central, and Southern Climate Zones. This simplification still allows higher gain products to be used in the Northern Climate Zone while blocking heat gain and saving more energy in cooling-dominated zones. Manufacturers also may find the simpler criteria easier to label and implement since many skylight products come completely enclosed in a box.

Climate Zones

In the latest revisions to the IECC codes, the boundaries of the IECC Climate Zones have changed, with certain counties moving into warmer climate zones and others moving into cooler climate zones. These changes are driven by shifting climate patterns as well as better data. EPA proposes to update the ENERGY STAR Climate Zone map to match these changes to the IECC Climate Zones and ensure that consumers living in the affected counties will have ENERGY STAR criteria that best reflect their typical climate. EPA has provided an explanation of the counties that changed zones in the Supplemental Data Package.

The proposed Version 7.0 Climate Zone map also includes several areas that differ from the Version 6.0 map, specifically in California and North Carolina. These areas did not have a change in IECC Climate Zone; instead, EPA had previously included them in the same ENERGY STAR Climate Zone as the surrounding region to create a more contiguous map. EPA is proposing to follow the IECC Climate Zones going forward to ensure that consumers have product criteria that is best targeted for their location. EPA is seeking comment from stakeholders on the impact this would have on the market.

In the Discussion Guide, EPA raised the concept of combining the South-Central and Southern Climate Zones and moving IECC Zone 5 to the North-Central Zone. After conducting energy savings analysis, EPA concluded that four separate ENERGY STAR Climate Zones are appropriate.

Next Steps

Stakeholder Feedback

Stakeholder engagement is vital for the success of the ENERGY STAR program, and EPA looks forward to collaborating with stakeholders to develop the Version 7.0 specification. Stakeholders are requested to provide **comments** on the Draft 1 Version 7.0 specification **no later than August 20, 2020**. Please send comments via email to windows@energystar.gov. All comments received will be posted to the ENERGY STAR Residential Window, Door, and Skylight Version 7.0 Specification Development web page.

Schedule

This is the schedule for upcoming significant dates in the ENERGY STAR Residential Window, Door, and Skylight Version 7.0 specification development.

Next Steps	Date
Draft 1 Version 7.0 Virtual Meeting	July 27, 2021
Draft 1 Version 7.0 Comments Due	August 20, 2021
Draft 2 Version 7.0	September–October 2021
Final Draft Version 7.0	November–December 2021
Final Specification	January 2022
Specification Effective	TBD

Glossary

≤ ½ Lite	ENERGY STAR classification for a door with ≤ 29.8% glazing (based on NFRC 100-2010). Includes ¼-lite and ½-lite doors.
>½ Lite	ENERGY STAR classification for a door with > 29.8% glazing (based on NFRC 100-2010). Includes ¾-lite and fully glazed doors.
¼ Lite	Descriptor for a door with < 13.6% glazing (based on NFRC 100-2010). See also ≤ ½ Lite.
½ Lite	Descriptor for a door with > 13.6%, but < 29.8% glazing (based on NFRC 100-2010). See also ≤ ½ Lite.
¾ Lite	Descriptor for a door with > 29.8%, but < 36.4% glazing (based on NFRC 100-2010). See also > ½ Lite.
Certified Products Directory (CPD)	A database containing fenestration that has received certification authorization from an NFRC-approved inspection agency.
Door	A sliding or swinging entry system designed for and installed in a vertical wall separating conditioned and unconditioned space in a residential building. See also Opaque, ≤ ½ Lite, > ½ Lite, Sliding Entry Door, and Swinging Entry Door.
Dynamic Glazing	Any window, door, or skylight that has the fully reversible ability to change its performance properties, including U-factor, SHGC, or visual transmittance. This includes, but is not limited to, electrochromic glass systems that can be tinted in response to an electronic control signal or environmental change and fenestration with operable blinds or shades positioned between glass panes.
Energy Efficiency Program Sponsor (EEPS)	Electric or gas utilities, state agencies, and other regional groups that sponsor programs to promote the sale of energy-efficient products and the adoption of energy conservation measures.
Fenestration	Products that fill openings in a building envelope, including windows, doors, and skylights, designed to permit the passage of air, light, and/or people.
Fully Glazed	Descriptor for a door with > 36.4% glazing (based on NFRC 100-2010). See also > ½ Lite.
Gap Width	The distance between two adjacent glazing surfaces.
Glazed	Descriptor for a fenestration product containing glass.
Glazing	Glass used in a fenestration product.
Insulating Glass Unit (IGU)	A preassembled unit comprising panes of glass that are sealed at the edges and separated by dehydrated space(s).
International Energy Conservation Code (IECC)	A building energy code published by the International Code Council.
LBNL	See Lawrence Berkley National Laboratory.
Lite	A pane of glass used in fenestration.
Low-e Coating	Microscopically thin metal, metal oxide, or multi-layer coating deposited on a glazing surface to reduce its thermal infrared emittance.
Low-Emissivity Coating	See Low-e Coating.
National Fenestration Rating Council (NFRC)	A nonprofit organization that administers the only uniform, independent rating and labeling system for the energy performance of windows, doors, and skylights.
Opaque	ENERGY STAR classification for a door with no glazing (based on NFRC 100-2010).
Peak Load	The maximum daily, weekly, or seasonal electric load.
Residential Building	A structure used primarily for living and sleeping that is three stories or less in height and not governed by commercial building codes.

Skylight	A window designed for sloped or horizontal application in the roof of a residential building, the primary purpose of which is to provide daylighting and/or ventilation. May be fixed or operable. See also Tubular Daylighting Device.
Sliding Glass Door	A system that contains one or more manually operated panels that slide horizontally within a common frame.
Solar Heat Gain Coefficient (SHGC)	The ratio of the solar heat gain entering the space through the fenestration product to the incident solar radiation. Expressed as a value between 0 and 1.
Spacer	The component that separates and maintains the space between the glazing surfaces of insulating glass.
Swinging Door	A system having, at a minimum, a hinge attachment of any type between a leaf and jamb, mullion, or edge of another leaf or having a single, fixed vertical axis about which the leaf rotates between open and closed positions.
Swinging Entry Door	See Swinging Door.
Tubular Daylighting Device (TDD)	A non-operable skylight primarily designed to transmit daylight from a roof surface of a residential building to an interior ceiling surface via a conduit. The product consists of an exterior glazed weathering surface, a light transmitting tube with a reflective inside surface, and an interior sealing surface, such as a translucent ceiling panel.
Tubular Skylight	See Tubular Daylighting Device.
U-Factor	The heat transfer per time per area and per degree of temperature difference, which when multiplied by the interior-exterior temperature difference and by the projected fenestration product area yields the total heat transfer through the fenestration product due to conduction, convection, and long-wave infrared radiation. Expressed in units of $Btu/h•ft^2•°F$.
Visible Transmittance (VT)	The ratio of visible radiation entering the space through the fenestration product to the incident visible radiation, determined as the spectral transmittance of the total fenestration system, weighted by the photopic response of the eye, and integrated into a single dimensionless value. Weighted by a standard solar spectrum.
Window	An assembled unit consisting of a frame/sash component holding one or more pieces of glazing functioning to admit light and/or air into an enclosure and designed for a vertical installation in an external wall of a residential building.

Appendix

Market Share by Climate Zone

Table 27. ENERGY STAR Market Share for New Construction – 2019 Shipments

Climate Zone	All Windows	ES Windows	ES Market Share
Northern	7,744,920	6,576,665	85%
North-Central	4,486,630	3,971,838	89%
South-Central	6,920,040	5,870,380	85%
Southern	3,836,410	2,573,594	67%
Totals	22,988,000	18,992,477	83%

Table 28. ENERGY STAR Market Share for Replacement – 2019 Shipments

Climate Zone	All Windows	ES Windows	ES Market Share
Northern	12,145,600	11,084,395	91%
North-Central	5,861,870	5,398,871	92%
South-Central	7,452,520	6,517,416	87%
Southern	3,146,010	2,242,056	71%
Totals	28,606,000	25,242,738	88%

CPD Performance Distributions

Alternate Frame Materials and Operator Types

Figure 20. Distribution of Product Lines for Wood Vertical Slider Windows

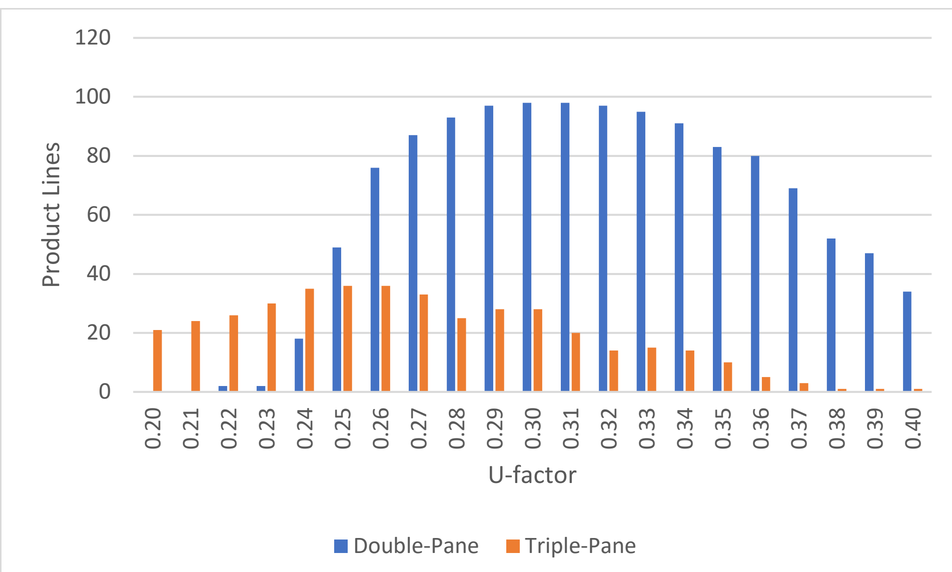


Figure 21. Product Line Distribution of Vinyl Casement Windows

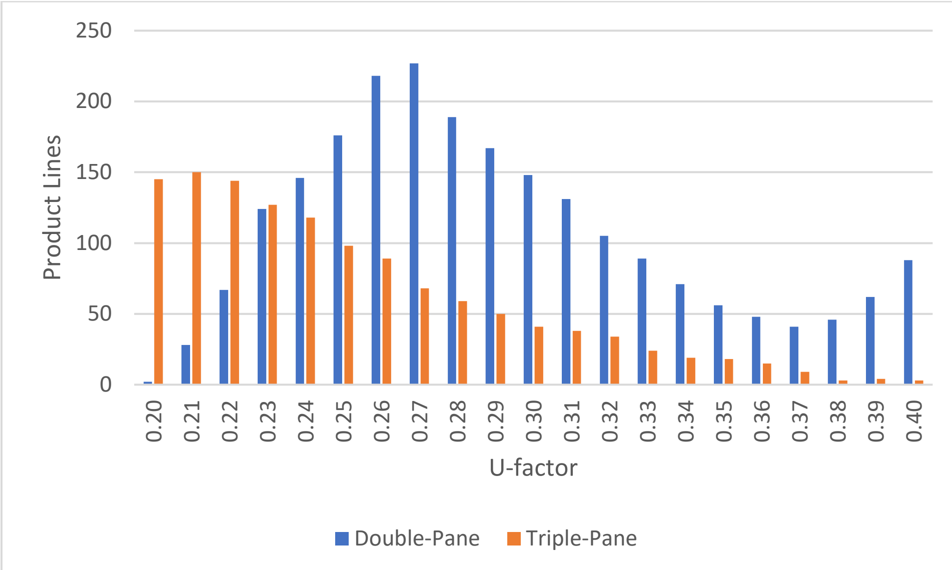
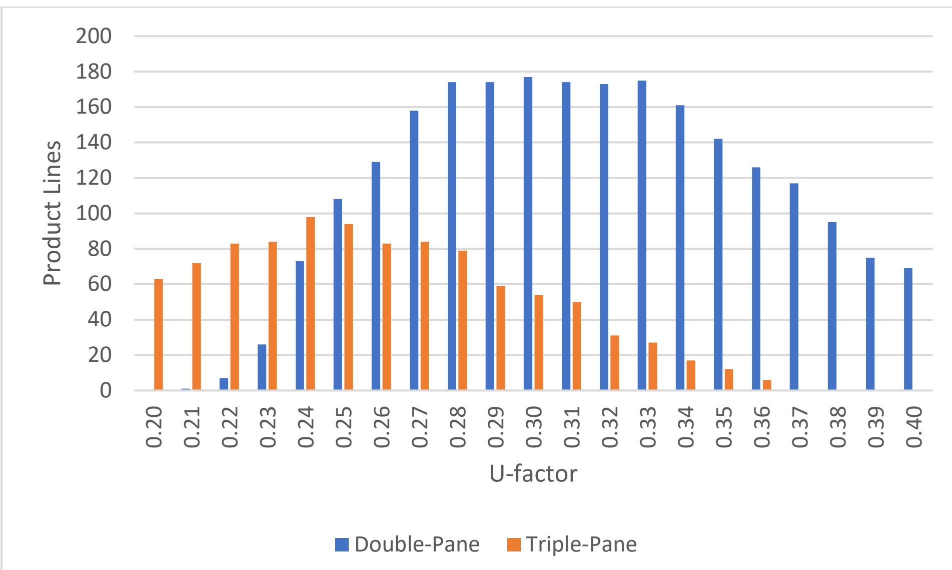


Figure 22. Product Line Distribution of Wood Casement Windows



Solar Heat Gain by Low-e Coating Type

Figure 23. Number of Options by U-Factor and SHGC for Single-Silver Low-e Coatings

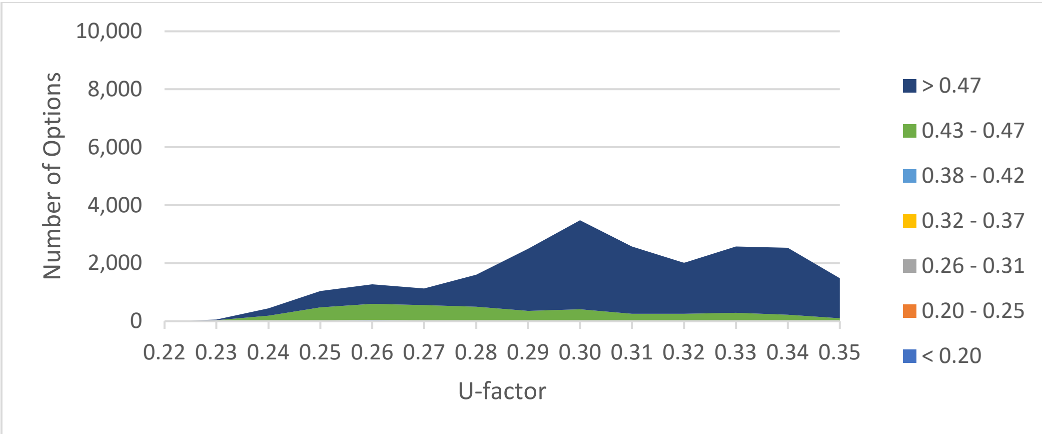


Figure 24. Number of Options by U-Factor and SHGC for Double-Silver Low-e Coatings

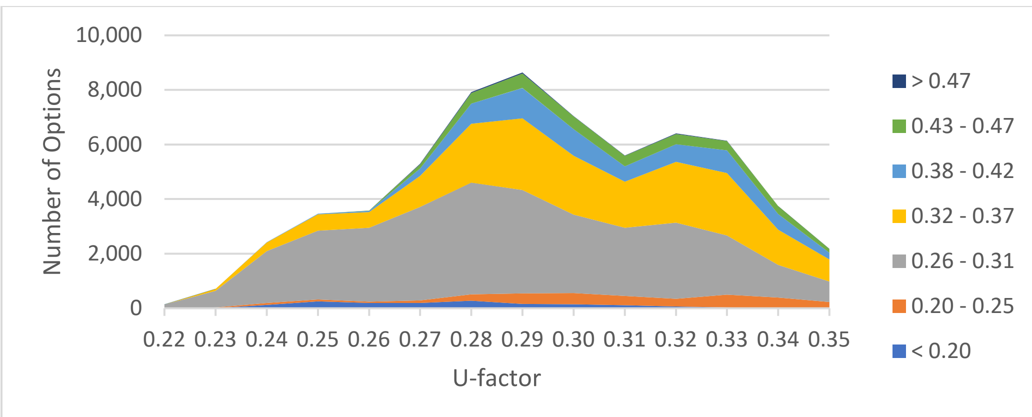
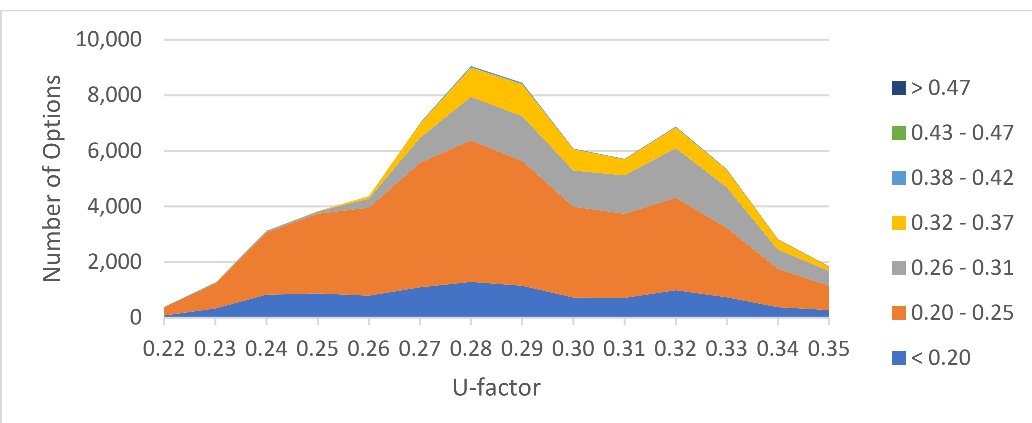


Figure 25. Number of Options by U-Factor and SHGC for Triple-Silver Low-e Coatings



Orientation Sensitivity

This sensitivity analysis shows that throughout the Northern Climate Zone, energy savings increase as SHGC increases. This analysis assumed a U-factor of 0.25 for all cases—equal orientation, 50% north and 50% south, and 50% east and 50% west.

Figure 26. Energy Savings for High Solar Gain at Different Window Orientations by City