U.S. Department of Energy
ENERGY STAR Program

Windows, Doors, and Skylights
Draft Criteria and Analysis

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Executive Summary

ENERGY STAR no longer effectively differentiates energy-efficient windows, doors, and skylights from standard products. In many areas of the country, state and local building codes already exceed ENERGY STAR levels. ENERGY STAR market share is at 59 percent nationally, and close to 90 percent in the replacement market. In the Northeast and Pacific Northwest, ENERGY STAR market share also approaches 90 percent. The proposed 2009 International Energy Conservation Code (IECC) model energy code includes prescriptive levels above ENERGY STAR in most regions of the country. As more states adopt this code, the ENERGY STAR label will become even less meaningful for consumers and homebuilders.

The analysis completed for this report shows it is technologically feasible and cost-effective to increase the efficiency levels for the ENERGY STAR label. After reviewing the National Fenestration Rating Council's (NFRC) product database, evaluating products advertised for sale, and gathering information from manufacturers, the U.S. Department of Energy (DOE) determined energy efficiency improvements of that deliver annual energy savings of over 8.5 trillion BTUs can be achieved with currently available technologies and the application of superior design. These more efficient products can be produced at moderate incremental costs that offer homeowners a positive return on their investment.

Recognizing it takes manufacturers time to design new products and adopt and optimize new technologies and production methods, DOE is proposing to roll out new criteria for windows and skylights in two phases:

- **Phase 1**, effective in at the earliest Aug 3, 2009 (270 days after finalization of the criteria), will tighten the criteria to ensure ENERGY STAR labeled windows meet or exceed code. DOE's analysis shows the proposed efficiency levels can be achieved by most manufacturers without major product redesign, and a wide range of products are already available on the market. Consumers purchasing these windows are likely to face only small price premiums, if any, and will quickly recover their investment in most regions of the country.
- **Phase 2**, beginning in 2013, will establish higher levels of performance well beyond current building codes. The proposed Phase 2 criteria can be met with existing window technologies and do not require adoption of advanced or emerging technologies. Products qualifying in all zones are currently available. However, most manufacturers will need to alter product designs and upgrade manufacturing processes to produce qualified windows. For example, manufacturers will need to develop new triple-pane products to meet the most stringent criteria for northern climates. Most of the currently qualifying triple-pane products use krypton gas, which DOE believes will not be cost-effective in

2013. Setting the effective date for 2013 should provide manufacturers adequate time to design, test, and produce these new products.[1]

DOE proposes to establish separate criteria for doors, which are typically more efficient than windows. The new window criteria, described above, are not stringent enough to reestablish ENERGY STAR as an identifier of doors with superior energy efficiency. Separate criteria for doors are also expected to deliver additional energy savings.

DOE proposes to establish new skylight criteria that will deliver additional energy savings. These criteria are not as aggressive as those for windows and doors because DOE's analysis shows more stringent criteria levels would not be cost-effective.

DOE is proposing to require certified insulating glass units (IGU) for ENERGY STAR qualified windows. IGU failure compromises the energy performance of a window and can require premature replacement. DOE expects ENERGY STAR's IGU certification to occur through NFRC Since NFRC-certification is a prerequisite for ENERGY STAR qualification, the addition of NFRC IGU certification means all ENERGY STAR qualified products will have certified IGUs.

DOE also proposes to revise the ENERGY STAR climate zone map to align more closely with IECC climate zones and California's Title 24 climate zones. This change would make ENERGY STAR criteria more consistent and directly comparable to code, meaning ENERGY STAR qualified windows would better match the local climate and yield greater energy savings.

At the request of regional utilities and other energy efficiency program sponsors (EEPS), and to meet more stringent building code requirements, DOE has created a separate zone for the Pacific Northwest in Phase 1. This zone is reintegrated into the climate zone with the most stringent U-factor criteria in Phase 2. EEPS in the region have successfully promoted high-performance windows and pledged to promote ENERGY STAR qualified windows if DOE sets criteria at the requested levels. Many regional EEPS already offer and intend to continue generous rebates for windows that would qualify under the proposed criteria.

The Canadian ENERGY STAR program is also revising its criteria. DOE has been working with Natural Resources Canada (NRCan) to harmonize draft criteria in climate zones adjacent to the United States to the extent possible. NRCan has not yet made final decisions on its draft criteria, but DOE expects the two sets of criteria to be similar enough that many products will qualify in both countries.

[1] D&R International, Ltd., 2008. Based on industry interviews, manufacturers report that the cycle time from design to production is three years.

Following publication of this report the criteria development process will proceed as described in Table 1.

Table 1: ENERGY STAR Windows, Doors, and Skylights Criteria Schedule	
Stakeholder Meeting in Washington, DC.	August 13, 2008
Public Comment Period	Aug. 14 – Sept. 14, 2008
IECC Final Status Hearings	Sept. 14 – Sept. 23, 2008
DOE Reviews Comments and Final 2009 IECC	Sept. 15 – Oct. 31, 2008
Final ENERGY STAR Criteria Published	Fall 2008
Effective Date for Phase 1 Criteria (at least 270 days later)	August 3, 2009 Earliest possible
Phase 1 Transition Period Ends All products in distribution chain must be qualified and labeled in accordance with Phase 1 criteria.	November 2, 2009 Earliest possible
Effective Date for Phase 2 Criteria	January 1, 2013
Phase 1 Transition Period Ends All products in distribution chain must be qualified and labeled in accordance with Phase 2 criteria.	April 1, 2013 Earliest possible

1 Guiding Principles for Criteria Revision

To assess whether a product category will qualify for the ENERGY STAR label—and to develop appropriate performance-based specifications—DOE applies six principles:

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 within a reasonable period of time.
4. Energy efficiency can be achieved with several technology options, at least one of which is non-proprietary.
5. Product energy consumption and performance can be measured and verified with testing.
6. Labeling would effectively differentiate products and be visible for purchasers.

NFRC U-factor and SHGC rating will be retained in the new criteria, ensuring that ENERGY STAR for Windows, Doors, and Skylights meets Principle 5. Similarly, and certification requirements for display units and product labeling will also be retained ensuring that the program meets Principle 6.

2 Motivation for Criteria Change

ENERGY STAR for Windows, Doors, and Skylights is a voluntary program designed to help reduce national energy consumption by increasing the energy efficiency of fenestration products in residential buildings. The program regularly develops qualification criteria identifying products with superior energy performance. ENERGY STAR provides a brand platform manufacturers and retailers can use to market their products, consumers can use to identify efficient products, and EEPS can use as the basis for rebates and incentives that enhance demand.

The current prescriptive criteria have been in place for most of the country since 2003. They were amended in 2005 with equivalent energy performance criteria for the South/Central and Southern climate zones. Since then, both the average and absolute performance of fenestration products has increased. Market share of ENERGY STAR qualified windows has also risen steadily: it now exceeds 50 percent nationally[2] and in some regions approaches 90 percent[3]. In the renovation and replacement market segments—the primary market for ENERGY STAR qualified windows—these windows represent 80 to 90 percent of all sales.[4]

The current ENERGY STAR criteria do not ensure significant energy savings above prevailing building codes, which are at or above ENERGY STAR levels in 28 states. The International Code Council (ICC) approved proposals in February 2008 to exceed ENERGY STAR levels in several regions; these proposals will be heard at the International Energy Conservation Code (IECC) hearings in September 2008.[5]

Because today's windows are much more efficient, ENERGY STAR no longer identifies products with truly superior energy performance or drives production of more efficient products. As a result of these market changes, DOE determined in May 2007 that the ENERGY STAR criteria for windows, doors, and skylights should be reevaluated. To assess the benefits of criteria revision, DOE followed five steps:

1) Announced initiation of a criteria review and revision process (September 16, 2007).
2) Invited and received input and recommendations from manufacturers, stakeholders, and 39 industry associations[6] (September 2007–July 2008).

[2] Ducker Research, 2008. Exhibit D.15: Conventional Residential Windows – Energy Ratings. *Study of the U.S. Market for Windows, Doors, and Skylights*, published by the American Architectural Manufacturers Association and Window and Door Manufacturers Association.
[3] D&R International, Ltd., 2008. Analysis of bi-yearly national ENERGY STAR market share and the market share of low-e glass as published in Ducker Research, 2004, 2006, and 2008. Appendix F in *Study of the U.S. Market for Windows, Doors, and Skylights*, published by the American Architectural Manufacturers Association and Window and Door Manufacturers Association.
[4] D&R International, Ltd., 2008. Based on confidential data from multiple manufacturers and analysis of regional shipment data for new construction and remodeling and replacement and low-e glass published in *Study of the U.S. Market for Windows, Doors, and Skylights,* Ducker Research, 2008.
[5] International Code Council, 2008. *2007/2008 Proposed Changes to the International Energy Conservation Code.*
[6] Associations that provided input include the Aluminum Extruders Council, American Architectural Manufacturers Association, Fenestration Manufacturers Association, Glazing Industry Code Committee,

3) Evaluated technological feasibility, cost-effectiveness, energy savings potential, and market impacts of possible criteria (October 2007–July 2008).
4) Alerted stakeholders of window criteria elements under consideration, including revisions to the climate zone map, and invited stakeholder input (January 18, 2008).
5) Announced preliminary criteria for swinging doors and skylights and invited stakeholder input (May 2008).

Based on its analysis and feedback received from industry stakeholders, DOE decided to proceed with the following modifications: revision to the climate zone map, tightening of performance levels for windows and skylights, establishing separate criteria for doors, and adding an insulating glass certification requirement. Each change is described in more detail below.

Interested stakeholders are invited to comment both in writing and/or in person at a meeting at DOE headquarters in Washington, DC, on August 13, 2008.

3 Revisions to the ENERGY STAR Climate Zone Map

DOE revised the ENERGY STAR climate zone map for the draft criteria. The new map aligns the structure of the windows program more closely with state and local building codes, and supports establishment of rebate and promotional programs by EEPS in the Pacific Northwest.

The map defines six climate zones for Phase 1 and five climate zones for Phase 2, following the contours of the IECC's 2006 climate zones everywhere but in California and the Pacific Northwest. DOE simplified the IECC and Title 24 climate zones to reduce complexity for manufacturers and consumers (Figure 2). Several of the eight IECC climate zones are grouped together and the 16 Title 24 climate zones are reduced to two. Small border regions and islands of one zone surrounded by another zone were reassigned, allowing consumers to determine the zone for their geographic region on small-scale ENERGY STAR display unit labels. Figure 1 shows an example display unit label at scale to illustrate the small size of the label maps.

Insulating Glass Manufacturers Association, Midwest Energy Efficiency Alliance, Northeast Energy Efficiency Partnerships, Northwest Energy Efficiency Alliance, and the Window and Door Manufacturers Association.

Figure 1: ENERGY STAR Display Unit Label, at Minimum Size (3.1" x 2.5")

The greatest impacts of the proposed changes are:

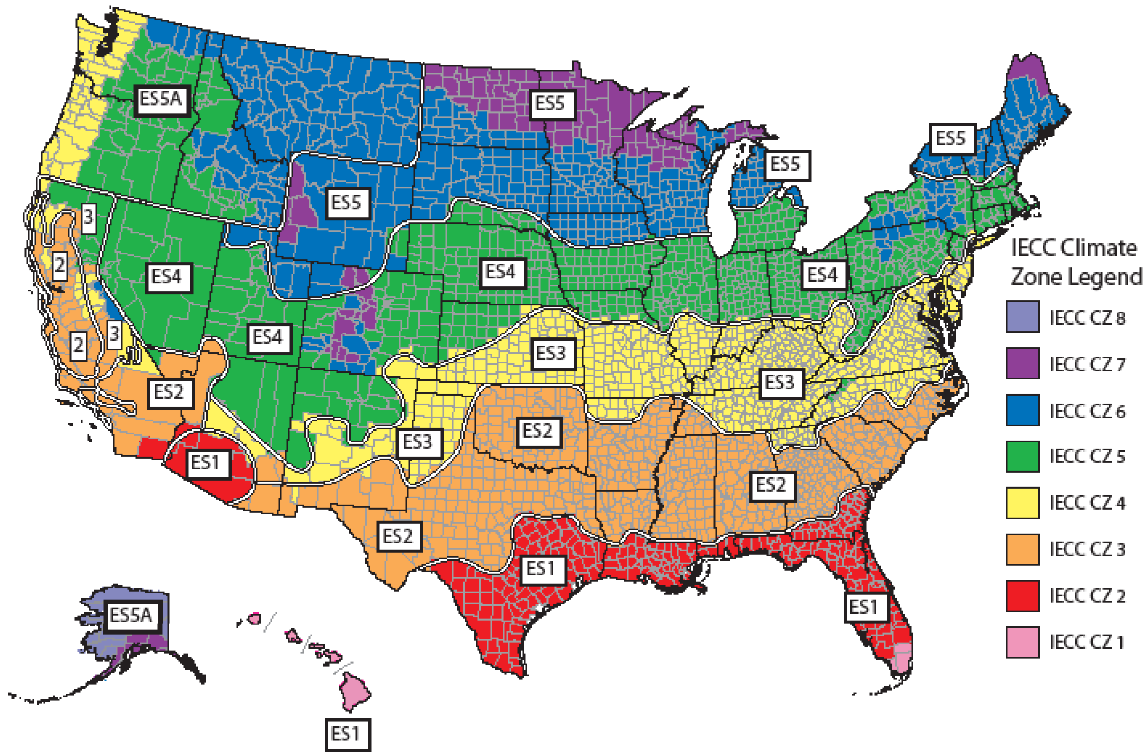
1) Expansion of the Southern Zone (ES1) by moving the boundary north and including southern Arizona, thus increasing the zone's population by 6.5 million people.
2) Division of one northern zone into three zones for Phase 1 (ES4, ES5, and ES5a) and two zones for Phase 2 (ES4 and ES5).
3) Division of California into two zones (ES2 and ES3).

The proposed ENERGY STAR map (Figure 3) has smooth contours but formally follows county lines in all states except California, where assignment is by zip code to align with Title 24. For a detailed discussion of adjustments to the IECC climate zone map and rationales, please see Appendix A.

DOE is seeking closer alignment with IECC's climate zones, because the IECC has become the dominant energy code that manufacturers consider when shipping product. Twenty-eight states, representing over 90 percent of the U.S. population, have adopted IECC 2003 or a more recent version of the code.[7] Because California maintains its own energy code (Title 24), DOE has selected climate zone boundaries that follow Title 24 boundaries. DOE has created a separate zone (ES5a) for the Pacific Northwest in Phase 1 that merges into ES5 in Phase 2.

[7] D&R International, Ltd., 2008. Based on 2006 U.S. Census population data retrieved from http://quickfacts.census.gov/qfd/ and state-reported code adoption by jurisdiction retrieved from www.bcap-energy.org \node\123.

Figure 2: IECC Climate Zone Map with Proposed ENERGY STAR Climate Zone Overlay



The Pacific Northwest is separated into a stand-alone zone in Phase 1 for two reasons. First, very stringent building energy codes in the Pacific Northwest (U ≤ 0.30 in eastern Washington and U ≤ 0.33 in Alaska) require a separate zone with more stringent criteria than DOE can justify elsewhere in ES5. Second, the Northwest Energy Efficiency Alliance (NEEA) has requested a separate zone for the Pacific Northwest and a simple prescriptive U-factor of ≤ 0.30, a level that NEEA members have already committed to and is promoting.

NEEA members include electric utilities, public benefits administrators, the Bonneville Power Administration, and other interest groups representing over 98 percent of the electricity load in the Pacific Northwest. NEEA helped create the Northwest ENERGY STAR windows promotion from 1997 to 2001, which increased market share for windows with a U-factor ≤ 0.35 from 13 percent to 66 percent in just three years.[8] Two NEEA members, the Energy Trust of Oregon and the Bonneville Power Administration, already offer rebates of $2.25 per sq. ft. and $0.50 per sq. ft., respectively, on windows with U-factors < 0.30 installed in single-family residences.[9]

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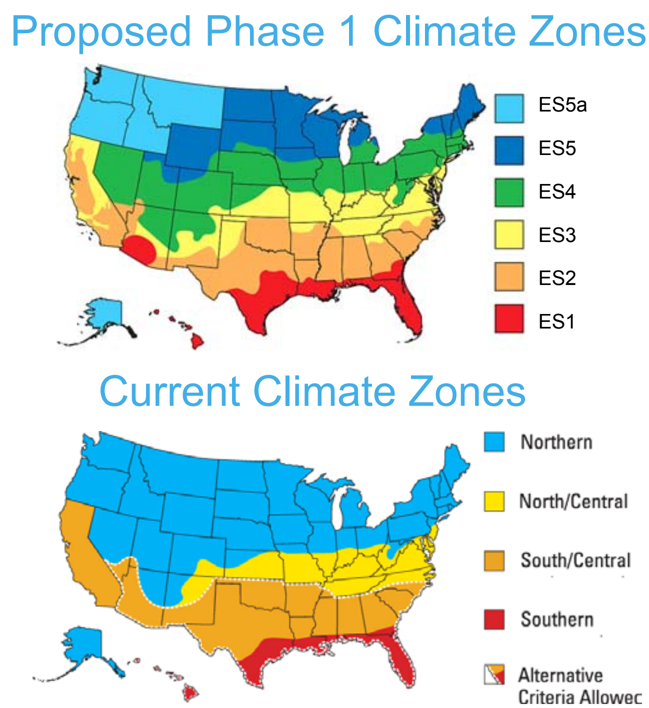
[8] D&R International, Ltd., 2008. Comparison of 2006, 2007, and 2008 DOE *ENERGY STAR for Windows, Doors, and Skylights State and Utility Incentive and Activities.*

[9] NEEA letter to DOE dated July 16, 2008.

Expanded investment and promotion of ENERGY STAR qualified windows in the Pacific Northwest would greatly assist DOE in securing adoption of incentives and promotion for ENERGY STAR qualified windows in regions nationwide—something both stakeholders and members of Congress have urged DOE to pursue.

Figure 3: Proposed ENERGY STAR Climate Zone Map versus Current ENERGY STAR Climate Zone Map



4 Draft ENERGY STAR Criteria for Window

4.1 Overview of Window Criteria

The draft criteria for windows differ from the current ENERGY STAR criteria in several important ways:

1. Central and Southern Zones (ES1, ES2, and ES3) and the Pacific Northwest (ES5a) have prescriptive criteria that require greater insulating capacity (lower U-factors). The Central and Southern Zones (ES1, ES2, and ES3) have criteria requiring greater solar control (lower SHGC).
2. In the heating-dominated North, except the Pacific Northwest, window criteria are based on minimum aggregate annual energy performance rather than a prescriptive U-factor and are accompanied by U-factor and SHGC caps.
3. The Pacific Northwest in Phase 1 has its own set of more stringent window criteria, defined in simple prescriptive terms. The entire region, including coastal regions with more moderate climates, is assigned to the northernmost zone.
4. Criteria in the southern region are set as prescriptive maxima. Equivalent performance criteria are no longer included.
5. Criteria include a new requirement for IGU certification.

Figure 4 presents the current ENERGY STAR window and door criteria, set in 2003. Criteria for all zones were specified as minimum prescriptive criteria only. In a modification in 2005, DOE established criteria for the Southern and South/Central Zones allowing qualification of U-factor and SHGC combinations with aggregate, population-weighted, annual energy performance equivalent to the 2003 prescriptive criteria (Figure 4).

Figure 4: Current ENERGY STAR Window Criteria

Windows & Doors

Climate Zone	U-Factor	SHGC	
Northern	≤ 0.35	Any	
North/Central	≤ 0.40	≤ 0.55	
South/Central	≤ 0.40	≤ 0.40	Prescriptive
	≤ 0.41	≤ 0.36	Equivalent Performance *(Excluding CA)*
	≤ 0.42	≤ 0.31	
	≤ 0.43	≤ 0.24	*Products meeting these criteria also qualify in the Southern zone.*
Southern	≤ 0.65	≤ 0.40	Prescriptive
	≤ 0.66	≤ 0.39	Equivalent Performance
	≤ 0.67		
	≤ 0.68	≤ 0.38	
	≤ 0.69	≤ 0.37	
	≤ 0.70		
	≤ 0.71	≤ 0.36	
	≤ 0.72	≤ 0.35	
	≤ 0.73		
	≤ 0.74	≤ 0.34	
	≤ 0.75	≤ 0.33	

DOE tightened prescriptive criteria for both U-factor and SHGC in the Central and Southern Zones to gain additional heating and cooling energy savings (Table 2).

In the heating-dominated northern climates, DOE is setting criteria based on annual aggregate energy performance, similar in concept to the equivalent performance criteria established for the current South/Central and Southern Zones.

Lawrence Berkeley National Laboratory (LBNL) developed a regression model revealing how changes in U-factor and SHGC affect aggregate energy consumption for each preliminary climate zone. For proposed zones ES4 and ES5, DOE then used the results of this model to select a maximum annual energy consumption benchmark a window must not exceed in order to qualify. See Appendix B and LBNL's report, "A National Energy Savings Model of US Window Sales," at windows.lbl.gov/EStar2008 for a detailed discussion of this model.

To simplify compliance, DOE specified the qualifying products for ES4 and ES5 in matrices. For each U-factor, DOE has defined a corresponding minimum SHGC (Figure 5, Figure 6, Figure 7, and Figure 8). Windows with that specific U-factor and the corresponding SHGC or higher will qualify. As the U-factor declines, so does the minimum qualifying SHGC threshold.

DOE's energy savings analysis reveals that in ES5, a 0.01 reduction in U-factor produces the same energy benefits as a 0.05 increase in SHGC. Therefore, in the ES5 tables in which the pairs of U-factor and minimum qualifying SHGC listed all have equivalent aggregate annual energy performance, the minimum required SHGC drops 0.05 balancing the 0.01 decline in U-factor. Similarly, in ES4, a 0.01 reduction in U-factor produces the same energy benefits as a 0.08 increase in SHGC. Therefore, in the ES4 tables, the minimum required SHGC drops 0.08 balancing each 0.01 decline in U-factor.

In ES4, ES5, and ES5a, DOE has set an upper bound of 0.55 on SHGC to prevent qualification of products with very high solar gain that would lead to overheating, discomfort, and customer dissatisfaction.

DOE has not set a lower bound on SHGC. Stakeholders suggested a SHGC floor would prevent the sale of dark products with very low visual transmittance that could also lead to customer dissatisfaction. However, since consumers can directly evaluate visible transmittance, they will reject windows that are too dark. Therefore, DOE does not need to require a minimum SHGC.

Criteria will be introduced in two phases. Phase 1 criteria will be effective 270 days after the final criteria announcement[10] until January 1, 2013, when windows must meet Phase 2 qualification criteria. Phase 2 of the draft criteria is significantly more stringent than Phase 1, but is being set well in advance of the effective date to allow manufacturers adequate time to develop cost-effective products.

Expected changes in IECC code criteria in 2009 necessitate the immediate tightening in Phase 1. If DOE waited to establish Phase 2 criteria to follow future code changes, manufacturers would not have enough lead time and face steeper costs and greater competitive disadvantages.

[10] The earliest possible date would be August 3, 2009.

Table 2: Draft Criteria for ENERGY STAR Qualified Windows and Sliding Glass Doors

	Phase 1			Phase 2		
Climate Zone	**U-Factor[1]**	**SHGC[2]**	**Energy Performance**	**U-Factor**	**SHGC**	**Energy Performance**
ES5a	$\leq$ 0.30	$\leq$ 0.55	-	-	-	See Figure 7
ES5	-	-	See Figure 5			
ES4	-	-	See Figure 6	-	-	See Figure 8
ES3	$\leq$ 0.33	$\leq$ 0.40	-	$\leq$ 0.30	$\leq$ 0.40	-
ES2	$\leq$ 0.35	$\leq$ 0.30	-	$\leq$ 0.30	$\leq$ 0.30	-
ES1	$\leq$ 0.50	$\leq$ 0.25	-	$\leq$ 0.45	$\leq$ 0.20	-

Window: An assembled unit consisting of a frame/sash component holding one or more pieces of glazing functioning to admit light and/or air to an enclosure. May be fixed or operable. For ENERGY STAR criteria, this category includes sliding glass doors.
Sliding glass door: A door that contains one or more manually operated glass panels that slide horizontally within a common frame.

Products must be NFRC rated, certified, and labeled for U-factor and SHGC. Products that use a sealed IGU must have IGU certification once the NFRC IGU certification program is fully implemented.

[1] Btu/hr-ft^2-ºF.
[2] Fraction of incident solar radiation.

Figure 5: Draft Criteria for ENERGY STAR Windows in ES5, Phase 1

U-Factor	SHGC ($\geq$ X and $\leq$ 0.55) X
0.35	0.40
0.34	0.35
0.33	0.30
0.32	0.25
0.31	0.20
0.30	0.15
0.29	0.10
0.28	0.05
0.27	0.00
0.26	0.00
0.25	0.00
0.24	0.00
0.23	0.00
0.22	0.00
0.21	0.00
0.20	0.00
0.19	0.00
0.18	0.00
0.17	0.00
0.16	0.00
0.15	0.00

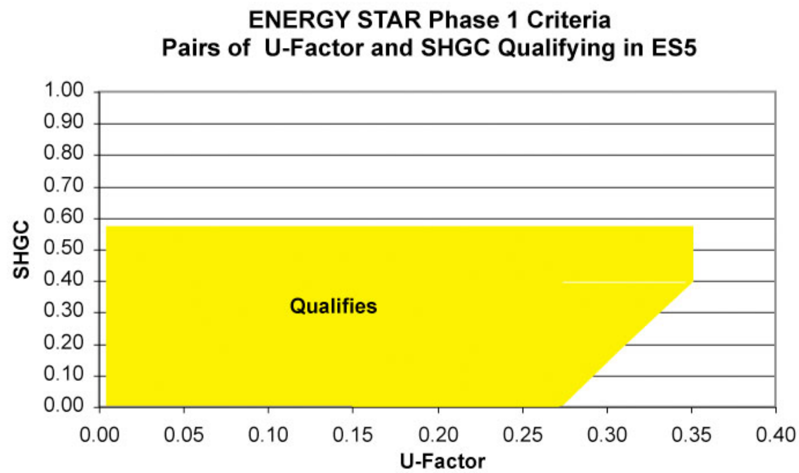


Figure 6: Draft Criteria for ENERGY STAR Windows in ES4, Phase 1

U-Factor	SHGC (> X and < 0.55) X
0.35	0.41
0.34	0.33
0.33	0.25
0.32	0.17
0.31	0.09
0.30	0.01
0.29	0.00
0.28	0.00
0.27	0.00
0.26	0.00
0.25	0.00
0.24	0.00
0.23	0.00
0.22	0.00
0.21	0.00
0.20	0.00
0.19	0.00
0.18	0.00
0.17	0.00
0.16	0.00
0.15	0.00

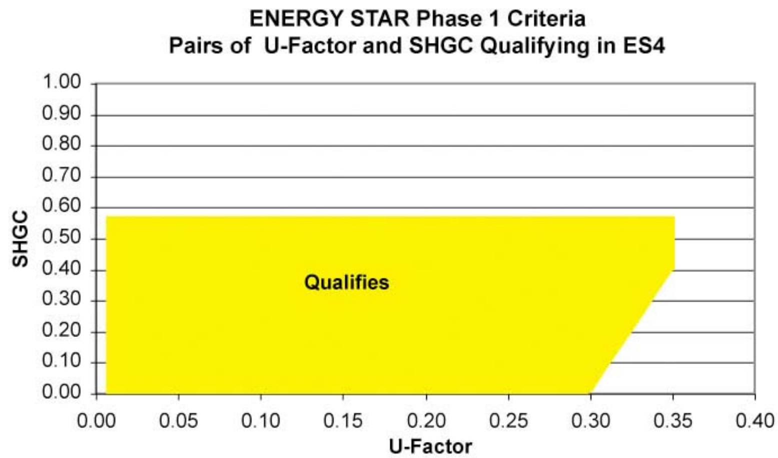


Figure 7: Draft Criteria for ENERGY STAR Windows in ES5, Phase 2

U-Factor	SHGC ($\geq$ X and $\leq$ 0.55) X
0.28	0.55
0.27	0.50
0.26	0.45
0.25	0.40
0.24	0.35
0.23	0.30
0.22	0.25
0.21	0.20
0.20	0.15
0.19	0.10
0.18	0.05
0.17	0.00
0.16	0.00
0.15	0.00
0.14	0.00
0.13	0.00
0.12	0.00
0.11	0.00
0.10	0.00

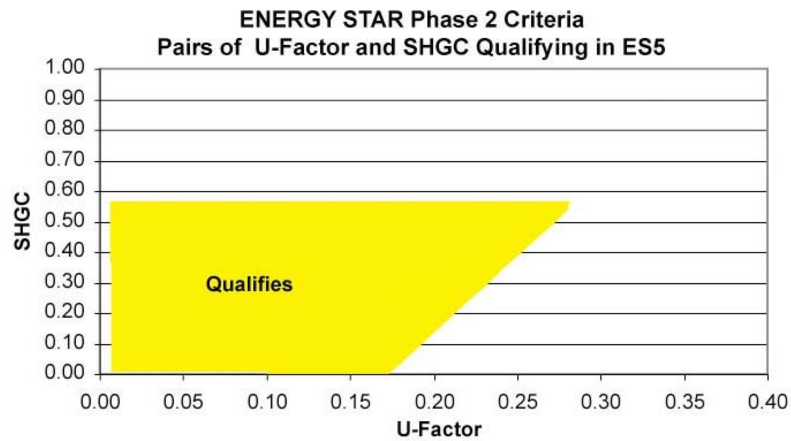
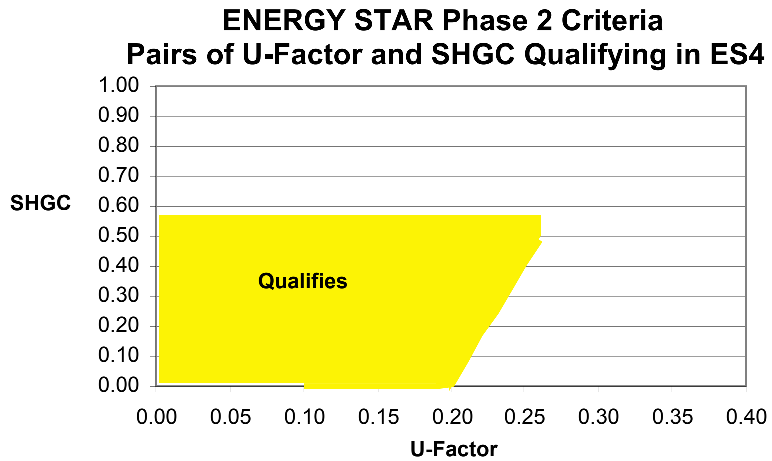


Figure 8: Draft Criteria for ENERGY STAR Windows in ES4, Phase 2

U-Factor	SHGC (≥ X and ≤ 0.55) X
0.26	0.49
0.25	0.41
0.24	0.33
0.23	0.25
0.22	0.17
0.21	0.09
0.20	0.01
0.19	0.00
0.18	0.00
0.17	0.00
0.16	0.00
0.15	0.00
0.14	0.00
0.13	0.00
0.12	0.00
0.11	0.00
0.10	0.00



4.1.1 Additional Qualification Requirement: IGU Certification

With increasing use of argon-gas-filled IGUs under the new criteria, certified IGUs in all ENERGY STAR qualified products will become quite important. DOE proposes to add IGU certification as a requirement for ENERGY STAR qualification of windows, doors, and skylights.

DOE believes that the most rigorous yet practical requirements lead to durable and affordable ENERGY STAR qualified products. Future energy savings are difficult to substantiate without a durability requirement. DOE expects that IGU certification recognized by NFRC will include six elements:

- All IGU models for use in NFRC certified products shall be certified in a 3rd party IGU certification program acceptable to NFRC, which complies with ISO Guide 65. Proof of certification shall be validated at annual NFRC plant audits by demonstrating current listing of the IGU model in the accepted IGU certification program's current certified products directory or by supporting documentation from the IGU certifier.
- Mandatory IGU testing at least once every 2 years utilizing independent testing laboratories that are accredited to ISO 17025. IGU Certification Programs will provide as part of their documentation submission to NFRC, testing laboratory approval process for specific test procedures and their list of approved test facilities.

- All IGUs must pass the requirements of ASTM E2190 or CGSB 12.8. The CGSB 12.8 standard will be acceptable until the ASTM E2189 fog box text requirements meet or exceed the requirements in the CGSB 12.8 standard.
- Proof of gas content certification to an average minimum initial 90 percent insulating gas fill content and an average minimum of 80 percent insulating gas fill content following completion of respective IGU durability testing. Demonstration of gas content for argon shall qualify other gases providing the same gas filling method is used.
- The testing lab approval process shall include inspections as needed, with a minimum of once every two years, to ensure the testing laboratory is in full compliance with ASTM E2190 or CGSB 12.8.
- Certification agencies will perform least two (2) audits per year of program participant's IGU fabrication facilities.

The Department also believes it essential an IGU certification expiration date be included in the NFRC CPD record of every certified window, door, or skylight. This will ensure that DOE and consumers can validate manufacturers' IGU certification claims.

4.1.2 Dynamic Glazings and Impact-Resistant Fenestration Products

DOE is initially only proposing criteria for the highest-volume windows, doors, and skylights. After these criteria are finalized, DOE will evaluate the feasibility of developing equivalent performance criteria for dynamic glazings and the necessity of establishing separate criteria for impact-resistant products.

4.2 Window Criteria – Phase 1

Phase 1 (2009) window criteria restore the necessary minimum differentiation among products by meeting or exceeding both 2006 and proposed 2009 IECC energy code requirements (Table 3). These criteria would deliver significant energy savings at little or no cost increase to consumers and would require no major product redesign. As Figure 5 and Figure 6 show, the proposed criteria also give credit for solar gain when it offers net energy benefits, but do not exclude lower-solar-gain products with equal or better energy performance.

Table 3: Comparison of ENERGY STAR and IECC Window Criteria									
	Current ENERGY STAR Criteria		2006 IECC		Proposed 2009 IECC Levels		Draft ENERGY STAR Criteria Phase 1		
Climate Zone	U-Factor	SHGC	U-Factor	SHGC	U-Factor	SHGC	U-Factor	SHGC	Energy Performance
ES5a	≤ 0.35	NR	≤ 0.35	NR	≤ 0.35	NR	≤ 0.30	≤ 0.55	
ES5	≤ 0.35	NR	≤ 0.35	NR	≤ 0.35	NR	-	-	See Figure 5
ES4	≤ 0.35	NR	≤ 0.35	NR	≤ 0.35	NR	-	-	See Figure 6
ES3	≤ 0.40	≤ 0.55	≤ 0.4	NR	≤ 0.35	NR	≤ 0.33	≤ 0.40	
ES2	≤ 0.40	≤ 0.40	≤ 0.65	≤ 0.40	≤ 0.40	≤ 0.30	≤ 0.35	≤ 0.30	
ES1	≤ 0.65	≤ 0.40	≤ 0.75	≤ 0.40	≤ 0.50	≤ 0.30	≤ 0.50	≤ 0.25	

Sources: DOE, *ENERGY STAR Windows, Doors, and Skylights Program Requirements for Residential Windows, Doors, and Skylights, Version 4.0*. May 14, 2007; International Code Council, 2006. *International Energy Conservation Code 2006;* International Code Council, 2008. *2007/2008 Proposed Changes to the International Energy Conservation Code.*

ENERGY STAR ZONE 5a (ES5a)

As discussed in section 3, DOE set criteria for ES5a at 0.30 to meet or exceed more stringent regional energy codes (U-factor ≤ 0.30 in eastern Washington state and ≤ 0.33 in Alaska), to respond to the concerns of the Northwest Energy Efficiency Alliance (NEEA), and to catalyze the establishment of incentive and promotional programs by utilities and other EEPS.[11] Many EEPS in the Pacific Northwest have already committed to promoting this criterion level, and rebates are already available in much of the region through the Energy Trust of Oregon and the Bonneville Power Administration.[12]

ENERGY STAR ZONE 5 (ES5)

Phase 1 ES5 criteria reflect a minimum aggregate annual energy performance and are defined in Figure 5. As discussed in section 4, Overview of Window Criteria, solar heat gain offers greater benefits in this zone, because each increase of 0.05 in SHGC provides the same energy benefits as a reduction of 0.01 in U-factor.

ENERGY STAR ZONE 4 (ES4)

Phase 1 ES4 criteria also reflect a minimum aggregate annual energy performance. Figure 6 illustrates the combinations of U-factor and SHGC that meet the minimum energy performance level for Phase 1 ES4. Solar gain provides a modest net energy benefit in this zone, so a much greater increase in SHGC (0.08) is needed in ES4 to provide the same energy benefit as a 0.01 reduction in U-factor.

ENERGY STAR ZONE 3 (ES3)

The maximum U-factor for ES3 has been lowered from 0.40 to 0.33, which is 0.02 below the level proposed for the 2009 IECC. SHGC has been lowered from 0.55 to 0.40. IECC 2009 has no SHGC criterion for this region, because the energy savings analysis shows that solar control provides only modest benefits in this climate zone.

ENERGY STAR ZONE 2 (ES2)

[11] D&R International, Ltd., 2008. Comparison of 2006, 2007, and 2008 DOE *ENERGY STAR for Windows, Doors, and Skylights State and Utility Incentive and Activities.*
[12] NEEA letter to DOE dated July 16, 2008.

The maximum U-factor for ES2 has been tightened to 0.35, which is 0.05 below the proposed IECC 2009 code. SHGC has been set at 0.30, 0.10 lower than the current ENERGY STAR level but equivalent to IECC 2009 code. While many climates in Zone 2 would benefit from a lower SHGC, the wide range of sub-climates included in Zone 2 included some climates where a lower SHGC does not provide significant energy benefits (particularly where heating is from electricity). As a result, the SHGC was set at 0.30 and not 0.25.

ENERGY STAR ZONE 1 (ES1)

DOE set the maximum U-factor in ES1 at 0.50, the level proposed for IECC 2009. DOE decided not to exceed this level because it is already significantly lower than the current ENERGY STAR maximum of 0.65. Since the U-factor is set at and not below code, there was no possibility of using a minimum energy performance metric, as under the current criteria. Should IECC set a less stringent U-factor at the final status hearings, DOE will relax its U-factor to that level or to 0.60, whichever is more stringent.

4.2.1 Energy Savings Potential

The energy savings model developed by LBNL estimates that implementation of Phase 1 of the draft criteria for ENERGY STAR windows would save 8.51 trillion BTU (tBTU) in primary energy consumption compared to the IECC 2006 reference scenario. Compared to other DOE products, these savings are significant. For instance, they are 45 percent greater than the annual primary energy savings estimated for the recent revision of the ENERGY STAR clothes washer criteria (Table 4).

Table 4: Estimated Annual Primary Energy Savings from ENERGY STAR Criteria Revisions

Product Category	Savings (tBTU)
Windows (Draft Criteria – Phase 1)	8.51
Clothes Washers (2008)	5.85
Room A/C (2008)	3.41
Refrigerators (2008)	2.58
Dishwashers (2008)	2.08

Source: DOE, ENERGY STAR Program, 2008. Savings are annual energy savings.

The criteria also generate savings in all climate zones (Table 5).

Table 5: Phase 1 Window Energy Savings by Zone

Climate Zone	Consumption		Savings (tBTU)
	2006 IECC (tBTU)	Phase 1 ENERGY STAR (tBTU)	
ES5a	12.17	11.84	0.33
ES5	18.88	18.70	0.18
ES4	73.93	73.54	0.38
ES3	62.89	61.24	1.65
ES2	49.37	45.28	4.09
ES1	35.29	33.41	1.88
National			**8.51**

Source: LBNL, 2008. Energy Savings are the difference between primary energy consumption of 2006 IECC and Phase 1 ENERGY STAR market penetration scenarios developed by D&R and as calculated by LBNL.

DOE evaluates energy savings relative to building energy codes. Based on adoption rates for IECC 2003 and IECC 2006, in 2009, more than 70 percent of the U.S. population will live in jurisdictions with those codes. Of that 70 percent, about half of the population will be covered by IECC 2006 and half by IECC 2003. By 2011, even with IECC 2009, the majority of the U.S. population under IECC will still live in regions subject to IECC 2003 or IECC 2006.[13]

Based on this assumption, energy savings for Phase 1 represent the difference between the estimated annual aggregate energy consumption for the 2006 IECC sales scenario and a Phase 1 ENERGY STAR sales scenario. For supporting data and a detailed description of the methodology, please see windows.lbl.gov/EStar2008.

In brief, consumption was calculated on a per-home basis for a set of model homes in 98 U.S. cities and using RESFEN 6 assumptions described in windows.lbl.gov/EStar2008. Per-home savings were then weighted to reflect residential energy use data from RECS, population, window sales, and regional frequency of building types. Consumption was calculated separately for new and existing homes, reflecting differences in model home design and sales of new and replacement windows.

To evaluate proposed criteria, LBNL applied market penetration scenarios developed by D&R to provide more accurate estimates of annual energy savings from the draft Phase 1 and Phase 2 ENERGY STAR window criteria.

D&R developed five conservative regional shipment scenarios: three ENERGY STAR scenarios (Current, Phase 1, and Phase 2) and two reference case scenarios (IECC 2006, and IECC 2009). Scenarios estimate market share and corresponding regional shipments to the new construction and remodel/replacement (R/R) markets for six categories of window: (1) double-pane clear (DC), (2) IECC 2006 compliant, (3) IECC 2009

[13] D&R International, Ltd., 2008. Based on 2006 U.S. Census population estimates retrieved from http://quickfacts.census.gov/qfd/ and the Building Energy Codes Assistance Project's "State Code History," 2009. www.bcap-energy.org \node\123.

compliant, (4) current ENERGY STAR qualified, (5) Phase 1 ENERGY STAR qualified, and (6) Phase 2 ENERGY STAR qualified windows.

To develop these scenarios D&R used historic and forecast window and glass shipment data, manufacturer estimates of new construction and replacement market share for ENERGY STAR qualified, and conservative estimates of ENERGY STAR market share under Phase 1 and Phase 2 criteria. Scenarios represent anticipated average market penetration during the criteria period. These estimates represent minimum energy savings, because they are for ENERGY STAR windows at the minimum qualifying criteria and a 45-percent national market share. DOE expects actual market share to decrease to 52 percent. The average performance of qualifying windows actually sold is certain to exceed the minimum requirements.

Reductions in both heating and cooling load contribute to total energy savings, with aggregate net energy savings coming primarily from reductions in heating load (Table 6).

The savings are from both the fact that ENERGY STAR levels are reduced as well as energy performance of non-ENERGY STAR products improves as non-ENERGY STAR products performance is pulled by the more stringent standards.

Table 6: Source of Energy Savings for Phase 1 Criteria by Zone

Climate Zone	Heating Energy (tBTU)	Cooling Energy (tBTU)	Total Savings (tBTU)
ES5a	0.32	0.01	0.33
ES5	0.06	0.12	0.18
ES4	(0.05)	0.43	0.38
ES3	1.31	0.35	1.65
ES2	3.56	0.53	4.09
ES1	0.96	0.92	1.88
Total	**6.16**	**2.35**	**8.51**

Source: LBNL, 2008. Heating Energy is annual energy reduction in heating load. Cooling Energy is annual energy reduction in cooling load. Total Savings is the total annual energy reduction in both heating and cooling loads.

4.2.2 Technological Feasibility

Based on an analysis of currently available products and discussions with industry, DOE believes the proposed criteria are technologically feasible. Many existing products will qualify, and many products not currently qualifying will be able to with straightforward upgrades to the insulating glass unit.

Analysis of the vertical sliders in the NFRC Certified Product Directory (CPD) and a statistically valid sample of over 1,100 products advertised for sale showed 50 percent or more of windows qualifying under the current criteria will qualify under the proposed criteria in all zones but ES5a. Even there, 20–30 percent of currently qualified products will still qualify in Phase 1 (Table 7).

Stakeholders questioned whether the NFRC database is sufficiently reflective of actively marketed products. DOE therefore ran a parallel analysis on a subset of window types advertised for sale, and confirmed that the NFRC database is sufficiently accurate.

Table 7: Windows in NFRC Certified Product Directory Meeting Current and Proposed Phase 1 ENERGY STAR Criteria

	NFRC Certified Product Directory			Products for Sale
ENERGY STAR Climate Zone	**Meet Current Criteria**	**Meet Proposed Criteria**	**Percent Qualified without Modification**	**Percent Qualified without Modification**
ES5a	244,999	82,516	34	20
ES5	244,999	137,118	56	49
ES4	244,999	169,679	69	57
ES3	245,168	177,928	73	NA
ES2	240,564	205,452	85	NA
ES1	263,239	137,395	52	NA

Source: D&R International Ltd., 2008. Based on analysis of vertical sliders in the NFRC CPD as of July 2008 and products currently available for sale.

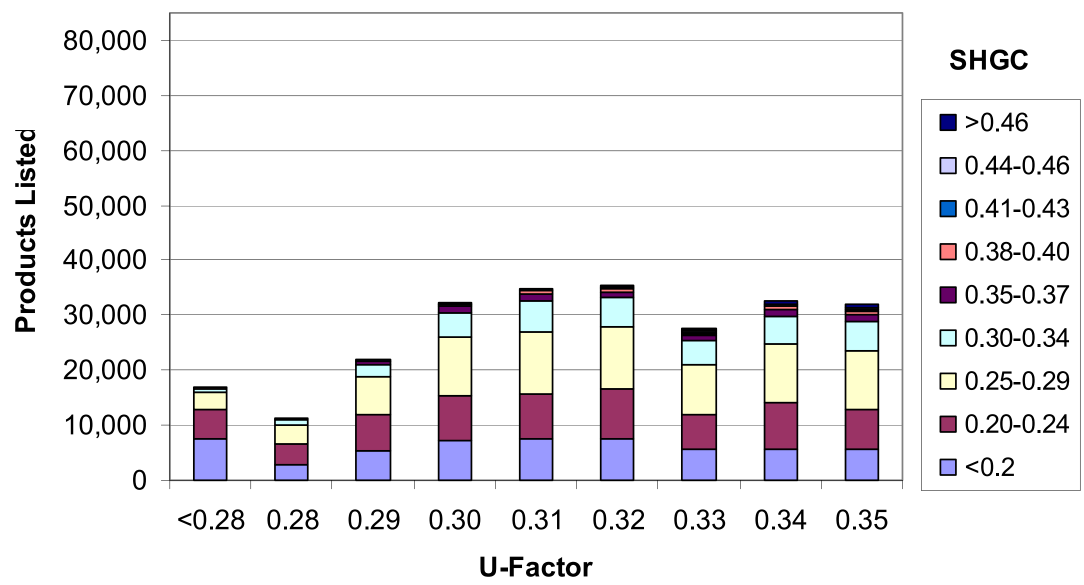
The NFRC CPD represents all products that manufacturers have tested, simulated, and listed with NFRC. Only a fraction of those products are actively marketed by manufacturers. To confirm the NFRC dataset is reasonably reflective of products available for sale, DOE gathered data on products with U-factors $\leq$ 0.35 available for sale online from a statistically valid sample of manufacturers. DOE chose varying sizes of manufacturers both within and beyond the CPD's Top 100. The methodology for this analysis is described in Appendix C.

Figure 9, Figure 10, and Table 8 show the distribution of products in the NFRC database and in the sample of products for sale are similar, although products just meeting the current ENERGY STAR Northern Zone criteria make up a greater proportion of products for sale.

Table 8: Comparison of NFRC's Certified Products Directory and Products for Sale

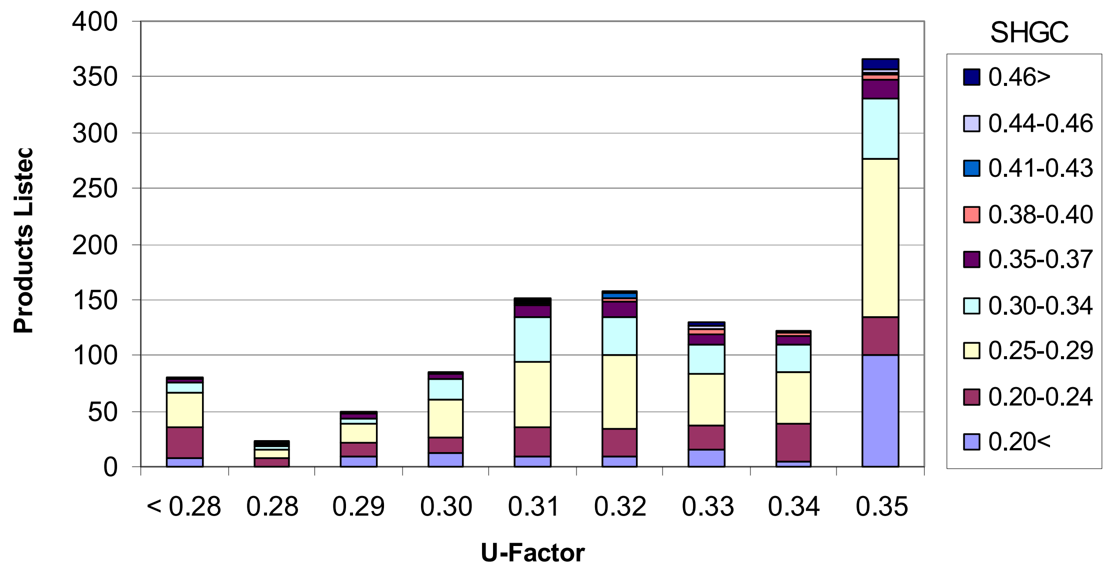
	Median U-Factor	Average U-Factor	Median SHGC	Average SHGC
NFRC CPD Directory	0.33	0.31 $\pm$ 0.03	0.25	0.25 $\pm$ 0.07
Windows Available for Sale	0.33	0.32 $\pm$ 0.03	0.27	0.27 $\pm$ 0.06

Figure 9: Vertical Sliders with U-Factor ≤ 0.35 in the NFRC Certified Product Directory



Source: D&R International, 2008. Based on analysis of vertical sliders in the NFRC CPD as of July 2008.

Figure 10: Vertical Sliders with U-Factors < 0.35 Listed for Sale Online



Source: D&R International, 2008. Based on analysis of products available for sale.

Composition of Qualifying Windows

Table 9 shows the common characteristics of windows qualifying for the proposed criteria. Qualification for Phase 1 will require using more efficient insulating glass package components.

Table 9: Typical Components of Windows Qualifying for Phase 1 ENERGY STAR Criteria by Zone

	ES1	ES2	ES3	ES4	ES5	ES5a
Frame Material	Vinyl Wood (non-aluminum clad) Aluminum-clad wood Aluminum Fiberglass	Vinyl Wood (non-aluminum clad) Aluminum clad Aluminum Fiberglass	Vinyl Wood (non-aluminum clad) Aluminum-clad wood Aluminum Composite Cellular	Vinyl Wood (non-aluminum clad) Aluminum-clad wood Aluminum Composite Cellular	Vinyl Wood (non-aluminum clad) Aluminum-clad wood Composite Aluminum Cellular	Vinyl and wood (non-aluminum clad) Aluminum-clad wood Composite Cellular
Lites	2	2	2	2	2	2 or 3
Glass - Emissivity	0.04 +/-0.20	0.04 +/-0.15	0.04 +/-0.15	0.04 +/-0.15	0.04 +/-0.15	0.04 +/-0.15
Gap Width (inches)	Range .21-1.06 68% ≥ 0.5	Range 0.21–1.06 71% ≥ 0.5	Range 0.25-0.75 80% ≥ 0.5	Range 0.25-0.75 81% ≥ 0.5	Range 0.25–0.75 59% ≥ 0.5	Range 0.36–0.75 64% ≥ 0.5
Gas Fill	59% use argon 27% use air 14% use krypton	66% use argon 11% use krypton 23% use air	81% use argon 5% use krypton 15% use air	82% use argon 5% use krypton 13% use air	84% use argon 5% use krypton 11% use air	70% use argon 18% use krypton 12% use air
Spacer*	46% foam spacers 29% tin-plated spacers 11% thermally improved spacers 8% stainless steel spacers	43% foam spacers 30% tin-plated spacers 12% thermally improved spacers 8% stainless steel spacers	30% non-metal/foam spacers 25% stainless steel spacers 16% metal-polymer 4% tin-plated	30% non-metal/foam spacers 21% stainless steel spacers 17% metal-polymer 5% tin-plated	30% non-metal/foam spacers 20% metal-polymer spacers 17% stainless steel 4% tin-plated	53% non-metal/foam spacers 24% stainless steel spacers

*Spacer construction was absent or ambiguous for 25% of products for sale data (ES3-ES5a). Spacers with frequencies less than 4% not reported.
D&R International, Ltd. 2008. Findings for ES1 and ES2 are based on analysis of the NFRC database. Findings for ES3, ES4, ES5, and ES5a are based on analysis of a sample of vertical sliders for sale with U-factors < 0.35. Data are consistent with manufacturer input.

For most zones, manufacturers whose products no longer qualify should be able to upgrade their glass packages to meet the new criteria without major redesign in most cases. Potential upgrades and associated performance improvements are summarized in Table 10.

Table 10: Potential Design Changes and Associated Performance Benefits

	Type of Change	U-Factor	SHGC
Spacer	Tin plated to stainless steel or foam, metal hybrid to polycarbonate or foam, etc.	-0.01 to -0.03	N/A
Gas Fill	Air to argon	-0.04	N/A
Glass	Higher to lower emissivity glass	-0.01	-0.05 to -0.10
	Lower to higher SHGC glass	0 to+0.02	+0.05 to +0.20
	Higher to lower SHGC glass	0 to -0.01*	-0.05 to -0.20
Frame Insulation	Inject large cavities with foam	+0.01 to +0.03	N/A

*If upgraded to triple silver-coated low-e or equivalent.

Only a subset of products with greater than a 0.30 U-factor can be upgraded to qualify for ES5a. Products sold in this zone will more frequently require argon gas fill, foam frame insulation, ultra-low emissivity glass, and highly insulating spacer systems.

Most windows qualifying in ES4 and ES5 use low-solar-gain low-e glass, but a minority of products will qualify by using moderate-solar-gain low-e glass. Manufacturers of low-SHGC windows with U-factors between 0.33 and 0.35 excluded under the proposed criteria should be able to qualify products by substituting a higher-solar-gain glass. In some cases, they may need to upgrade to a higher-performance spacer (e.g., from a tin-plated metal spacer to a stainless steel spacer) to maintain their U-factor performance.

Nearly all products currently qualifying in the South/Central and North/Central Climate Zones will qualify in ES2 and ES3 (85 and 72 percent, respectively). Many manufacturers can requalify products using one or more of the upgrades listed in Table 10.

Most manufacturers will be able to meet the new ES1 criteria at nominal cost by using newer lower solar gain low-e glass products that retain high visible transmittance. Continuous aluminum frame windows will not qualify.

4.2.3 Cost-Effectiveness

ENERGY STAR principles require homeowners to recover the increase marginal cost for efficient products with reduced energy bills over the lifetime of the product. More simply, the energy cost savings must pay for the increase in capital cost of the product over the life of the product.

The draft Phase 1 window criteria are cost-effective for nearly all consumers in all zones. Because the majority of products meeting current ENERGY STAR criteria also meet the proposed criteria, retail prices will increase little if at all in most zones. Lower energy costs will immediately pay back the additional costs of choosing ENERGY STAR over code-compliant windows in all zones except ES5a. In ES5a, utility rebates are expected to make products cost-effective. When there is a price premium, consumers will recover the added expense within 2 to 5 years through lower heating and cooling costs.

For the cost-effectiveness calculations, DOE estimated lifetime savings for each city by discounting average annual home savings for new and existing model homes, as calculated by RESFEN 6 over a 20-year period. DOE's assumptions included a cost of $250 per window, 24 windows per home, a 3-percent discount rate, no increase in real energy prices, and the marginal costs listed in Table 11. The savings-to-cost ratio was then calculated by comparing the discounted lifetime savings to the total marginal costs. Simple payback is total marginal cost divided by annual home energy savings. See Appendix D for a detailed description of how average cost savings for each city was calculated.

Half of manufacturers that agreed to share marginal cost data reported zero marginal cost to achieve performance levels meeting Phase I criteria in all zones except ES5a. The other half of manufacturers reported marginal costs of 5 to 7 percent to make those upgrades. Given that the majority (52–85 percent) of windows currently qualified for ENERGY STAR will qualify for Phase 1 in all zones except ES5a (Table 7), the draft ENERGY STAR criteria will lead to negligible increases in manufacturing cost or retail prices. Pricing pressure from these manufacturers is expected to keep increases in average retail prices in all of these zones close to zero, making Phase 1 of the draft criteria immediately cost-effective in all zones except ES5a.

For half of the manufacturers that shared marginal cost data for ES5a, current ENERGY STAR qualified windows already meet the draft ES5a criteria. Thus, these manufacturers again reported zero marginal cost. The remaining manufacturers sharing cost data stated they would need to increase wholesale prices by 15 percent to cover the cost of producing ES5a-qualifying windows. Despite pricing pressure from competitors, DOE assumes these manufacturers will have to pass two-thirds of this marginal cost to consumers as a price premium.

DOE's analysis indicates energy savings alone are insufficient to pay back the additional costs of buying the ES5a-qualified products with higher prices. However, for 80 percent of Oregonians, the $2.25-per-sq.-ft. rebate currently offered by the Energy Trust of Oregon will more than cover the marginal cost. Although the Bonneville Power Administration's current rebate level of $0.50 per sq. ft. is not large enough make up the difference between discounted lifetime savings and the price premium for residents living in western Washington State, Bonneville is considering increasing the rebate. A rebate of $1.50 per sq. ft. would bring simple payback down to 5.5 years in Seattle.

Although DOE expects marginal costs to be negligible in all regions except ES5a, even at a marginal cost of 3 percent, consumers will earn healthy returns on their investment in nearly all zones (Table 11). Consumer savings are 300–900 percent of costs in almost all ES1, ES2, ES4, and ES5 representative cities, and will have simple paybacks of 2 to 5 years. The investment is also cost-effective in ES3. Savings-to-cost ratios, however, are just shy of 100 percent because DOE chose to use a window with 0.35 U-factor as the 2006 IECC reference case. The performance of this window is more typical of available products than a window with the minimum 0.40 U-factor rating allowed under code.

Table 11 : Cost-Effectiveness of Phase 1 ENERGY STAR Window Criteria for Twenty Representative Cities When Marginal Cost is Not Zero						
Climate Zone	City	Annual Energy Cost Savings (dollars)	Marginal Cost Rate (percent)	Total Marginal Cost (dollars)	Savings to Cost Ratio (percent)	Simple Payback Period (years)
ES5a	Portland, OR	11.47	10	600	30	52.3
	Seattle, WA	10.94	10	600	29	54.8
ES5	Burlington, VT	85.95	3	180	752	2.1
	Madison, WI	68.11	3	180	596	2.6
	Minneapolis, MN	73.22	3	180	641	2.5
ES4	Boston, MA	85.49	3	180	748	2.1
	Chicago, IL	50.33	3	180	440	3.6
	Denver, CO	46.84	3	180	410	3.8
ES3	Albuquerque, NM	10.13	3	180	89	17.8
	Kansas City, MO	10.92	3	180	96	16.5
	San Francisco, CA	9.84	3	180	86	18.3
	Washington, DC	13.80	3	180	121	13.0
ES2	Atlanta, GA	33.85	3	180	296	5.3
	Ft Worth, TX	38.99	3	180	341	4.6
	Las Vegas, NV	43.69	3	180	382	4.1
	San Diego, CA	10.73	3	180	94	16.8
ES1	Tampa, FL	77.00	3	180	674	2.3
	Lake Charles, LA	75.74	3	180	663	2.4
	Phoenix, AZ	101.10	3	180	885	1.8

Source: D&R International, Ltd., 2008. Annual energy cost savings are the difference between the average of multiple simulations of Phase 2 ENERGY STAR and 2009 IECC reference skylights calculated using DOE2.E and RESFEN6 assumptions. DOE selected simulations that reflect the range of typical energy consumption of local housing stock for each city. Lifetime savings were calculated for 24 windows over 20 years at a 3-percent discount rate. Total marginal cost was calculated using the marginal cost rate for 24 windows with a base price of $250 per window. Total marginal cost is 3 percent of the window with a base price of $250 for all zones except ES5a, where it is 10 percent. Product price excludes installation. The savings-to-cost ratio is based on 20 years of annual energy cost savings, with a discount rate of 3 percent, over total marginal cost. The simple payback period is based on marginal cost divided by annual energy cost savings, with no discounting.

4.2.4 Market Impact

DOE expects Phase 1 of the window criteria to have little impact on price, product availability, or ENERGY STAR market share, except in ES1 and ES5a. Most manufacturers already have qualifying products (Table 12) or can adjust their glass packages to meet the draft criteria. Retail prices will remain relatively steady except in ES5a, which will keep ENERGY STAR market share near its current level. The ES5a market share may drop moderately, but only where EEPS rebates are not sufficient to cover the price premium.

The aggregate performance of windows sold in the United States is expected to increase. New criteria will raise the average performance of ENERGY STAR qualified windows. The criteria will also likely raise the average performance of non-qualified low-e windows because replacement window purchasers seeking efficiency will prefer windows with performance as close to ENERGY STAR as possible, if ENERGY STAR is not an option for them.

The selection of qualifying aluminum frame windows will be very limited in ES1 (Table 12) due to the much lower U-factor, unless the ICC relaxes the U-factor requirement for IECC Zone 2.

Manufacturing of single-IGU, aluminum-clad wood windows for ES5a is expected to be limited because it is difficult to design such products with U-factors of 0.30 or less. Triple-pane, aluminum-clad wood windows can easily meet a U-factor of 0.30.

Table 12: Proportion of Vertical Sliders in the NFRC CPD Meeting Current ENERGY STAR Criteria That Will Still Qualify Under Draft Phase 1 Window Criteria, by Framing Material

Climate Zone	Vinyl (percent qualified)	Aluminum-Clad Wood (percent qualified)	Wood & Wood-Clad (Non-Aluminum) (percent qualified)	Fiberglass (percent qualified)	Aluminum (percent qualified)
ES5a	34	16	23	57	0
ES5	70	50	57	78	1
ES4	70	50	57	78	1
ES3	63	56	56	71	0
ES2	84	90	84	88	1
ES1	55	68	60	63	5

Source: D&R International, Ltd., 2008. Analysis of products listed in NFRC CPD as of July 2008.

- Windows with moderate solar gain (SHGC 0.35–0.45) will be more readily available in ES3, 4, and 5, but DOE does not anticipate any measurable impact on peak electricity load. DOE expects these products will represent less than 7 percent of all sales. Only a portion of aluminum-clad wood window manufacturers will have to use this strategy to qualify their products. Aluminum-clad wood windows accounted for only 16 percent of window sales in 2007,[14] and manufacturers estimate that less than 5 percent of all windows sold today use high-solar-gain low-e glass.
- The draft criteria will make it more difficult for manufacturers to competitively market a single product offering that qualifies for all zones. It is possible to manufacture a window qualifying in all zones under the draft criteria ($U \leq 0.30$ and SHGC between 0.15 and 0.25), and in fact 18 percent of windows in the NFRC database meet these criteria. However, this product is likely to cost more than the typical product qualifying elsewhere, but not in the Pacific Northwest.
- Demand for lower-emissivity glass and highly insulating spacers may increase revenue to spacer and glass manufacturers, but will not provide a competitive advantage to any particular manufacturer. Nearly all manufacturers have or are capable of offering products with similar ranges of performance.
- Sales of units filled with argon gas will increase as manufacturers use this technology to achieve the lower U-factors demanded by the draft Phase 1 criteria.

[14] Ducker Research, 2008. Exhibit D.5 Conventional Residential Window Usage. *Study of the U.S. Market for Windows, Doors, and Skylights*, published by the American Architectural Manufacturers Association.

- In ES4 and ES5, some products will only qualify without grids, which typically lower SHGC by 0.04.

4.3 Window Criteria - Phase 2

Phase 2 of the draft ENERGY STAR criteria are technologically feasible, will deliver significant energy savings, are cost-effective, and require no proprietary technologies to qualify. Phase 2 of the draft ENERGY STAR criteria would lead to energy savings of 11.41 trillion BTUs—even greater energy savings than from Phase 1.

Manufacturers will be able to meet the criteria with existing technologies, even without krypton gas, which DOE assumes will no longer be a cost-effective technology option in 2013. Virtually all manufacturers will need to design and test new triple-pane products qualifying for ES4 and ES5. While many manufacturers can already produce windows meeting the Phase 2 criteria for ES1, ES2, and ES3, only a small number produce windows qualifying in ES4 or ES5 without krypton gas.

Consumers who purchase windows that qualify in Phase 2 after January 1, 2013 will recover their investment over the lifetime of the product. Through annual energy cost savings, DOE estimates payback anywhere from 2.5 to 20 years. Homeowners who move in 1 to 2 years will likely recover the residual marginal cost of their investment (or more) through a higher home sale price.[15]

Draft Phase 2 criteria for windows, effective January 1, 2013, are described in section 4 (Table 2, Figure 8, and Figure 7).

Table 13 presents Phase 1 and Phase 2 draft criteria and the proposed IECC 2009 criteria.

In Phase 2, DOE proposes lower U-factor criteria in all zones and lower SHGC criteria in ES1 but not ES2 or ES3. In ES1, reductions in solar gain produce large reductions in total energy consumption. In ES2, various climates display considerable variability in SHGC impact on energy consumption. In some climates, SHGC leads to significantly higher energy use; in other climates, changes in SHGC have little net effect on consumption. In some of these ES2 climates, heating can be significant. ES3 is similar to ES2, although the intensity of SHGC impacts is lower due to greater heating requirements.

Phase 2 criteria for ES4 and ES5 (Figure 5, Figure 6, Figure 7, and Figure 8) are significantly lower than in Phase 1, reflecting the performance potential of triple-pane windows. The Pacific Northwest is reincorporated into ES5. The U-factor and SHGC tradeoffs implicit in the ES4 and ES5 criteria remain the same: increases of 0.08 SHGC in ES 4 and 0.05 SHGC in ES5 provide energy benefits equivalent to a 0.01 reduction in U-factor.

[15] *Remodeling Magazine*'s 2007 cost vs. value study estimates that 80% of the investment for replacing a household of windows is recouped through increased home sale price.

Table 13: Comparison of Proposed 2009 IECC and Draft ENERGY STAR Window Criteria

	IECC		Draft ENERGY STAR Criteria					
			Phase 1			Phase 2		
Climate Zone	U-Factor	SHGC	U-Factor	SHGC	Energy Performance	U-Factor	SHGC	Energy Performance
ES5a**	≤ 0.35	NR	≤ 0.30	≤ 0.55	-	-	-	See Figure 7
ES5	≤ 0.35	NR	-	-	See Figure 5			
ES4	≤ 0.35	NR	-	-	See Figure 6	-	-	See Figure 8
ES3	≤ 0.35	NR	≤ 0.33	≤ 0.40	-	≤ 0.30	≤ 0.40	-
ES2	≤ 0.40	≤ 0.30	≤ 0.35	≤ 0.30	-	≤ 0.30	≤ 0.30	-
ES1	≤ 0.50	≤ 0.30	≤ 0.50	≤ 0.25	-	≤ 0.45	≤ 0.20	-

*Criteria based on aggregate annual energy performance, a maximum annual energy consumption benchmark that a window must not exceed in order to qualify.
**ES5a regions become part of ES5 in Phase 2.
Sources: DOE, *ENERGY STAR Windows, Doors, and Skylights Program Requirements for Residential Windows, Doors, and Skylights*, Version 4.0. May 14, 2007; International Code Council, *International Energy Conservation Code 2006;* International Code Council, *2007/2008 Proposed Changes to the International Energy Conservation Code.*

4.3.1 Energy Savings

The energy savings model developed by LBNL estimates implementation of Phase 2 of the draft criteria for ENERGY STAR windows would result in energy savings of 11.41 trillion BTU compared to the IECC 2009 scenario. These savings are 34 percent higher than the estimated savings from Phase 1 and almost double the annual primary energy savings estimated for the recent revision of the ENERGY STAR clothes washer criteria (Table 14).

These estimates represent minimum energy savings, because they are for ENERGY STAR windows at the minimum qualifying criteria and an assumed 25-percent national market share. DOE has assumed in its energy savings model that current ENERGY STAR market share will decrease to 45 percent in Phase 1, with Phase 2 market share dropping further to 25 percent only in ES4 and ES5, where price premiums are highest. The average performance of qualifying windows actually sold is certain to exceed the minimum requirements.

Energy savings represent the difference in estimated annual aggregate energy consumption of a 2009 IECC sales scenario and a Phase 2 ENERGY STAR sales scenario. See Appendix B for a detailed methodology and supporting data.

DOE evaluated the energy savings from the Phase 2 criteria relative to the proposed 2009 IECC criteria. Based on adoption rates for IECC 2003 and IECC 2006, IECC 2009 will be the dominant energy code in 2013, with more than half of the U.S. population living in jurisdictions that have adopted the 2009 IECC.[16]

Energy savings were calculated as described in section 4.2.1, except 2009 IECC and Phase 2 ENERGY STAR sales scenarios were substituted for the 2006 IECC and Phase 1 ENERGY STAR sales scenario.

Energy savings calculations for each scenario reflect the relative proportion and performance of windows sold. In the ENERGY STAR scenario, sales were estimated for windows meeting the minimum performance criteria for double clear glass windows, and for windows meeting current, Phase 1, and Phase 2 ENERGY STAR criteria for the 11 regions described in section 4.2.1. Regional market share for the scenarios is described in Appendix C. DOE assumed national ENERGY STAR market share of 25 percent for Phase 2 qualified windows. In the IECC 2009 scenario, all windows sold are either double clear glass or 2009 IECC-compliant.

Table 14: Annual Primary Energy Savings from Recent ENERGY STAR Criteria Revisions

Criteria Revision	Savings (tBTU)
Windows (Draft Criteria – Phase 2)	11.41
Windows (Draft Criteria – Phase 1)	8.51
Clothes Washers (2008)	5.85
Room A/C (2008)	3.41
Refrigerators (2008)	2.58
Dishwashers (2008)	2.08
Source: DOE, ENERGY STAR Program, 2008.	

The criteria generate savings in all climate zones (Table 15). Zones ES1 through ES4 contribute roughly equal shares of savings. ES5, with its smaller population, contributes about 15 percent of all savings (Table 15).

[16] D&R International, Ltd., 2008. Based on 2006 U.S. Census population estimates retrieved from http://quickfacts.census.gov/qfd/ and the Building Energy Codes Assistance Project's "State Code History," www.bcap-energy.org \node\123.

Table 15: Estimated Primary Energy Savings from Phase 2 of the Draft ENERGY STAR Window Criteria by Climate Zone			
Climate Zone	Consumption (tBTU)		Savings (tBTU)
	IECC 2009	ENERGY STAR Phase 2	
ES 5	30.92	29.49	1.43
ES 4	73.93	71.17	2.76
ES 3	61.68	59.46	2.22
ES 2	46.11	43.76	2.35
ES 1	34.03	31.39	2.64
National			**11.41**
Source: Lawrence Berkeley National Laboratory, 2008.			

One-quarter of total energy savings comes from heating energy savings, primarily in ES3, ES4, and ES5. Three-quarters of total savings comes from reduced cooling load, with ES1 providing over 40 percent of those savings (Table 16).

Table 16: Source of Primary Energy Savings for Phase 2 Window Criteria by Climate Zone			
Climate Zone	Heating Energy (tBTU)	Cooling Energy (tBTU)	Total Savings (tBTU)
ES 5	1.08	0.36	1.43
ES 4	1.64	1.11	2.76
ES 3	0.72	1.50	2.22
ES 2	0.39	1.96	2.35
ES 1	(0.84)[17]	3.49	2.64
National	**2.98**	**8.42**	**11.41**
Source: Lawrence Berkeley National Laboratory, 2008.			

4.3.2 Technological Feasibility

Based on stakeholder interviews and an analysis of NFRC-certified products and products qualified for ENERGY STAR in Canada, the proposed Phase 2 criteria are technologically feasible.[18] Products qualifying in all zones are available for purchase (Table 17).

[17] In ES1, energy use is predominantly cooling-load driven, and the key to obtaining total energy savings is to reduce cooling energy. SHGC is the primary driver in reducing cooling energy. Dropping the SHGC from 0.30 to 0.25 (Phase I) and to .20 (Phase 2) reduces cooling energy substantially. This decrease in SHGC has a small negative effect on heating energy (which benefits from a higher SHGC). However, since heating energy is a small fraction of total energy use, total energy use clearly benefits from the proposed change.

[18] The ENERGY STAR Canada database was used in analysis only for Phase 2 windows, because the criteria in Canada are much more stringent than current ENERGY STAR criteria or draft criteria for Phase 1.

Table 17: Vertical Sliders Listed in the NFRC CPD and ENERGY STAR Canada's Database Qualifying for Phase 2 Window Criteria*	
Climate Zone	**Total Number of Qualifying Products**
ES 5	4,881
ES 4	7,123
ES 3	46,632
ES 2	40,788
ES 1	15,480**

*Krypton-filled and quad-pane windows are not included in these numbers.
**ENERGY STAR Canada's (Canadian) Database contains no products with U-factors greater than 0.35. Only NFRC records for products with U-factors < 0.30 were used in this analysis.
Source: D&R International, Ltd., 2008. Analysis of Canadian database of ENERGY STAR qualified products and of all products with U-factors < 0.30 listed in the NFRC Certified Product Directory. The U-factor and SHGC for both data sets use the same testing procedures (NFRC 100 and NFRC 200).

The great majority of products currently qualifying for ES4 and ES5 use krypton gas fill to achieve ultra-low U-factors. However, 30 manufacturers have tested or simulated 50 products qualifying for the proposed ES4 and ES5 criteria that do not use krypton gas (Table 18).

Table 18: Vertical Sliders Listed in the NFRC CPD and ENERGY STAR Canada's Database Qualifying in ES4 and ES5		
Climate Zone	ES4	ES5
Total Number of Products Qualifying	7,055	4,824
Qualifying Quad-Panes Excluded	1,190	1,041
Qualifying Krypton Fills Excluded	4,395	3,203
Total Number of Products Qualifying	1,470	580
Total Number of "Unique"* Windows	57	46
Total Number of Manufacturers	37	29

*"Unique" windows are separate models, differentiated by more than simple glass or grid options.
Source: D&R International, Ltd., 2008. Analysis of all products with U-factors < 0.30 listed in the NFRC CPD.

DOE excluded krypton as a cost-effective option when assessing the technological feasibility for Phase 2 criteria. The price for krypton gas today is 100 times that of argon and has quadrupled in the last 2 years. Industry analysts predict demand for krypton will increase 8.1 percent each year over the next 3 years.[19] Contributing to this demand is the use of krypton in lasers, light bulbs, halogen headlights, and 30 percent of British and

[19] The Freedonia Group, 2008. *Noble Gases – Krypton*. http://www.freedoniagroup.com/FractionalDetails.aspx?DocumentId=361909.

German energy-efficient windows.[20] According to industrial gas suppliers serving the window industry, the gas is now in such short supply that some suppliers no longer offer it to new customers.[21]

Windows qualifying in ES1 will use similar construction to that of windows qualifying there for Phase 1 but will use glass with lower SHGC. Products qualifying for Phase 2 criteria in ES2 and ES3 will have the same characteristics as those qualified for ES5a in Phase 1.

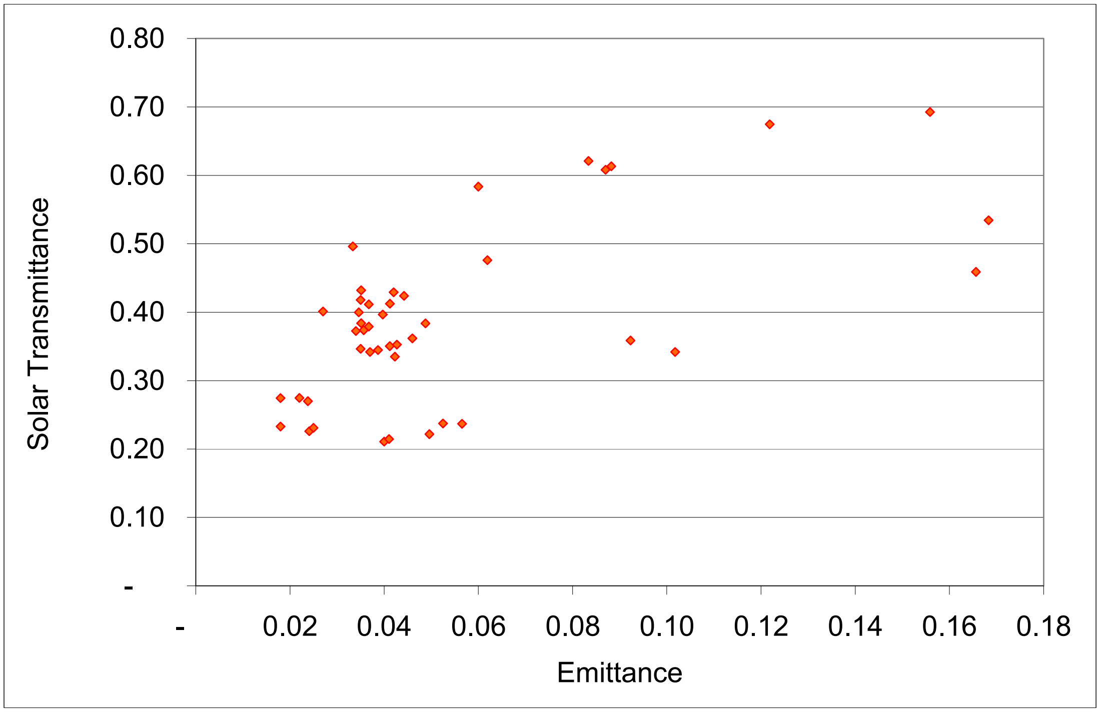
Table 19, Table 20, Table 21, and Table 22 show products qualifying in ES4 and ES5 without krypton do so by carefully designing triple-pane windows using mainstream technologies. Manufacturers use a variety of design strategies, but most qualifying windows use common framing materials and similar component assemblies: insulating framing material (vinyl, wood, or fiberglass), three lites of glass, argon gas fill, a single pane of low-e coated glass with an emissivity of 0.30–0.40, a low-emissivity spacer, and a gap width of 0.34" +/-0.11". Several qualifying products use a combination of air and argon gas fill or only air with a wider gap (Table 20 and Table 22). A few double-pane products are even able to qualify for ES5 (Table 19 and Table 21).

Most products that currently qualify with krypton gas have too narrow a gap width to qualify without a major redesign. (All gap widths are 0.29" to 0.328".) However, over 11,000 products, including aluminum-clad products, have U-factors < 0.28 but fail to qualify for ES5 because their SHGC is too low. Over 4,000 products with U-factors < 0.25 fail to qualify for ES4 for the same reason. Some, and possibly many, of these products may be able to qualify by changing the glass and spacer technologies (e.g., by replacing a low-SHGC, low-e with a higher-SHGC glass with a similar emissivity). Most low-emissivity glass products are also low SHGC, with emittance of 0.25 to 0.45 and solar transmittance of 0.21 to 0.35. However, there are glass products available with similar emittance but notably higher solar transmittance, e.g. emittance/solar transmittance 0.27/0.40, 0.35/0.43 that manufacturers might use to raise SHGC with little impact on U-factor (Figure 10).

[20] Praxair Technology, Inc, 2008. *Krypton Applications*. http://www.praxair.com/praxair.nsf/AllContent/C98AE71047137106052565660054433C?OpenDocument&URLMenuBranch=C02384720F10F9958525706F0028BC9A.

[21] D&R International, Ltd., 2008. Interviews with industrial gas suppliers.

Figure 11: Emittance and Solar Transmittance of Commercially Available Glass Products



Source: Lawrence Berkeley National Laboratory, 2008.

Table 19: Components of Windows Qualifying and Nearly Qualifying for ES4 Phase 2			
	Qualified		**Nearly Qualified***
Gas Fill	Argon or Air	Krypton/ Krypton+ Other	Argon or Air
Qualified Products (number)	1,482	4,370	4,022
Frame Material (percent)			
Vinyl	82.25	87.62	75.76
Vinyl, insulated	3.17	11.10	7.56
Wood, vinyl-clad wood, wood composite	9.02	0.16	4.90
Aluminum-clad wood, aluminum, and wood combination	0	0	9.87
Fiberglass	0.81	0.98	0
Other	4.73	0.14	1.91
Spacer (percent)			
Coated Steel	23.82	33.57	36.20
Silicone Foam	25.30	40.11	24.56
Stainless Steel	12.21	8.88	15.19
Thermo-Plastic/Stainless Steel	12.75	8.67	14.32
Thermo-Plastic	2.43	3.04	2.34
Aluminum	12.82	0.57	4.87
Other	10.67	5.16	2.52
Lites (percent)			
Two	0	2.00	0.65
Three	100.00	99.98	99.35
Number of Low-E Coated Surfaces (percent)			
None	0.07	0.80	4.53
One	87.04	86.73	88.64
Two	12.08	10.69	5.92
Three	0	1.78	0.92

*Windows with U-factor $\leq$ 0.26, but with SHGC too low to qualify.

Source: D&R International, Ltd., 2008. Analysis of vertical sliders in the NFRC CPD with combinations of U-factors < 0.26 and SHGC of any level that qualify for Phase 2 ES4 window criteria.

Table 20: Gas Fill and Gap Width for Windows Qualifying or Nearly Qualifying for ES4 Phase 2*					
Gas Fills			**Qualified**		**Nearly Qualified***
		Gases Used	Argon/Air	Krypton/Air/ Argon	Argon/Air
Both Argon		Frequency	49.25%	-	42.39%
	Gap Width (inches)	Median	0.34	-	0.307
		Range	0.261–0.603	-	0.228–0.678
Argon and Air		Frequency	37.14%	-	14.37%
	Gap Width (inches)	Median	0.5	-	1.701
		Range	0.29–1.863	-	0.219–1.94
Both Air		Frequency	13.61%	-	43.24%
	Gap Width (inches)	Median	0.563	-	0.366
		Range	0.306–1.85	-	0.125–1.863
Air and Argon/Krypton/Air Mix		Frequency	-	1.56%	-
	Gap Width (inches)	Median	-	0.321	-
		Range	-	0.29–0.328	-
Both Argon/Krypton/Air Mix		Frequency	-	5.10%	-
	Gap Width (inches)	Median	-	0.328	-
		Range	-	0.248–0.37	-
Argon and Krypton		Frequency	-	0.27%	-
	Gap Width (inches)	Median	-	0.295	-
		Range	-	0.295–0.295	-
Air and Krypton		Frequency	-	9.73%	-
	Gap Width (inches)	Median	-	0.313	-
		Range	-	0.188–0.366	-
Both Krypton		Frequency	-	83.34%	-
	Gap Width (inches)	Median	-	0.307	-
		Range	-	0.188–0.375	-

*U ≤ 0.26, but SHGC too low.
Source: D&R International, Ltd., 2008. Analysis of vertical sliders in the NFRC CPD with combinations of U-factors ≤ 0.26 and SHGC of any level that qualify for Phase 2 ES4 window criteria.

Table 21: Components of Windows Qualifying and Nearly Qualifying for ES5 Phase 2			
	Qualified		Nearly Qualified*
Gas Fill	Argon or Air	Krypton/ Krypton & Other	Argon or Air
Qualified Products	578	3,182	11,726
Frame Material (percent)			
Vinyl	77.34	84.32	77.6
Vinyl, insulated	3.98	14.24	12.2
Wood, vinyl-clad wood, wood composite	11.07	0.06	2.5
Aluminum-clad wood, aluminum, and wood combination	0	0	5.64
Fiberglass	1.38	1.16	0.07
Other	6.23	0.22	1.99
Spacer (percent)			
Coated Steel	26.3	30.04	21.05
Silicone Foam	21.8	38.65	45.21
Stainless Steel	11.94	10.09	10.13
Thermo-Plastic/Stainless Steel	2.77	10.84	10.60
Thermo-Plastic	2.6	3.52	2.98
Aluminum	13.32	0.57	3.01
Other	21.27	6.29	7.02
Lites (percent)			
Two	1.21	0.03	46.96
Three	98.79	99.97	53.04
Number of Low-E Coated Surfaces (percent)			
None	1.73	0.66	5.02
One	81.14	89.09	80.72
Two	17.47	8.83	13.72
Three	0	1.41	0.54

*U $\leq$ 0.28, but SHGC too low.
Source: D&R International, Ltd., 2008. Analysis of vertical sliders in the NFRC CPD with combinations of U-factors $\leq$ 0.28 and SHGC of any level that qualify for Phase 2 ES5 window criteria.

Table 22: Gas Fill and Gap Width for Windows Qualifying or Nearly Qualifying for ES5 Phase 2*					
Gas Fills			**Qualified**		**Nearly Qualified***
		Gases Used	Argon/Air	Krypton/Air/ Argon	Argon/Air
Both Argon		Frequency	36.16%	-	68.61%
	Gap Width (inches)	Median	0.37	-	0.5
		Range	0.25–0.603	-	0.228–1.067
Argon and Air		Frequency	49.31%	-	10.46%
	Gap Width (inches)	Median	0.563	-	0.563
		Range	0.246–1.863	-	0.219–1.94
Both Air		Frequency	14.53%	-	20.93%
	Gap Width (inches)	Median	0.603	-	0.366
		Range	0.5–1.86	-	0.125–1.94
Air and Argon/ Krypton/Air Mix		Frequency	-	0.28%	-
	Gap Width (inches)	Median	-	0.328	-
		Range	-	0.29–0.328	-
Both Argon/ Krypton/Air Mix		Frequency	-	2.45%	-
	Gap Width (inches)	Median	-	0.33	-
		Range	-	0.248–0.37	-
Argon and Krypton		Frequency	-	0.25%	-
	Gap Width (inches)	Median	-	0.295	-
		Range	-	0.295–0.295	-
Air and Krypton		Frequency	-	7.23%	-
	Gap Width (inches)	Median	-	0.313	-
		Range	-	0.188–0.366	-
Both Krypton		Frequency	-	89.79%	-
	Gap Width (inches)	Median	-	0.307	-
		Range	-	0.188–0.375	-

*U $\leq$ 0.28, but SHGC too low.
Source: D&R International, Ltd., 2008. Analysis of vertical sliders in the NFRC CPD with combinations of U-factors$\leq$ 0.28 and SHGC of any level that qualify for Phase 2 ES5 window criteria.

4.3.3 Cost-Effectiveness

Based on stakeholder marginal cost data and energy cost savings in 20 representative cities, DOE finds Phase 2 of the draft ENERGY STAR criteria is cost-effective.

Consumers who do not move from their homes will recover the marginal cost of these windows through reduced heating and cooling costs over the lifetime of the product, even when future savings are discounted. The only exceptions are climates with limited heating and cooling loads, as in San Diego, (Table 23).

DOE's estimate of 15 percent marginal cost for triple-pane windows meeting the Phase 2 ES4 and ES5 criteria is based on a high-volume production scenario. This figure is based on the difference in material costs and wholesale prices provided by two manufacturers currently producing large volumes of double- and triple-pane windows.

DOE forecasts the marginal cost to produce windows qualifying in ES2 and ES3 at 5 percent. For the most part, these windows will be identical to those qualifying for ES5a in Phase 1. Given the historic rate of price deflation for energy-efficient windows, DOE expects the marginal cost to produce these windows will decline from 10 percent in 2009 to 5 percent in 2013 as manufacturers innovate and compete.

Savings-to-cost ratios, excluding San Diego, range from 101-644 percent. Savings are greatest in ES1 and ES2, yielding simple paybacks of approximately 2.5–4.5 years. Savings-to-cost ratios are lower in ES4 and ES5. While these super-efficient windows offer double the annual energy cost savings of windows qualifying in ES1, ES2, and ES3, the marginal costs are threefold.

Consumers in ES3, ES4, and ES5 who install ENERGY STAR qualified windows after January 1, 2013 will recover the entire marginal cost of their installation in as little as two to three years if they sell their home. *Remodeling Magazine* consistently reports homeowners recover approximately 80 percent of the cost of window replacement through increased home value. The 80-percent cost recovery figure holds for both moderate and high-end (low-e) replacements, and in high-cost and low-cost markets.[22] It follows that those homeowners who sell their homes after upgrading to ENERGY STAR qualified windows will also recover 80 percent of the marginal cost of choosing ENERGY STAR. They will likely recoup the remaining 20 percent from heating and cooling cost savings (Table 24).

[22] Hanley Wood, LLC, 2007. "Cost vs. Value Study 2007," *Remodeling Magazine*, http://www.costvsvalue.com/index.html.

Table 23: Cost-Effectiveness of Phase 2 ENERGY STAR Window Criteria in Twenty Representative Cities for Homeowners That Do Not Sell Their Homes						
Climate Zone	**City**	**Annual Home Savings (dollars)**	**Marginal Cost Rate (percent)**	**Total Marginal Cost (dollars)**	**Savings to Cost Ratio (percent)**	**Simple Payback Period (years)**
ES5	Portland, OR	60.39	15	900	106	14.9
	Seattle, WA	57.57	15	900	101	15.6
	Burlington, VT	124.90	15	900	219	7.2
	Madison, WI	101.32	15	900	177	8.9
	Minneapolis, MN	105.92	15	900	185	8.5
ES4	Boston, MA	123.15	15	900	216	7.3
	Chicago, IL	74.72	15	900	131	12.0
	Denver, CO	70.38	15	900	123	12.8
ES3	Albuquerque, NM	25.32	5	300	133	11.8
	Kansas City, MO	27.30	5	300	143	11.0
	San Francisco, CA	24.59	5	300	129	12.2
	Washington, DC	34.49	5	300	181	8.7
ES2	Atlanta, GA	70.80	5	300	372	4.2
	Ft Worth, TX	64.63	5	300	339	4.6
	Las Vegas, NV	76.39	5	300	401	3.9
	San Diego, CA	16.10	5	300	85	18.6
ES1	Tampa, FL	93.35	5	300	490	3.2
	Lake Charles, LA	93.03	5	300	488	3.2
	Phoenix, AZ	122.70	5	300	644	2.4

Source: D&R International, Ltd., 2008. Annual energy cost savings are the difference between the average of multiple simulations of Phase 2 ENERGY STAR and 2009 IECC reference skylights calculated using DOE2.E and RESFEN6 assumptions. DOE selected simulations to reflect the range of typical energy consumption of local housing stock for each city. Lifetime savings were calculated for 24 windows over 20 years at a 3-percent discount rate. Total marginal cost was calculated using the marginal cost rate for 24 windows with a base price of $250 per window. Total marginal cost is 5 percent of the window with a base price of $250 for all zones except ES4 and ES5, where it is 15 percent. Product price excludes installation. The savings-to-cost ratio is based on 20 years of annual energy cost savings, with a discount rate of 3 percent, over total marginal cost. The simple payback period is based on marginal cost divided by annual energy cost savings, with no discounting.

Table 24: Cost-Effectiveness of Phase 2 ENERGY STAR Window Criteria in Twenty Representative Cities for Homeowners That Sell Their Homes						
Climate Zone	**City**	**Annual Energy Cost Savings (dollars)**	**Total Marginal Cost (dollars)**	**Recouped Cost (dollars)**	**Adjusted Marginal Cost (dollars)**	**Simple Payback Period (years)**
ES5	Portland, OR	60.39	900	720	180	1.4
	Seattle, WA	57.57	900	720	180	1.8
	Burlington, VT	124.90	900	720	180	1.7
	Madison, WI	101.32	900	720	180	3.0
	Minneapolis, MN	105.92	900	720	180	3.1
ES4	Boston, MA	123.15	900	720	180	1.5
	Chicago, IL	74.72	900	720	180	2.4
	Denver, CO	70.38	900	720	180	2.6
ES3	Albuquerque, NM	25.32	300	240	60	2.4
	Kansas City, MO	27.30	300	240	60	2.2
	San Francisco, CA	24.59	300	240	60	2.4
	Washington, DC	34.49	300	240	60	1.7
ES2	Atlanta, GA	70.80	300	240	60	0.8
	Fort Worth, TX	64.63	300	240	60	0.9
	Las Vegas, NV	76.39	300	240	60	0.8
	San Diego, CA	16.10	300	240	60	3.7
ES1	Tampa, FL	93.35	300	240	60	0.6
	Lake Charles, LA	93.03	300	240	60	0.6
	Phoenix, AZ	122.70	300	240	60	0.5

Source: D&R International, Ltd., 2008. Annual Energy Cost Savings calculated using RESFEN 6 assumptions. Total Marginal Cost based on data provided by six window manufacturers. Recouped cost based on rate of 80 percent calculated by *Remodeling Online*, "Cost Vs. Value Report 2007." http://costvalue.remodelingmagazine.com/index.html. Simple payback period based on adjusted marginal cost divided by annual energy cost savings, with no discounting.

4.3.4 Market Impacts

- DOE expects Phase 2 of the window criteria to have some impact on price and product availability and to notably reduce ENERGY STAR market share in ES4 and ES5. Some manufacturers already have qualifying products, but the great majority will need to invest in new design, testing, and production methods in order to offer triple-pane products for ES4 and ES5—and, in some cases, to offer qualified double-pane products for ES2 and ES3.
- Retail prices will increase modestly in ES1, ES2, and ES3, but more sharply in ES4 and ES5. However, DOE will work to ensure increased costs in ES4 and ES5 are moderated by utility incentives.
- The aggregate performance of windows sold in the United States is expected to increase due to improved performance of the average ENERGY STAR window; consumer selection of higher-performing, non-qualified low-e windows; and tightening of the IECC, enabled by market transformation during Phase 1.

- No proprietary technologies are required to meet the proposed criteria.
- Sales of triple-pane windows will likely rise in the northern United States and possibly elsewhere, although the rate of that rise and market share for ENERGY STAR qualified windows will depend on the level of utility incentives.
- Sales of moderate-solar-gain low-e glass will increase due to the use of this glass in products that qualify in ES4 and ES5.
- Windows with moderate solar gain (SHGC 0.35–0.45) and high solar gain (SHGC 0.46–0.55) will be more readily available in ES4 and ES5. Moderate-solar-gain products will be more readily available only in ES3. Some stakeholders have expressed concern that criteria permitting use of moderate- and high-solar-gain products will lead to higher overall peak load than would be the case if SHGC were capped at a lower level. However, despite the fact the criteria do allow such products to qualify, DOE does not anticipate any measurable impact on peak load. DOE expects these products will represent less than 7 percent of all sales. Unless glass technology changes dramatically, most windows will use glass products with solar transmittance < 0.40. These solar transmittance levels will yield whole-window SHGCs < 0.40, the level set under the current ENERGY STAR criteria to ensure solar control in the southern United States.
- As in Phase 1, demand for high-performance spacers and lower-emissivity glass may increase revenue to spacer and glass manufacturers, but will not provide a competitive advantage to any particular manufacturer. Nearly all manufacturers have or are capable of offering products with similar ranges of performance. In ES4 and ES5, some products will qualify only without grids, which typically lower SHGC by 0.04.
- Manufacturers distributing products to the northern part of the country as well as more central and southern regions and wish to offer an ENERGY STAR qualified option will have to offer at least two standard glass packages: double and single IGU. It will be possible to design a triple-pane window that qualifies everywhere, but it is unlikely to be cost-competitive with single IGU products in the central and southern region of the country.

5 Draft ENERGY STAR Criteria for Swinging Entry Doors

For the first time, DOE is proposing separate criteria for swinging entry doors to provide differentiation between more and less efficient products, deliver additional national energy savings, and drive further technological development in the market. The draft criteria for swinging doors are shown in Table 25.

Table 25: Draft ENERGY STAR Criteria for Swinging Entry Doors

Glazing	Phase 1		Phase 2	
	U-Factor	SHGC	U-Factor	SHGC
Opaque	≤ 0.21	NR	≤ 0.16	NR
≤ ½-Lite	≤ 0.25	≤ 0.30	≤ 0.20	≤ 0.30
> ½-Lite	≤ 0.32	≤ 0.30	≤ 0.28	≤ 0.30

Swinging entry doors: A door 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. ENERGY STAR recognizes three categories of doors:

- **Opaque:** No lite.
- **≤ ½-Lite:** A swinging entry door with ≤ 29.8% glazing. Includes ¼-lite and ½-lite doors.
- **½-Lite:** A swinging entry door with > 29.8% glazing. Includes ¾-lite and fully glazed doors.

Products must be NFRC rated, certified, and labeled for U-factor and SHGC. Glazed doors using a sealed IGU must have IGU certification once NFRC IGU certification is implemented.

Historically, DOE focused its analysis on optimizing criteria for windows, because they represent the great majority of fenestration sales. DOE then extended these criteria to allow for qualification of swinging entry doors to ensure consumers could purchase fenestration products meeting at least a minimum performance level. As a result, most doors—even uninsulated doors—have qualified for ENERGY STAR. ENERGY STAR has thus not provided adequate differentiation for or stimulated the development of increasingly efficient swinging entry doors.

Swinging entry doors represent 16–17 percent of all fenestration shipments[23] and a similar proportion of installed residential fenestration products.[24] Requiring higher performance for doors than windows will generate additional energy savings for homeowners and the country. Doors can and do perform better than windows: opaque doors, for example, regularly achieve U-factors of 0.23, lower than currently required by IECC or the draft Phase 1 ENERGY STAR window criteria.

The proposed criteria levels vary by glazing area rather than climate zone. Climatic conditions and level of glazing both play a role in the energy performance of installed doors. Theoretically, criteria tailored both to glazing area and climate zone would deliver the greatest energy savings. However, the complex door manufacturing process in which

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[23] AAMA/WDMA 2001, 2003, 2005, 2007.
[24] NAHB, 2004. *Housing Facts, Figures and Trends*.

products are frequently manufactured in two stages (slab and hanging) by different companies requires a relatively easy-to-apply system that could be accurately and consistently applied in such a two-step process.

DOE selected three proposed glazing categories to generate additional energy savings while maintaining simplicity. Opaque doors are capable of significantly better performance than glazed doors and represent approximately half of the door market. U-factor levels for < ½-lite and > ½-lite are set at levels readily achievable by existing products. Products with intermediate glazing levels, e.g., ¼- and ¾-lite, represent such a small share of the door market[25] that few savings are gained by establishing separate criteria for them. Since the proposed criteria apply for all climate zones, DOE specified an SHGC maximum that will balance the negative impacts of solar gain in the South with the positive benefits of solar gain in the North.

The proposed Phase 1 criteria ensure ENERGY STAR differentiates doors with superior energy performance. Phase 2 criteria levels ensure ENERGY STAR continues to drive technological development in the market. The analysis shows the new criteria system can deliver significant savings. In addition, the proposed Phase 1 criteria are technologically feasible and can be achieved at little to no additional cost.

Phase 2 criteria are technologically feasible, generate additional energy savings, and are cost-effective in about half of the 20 cities DOE evaluated. Cost-effectiveness is very sensitive to both marginal cost and energy prices. DOE expects marginal costs to decline as manufacturers innovate and compete in the intervening years. DOE will recalculate cost-effectiveness in 2011 to ensure the criteria are cost-effective for the majority of purchasers and, if not, adjust the criteria accordingly.

The following sections examine in detail the conditions for the proposed door criteria.

5.1 Energy Savings Potential

The draft criteria will offer positive energy savings. Table 26, shows the proposed door criteria exceed both 2006 and proposed 2009 IECC code and most of the proposed ENERGY STAR window criteria in both phases. Increased performance will maximize the potential savings that doors offer.

[25] Manufacturer data indicates that ¼- and ¾-lites each represent < 10 percent of the market.

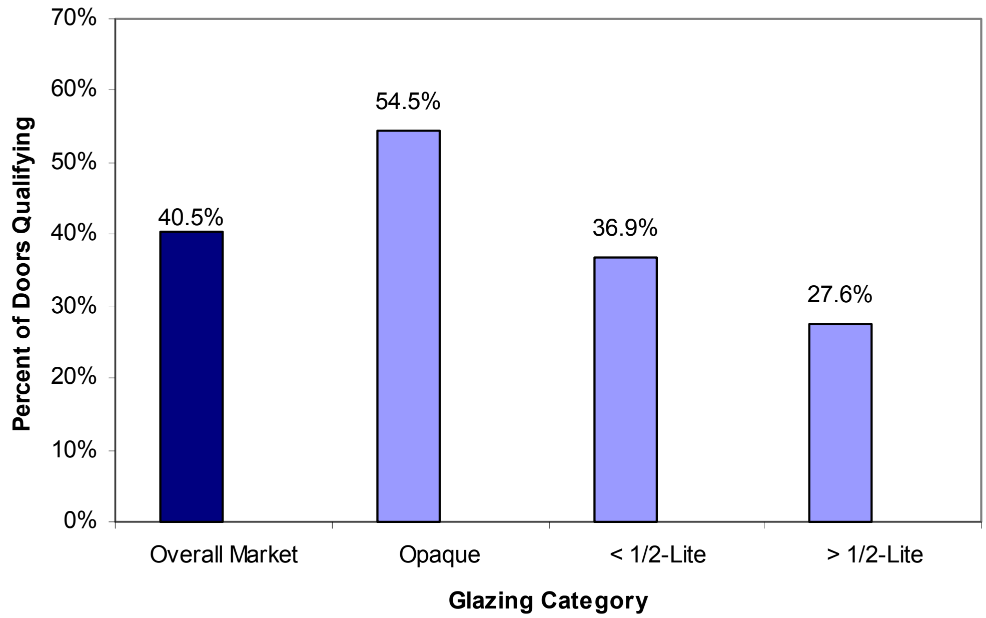
Table 26: Context for Draft ENERGY STAR Door Criteria						
Climate Zone	2006 IECC		Proposed 2009 IECC		Current ENERGY STAR	
	U-Factor	SHGC	U-Factor	SHGC	U-Factor	SHGC
ES5a	≤ 0.35	NR	≤ 0.35	NR	≤ 0.35	NR
ES5	≤ 0.35	NR	≤ 0.35	NR	≤ 0.35	NR
ES4	≤ 0.35	NR	≤ 0.35	NR	≤ 0.35	NR
ES3	≤ 0.40	NR	≤ 0.35	NR	≤ 0.40	≤ 0.55
ES2	≤ 0.65	≤ 0.40	≤ 0.40	≤ 0.30	≤ 0.40	≤ 0.40
ES1	≤ 0.75	≤ 0.40	≤ 0.50	≤ 0.30	≤ 0.65	≤ 0.40
Draft ENERGY STAR Criteria for Swinging Entry Doors						
Climate Zone	**Glazing Category**	**Phase 1**		**Phase 2**		
		U-Factor	SHGC	U-Factor	SHGC	
All	Opaque	≤ 0.21	NR	≤ 0.16	NR	
All	≤ ½-Lite	≤ 0.25	≤ 0.30	≤ 0.20	≤ 0.30	
All	> ½-Lite	≤ 0.32	≤ 0.30	≤ 0.28	≤ 0.30	

Sources: International Code Council, 2006. *International Energy Conservation Code 2006*; International Code Council, 2008; *2007/2008 Proposed Changes to the International Energy Conservation Code; DOE*, *ENERGY STAR Windows, Doors, and Skylights Program Requirements for Residential Windows, Doors, and Skylights--Version 4.0*. May 14, 2007.

5.2 Technological Feasibility

Based on conversations with manufacturers and an analysis of door products listed in the NFRC product database, the proposed swinging door criteria are technologically feasible. [0] Fully 40 percent of 174,588 swinging doors in the NFRC database as of January 2008 already meet the Phase 1 criteria levels and 20 percent qualify for Phase 2 (Figure 12).

Figure 12: Percentage of Swinging Entry Doors Qualifying for Proposed Criteria



Source: D&R International, Ltd., 2008. Based on analysis of 174,588 unique door records listed in the NFRC Certified Product Directory as of February 2008.

Doors qualifying under the proposed criteria share common characteristics both within and across glazing categories: they primarily use insulated cores and insulating glass units. Some > ½-lite doors qualify without insulated cores and many require low-e glass to qualify.

Table 27: Characteristics of Doors Qualifying Under Phase 1 Criteria

Opaque		≤ ½-Lite		> ½-Lite	
Core/ Fill	77% PU 21% EXP 1% EXT	Core/ Fill	85% PU 7% EXP 7% EXT	Core/ Fill	59% UI 31% PU 5% Solid wood 5% EXP 1% EXT
		Glazing Layers	82% Double pane 18% Triple pane	Glazing Layers	85% Double pane 14% Triple pane 1% Quad pane 0.03% Single pane
		Glass	65% Clear glass 15% Low-e 14% Tinted glass	Glass	37% Clear glass 36% Low-e 24% Tinted glass

PU: polyurethane; EXT: extruded polystyrene; EXP: expanded polystyrene; UI: uninsulated
Source: D&R International, Ltd., 2008. Based on analysis of 174,588 unique door records listed in the NFRC Certified Product Directory as of February 2008.

Table 28: Characteristics of Doors Qualifying Under Phase 2 Criteria					
Opaque		**≤ ½-Lite**		**> ½-Lite**	
Core/ Fill	98% PU 2% EXP	Core/ Fill	96% PU 4% EXP	Core/ Fill	67% PU 26% UI 6% EXP 1% Solid wood
		Glazing Layers	66% Triple pane 34% Double pane	Glazing Layers	59% Double pane 39% Triple pane 2% Quad pane 0.1% Single pane
		Glass	83% Clear glass 12% Low-e 3% Tinted glass	Glass	75% Clear glass 12% Low-e 9% Tinted glass
Source: D&R International, Ltd., 2008. Based on analysis of 174,588 unique door records listed in the NFRC Certified Product Directory as of February 2008.					

5.3 Cost-Effectiveness

Based on data provided by manufacturers and DOE's analysis of unique doors listed in the NFRC database, the Phase 1 and Phase 2 draft criteria are cost-effective.

Nearly 70,000 doors listed in the NFRC database already qualify under Phase 1 and nearly 35,000 doors qualify for Phase 2. Manufacturers report many additional doors can be upgraded at little cost to qualify for Phase 1 (Table 29). Upgrades for Phase 1 will typically involve the addition of core insulation and/or low-e glass.[26] While the marginal costs for this change vary by glazing category and manufacturer, manufacturers indicate the costs translate into price increases for consumers of zero to 5 percent. For the many manufacturers who already produce doors meeting the proposed criteria, such as opaque doors, the marginal cost is zero. As a result, pricing pressure will result in negligible price increases for the consumer across all products.

Table 29: Marginal Costs for Proposed Criteria Changes				
Glazing Level	**Phase 1**		**Phase 2**	
	Avg. Cost Increase	Marginal Cost	Avg. Cost Increase	Marginal Cost
Opaque	0%	$0	N/A	N/A
≤ ½-Lite	4%	$20	14%	$70
> ½-Lite	5%	$25	15%	$75
* Average cost increase is based on data provided by three leading door manufacturers. Marginal cost is based on retail price of $500. Price does not include installation costs. Source: Manufacturer interviews, D&R International, Ltd., 2008.				

[26] Manufacturer interviews, D&R International, Ltd., 2008.

Design changes for Phase 2 will be slightly more extensive, involving a change to the insulation or glazing package. Manufacturers indicate the marginal costs to make these changes will be higher: while marginal costs for opaque doors are not available, manufacturers estimate the costs for ½- or ¼-lite doors at 14 percent, and for ¾-lites and fully glazed doors 15 percent.[27] DOE expects these costs will decrease as technology advances over the next four years.

On the other side of the cost-effectiveness equation are consumer energy cost savings resulting from the new door criteria. DOE's analysis of a sample of U.S. cities shows that, with the exception of San Francisco, Phase 1 yields average annual savings of $1−$9 per door Phase 2 will yield additional incremental savings of $1−$10 per door (Table 30).

[27] Manufacturer interviews, D&R International, Ltd., 2008. D&R asked five door manufacturers to share marginal cost data with confidentiality guaranteed under a non-disclosure agreement. Three manufacturers decided to provide data.

Table 30: Annual Energy Savings in a Sample of Cities		
	Average Annual Savings for Opaque Doors ($)	
City	**Phase 1**	**Phase 2**
AZ_Phoenix	8.73	6.14
CA_San_Diego	0.95	1.24
CA_San_Francisco	-4.80	-3.77
CO_Denver	2.16	3.57
DC_Washington	2.00	3.21
FL_Tampa	7.86	5.70
GA_Atlanta	5.42	2.63
IL_Chicago	4.93	6.60
LA_Lake_Charles	6.99	5.01
MA_Boston	5.62	8.25
MI_Detroit	4.43	6.18
MN_Minneapolis	5.48	7.47
MO_Kansas City	2.25	3.31
NM_Albuquerque	0.30	1.40
NV_Las_Vegas	8.44	4.97
NY_Buffalo	7.65	10.27
NJ_Atlantic_City	2.00	3.38
OR_Portland	2.32	3.42
PA_Philadelphia	1.99	3.39
PA_Pittsburgh	5.26	7.12
TN_Nashville	2.53	3.37
TX_Fort_Worth	8.46	4.75
VT_Burlington	6.21	8.89
WA_Seattle	1.31	2.49
WI_Madison	5.28	7.34

D&R International, Ltd., 2008. Annual energy cost savings are the difference between the average of multiple simulations of an ENERGY STAR and IECC reference door calculated with RESFEN 5. DOE selected simulations that reflect the range of typical energy consumption of local housing stock for each city. Savings for Phase 1 are relative to the 2006 IECC. Savings for Phase 2 are relative to the proposed 2009 IECC.

DOE calculated the cost-effectiveness for doors as a minimum/maximum range for payback period. Because manufacturers estimated the marginal cost to produce Phase 1 qualifying doors to be zero, opaque doors are immediately cost-effective and consumers benefit from lifetime savings of $5 to $138 across the sample of cities evaluated (Table 31). Because opaque doors represent 50 percent of the total market, the new criteria are guaranteed to deliver energy savings on half of all door sales.[28]

At the other end of the spectrum, the maximum payback period is represented by the > ½-lite category, which has both the greatest marginal cost and the lowest annual savings. These estimates are derived from the savings per square foot of windows meeting the Phase 1 ENERGY STAR window criteria. They are conservative for all cities except

[28] Manufacturer interviews, D&R International, Ltd., 2007–2008.

those in the central and southern regions of most portions of the country because the glazed door criteria exceed window criteria in these cities. The estimates for cities in the Midwest and Northeast are realistic because the criteria are equivalent. For ES5a, they are likely overestimates because the glazed door criteria are less stringent than the draft window criteria.

DOE estimates that savings over the lifetime of a > ½-lite door range between $9 and $88, with the exception of San Francisco. Consumers will recover the price premium over the product's lifetime for most doors in this category, with payback periods ranging from 4–13 years. Homeowners in some cities outside the Pacific coast see only partial paybacks due to the moderate climate or small difference between the ENERGY STAR and IECC criteria in these regions. Sales in this door category represent about 25 percent of the door market.[29] Savings and payback for the ≤ ½-lite category are expected to fall between the savings of the opaque and > ½-lite categories. DOE expects manufacturer innovation and competitive pressure to ultimately bring costs for fully glazed products within an effective range.

For Phase 2, manufacturers predicted slightly higher costs to make the necessary technology changes, but the Phase 2 criteria will still be cost-effective in most locations in the country. With lifetime savings for opaque doors ranging from $20–$140, most opaque doors pay for the price premium within the product's lifetime. The exceptions will again be temperate climates and regions with low energy costs, but due to the predominance of opaque doors in the market, the new criteria are guaranteed to deliver important energy savings.

The minimum savings scenario, represented by the > ½-lite category, has higher marginal costs to overcome in Phase 2. Savings again are conservatively estimated using ENERGY STAR Phase 2 window savings per sq. ft. normalized for a larger door area. However, because the Phase 2 window criteria in ES4 and ES5 exceed the glazed door criteria, they can no longer be used to estimate savings. Savings estimates are therefore only available for ES1, ES2, and ES3. With a few exceptions, glazed doors yield lifetime savings of $20–$97. The savings pay back the price premium in only about one-quarter of the country, but again these cases do not detract from overall savings due to their small market presence. In this case, too, DOE expects manufacturer innovation and competitive pressure to ultimately bring costs within an effective range.

[29] Manufacturer interviews, D&R International, Ltd., 2007–2008.

Table 31: Payback Period for Swinging Entry Doors – Phase 1 Minimum						
Energy Savings Zone	**City**	**Annual Energy Cost Savings ($)**	**Lifetime Savings ($, discounted)**	**Total Marginal Cost ($)**	**Savings to Cost Ratio**	**Simple Payback Period (years)**
ES5a	Portland, OR	2.32	36.54	-	No Costs	0.00
	Seattle, WA	1.31	20.63	-	No Costs	0.00
ES5	Burlington, VT	6.21	97.81	-	No Costs	0.00
	Madison, WI	5.28	83.16	-	No Costs	0.00
	Minneapolis, MN	5.48	86.31	-	No Costs	0.00
ES4	Boston, MA	5.62	88.52	-	No Costs	0.00
	Chicago, IL	4.93	77.65	-	No Costs	0.00
	Denver, CO	2.16	34.02	-	No Costs	0.00
ES3	Albuquerque, NM	0.30	4.73	-	No Costs	0.00
	Kansas City, MO	2.25	35.44	-	No Costs	0.00
	San Francisco, CA	(4.80)	(75.60)	-	No Costs	0.00
	Washington, DC	2.00	31.50	-	No Costs	0.00
ES2	Atlanta, GA	5.42	85.37	-	No Costs	0.00
	Ft Worth, TX	8.46	133.25	-	No Costs	0.00
	Las Vegas, NV	8.44	132.94	-	No Costs	0.00
	San Diego, CA	0.95	14.96	-	No Costs	0.00
ES1	Tampa, FL	7.86	123.80	-	No Costs	0.00
	Lake Charles, LA	6.99	110.10	-	No Costs	0.00
	Phoenix, AZ	8.73	137.50	-	No Costs	0.00

Source: D&R International, Ltd., 2008. Savings based on savings per sq. ft. for draft ENERGY STAR Phase 1 criteria for windows normalized to reflect a 20-sq.-ft. door. Phase 1 window criteria are used to estimate minimum savings in all zones for which they are equivalent to or less stringent than the Phase 1 > ½-lite door criteria.

Table 32: Payback Period for Swinging Entry Doors – Phase 1 Maximum

Energy Savings Zone	City	Annual Energy Cost Savings ($)	Lifetime Savings ($, discounted)	Total Marginal Cost ($)	Savings to Cost Ratio (%)	Simple Payback Period (years)
ES5a	Portland, OR	0.64	66.28	25.00	265	5.94
	Seattle, WA	0.61	88.47	25.00	354	4.45
ES5	Burlington, VT	4.78	38.23	25.00	153	10.30
	Madison, WI	3.78	9.39	25.00	38	41.94
	Minneapolis, MN	4.07	67.38	25.00	270	5.84
ES4	Boston, MA	4.75	12.08	25.00	48	32.61
	Chicago, IL	2.80	29.62	25.00	118	13.29
	Denver, CO	2.60	34.12	25.00	136	11.54
ES3	Albuquerque, NM	0.56	40.99	25.00	164	9.61
	Kansas City, MO	0.61	8.86	25.00	35	44.42
	San Francisco, CA	0.55	9.56	25.00	38	41.21
	Washington, DC	0.77	8.61	25.00	34	45.73
ES2	Atlanta, GA	1.88	59.60	25.00	238	6.61
	Ft Worth, TX	2.17	64.07	25.00	256	6.15
	Las Vegas, NV	2.43	74.81	25.00	299	5.26
	San Diego, CA	0.60	44.04	25.00	176	8.94
ES1	Tampa, FL	4.28	10.04	25.00	40	39.23
	Lake Charles, LA	4.21	9.57	25.00	38	41.13
	Phoenix, AZ	5.62	75.21	25.00	301	5.24

Source: D&R International, Ltd., 2008. Combined analysis of RESFEN 5.0 runs, energy savings analysis (also performed by D&R), manufacturer interviews for marginal costs, and survey of advertised and published door prices.

Table 33: Payback Period for Swinging Entry Doors – Phase 2 Minimum						
Energy Savings Zone	**City**	**Annual Energy Cost Savings ($)**	**Lifetime Savings ($, discounted)**	**Total Marginal Cost**	**Savings to Cost Ratio (%)**	**Simple Payback Period (years)**
ES5	Burlington, VT	8.89	140.02	50.00	280	5.62
	Madison, WI	7.34	115.61	50.00	231	6.81
	Minneapolis, MN	7.47	117.66	50.00	235	6.69
	Portland, OR	3.42	53.87	50.00	108	14.62
	Seattle, WA	2.49	39.22	50.00	78	20.08
ES4	Boston, MA	8.25	129.94	50.00	260	6.06
	Chicago, IL	6.60	103.95	50.00	208	7.58
	Denver, CO	3.57	56.23	50.00	112	14.01
ES3	Albuquerque, NM	1.40	22.05	50.00	44	35.71
	Kansas City, MO	3.31	52.13	50.00	104	15.11
	San Francisco, CA	(3.77)	(59.38)	50.00	-119	No Savings
	Washington, DC	3.21	50.56	50.00	101	15.58
ES2	Atlanta, GA	2.63	41.42	50.00	83	19.01
	Ft Worth, TX	4.75	74.82	50.00	150	10.53
	Las Vegas, NV	4.97	78.28	50.00	157	10.06
	San Diego, CA	1.24	19.53	50.00	39	40.32
ES1	Tampa, FL	5.70	89.78	50.00	180	8.77
	Lake Charles, LA	5.01	78.91	50.00	158	9.98
	Phoenix, AZ	6.14	96.71	50.00	193	8.14

Source: D&R International, Ltd., 2008. Savings are based on savings per sq. ft. for draft ENERGY STAR Phase 2 criteria for windows normalized to reflect a 20-sq.-ft. door. Phase 2 window criteria are used to estimate minimum savings in all zones for which they are equivalent to or less stringent than the Phase 2 ≥ ½-lite criteria for doors. Phase 2 window criteria in ES4 and ES5 exceed Phase 2 door criteria and cannot be used as a proxy.

Table 34: Payback Period for Swinging Entry Doors – Phase 2 Maximum						
Energy Savings Zone	**City**	**Annual Energy Cost Savings ($)**	**Lifetime Savings ($, discounted)**	**Total Marginal Cost ($)**	**Savings to Cost Ratio (%)**	**Simple Payback Period (years)**
ES5	Burlington, VT	6.94	66.84	75.00	89	17.67
	Madison, WI	5.63	14.09	75.00	19	83.85
	Minneapolis, MN	5.88	81.68	75.00	109	14.46
	Portland, OR	3.36	81.40	75.00	109	14.51
	Seattle, WA	3.20	107.37	75.00	143	11.00
ES4	Boston, MA	6.84	30.18	75.00	40	39.14
	Chicago, IL	4.15	61.95	75.00	83	19.07
	Denver, CO	3.91	56.55	75.00	75	20.89
ES3	Albuquerque, NM	1.41	61.59	75.00	82	19.18
	Kansas City, MO	1.52	22.16	75.00	30	53.32
	San Francisco, CA	1.37	23.89	75.00	32	49.45
	Washington, DC	1.92	21.52	75.00	29	54.90
ES2	Atlanta, GA	3.93	52.84	75.00	70	22.35
	Ft Worth, TX	3.59	50.38	75.00	67	23.45
	Las Vegas, NV	4.24	107.76	75.00	144	10.96
	San Diego, CA	0.89	65.38	75.00	87	18.07
ES1	Tampa, FL	5.19	109.29	75.00	146	10.81
	Lake Charles, LA	5.17	88.66	75.00	118	13.32
	Phoenix, AZ	6.82	92.68	75.00	124	12.75
Source: D&R International, Ltd., 2008. Combined analysis of RESFEN 5.0 runs, energy savings analysis (also performed by D&R), manufacturer interviews for marginal costs, and survey of advertised and published window prices.						

5.4 *Market Impact*

Based on analysis of the NFRC database, almost half of advertised products are likely to qualify at the Phase 1 proposed criteria levels and about one-fifth for Phase 2. Consumers will continue to have a range of door products available to them in the three major door slab materials and at each glazing level (Table 11).

Table 35: Qualified Doors by Slab Material & Glazing Category			
Glazing Category	**Slab Material**		
	Steel (%)	Fiberglass (%)	Solid Wood (%)
Opaque	60.1	59.8	44.4
≤ ½-Lite	18.9	30.7	55.2
> ½-Lite	30.6	28.8	44.2
Total Phase 1	34.5	30.9	46.3
Opaque	1.4	18.6	43.7
≤ ½-Lite	0.5	1.8	8.1
> ½-Lite	4.8	8.6	15.3
Total Phase 2	2.7	5.5	17.8
Source: D&R International, Ltd., 2008. Based on analysis of 174,588 unique door records listed in the NFRC Certified Product Directory as of February 2008.			

Across both phases, most uninsulated and single-pane doors will no longer qualify, possibly leading to a decline in sales of these products. The exception would be solid wood doors, whose beauty and allure should protect their market share. There will also likely be a shift toward triple-pane doors, although it will not be strictly necessary to meet the criteria levels.

The overall performance of non-qualifying doors is likely to increase as those products strive to stay competitive with doors performing at increasingly stringent ENERGY STAR levels. The proposed criteria will fulfill ENERGY STAR's goals: to identify products with superior energy efficiency and serve as a marketing tool for retailers and manufacturers.

6 Draft ENERGY STAR Criteria for Skylights

DOE is also proposing new criteria for skylights. The criteria will yield moderate improvements in skylight performance despite the product's relatively low market share (2 percent of the total fenestration market) and limited energy savings opportunities.[30] DOE is not establishing criteria for tubular daylighting devices due to limitations in the existing test procedure.

DOE proposes the following criteria for skylights:

Table 36: Draft Criteria for ENERGY STAR Qualified Skylights

	Proposed for Phase 1		Proposed for Phase 2	
Climate Zone	U-Factor	SHGC	U-Factor	SHGC
ES 5a	≤ 0.50	NR	≤ 0.42	NR
ES 5	≤ 0.50	NR	≤ 0.42	NR
ES 4	≤ 0.50	NR	≤ 0.42	NR
ES 3	≤ 0.55	≤ 0.40	≤ 0.47	≤ 0.30
ES 2	≤ 0.55	≤ 0.30	≤ 0.47	≤ 0.20
ES 1	≤ 0.55	≤ 0.30	≤ 0.57	≤ 0.20

Skylight: A window designed to provide daylighting and/or ventilation for sloped or horizontal applications.

Products must be NFRC rated, certified, and labeled for U-factor and SHGC. Products that use a sealed IGU must have IGU certification once NFRC IGU certification is fully implemented.

The following analysis shows the energy savings, technological feasibility, cost-effectiveness, and market impact support the proposed criteria changes for both phases of the criteria revision for skylights.

6.1 Tubular Daylighting Devices

A physical test procedure exists for Tubular Daylighting Devices (TDDs), but NFRC has determined the approved simulation method does not accurately model product performance.[31] DOE will set ENERGY STAR criteria for TDDs when there is a sufficient body of physical test results on which to determine relative performance.

6.2 Energy Savings Potential

Table 37 shows the proposed skylight criteria, which go beyond IECC 2006 and proposed IECC 2009. The criteria will encourage superior product performance, maximizing the

[30] Ducker Research, 2008. *Study of the U.S. Market for Windows, Doors, and Skylights.* American Architectural Manufacturers Association and Window and Door Manufacturers Association.
[31] Architectural Testing, Inc., 2006. *Experimental U-Factor Research to Validate NFRC Simulation Procedure for Tubular Daylighting Devices (TDD).*

potential savings that skylights offer. Despite the market's small size, the resulting energy savings will be valuable.

Table 37: Context for Draft ENERGY STAR Criteria for Skylights

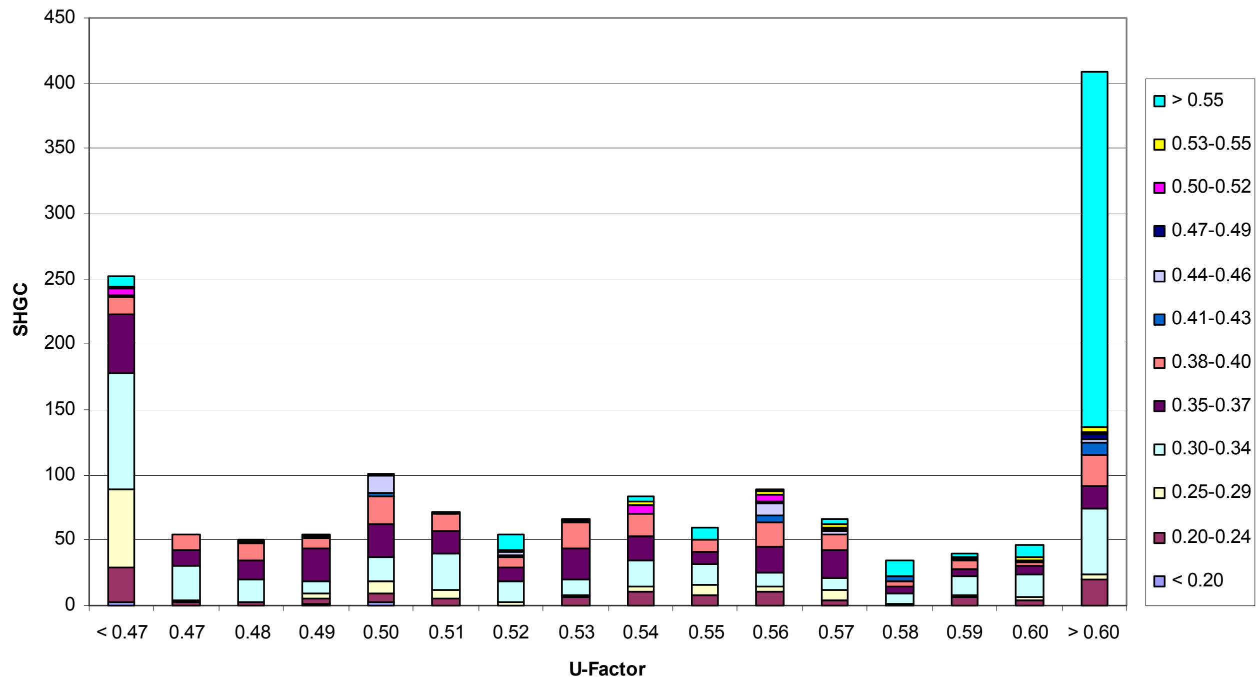
					Draft Criteria			
	Current ENERGY STAR and 2006 IECC		Proposed 2009 IECC		Phase 1		Phase 2	
Climate Zone	U-Factor	SHGC	U-Factor	SHGC	U-Factor	SHGC	U-Factor	SHGC
ES 5a	≤ 0.60	NR	≤ 0.60	NR	≤ 0.50	NR	≤ 0.42	NR
ES 5	≤ 0.60	NR	≤ 0.60	NR	≤ 0.50	NR	≤ 0.42	NR
ES 4	≤ 0.60	NR	≤ 0.60	NR	≤ 0.50	NR	≤ 0.42	NR
ES 3	≤ 0.60	≤ 0.40	≤ 0.60	NR	≤ 0.55	≤ 0.40	≤ 0.47	≤ 0.30
ES 2	≤ 0.60	≤ 0.40	≤ 0.65	≤ 0.30	≤ 0.55	≤ 0.30	≤ 0.47	≤ 0.20
ES 1	≤ 0.75	≤ 0.40	≤ 0.75	≤ 0.30	≤ 0.55	≤ 0.30	≤ 0.57	≤ 0.20

Sources: DOE, *ENERGY STAR Windows, Doors, and Skylights Program Requirements for Residential Windows, Doors, and Skylights*--Version 4.0. May 14, 2007; International Code Council, 2006. International Energy Conservation Code 2006; International Code Council, 2008. 2007/2008 Proposed Changes to the International Energy Conservation Code.

6.3 Technological Feasibility

Industry feedback indicates the proposed criteria for skylights are technologically feasible. Figure 1 shows the performance range of the 1,538 certified skylights listed in the NFRC CPD as of September 2007. Analysis of these products confirms 53 percent of them already qualify at the criteria levels proposed for Phase 1, and 12 percent continue to qualify at the levels proposed for Phase 2.

Figure 13: Skylights Listed in the NFRC Certified Product Directory



Source: D&R International, Ltd., 2008. Based on analysis of 1,538 unique skylight records in the NFRC Certified Product Directory as of September 2007.

Manufacturers suggested modifications required for Phase 1 could be as simple as changing the IGU unit.[32] DOE's interviews with manufacturers and analysis of the NFRC Directory confirm manufacturers can build skylights to meet the proposed criteria with a slight change to the glass package (Table 38). For Phase 2, changes include a change to the glass package and spacer. Glass products and spacers capable of delivering the lower U-factors and SHGCs are readily available in the marketplace today.

[32] Mary Louise Pace of Circle Redmont, Inc., in "DOE Completes Initial Analysis for Doors and Skylights," *DWM News*, May 19, 2008.

Table 38: Characteristics of Qualifying Skylights		
	Phase 1	**Phase 2**
Frame Material	Aluminum, aluminum-clad wood, vinyl, wood, and wood composite	Aluminum, aluminum-clad wood, vinyl, wood, and wood composite
Gap Width (in.)	Range: 0.246–2.634 60% at 0.5 and above	Range: 0.246–2.625 15% at 0.5 and above
Gas Fill	74% use argon 25% use air 0.5% use other 0.1% use krypton	72% use argon 28% use air
Spacer	49% stainless steel 34% aluminum 11% tin-plated	75% stainless steel 21% aluminum
Spacers with frequencies less than 4% not reported. Source: D&R International, Ltd., 2008. Based on data from manufacturer interviews and the NFRC Certified Product Directory.		

6.4 Cost-Effectiveness

Because the criteria levels have been proposed to reflect currently available skylight performance, only some skylights require modest, technologically feasible upgrades. The resulting energy savings, however, offset the resulting cost increases.

DOE estimates the costs for these upgrades to be 3 percent, but these costs are more than offset by the energy cost savings resulting from the new skylight criteria. Analysis of a sample of U.S. cities shows that with the exception of San Francisco, Phase 1 yields average annual savings of up to $3 per skylight (Table 39). Phase 2 will yield additional incremental savings of $1–$6 per skylight.

Table 39: Annual Skylight Savings in a Sample of Cities		
	Average Annual Savings	
City	Phase 1	Phase 2
AZ_Phoenix	$0.69	$1.48
CA_San_Diego	$0.42	$0.97
CA_San_Francisco	$0.83	$1.11
CO_Denver	$1.64	$3.15
DC_Washington	$1.07	$2.69
FL_Tampa	$1.26	$1.37
GA_Atlanta	$0.94	$2.11
IL_Chicago	$2.11	$3.96
LA_Lake_Charles	$1.10	$1.47
MA_Boston	$3.09	$5.94
MI_Detroit	$2.12	$3.98
MN_Minneapolis	$2.46	$4.63
MO_Kansas City	$0.80	$2.10
NM_Albuquerque	$0.72	$1.82
NV_Las_Vegas	$1.49	$2.51
NY_Buffalo	$3.15	$5.93
NJ_Atlantic_City	$1.67	$2.82
OR_Portland	$1.24	$2.41
PA_Philadelphia	$1.11	$2.89
PA_Pittsburgh	$2.30	$4.30
TN_Nashville	$0.64	$1.90
TX_Fort_Worth	$1.46	$2.35
VT_Burlington	$3.01	$5.80
WA_Seattle	$1.18	$2.37
WI_Madison	$2.51	$4.72

D&R International, Ltd., 2008. Annual energy savings are the difference between the average of multiple simulations of an ENERGY STAR and IECC reference skylights calculated with RESFEN 5. DOE selected simulations that reflect the range of typical energy consumption of local housing stock for each city. Savings for Phase 1 are relative to the 2006 IECC; savings for Phase 2 are relative to the proposed 2009 IECC.

These savings mean Phase 1 skylight criteria are cost-effective for most of the country. For skylights needing modifications to qualify for Phase 1, the change is a modest upgrade in glass package, similar to the change required for windows in Phase 1. DOE estimates the cost increase for the skylight change to be zero. Consumers will therefore experience immediate savings of $7–$49 in most zones during Phase 1 over the lifetime of the skylight. Payback in ES4 and ES5 will be within 5–7 years, well within the lifetime of the skylight and the 7-year timeframe homeowners typically stay in their homes. The two exceptions are Portland and Seattle, where payback will take 12 years due to low energy prices and temperate climates.

Phase 2 requirements in ES1, ES2, and ES3 also require no costs, so the payback there is immediate as well. In the northern zones, however, meeting the criteria will require more extensive modifications, such as changing spacers. DOE estimates the costs in those zones to be 6 percent. This level of marginal cost extends the payback period, but the changes are still cost-effective across the cities studied, yielding lifetime savings of $15–$94. With the exceptions of northwestern cities, the payback periods are well within the 20-year skylight lifetime, ranging from 5–13 years.

Table 40: Payback Period for Skylights – Phase 1

ENERGY STAR Zone	City	Annual Energy Cost Savings ($)	Lifetime Savings ($, discounted)	Total Marginal Cost ($)	Savings-to-Cost Ratio (%)	Simple Payback Period (years)
ES5a	Portland, OR	1.24	19.53	15.00	130	12.10
	Seattle, WA	1.18	18.59	15.00	124	12.71
ES5	Burlington, VT	3.01	47.41	15.00	316	4.98
	Madison, WI	2.51	39.53	15.00	264	5.98
	Minneapolis, MN	2.46	38.75	15.00	258	6.10
ES4	Boston, MA	3.09	48.67	15.00	324	4.85
	Chicago, IL	2.11	33.23	15.00	222	7.11
	Denver, CO	1.64	25.83	15.00	172	9.15
ES3	Albuquerque, NM	0.72	11.34	-	No Costs	0.00
	Kansas City, MO	0.80	12.60	-	No Costs	0.00
	San Francisco, CA	0.83	13.07	-	No Costs	0.00
	Washington, DC	1.07	16.85	-	No Costs	0.00
ES2	Atlanta, GA	0.94	14.81	-	No Costs	0.00
	Ft Worth, TX	1.46	23.00	-	No Costs	0.00
	Las Vegas, NV	1.49	23.47	-	No Costs	0.00
	San Diego, CA	0.42	6.62	-	No Costs	0.00
ES1	Tampa, FL	1.26	19.85	-	No Costs	0.00
	Lake Charles, LA	1.10	17.33	-	No Costs	0.00
	Phoenix, AZ	0.69	10.87	-	No Costs	0.00

Source: D&R International, Ltd., 2008. Annual energy cost savings are the difference between the average of multiple simulations of Phase 1 ENERGY STAR and 2006 IECC reference skylights calculated with RESFEN 5. DOE selected simulations that reflect the range of typical energy consumption of local housing stock for each city. Lifetime savings were calculated over 20 years at a 3-percent discount rate. Total marginal cost is 3 percent of the skylight with a base price of $500. Product price excludes installation. The savings-to-cost ratio was calculated by comparing lifetime savings to the total marginal cost. The simple payback period was calculated by dividing the total marginal cost by the annual energy cost savings, with no discounting.

Table 41: Payback Period for Skylights – Phase 2						
ENERGY STAR Zone	**City**	**Annual Energy Cost Savings ($)**	**Lifetime Savings ($, discounted)**	**Total Marginal Cost ($)**	**Savings-to-Cost Ratio (%)**	**Simple Payback Period (years)**
ES5	Burlington, VT	5.80	91.35	30.00	305	5.17
	Madison, WI	4.72	74.34	30.00	248	6.36
	Minneapolis, MN	4.63	72.93	30.00	243	6.48
	Portland, OR	2.41	37.96	30.00	127	12.45
	Seattle, WA	2.37	37.33	30.00	124	12.66
ES4	Boston, MA	5.94	93.56	30.00	312	5.05
	Chicago, IL	3.96	62.37	30.00	208	7.58
	Denver, CO	3.15	49.61	30.00	165	9.52
ES3	Albuquerque, NM	1.82	28.67	-	No Costs	0.00
	Kansas City, MO	2.10	33.08	-	No Costs	0.00
	San Francisco, CA	1.11	17.48	-	No Costs	0.00
	Washington, DC	2.69	42.37	-	No Costs	0.00
ES2	Atlanta, GA	2.11	33.23	-	No Costs	0.00
	Ft Worth, TX	2.35	37.01	-	No Costs	0.00
	Las Vegas, NV	2.51	39.53	-	No Costs	0.00
	San Diego, CA	0.97	15.28	-	No Costs	0.00
ES1	Tampa, FL	1.37	21.58	-	No Costs	0.00
	Lake Charles, LA		23.15	-	No Costs	0.00
		1.48	23.31	-	No Costs	

Source: D&R International, Ltd., 2008. Annual energy cost savings are the difference between the average of multiple simulations of Phase 2 ENERGY STAR and 2009 IECC reference skylights calculated with RESFEN 5. DOE selected simulations that reflect the range of typical energy consumption of local housing stock for each city. Lifetime savings were calculated over 20 years at a 3-percent discount rate. Total marginal cost is 6 percent of the skylight with a base price of $500. Product price excludes installation. The savings-to-cost ratio was calculated by comparing lifetime savings to the total marginal cost. The simple payback period was calculated by dividing the total marginal cost by the annual energy cost savings, with no discounting.

6.5 Market Impact

DOE expects the market impact of the proposed criteria to be minimal. Phase 1 qualifying products are already widely available, because over half of today's skylights already qualify for proposed Phase 1 levels.

Although there are fewer qualifying models currently listed in the NFRC database for Phase 2, DOE expects that with time to make technological improvements, qualifying products will be readily available by the time Phase 2 criteria go into effect in 2013. ENERGY STAR market share may decline somewhat in ES4 and ES5 due to the price premium, but DOE expects aggregate skylight performance to rise, because qualified products will make non-qualifying products appear to perform much worse in comparison.

7 Glossary

Certified Product Directory (CPD)	A directory of fenestration products in electronic form, listing fenestration products and their performance ratings, for which product certification authorization has been granted by a licensed IA, and can be searched by the public.
CPD	See Certified Product Directory
Dynamic glazing product	Any fenestration product that has the fully reversible ability to change its performance properties, including U-factor, SHGC, or VT. This includes, but is not limited to, shading systems between the glazing layers and chromogenic glazing.
EEPS	See Energy Efficiency Program Sponsor
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 adoption of energy conservation measures.[33]
Gap width	The distance between two adjacent glazing surfaces.
Glazing	The glass in a fenestration product. This report uses the term "lite" to describe entry door glazing. See Lite.[34]
IECC	See International Energy Conservation Code
IGU	Insulated Glass Unit
IGU certification	A third party certification of IGU performance. Official DOE definition for ENERGY STAR will follow NFRC.[35]
Impact-resistant windows	Windows that use glass designed to meet local and state structural building code requirements for impact resistance and hurricane protection. [36]
International Energy Conservation Code (IECC)	The comprehensive building energy code published by the International Code Council.[37]
Fully glazed (door)	A swinging entry door with > 36.4 percent glazing.[38]
¾-Lite (door)	A swinging entry door with >29.8 percent to 36.4 percent glazing.
¼-Lite (door)	A swinging entry door with < 13.6 percent glazing.
½-Lite (door)	A swinging entry door with $\geq$ 13.6 percent to <29.8 percent glazing.
LBNL	Lawrence Berkeley National Laboratory

[33] D&R International, Ltd
[34] Ibid.
[35] NFRC *Glossary and Terminology* 2006 and D&R International, Ltd.
[36] D&R International, Ltd.
[37] Construction Book Express website, IECC codebook description.
[38] Based on NFRC100-2004

Low-e coating	Low-emissivity coating. Microscopically thin metal, metal oxide or multilayer coating, deposited on a glazing surface to reduce its thermal infrared emittance.
National Fenestration Rating Council (NFRC)	A non-profit organization that administers the only uniform, independent rating and labeling system for the energy performance of windows, doors, skylights, and attachment products.[39]
NFRC	See National Fenestration Rating Council
Opaque	Not allowing visible light to pass through. In this report used to describe entry doors with no glazing.
Peak load	The maximum daily, weekly, or seasonal electric load.
Primary energy consumption	Primary energy consumption is the amount of fossil and renewable fuels consumed by an end-use sector (e.g. transportation, industry, residential building and commercial buildings) plus the total of fuels used in the generation of electricity.
SHGC	See Solar Heat Gain Coefficient
Solar Heat Gain Coefficient (SHGC)	The ratio of the solar heat gain entering the space through the fenestration product to the incident solar radiation.
Skylight	A window designed for sloped or horizontal application, the primary purpose of which is to provide daylighting and/or ventilation. May be fixed or operable. Skylights have their own set of ENERGY STAR criteria.
Sliding glass door	A door that contains one or more manually operated glass panels that slide horizontally within a common frame.
Spacer	The component that separates and maintains the space between the glazing surfaces of insulating glass.
Swinging entry door	A door 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. ENERGY STAR recognizes three categories of doors.
TDD	See tubular daylighting device
Tubular daylighting device (TDD)	A non-operable device primarily designed to transmit daylight from a roof surface to an interior ceiling surface via a tubular conduit. The device consists of an exterior glazed weathering surface, a light transmitting tube with a reflective inside surface and an interior sealing device, such as a translucent ceiling panel.

[39] NFRC website

U-factor	The heat transfer per time per area and per degree of temperature difference. The U-factor 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 infra-red radiation. In this report, U-factor values are expressed in Btu/hr-ft^2-ºF.
Window	An assembled unit consisting of a frame/sash component holding one or more pieces of glazing functioning to admit light and/or air to an enclosure. May be fixed or operable.

Appendix A: Revisions to ENERGY STAR Climate Zone Map

The ENERGY STAR (ES) climate zones compare to International Energy Conservation Code 2006 (IECC) climate zones as follows:

ES5 maps to IECC Zones 6, 7, and 8

ES4 maps to IECC Zone 5

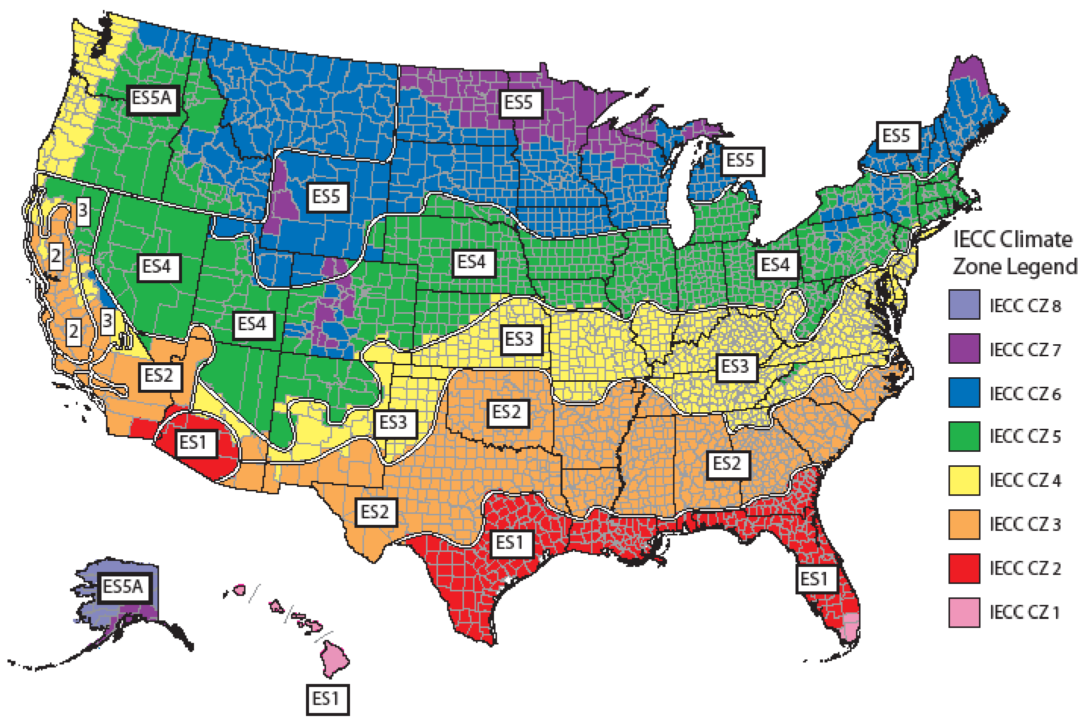
ES3 maps to IECC Zone 4

ES2 maps to IECC Zone 3

ES1 maps to IECC Zones 1 and 2

Figure A-1 depicts these equivalents. Deviations from default IECC equivalents are detailed below.

Figure A-1: IECC Climate Zone Map with Proposed ENERGY STAR Climate Zone Overlay



1 *ES5a Designation for Pacific Northwest in Phase 1*

Energy Performance (EP) tradeoffs in ES5 conflict with Pacific Northwest codes that have U-factor criteria as low as 0.30. The Northwestern Energy Efficiency Alliance expects codes to tighten even further in the next 3 years. Regional energy efficiency program sponsors have also pledged to consider offering incentives that stimulate demand for these more expensive products.

For the Phase 1 criteria, Alaska, Idaho, Montana, Oregon, and Washington will be included in ES5a. In Phase 2, these states will be reincorporated into the Northern Zone, ES5.

Table A-1: Population Included in ES5a

State	Population Included in ES5a
AK	670,053
ID	1,466,465
MT	944,632
OR	3,700,758
WA	6,395,798
Total	**13,177,706**

2 Splitting the Current Northern Zone

ES5 splits the current Northern Zone along the border between IECC Zones 5 and 6. IECC Zones 6 and 7 form the basis for ES5 (Figure A-1). Major exceptions occur in Colorado, New York, and the Pacific Northwest. Table A-2 provides a breakdown of the populations affected in Colorado and New York.

The 22 IECC Zone 6 and 7 counties that divide Colorado in two also split ES4. Including these 246,058 people in ES4 rather than ES5 maintains a continuous zone. This deviation also makes the climate zone for the Denver metro area clearly identifiable on ENERGY STAR product and display labels.

Faithfully following IECC boundaries in upstate New York and northern Pennsylvania presented two problems:

- There is a thin sliver of IECC Zone 6 counties that border Lake Erie; and
- There are three major population centers included in IECC Zone 6 that surround counties located in IECC Zone 5

Of all the options considered, the border DOE chose reassigns the smallest number of people to the adjacent zone and was most easily shown on the map. DOE placed 25 counties in New York and Pennsylvania with a combined population of 1,767,010 in ES4 rather than ES5. Many windows will qualify in both ES4 and ES5, so the impact on energy savings will be minimal.

Table A-2: Population Included in ES5			
State	**Population Included in ES5**	**IECC Zone 6 & 7 Populations Included in ES4**	**Notes**
CO	42,846	276,751	Excludes elevations over 6,000’ and smoothes contours
IA	751,015		
ME	1,300,000		
MI	1,232,000		
MN	5,100,000		
NH	418,456		
NY	495,265	1,830,342	Counties isolated/surrounded by major population centers
ND	636,000		
PA	0	316,698	Smoothes contours
SD	677,332		
UT	228,632		
VT	623,908		
WI	5,556,000		
WY	515,004		
Total	**17,576,458**		

Table A-3 provides the population breakdown for ES4.

Table A-3: Population Included in ES4

State	Population Included in ES4	Notes
AZ	307,470	
CO	4,710,531	
CT	3,504,809	
IA	2,231,070	
IL	11,154,733	Includes Chicago
IN	5,299,499	
KS	2,288	
MA	6,437,193	
MI	8,863,643	
MO	361,601	
NE	1,766,928	
NH	896,439	
NJ	3,930,797	
NM	598,839	
NV	512,472	
NY	7,801,115	Excludes New York City
OH	10,195,740	
OK	3,576,405	
PA	8,555,226	
RI	1,067,610	
SD	104,587	
UT	2,321,431	
VT	80,827	
WV	528,405	
Total	**84,809,658**	

3 California Title 24 Climate Zones

Many California counties encompass at least two of the following climates:

- A mild Mediterranean that benefits substantially from winter solar gain
- A colder Alpine climate that benefits substantially from winter solar gain
- A warmer, dry climate that benefits most from summer solar control

IECC relies on a county-level resolution whereas California's Title 24 establishes 16 climate zones that cross county lines. Historically, DOE has relied on counties as the minimum units of organization, but the energy savings analysis supports use of Title 24 climate zones.

Three of California's Title 24 climate zones—1, 3, and 16—have relaxed Solar Heat Gain Coefficient (SHGC) requirements. Zones 1 and 3 encompass the California coast north of Santa Barbara, while Zone 16 covers the state's mountainous regions. DOE included these zones in ES3, which allows for a higher SHGC than ES2. DOE also included California's Title 24 Zones 5 and 6 in ES3 as a result of the energy savings analysis and the Title 24 restriction on westward-facing glazing in these zones. Zone 5 includes the Santa Barbara coast; Zone 6 includes the Los Angeles coast, stopping just north of San Diego.

4 Expanding the Current Southern Zone

By including all of IECC Zones 1 and 2, ES1 now includes an additional 6.5 million people (Table A-4). Imperial County in California is the only exception to IECC in the new Southern Zone (see "California Title 24 Climate Zones").

Table A-4: ES1 – Population Added to Current Southern Zone

State	Population Added	Exclusions	Notes
AZ	5,193,355		
CA	0	160,301	Excluded in favor of CA Title 24 Zones
GA	527,091		
LA	172,864		
TX	622,282		
Total	**6,515,592**		

5 Other Deviations from IECC Climate Zones

Table A-5 provides the population breakdown of other deviations from IECC.

Graham and Greenlee Counties in Arizona are assigned to ES3 rather than ES2 in order to link major population centers located in Gila and Yavapai Counties to the rest of ES3. Graham and Greenlee Counties have a combined population of 41,398 people.

DOE assigned six counties in North Carolina to ES3 rather than ES4 because they form a small island surrounded by ES3 counties. These counties cannot be included in ES4 because they would be too small to discern on the ENERGY STAR label. The total affected population is 130,887.

By including Laramie County, Wyoming, in ES4 rather than ES5, residents of Cheyenne will be able to more easily discern their climate zone. Additionally, criteria in ES4 and ES5 are sufficiently similar that many windows will qualify in both zones.

Table A-5: Other Deviations from IECC Climate Zones		
Deviation	**Population Affected**	**Benefit**
Graham and Greenlee Counties, AZ	41,398	Link major population centers
Six Counties in North Carolina	130,887	Feature too small for label
Laramie County, WY	85,384	Clarity for residents of Cheyenne
Total	**257,669**	

Appendix B: Energy Saving and Cost-Effectiveness Methodologies

1 Objectives

1. Determine the aggregate energy savings that could be attained from more stringent ENERGY STAR criteria for windows
2. Determine the energy savings per household from more stringent ENERGY STAR criteria for window, doors, and skylights
3. Determine whether draft ENERGY STAR criteria are cost-effective for individual homeowners

2 Aggregate Energy Savings

D&R International, Ltd. (D&R) and Lawrence Berkeley National Laboratory (LBNL) collaborated on developing a model and methodology to calculate aggregate annual energy savings of the current and future housing stock for proposed ENERGY STAR climate zones.

The analysis was completed in two stages.

2.1 Stage I of Energy Savings Analysis

In the first stage, LBNL evaluated the sensitivity of energy consumption to changes in window U-factor and SHGC performance for revised ENERGY STAR climate zones.

See LBNL's "A National Energy Savings Model of US Window Sales" for a description of how space heating and cooling energy consumption was calculated. This paper and the results of the regression analysis are available at http://windows.lbl.gov/estar2008.

To understand the major trends, the analysis methodology was first used to examine the "technical potential" case, in which all windows in a given region move from one level to another. This allowed LBNL to compare total electricity and natural gas consumption for different criteria. Later stages of the analysis involved modeling the impacts of various products at given penetration rates.

The methodology developed by LBNL produced results based on RESFEN-only calculations and results that took the RESFEN calculations and calibrated them with RECS data on real world energy use (RECS-calibrated results). Generally, the non-calibrated or RESFEN results overestimate heating (20 percent) and cooling (30 percent) at the national level. Overestimates in heating vary by region from -50 percent to 80 percent; overestimates in cooling vary from 0 to 150 percent. While LBNL believes the RECS calibration factors at a national level, their application at the regional level should not be taken for granted. This is primarily because the underlying Census and RECS data is presented at a Census region/zone level—and these divisions do not correspond to window energy subdivisions. For example, data presented for the whole Mountain or

Pacific Census division are not necessarily equally applicable to all micro-climates in these regions. For this reason, the criteria developed are consistent with the trends from both the RESFEN and RECS-calibrated results. As a simplifying assumption for this analysis, the capture for new and replacement markets is 100 percent. This eased the analysis and also provided a baseline to compare total electricity and natural gas consumption for criteria.

LBNL's initial analysis showed the following:

- SHGC has a great influence on reducing total energy consumption of ES1, where cooling dominates space heating and cooling energy consumption.
- Aggregate space heating consumption in ES2 and ES3 are greater than space cooling. Thus, it is critical to energy savings to focus on the benefits from lower U-factors.
- While many climates in ES2 would benefit from a lower SHGC, the wide range of sub-climates included in ES2 included some where a lower SHGC does not provide significant energy benefits (particularly where heating is from electricity). As a result, the SHGC was set at 0.30 and not at 0.25.
- In ES3, the impact of SHGC on total energy use is essentially neutral. In the interests of minimizing peak demand, a SHGC limit of 0.4 was selected.
- Annual space heating and cooling energy consumption in zones ES4 and ES5 are driven by space heating. The analysis shows that increasing SHGC increases the energy savings potential for each zone. Tradeoffs in these zones should be explored.

Following the first stage of the analysis, two changes were made to the climate zone map at DOE's direction: (1) the Pacific Northwest was segregated into a separate zone for the first phase of the two-phase criteria, and (2) the climate zone boundaries in California were redrawn to follow Title 24 rather than IECC climate zone boundaries. Explanations for these decisions are described in section 3.

Based on the revised map, LBNL determined the U-factor and SHGC equivalencies for ES4 and ES5 for DOE to use in developing criteria for these zones. See "A National Energy Savings Model of US Window Sales" at http://windows.lbl.gov/estar2008 for a description of how LBNL determined the U-factor/SHGC tradeoff coefficients.

Guided by the equivalency factors, the technological feasibility analysis, and the cost-effectiveness analysis, DOE selected draft criteria levels for LBNL and D&R to evaluate.

2.2 Stage II of the Energy Savings Analysis

For the second stage of this analysis, LBNL and D&R included penetration rates to calculate more accurate estimates of annual energy savings from the draft Phase 1 and Phase 2 ENERGY STAR window criteria.

D&R developed five conservative regional shipment scenarios: three ENERGY STAR scenarios (current, Phase 1, and Phase 2) and two reference case scenarios (IECC 2006 and IECC 2009). Scenarios estimate regional shipments and corresponding market share for the new construction and remodel/replacement (R/R) markets for six categories of window:

(1) Double-pane clear
(2) IECC 2006 compliant
(3) IECC 2009 compliant
(4) Current ENERGY STAR qualified
(5) Phase 1 ENERGY STAR qualified
(6) Phase 2 ENERGY STAR qualified

To develop these scenarios, D&R used historic and forecasted window and glass shipment data, manufacturer estimates of new construction and replacement market share for ENERGY STAR qualified windows, and conservative estimates of ENERGY STAR market share under Phase 1 and Phase 2 criteria. Scenarios represent anticipated average market penetration during the criteria period. D&R estimated shipments for 11 regions of the United States based on the U.S. Census divisions. California and Florida were separated from the Pacific and South Atlantic divisions and treated independently.

D&R first developed IECC 2006, IECC 2009, and current ENERGY STAR scenarios, which would most closely reflect current shipment volumes. Regional window and low-e sales volumes from Ducker[1] for 2003, 2005, and 2007 were averaged together to reflect typical annual window sales volumes. See Table B-1 for starting assumptions about market share.

[1] Ducker Research, 2004, 2006, 2008. *Study of the U.S. Market for Windows, Doors, and Skylights,* published by the American Architectural Manufacturers Association and Window and Door Manufacturers Association.

Table B-1: IECC 2006, IECC 2009, and Current ENERGY STAR Market Share			
Division	**Total (%)**	**New Construction (%)**	**Remodel/Replace (R/R) (%)**
Northeast	81.8	41	100
Mid-Atlantic	81.7	45	100
South Atlantic	56.7	19	100
Florida	40.7	10	84
East North Central	70.0	21	100
East South Central	31.1	20	40
West North Central	55.8	10	89
West South Central	41.2	10	72
Mountain	59.3	31	100
Pacific Northwest	80.6	62	100
California	63.6	24	90
U.S.	59.1	23	90

Grayed cells are assumptions based on information from Ducker Research. In each division, one market share is assumed and the remaining market share is calculated so that the overall division in market share is consistent with information from Ducker. Regional market share split between R/R and new construction was based on estimates from national manufacturers and regional stakeholders calibrated to match Ducker regional low-e glass volumes. As a simplifying assumption, where Ducker's estimates of regional ENERGY STAR market share exceeded 70 percent, D&R assumed 100-percent market penetration in the R/R market. Hence, R/R market shares for the Northeast, Mid-Atlantic, South Atlantic, East North Central, Mountain, and Pacific Northwest are all assumed to be 100 percent. The California R/R market is assumed to be 90 percent. For the new construction markets of Florida, East South Central, West North Central, and West South Central market, following historical trends capture is assumed to be low.

The IECC 2006 and IECC 2009 reference scenarios were developed by assigning the same division of low-e windows between new construction and R/R as in the current ENERGY STAR scenario. It is assumed that all low-e windows meet only the minimum IECC regional compliance level. See Table B-2.

Table B-2: IECC 2006 and IECC 2009 Market Shares of New Construction and Remodel/Replace					
	New Construction		Remodel/Replace		Total
Division	**Double-Pane, Clear Glass**	**IECC Prescriptive**	**Double-Pane, Clear Glass**	**IECC Prescriptive**	
Northeast	18	12	0	69	100
Mid-Atlantic	18	15	0	66	100
South Atlantic	43	10	0	47	100
Florida	53	6	6	35	100
East North Central	30	8	0	62	100
East South Central	36	9	33	22	100
West North Central	38	4	6	52	100
West South Central	45	5	14	36	100
Mountain	41	18	0	41	100
Pacific Northwest	19	31	0	50	100
California	30	10	6	54	100

D&R then combined the ENERGY STAR estimates with regional Ducker-based shipment estimates for double-pane, clear glass windows and regional low-e sales data to construct the following current ENERGY STAR shipment scenario.

Phase 1 penetration rates are calculated using the current sales from Ducker, maintaining historic growth trends for low-e glass and assuming a decline in ENERGY STAR market share.

In the new construction market:

- 5 percent of current double-pane, clear glass windows will move to the Phase 1 criteria
- 10 percent of current ENERGY STAR sales will move to the Phase 1 criteria

In the R/R market:

- 20 percent of double-pane, clear glass window sales will shift to the Phase 1 criteria
- 80 percent of the current ENERGY STAR window sales will shift to the Phase 1 criteria

Each assumption is applied to the markets in each division.

Table B-3 provides penetration rates for ENERGY STAR qualifying products in Phase 1, and sales of windows by market and criteria in each division.

Table B-3: Sales of Windows Occurring for Phase 1							
	New Construction			Remodel/Replace			Total (%)
		ENERGY STAR			ENERGY STAR		
Division	Double-Pane, Clear Glass (%)	Current (%)	Phase 1 (%)	Double-Pane, Clear Glass (%)	Current (%)	Phase 1 (%)	
Northeast	16	12	2	0	14	56	100
Mid-Atlantic	16	15	2	0	13	53	100
South Atlantic	39	11	3	0	9	37	100
Florida	48	8	3	2	10	29	100
East North Central	27	9	2	0	12	50	100
East South Central	32	10	3	10	21	24	100
West North Central	34	6	2	2	14	43	100
West South Central	40	7	3	4	14	32	100
Mountain	37	18	4	0	8	33	100
Pacific Northwest	17	29	4	0	10	40	100
California	27	10	2	2	14	44	100

Penetration rates for Phase 2 follow the same methodology for Phase 1. Phase 1 sales are carried over to estimate market share and penetration rates for Phase 2. It is anticipated that fewer windows sales will meet Phase 2 criteria than in Phase 1. This assumption is due to the aggressive window requirements and the cost premium associated with the higher-performing windows. This approach also provides a conservative estimate of annual energy savings. In the new construction market:

- 5 percent of current double-pane, clear glass windows will move to the Phase 2 criteria
- 10 percent of current ENERGY STAR sales will move to Phase 2 criteria
- 5 percent of Phase 1 ENERGY STAR sales will move to Phase 2 criteria

In the R/R market:

- 70 percent of double-pane, clear glass window sales will shift to Phase 2 criteria
- 40 percent of current ENERGY STAR sales will shift to Phase 2 criteria
- 40 percent of Phase 1 ENERGY STAR sales will move to Phase 2

Phase 2 penetration rates in Table B-4 show the projected sales of windows meeting criteria in each division.

Table B-4: Sales of Windows Occurring for Phase 2									
	New Construction				Remodel/Replace				Total (%)
	Double Pane, Clear Glass (%)	ENERGY STAR			Double Pane, Clear Glass (%)	ENERGY STAR			
Division		Current (%)	Phase 1 (%)	Phase 2 (%)		Current (%)	Phase 1 (%)	Phase 2 (%)	
Northeast	1	15	13	2	3	1	38	28	100
Mid-Atlantic	1	16	14	2	3	1	37	27	100
South Atlantic	1	28	21	3	2	0	26	19	100
Florida	1	32	22	3	1	1	22	17	100
East North Central	1	20	15	2	2	1	34	25	100
East South Central	1	23	18	3	1	2	27	25	100
West North Central	1	23	16	2	2	1	31	24	100
West South Central	1	27	19	3	2	1	26	21	100
Mountain	2	29	24	4	2	0	23	16	100
Pacific Northwest	2	22	23	4	2	0	27	20	100
California	1	21	16	3	2	1	32	24	100

To calculate energy consumption for these scenarios, LBNL and D&R needed to specify windows representing each category of product in each climate zone. Generally, where the criteria specified maximum U-factor and SHGC requirements, these U-factor and SHGC combinations were used in modeling energy consumption. This occurs in the southern zones of the IECC and ENERGY STAR climate maps. In the northern zones where there are no minimum or maximum SHGC requirements for IECC, D&R and LBNL specified an SHGC of 0.30 to reflect the performance of today's typical low-solar-gain low-e windows. To keep the comparison fair, D&R and LBNL modeled ENERGY STAR ES3 qualifying windows at 0.30 rather than the more favorable maximum of 0.40. Table B-5, Table B-6, Table B-7, and Table B-8 list the specific criteria for the 2006 and 2009 IECC, and ENERGY STAR Phase 1 and Phase 2.

Table B-5: 2006 IECC Window Criteria				
IECC Climate Zone	U-Factor		SHGC	
	Requirement	As Modeled	Requirement	As Modeled
8	≤ 0.35	0.35	NR	0.30
7	≤ 0.35	0.35	NR	0.30
6	≤ 0.35	0.35	NR	0.30
5	≤ 0.35	0.35	NR	0.30
4	≤ 0.40	0.40	NR	0.30
3	≤ 0.65	0.65	≤ 0.40	0.30
2	≤ 0.75	0.75	≤ 0.40	0.30
1	≤ 1.20	1.20	≤ 0.40	0.30

Table B-6: Proposed 2009 IECC Window Criteria				
IECC Climate Zone	U-Factor		SHGC	
	Requirement	As Modeled	Requirement	As Modeled
8	≤ 0.35	0.35	NR	0.30
7	≤ 0.35	0.35	NR	0.30
6	≤ 0.35	0.35	NR	0.30
5	≤ 0.35	0.35	NR	0.30
4	≤ 0.35	0.35	NR	0.30
3	≤ 0.40	0.40	≤ 0.30	0.30
2	≤ 0.50	0.50	≤ 0.30	0.30
1	≤ 0.65	0.65	≤ 0.30	0.30

Table B-7: Phase 1 ENERGY STAR Criteria and Model Criteria				
Climate Zone	U-Factor		SHGC	
	Requirement	As Modeled	Requirement	As Modeled
ES5a	≤ 0.30	0.30	≤ 0.55	0.30
ES5	EP ~ 0.32/0.25	0.32	EP ~ 0.32/0.25	0.25
ES4	EP ~ 0.33/0.25	0.33	EP ~ 0.33/0.25	0.25
ES3	≤ 0.33	0.33	≤ 0.40	0.30
ES2	≤ 0.35	0.35	≤ 0.30	0.30
ES1	≤ 0.50	0.50	≤ 0.25	0.25

Table B-8: Phase 2 ENERGY STAR Criteria and Model Criteria				
Climate Zone	U-Factor		SHGC	
	Requirement	As Modeled	Requirement	As Modeled
ES5	EP ~ 0.22/0.25	0.22	EP ~ 0.22/0.25	0.25
ES4	EP ~ 0.23/0.25	0.23	EP ~ 0.23/0.25	0.25
ES3	≤ 0.30	0.30	≤ 0.40	0.30
ES2	≤ 0.30	0.30	≤ 0.30	0.30
ES1	≤ 0.45	0.45	≤ 0.20	0.20

3 Household Energy Savings

3.1 Windows

Energy savings are estimates of whole-house energy savings from replacing an entire set of windows in a single-family residence with more efficient products. Savings listed in Table B-9 are based on energy simulations completed by LBNL using RESFEN6 assumptions. See "RESFEN6 Assumptions – Reference House for Energy Star Analysis" at http://windows.lbl.gov/08estar.html. Savings for Phase 1 are relative to the 2006 IECC window criteria. Savings for Phase 2 are relative to the proposed 2009 IECC.

Table B-9. Whole-House Energy Savings for Windows, by City

Location	Climate Zone	Energy Savings Phase 1		Energy Savings Phase 2	
		Average ($)	Standard Deviation ($)	Average ($)	Standard Deviation ($)
AK_Anchorage	ES5a	16.34	4.47	81.55	20.76
AK_Fairbanks	ES5a	24.66	6.87	104.53	28.38
ID_Boise	ES5a	12.62	4.17	63.12	33.18
MT_Billings	ES5a	19.38	5.33	86.09	25.32
MT_Great_Falls	ES5a	20.67	5.28	96.54	25.71
OR_Medford	ES5a	15.18	5.35	63.64	38.40
OR_Portland	ES5a	11.47	5.34	60.39	36.13
WA_Seattle	ES5a	10.94	4.78	57.57	31.40
WA_Spokane	ES5a	16.24	5.74	80.63	39.25
ME_Portland	ES5	102.63	68.49	146.61	39.37
MI_Houghton	ES5	79.82	37.08	114.86	28.47
MN_Duluth	ES5	102.13	66.85	143.08	34.97
MN_Intl_Falls	ES5	101.95	61.47	143.64	35.11
MN_Minneapolis	ES5	73.22	35.52	105.92	26.86
ND_Bismarck	ES5	77.97	45.17	111.89	27.15
NH_Concord	ES5	93.08	38.77	136.84	36.98
SD_Pierre	ES5	68.02	36.92	98.41	24.00
VT_Burlington	ES5	85.95	42.11	124.90	30.87
WI_Madison	ES5	68.11	26.53	101.32	27.16
WY_Cheyenne	ES5	64.27	54.43	90.81	31.61
AZ_Flagstaff	ES4	101.41	115.41	135.85	70.99
CO_Denver	ES4	46.84	23.78	70.38	18.19
CO_Grand_Junction	ES4	40.52	13.45	61.75	18.45
CT_Hartford	ES4	78.40	24.62	118.54	39.07
IA_Des_Moines	ES4	54.56	23.63	82.25	26.64
IL_Chicago	ES4	50.33	15.65	74.72	22.25
IL_Springfield	ES4	43.72	11.60	66.59	24.54
IN_Indianapolis	ES4	42.24	25.66	64.72	29.12
MA_Boston	ES4	85.49	48.18	123.15	29.36
MI_Detroit	ES4	54.82	23.29	82.22	24.83
MI_Grand_Rapids	ES4	58.46	21.89	89.01	26.46
NE_Omaha	ES4	41.58	22.19	63.02	25.26
NV_Reno	ES4	60.34	43.38	91.67	32.92
NY_Albany	ES4	76.59	23.37	117.31	35.97
NY_Buffalo	ES4	72.61	20.70	112.08	33.94

Table B-9. Whole-House Energy Savings for Windows, by City					
Location	Climate Zone	Energy Savings Phase 1		Energy Savings Phase 2	
		Average ($)	Standard Deviation ($)	Average ($)	Standard Deviation ($)
OH_Cleveland	ES4	49.19	27.81	76.27	32.52
OH_Dayton	ES4	52.11	28.92	77.88	30.79
PA_Pittsburgh	ES4	56.58	30.94	85.55	35.91
PA_Williamsport	ES4	59.07	34.22	88.05	37.27
RI_Providence	ES4	73.29	46.50	107.46	34.98
UT_Cedar_City	ES4	46.27	30.38	67.81	21.53
UT_Salt_Lake	ES4	36.32	18.79	57.24	22.59
AR_Little_Rock	ES3	7.89	4.09	19.73	10.23
AZ_Prescott	ES3	12.60	6.82	31.50	17.05
CA_Arcata	ES3	14.25	3.65	35.62	9.12
CA_San_Francisco	ES3	9.84	2.57	24.59	6.43
DC_Washington	ES3	13.80	5.85	34.49	14.63
DE_Wilmington	ES3	14.33	5.00	35.83	12.50
KS_Wichita	ES3	10.99	4.30	27.47	10.76
KY_Lexington	ES3	11.19	6.14	27.97	15.35
KY_Louisville	ES3	9.96	5.70	24.90	14.25
MD_Baltimore	ES3	12.64	5.57	31.61	13.93
MO_Kansas_City	ES3	10.92	5.60	27.30	14.00
MO_St_Louis	ES3	10.91	5.28	27.28	13.20
NC_Raleigh	ES3	10.07	5.30	25.18	13.24
NJ_Atlantic_City	ES3	13.04	5.23	32.59	13.08
NM_Albuquerque	ES3	10.13	4.54	25.32	11.35
NY_New_York	ES3	11.96	8.18	29.89	20.44
PA_Philadelphia	ES3	13.65	5.64	34.13	14.09
TN_Nashville	ES3	9.79	5.11	24.46	12.78
TX_Amarillo	ES3	13.52	4.12	33.79	10.31
VA_Richmond	ES3	9.83	5.08	24.59	12.70
WV_Charleston	ES3	10.12	5.90	25.30	14.74
AL_Birmingham	ES2	31.30	13.44	64.70	34.64
CA_Bakersfield	ES2	40.79	12.39	67.79	18.84
CA_Daggett	ES2	48.25	15.03	75.76	21.88
CA_Fresno	ES2	43.54	13.57	75.86	20.78
CA_Los_Angeles	ES2	9.52	3.69	20.79	6.42
CA_Red_Bluff	ES2	11.71	22.75	22.06	42.63
CA_Sacramento	ES2	31.61	7.81	62.59	14.64
CA_San_Diego	ES2	10.73	4.10	16.10	5.84
GA_Atlanta	ES2	33.85	15.20	70.80	39.19
GA_Savannah	ES2	26.64	10.51	49.12	24.80
LA_Shreveport	ES2	29.74	9.91	52.83	21.02
MS_Jackson	ES2	29.87	10.29	55.58	23.14
NC_Charlotte	ES2	32.99	12.62	71.56	34.51
NV_Las_Vegas	ES2	43.69	13.58	76.39	23.32
OK_Oklahoma_City	ES2	36.48	13.53	74.93	33.01
SC_Charleston	ES2	27.59	10.47	52.67	25.74
SC_Greenville	ES2	33.05	13.12	72.63	35.78
TN_Memphis	ES2	31.43	11.98	62.86	29.78
TX_El_Paso	ES2	36.90	11.36	64.98	18.33
TX_Fort_Worth	ES2	38.99	11.51	64.63	18.72
TX_Lubbock	ES2	43.32	12.33	84.20	23.43

Table B-9. Whole-House Energy Savings for Windows, by City					
Location	Climate Zone	Energy Savings Phase 1		Energy Savings Phase 2	
		Average ($)	Standard Deviation ($)	Average ($)	Standard Deviation ($)
AL_Mobile	ES1	73.90	30.82	90.98	38.41
AZ_Phoenix	ES1	101.10	31.64	122.70	38.82
AZ_Tucson	ES1	82.78	29.49	101.66	36.67
FL_Daytona_Beach	ES1	69.15	24.08	84.49	29.76
FL_Jacksonville	ES1	88.30	32.44	108.53	40.36
FL_Miami	ES1	66.60	23.84	80.45	28.61
FL_Tallahassee	ES1	82.95	29.71	101.31	36.94
FL_Tampa	ES1	77.00	25.49	93.35	31.15
HI_Honolulu	ES1	126.86	44.90	153.15	54.07
LA_Lake_Charles	ES1	75.74	26.88	93.03	33.32
LA_New_Orleans	ES1	68.07	25.63	83.51	31.65
TX_Brownsville	ES1	84.49	26.25	103.15	32.03
TX_Houston	ES1	90.44	26.76	110.51	32.53
TX_San_Antonio	ES1	98.67	28.83	120.81	35.35

LBNL modeled approximately 50 different fenestration technologies using RESFEN6 assumptions and provided the consumption by model residence. D&R selected a representative window for each ES Climate Zone; Table B-10 lists the corresponding U-factors and SHGCs.

Table B-10: U-Factor and SHGC by Climate Zone			
Climate Zone	Criteria	Window Criteria	
		U-Factor	SHGC
ES5a	Code Equivalent	0.339	0.294
	Phase 1	0.280	0.252
ES5	Code Equivalent	0.339	0.294
	Phase 1 (low gain) (high gain)	 0.253 0.291	 0.188 0.559
	Phase 2 (low gain) (high gain)	 0.175 0.271	 0.262 0.460
ES4	Code Equivalent	0.339	0.294
	Phase 1 (low gain) (high gain)	 0.253 0.291	 0.188 0.559
	Phase 2 (low gain) (high gain)	 0.175 0.271	 0.262 0.460
ES3	Code Equivalent	0.350	0.300
	Phase 1	0.330	0.300
	Phase 2	0.300	0.300
ES2	Code Equivalent	0.583	0.364
	Phase 1	0.339	0.294
	Phase 2	0.256	0.307
ES1	Code Equivalent	0.702	0.310
	Phase 1	0.465	0.211
	Phase 2	0.337	0.183

Energy savings for both phases is relative to the code-equivalent specifications listed in Table B-10. These figures represent average savings for existing and newly constructed single-family detached homes, with either a heat pump or furnace and central air-conditioner. In ES3, linear interpolation is necessary to estimate energy consumption because a fenestration model is within the relatively tight criteria range considered for ES3. For ES4, ES5, and ES5a, LBNL evaluated the option of using high-solar-gain windows. Annual energy expenditures are calculated by multiplying each model's annual energy consumption by the appropriate average residential fuel prices in selected cities. Fuel prices obtained from the Energy Information Administration represent average annual residential prices for each state.

3.2 Doors and Skylights

The annual energy savings are calculated as whole-house energy savings of replacing or upgrading a door or skylight only. Energy savings are averages of multiple simulations completed by D&R to demonstrate the range of consumption and savings of the local housing stock in each city. Phase 1 savings are relative to the 2006 IECC; Phase 2 savings are relative to the proposed 2009 IECC. Savings are listed in Table B-11 for opaque doors; Table B-12 for skylights.

Table B-11: Opaque Doors -- Annual Energy Savings					
Location	Climate Zone	Energy Savings Phase 1		Energy Savings Phase 2	
		Average ($)	Standard Deviation ($)	Average ($)	Standard Deviation ($)
OR_Portland	ES5a/ES5	2.32	0.62	3.42	0.96
WA_Seattle	ES5a/ES5	1.31	0.87	2.49	1.05
MN_Minneapolis	ES5	5.48	1.15	7.47	1.12
VT_Burlington	ES5	6.21	1.79	8.89	1.99
WI_Madison	ES5	5.28	1.28	7.34	1.33
CO_Denver	ES4	2.16	1.14	3.57	1.13
IL_Chicago	ES4	4.93	0.82	6.60	0.83
MA_Boston	ES4	5.62	1.47	8.25	1.62
MI_Detroit	ES4	4.43	0.90	6.18	0.88
NY_Buffalo	ES4	7.65	1.54	10.27	1.75
PA_Pittsburgh	ES4	5.26	0.86	7.12	0.95
CA_San_Francisco	ES3	-4.80	1.34	-3.77	1.31
DC_Washington	ES3	2.00	0.95	3.21	0.78
MO_Kansas City	ES3	2.25	0.68	3.31	0.59
NM_Albuquerque	ES3	0.30	1.01	1.40	0.87
NJ_Atlantic_City	ES3	2.00	1.16	3.38	0.63
PA_Philadelphia	ES3	1.99	0.97	3.39	0.73
TN_Nashville	ES3	2.53	0.60	3.37	0.44
CA_San_Diego	ES2	0.95	0.55	1.24	0.79
GA_Atlanta	ES2	5.42	1.19	2.63	0.43
NV_Las_Vegas	ES2	8.44	0.68	4.97	0.72
TX_Fort_Worth	ES2	8.46	0.49	4.75	0.67
AZ_Phoenix	ES1	8.73	0.75	6.14	0.94
FL_Tampa	ES1	7.86	0.70	5.70	1.28
LA_Lake_Charles	ES1	6.99	0.89	5.01	0.85

Table B-12: Skylights – Annual Energy Savings					
Location	Climate Zone	Energy Savings Phase 1		Energy Savings Phase 2	
		Average ($)	Standard Deviation ($)	Average ($)	Standard Deviation ($)
OR_Portland	ES5a/ES5	1.24	0.40	2.41	0.80
WA_Seattle	ES5a/ES5	1.18	0.39	2.37	0.86
MN_Minneapolis	ES5	2.46	0.12	4.63	0.21
VT_Burlington	ES5	3.01	0.37	5.80	0.68
WI_Madison	ES5	2.51	0.21	4.72	0.36
CO_Denver	ES4	1.64	0.11	3.15	0.20
IL_Chicago	ES4	2.11	0.13	3.96	0.26
MA_Boston	ES4	3.09	0.23	5.94	0.39
MI_Detroit	ES4	2.12	0.13	3.98	0.24
NY_Buffalo	ES4	3.15	0.37	5.93	0.72
PA_Pittsburgh	ES4	2.30	0.32	4.30	0.65
CA_San_Francisco	ES3	0.83	0.06	1.11	0.12
DC_Washington	ES3	1.07	0.32	2.69	0.56
MO_Kansas City	ES3	0.80	0.33	2.10	0.66
NM_Albuquerque	ES3	0.72	0.17	1.82	0.30
NJ_Atlantic_City	ES3	1.67	0.12	2.82	0.24
PA_Philadelphia	ES3	1.11	0.30	2.89	0.52
TN_Nashville	ES3	0.64	0.25	1.90	0.47
GA_Atlanta	ES2	0.94	0.18	2.11	0.79
NV_Las_Vegas	ES2	1.49	0.14	2.51	0.32
TX_Fort_Worth	ES2	1.46	0.25	2.35	0.24
CA_San_Diego	ES2	0.42	0.18	0.97	0.40
AZ_Phoenix	ES1	0.69	1.16	1.48	0.60
FL_Tampa	ES1	1.26	0.13	1.37	0.28
LA_Lake_Charles	ES1	1.10	0.22	1.47	0.34

D&R used RESFEN5 to estimate annual energy consumption of opaque doors and skylights. The models simulated with RESFEN follow those developed by LBNL. The opaque door and skylight criteria for savings comparisons are listed in Table B-13, Table B-14, Table B-15, and Table B-16.

D&R added 20 square feet of opaque door to the models previously developed by LBNL for the windows analysis. To remove orientation difficulties in estimating energy consumption, five square feet of an opaque door was added to each cardinal orientation to account for the variances in thermal loading. The overall U-factor and SHGC for each orientation were recalculated to include the more efficient door. For skylights, 10 square feet of skylight was added to LBNL models.

Table B-13: Skylight and Window Criteria for Modeling Phase 1					
Climate Zone	Criteria	Skylight Criteria		Window Criteria	
		U-Factor	SHGC	U-Factor	SHGC
ES4, ES5 & ES5a	Code Equivalent	0.600	0.500	0.339	0.294
	ES Phase 1	0.550	0.400		
ES3	Code Equivalent	0.600	0.400	0.350	0.300
	ES Phase 1	0.550	0.400		
ES2	Code Equivalent	0.650	0.400	0.583	0.364
	ES Phase 1	0.570	0.300		
ES1	Code Equivalent	0.750	0.400	0.702	0.310
	ES Phase 1	0.650	0.300		

Table B-14: Opaque Door and Window Criteria for Modeling Phase 1					
Climate Zone	Criteria	Opaque Door Criteria		Window Criteria	
		U-Factor	SHGC	U-Factor	SHGC
ES4, ES5 & ES5a	Code Equivalent	0.339	0.294	0.339	0.294
	Phase 1	0.210	0.030		
ES3	Code Equivalent	0.350	0.300	0.350	0.300
	Phase 1	0.210	0.030		
ES2	Code Equivalent	0.583	0.330	0.583	0.364
	Phase 1	0.210	0.030		
ES1	Code Equivalent	0.702	0.330	0.702	0.310
	Phase 1	0.210	0.030		

Table B-15: Skylight and Window Criteria for Modeling Phase 2					
Climate Zone	Criteria	Skylight Criteria		Window Criteria	
		U-Factor	SHGC	U-Factor	SHGC
ES4, ES5, & ES5a	Code Equivalent	0.600	0.400	0.339	0.294
	ES Phase 2	0.420	0.350		
ES3	Code Equivalent	0.600	0.400	0.330	0.300
	ES Phase 2	0.470	0.300		
ES2	Code Equivalent	0.650	0.300	0.339	0.294
	ES Phase 2	0.470	0.200		
ES1	Code Equivalent	0.750	0.300	0.465	0.211
	ES Phase 2	0.570	0.200		

Table B-16: Opaque Door and Window Criteria for Modeling Phase 2					
Climate Zone	**Criteria**	**Opaque Door Criteria**		**Window Criteria**	
		U-Factor	**SHGC**	**U-Factor**	**SHGC**
ES4, ES5 & ES5a	Code Equivalent	0.339	0.294	0.339	0.294
	Phase 2	0.160	0.030		
ES3	Code Equivalent	0.330	0.300	0.330	0.300
	Phase 2	0.160	0.030		
ES2	Code Equivalent	0.339	0.330	0.339	0.294
	Phase 2	0.160	0.030		
ES1	Code Equivalent	0.465	0.330	0.465	0.211
	Phase 2	0.160	0.030		

4 *Cost-Effectiveness Test for Proposed ENERGY STAR Criteria*

According to ENERGY STAR principles, homeowners will recover the marginal cost for efficient products with reduced energy bills over the lifetime of those products. More simply, the energy cost savings pay for the increase in capital cost of the product.

The annual energy savings of ENERGY STAR qualified products are used to determine the payback of more efficient windows, glazed doors, opaque doors, and skylights. The marginal cost divided by the annual energy savings provides the simple payback.

4.1 Marginal Costs

Cost information from manufacturers provided the marginal costs homeowners need to recoup. The marginal cost is the difference in cost between purchasing an ENERGY STAR qualified product and a standard product. Distribution charges are included. Installation costs are excluded. Window price is $250 per window.

D&R evaluated cost three cases: (1) zero marginal cost per window, (2) 3-percent marginal cost (10-percent in ES5a) per window, and (3) 10-percent marginal cost (15-percent in ES4 and ES5) per window. D&R anticipates that marginal costs in ES1 and ES2 will be zero for most manufacturers; however, other manufacturers could have some additional costs. To be conservative for ES1 and ES2, a 3-percent marginal price is used. For all zones except 5a, a marginal cost of $7.50 per window is estimated as the cost to move from a code-equivalent window to an ENERGY STAR qualified window. In ES5a, a marginal cost of $25 per window is expected. For a whole-house upgrade, D&R evaluated 24 3' x 5' windows. Total marginal costs are then $180 and $600 respectively. Table B-17 lists the medium marginal costs of windows which meet Phase 1 and Phase 2 ENERGY STAR criteria. Table B-18 and Table B-19 provide marginal prices for doors and skylights.

Table B-17: Marginal Retail Costs to Replace 24 Windows – Phase 1 and Phase 2 Criteria				
Climate Zone	Phase 1 Marginal Cost		Phase 2 Marginal Cost	
ES5a	10%	$600	15%	$900
ES5	3%	$180		
ES4	3%	$180	15%	$900
ES3	3%	$180	5%	$300
ES2	3%	$180	5%	$300
ES1	3%	$180	5%	$300

Table B-18: Marginal Retail Costs for Swinging Entry Doors - Phase 1 and Phase 2 Criteria				
Door Classification	Phase 1 Marginal Cost		Phase 2 Marginal Cost	
Opaque	0%	$0	10%	$100
≤ 1/2-Lite	4%	$40	14%	$140
> 1/2-Lite	5%	$50	15%	$150

Table B-19: Marginal Retail Cost for Skylights - Phase 1 and Phase 2 Criteria				
Climate Zone	Phase 1 Marginal Cost		Phase 2 Marginal Cost	
ES5a ES5 ES4	3%	$15	6%	$30
ES3 ES2 ES1	0%	$0	0%	$0

4.2 Window Payback

For Phase 1 criteria, D&R used the annual energy savings, discounted lifetime savings, and total marginal cost to calculate the savings-to-cost ratio and simple paybacks for selected cities; see Table B-20 window paybacks. For the savings-to-cost ratio, the future energy savings are discounted to present value. Window lifetime is 20 years. A 3-percent discount rate is used for savings-to-cost ratio calculations. *Remodeling Magazine* consistently reports that homeowners recover about 80 percent of the cost of window replacement through increased home value. The 80-percent cost recovery figure holds for both moderate and high-end (low-e) replacements, and in high-cost and low-cost markets. It follows that those homeowners who sell their homes after upgrading to ENERGY STAR qualified windows will also recover 80 percent of the marginal cost of choosing ENERGY STAR. They will likely recoup the remaining 20 percent from heating and cooling cost savings.

Table B-20: Payback of Phase 1 ENERGY STAR Windows

Climate Zone	City	Annual Energy Savings ($)	Total Marginal Cost ($)	Savings to Cost Ratio (%)	Simple Payback (years)	Simple Payback with 80% Recoup at Sale (years)
ES5a	Portland, OR	11	600	30	52.3	10.5
	Seattle, WA	11	600	29	54.8	11.0
ES5	Burlington, VT	86	180	752	2.1	0.4
	Madison, WI	68	180	596	2.6	0.5
	Minneapolis, MN	73	180	641	2.5	0.5
ES4	Boston, MA	85	180	748	2.1	0.4
	Chicago, IL	50	180	440	3.6	0.7
	Denver, CO	47	180	410	3.8	0.8
ES3	Albuquerque, NM	10	180	89	17.8	3.6
	Kansas City, MO	11	180	96	16.5	3.3
	San Francisco, CA	10	180	86	18.3	3.7
	Washington, DC	14	180	121	13.0	2.6
ES2	Atlanta, GA	34	180	296	5.3	1.1
	Ft Worth, TX	39	180	341	4.6	0.9
	Las Vegas, NV	44	180	382	4.1	0.8
	San Diego, CA	11	180	94	16.8	3.4
ES1	Tampa, FL	77	180	674	2.3	0.5
	Lake Charles, LA	76	180	663	2.4	0.5
	Phoenix, AZ	101	180	885	1.8	0.4

Table B-21 provides paybacks for Phase 2 ENERGY STAR Windows.

Table B-21: Payback of Phase 2 ENERGY STAR Windows						
Climate Zone	City	Annual Energy Savings ($)	Total Marginal Cost ($)	Savings to Cost Ratio (%)	Simple Payback (years)	Simple Payback with 80% Recoup at Sale (years)
	Burlington, VT	125	900	219	7.2	1.4
	Madison, WI	101	900	177	8.9	1.8
	Minneapolis, MN	106	900	185	8.5	1.7
ES5	Portland, OR	60	900	106	14.9	3.0
	Boston, MA	123	900	216	7.3	1.5
	Chicago, IL	75	900	131	12.0	2.4
ES4	Denver, CO	70	900	123	12.8	2.6
	Albuquerque, NM	25	300	133	11.8	2.4
	Kansas City, MO	27	300	143	11.0	2.2
	San Francisco, CA	25	300	129	12.2	2.4
ES3	Washington, DC	34	300	181	8.7	1.7
	Atlanta, GA	71	300	372	4.2	0.8
	Ft Worth, TX	65	300	339	4.6	0.9
	Las Vegas, NV	76	300	401	3.9	0.8
ES2	San Diego, CA	16	300	85	18.6	3.7
	Tampa, FL	93	300	490	3.2	0.6
	Lake Charles, LA	93	300	488	3.2	0.6
ES1	Phoenix, AZ	123	300	644	2.4	0.5

4.3 Opaque Door Payback

Table B-22 lists simple paybacks for opaque doors for Phase 1 and 2. Annual energy savings are from the prior section on household annual energy savings. For Phase 1, there is no marginal cost increase that consumers will need to recoup. The payback for Phase 1 is zero and homeowners will benefit with some energy savings that do not have any marginal costs. For Phase 2, the marginal cost of $50 (10 percent) is anticipated. The paybacks work in consumers’ favor in all but four locations: San Diego, Albuquerque, San Francisco, and Seattle.

Table B-22: Payback of ENERGY STAR Opaque Doors							
Window Climate Zone*	City	Annual Energy Savings ($)		Total Marginal Cost ($)		Simple Payback (years)	
		Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
ES5 and ES5a	Burlington, VT	6.21	8.89	-	50.00	0.00	5.6
	Madison, WI	5.28	7.34	-	50.00	0.00	6.8
	Minneapolis, MN	5.48	7.47	-	50.00	0.00	6.7
	Portland, OR	2.32	3.42	-	50.00	0.00	14.6
	Seattle, WA	1.31	2.49	-	50.00	0.00	20.1
ES4	Boston, MA	5.62	8.25	-	50.00	0.00	6.1
	Chicago, IL	4.93	6.60	-	50.00	0.00	7.6
	Denver, CO	2.16	3.57	-	50.00	0.00	14.0
ES3	Albuquerque, NM	0.30	1.40	-	50.00	0.00	35.7
	Kansas City, MO	2.25	3.31	-	50.00	0.00	15.1
	San Francisco, CA	(4.80)	(3.77)	-	50.00	0.00	No Savings
	Washington, DC	2.00	3.21	-	50.00	0.00	15.6
ES2	Atlanta, GA	5.42	2.63	-	50.00	0.00	19.0
	Ft Worth, TX	8.46	4.75	-	50.00	0.00	10.5
	Las Vegas, NV	8.44	4.97	-	50.00	0.00	10.1
	San Diego, CA	0.95	1.24	-	50.00	0.00	40.3
ES1	Tampa, FL	7.86	5.70	-	50.00	0.00	8.8
	Lake Charles, LA	6.99	5.01	-	50.00	0.00	10.0
	Phoenix, AZ	8.73	6.14	-	50.00	0.00	8.1

*Window Criteria Climate Zones included to assist in comparison with window findings. Climate zones do not apply to doors.

4.4 Glazed Door Payback

D&R calculated lower bound cost-effectiveness for glazed doors, using the energy savings per square foot for windows meeting the draft Phase 1 and Phase 2 criteria normalized to a 20-square-foot door. Door price is $500. For Phase 1, the cost to move from a code-equivalent to an ENERGY STAR door is $25 (5 percent). Door lifetime is 20 years. Savings-to-cost ratios do not yield notably different results and are not included. Phase 1 criteria for glazed doors are as or more stringent than window criteria in all zones except ES5a. See Table B-23 for Phase 1 payback of glazed doors.

Table B-23: Payback of Phase 1 ENERGY STAR Glazed Doors					
Window Climate Zone*	**City**	**Annual Energy Savings ($)**	**Lifetime Savings ($, discounted)**	**Total Marginal Cost ($)**	**Simple Payback (years)**
ES5a	Portland, OR	N/A	N/A	N/A	N/A
	Seattle, WA	N/A	N/A	N/A	N/A
ES5	Burlington, VT	4.78	75.21	25.00	5.2
	Madison, WI	3.78	59.60	25.00	6.6
	Minneapolis, MN	4.07	64.07	25.00	6.1
ES4	Boston, MA	4.75	74.81	25.00	5.3
	Chicago, IL	2.80	44.04	25.00	8.9
	Denver, CO	2.60	40.99	25.00	9.6
ES3	Albuquerque, NM	0.56	8.86	25.00	44.4
	Kansas City, MO	0.61	9.56	25.00	41.2
	San Francisco, CA	0.55	8.61	25.00	45.7
	Washington, DC	0.77	12.08	25.00	32.6
ES2	Atlanta, GA	1.88	29.62	25.00	13.3
	Ft Worth, TX	2.17	34.12	25.00	11.5
	Las Vegas, NV	2.43	38.23	25.00	10.3
	San Diego, CA	0.60	9.39	25.00	41.9
ES1	Tampa, FL	4.28	67.38	25.00	5.8
	Lake Charles, LA	4.21	66.28	25.00	5.9
	Phoenix, AZ	5.62	88.47	25.00	4.5
*Window criteria Climate Zones included to assist in comparison with window findings. Climate zones do not apply to doors.					

Phase 2 glazed door criteria are only as or more stringent than criteria for ES1, ES2, and ES3 and so window savings can not be used as a proxy. The marginal cost in Phase 2 is $75 (15 percent). Criteria have simple paybacks of approximately 20 years or less in southern regions of the country, but not in the central regions. Table B-24 provides paybacks of glazed doors for Phase 2.

Table B-24: Payback of Phase 2 ENERGY STAR Glazed Doors					
Window Climate Zone*	**City**	**Annual Energy Savings ($)**	**Lifetime Savings ($, discounted)**	**Total Marginal Cost ($)**	**Simple Payback (years)**
ES3	Albuquerque, NM	1.41	22.16	75.00	53
	Kansas City, MO	1.52	23.89	75.00	49
	San Francisco, CA	1.37	21.52	75.00	55
	Washington, DC	1.92	30.18	75.00	39
ES2	Atlanta, GA	3.93	61.95	75.00	19
	Ft Worth, TX	3.59	56.55	75.00	21
	Las Vegas, NV	4.24	66.84	75.00	18
	San Diego, CA	0.89	14.09	75.00	84
ES1	Tampa, FL	5.19	81.68	75.00	14
	Lake Charles, LA	5.17	81.40	75.00	15
	Phoenix, AZ	6.82	107.37	75.00	11
*Window criteria Climate Zones included to assist in comparison with window findings. Climate zones do not apply to doors.					

4.5 Skylight Payback

Table B-25 lists simple paybacks for skylights. Annual household energy savings are from the prior section. For Phase 1, there is no marginal cost increase for homeowners in either Phase 1 or 2 for the southern and central parts of the country. In northern climates, D&R anticipates modest marginal costs. Again, while the annual energy savings are small, homeowners will recoup more than the marginal cost over the life of the product. The paybacks work in consumers' favor in all locations.

Table B-25. Simple Paybacks for Skylights							
Climate Zone	**City**	**Annual Energy Savings ($)**		**Total Marginal Cost ($)**		**Simple Payback (years)**	
		Phase 1	**Phase 2**	**Phase 1**	**Phase 2**	**Phase 1**	**Phase 2**
ES5 and ES5a	Burlington, VT	3.01	5.80	15.00	30.00	5.0	5.2
	Madison, WI	2.51	4.72	15.00	30.00	6.0	6.4
	Minneapolis, MN	2.46	4.63	15.00	30.00	6.1	6.5
	Portland, OR	1.24	2.41	15.00	30.00	12.1	12.5
	Seattle, WA	1.18	2.37	15.00	30.00	12.7	12.7
ES4	Boston, MA	3.09	5.94	15.00	30.00	4.9	5.1
	Chicago, IL	2.11	3.96	15.00	30.00	7.1	7.6
	Denver, CO	1.64	3.15	15.00	30.00	9.2	9.5
ES3	Albuquerque, NM	0.72	1.82	-	-	0.0	0.0
	Kansas City, MO	0.80	2.10	-	-	0.0	0.0
	San Francisco, CA	0.83	1.11	-	-	0.0	0.0
	Washington, DC	1.07	2.69	-	-	0.0	0.0
ES2	Atlanta, GA	0.94	2.11	-	-	0.0	0.0
	Ft Worth, TX	1.46	2.35	-	-	0.0	0.0
	Las Vegas, NV	1.49	2.51	-	-	0.0	0.0
	San Diego, CA	0.42	0.97	-	-	0.0	0.0
ES1	Tampa, FL	1.26	1.37	-	-	0.0	0.0
	Lake Charles, LA	1.10	1.47	-	-	0.0	0.0
	Phoenix, AZ	0.69	1.48	-	-	0.0	0.0

Appendix C: Methodology for Research on Windows Available for Sale

DOE used the following methodology to research windows available for sale:

1. Collected a pool of potential window manufacturers to research
    a. 2008 List of Top 100 Manufacturers from *Window & Door Magazine* (February 2008)
    b. List of ENERGY STAR window partners
2. Determined the number of companies (62) needed to have a sample of companies that would represent the windows market with 90 percent statistical confidence.[2]
3. Calculated the share of window market revenue represented by several tiers of the windows market:
    a. Top 20 manufacturers (63-percent market share)
    b. Top 21-100 manufacturers (20-percent market share)
    c. Remaining manufacturers (17-percent market share)
4. Researched windows from the following sample (Table C-1), taking into account the distribution of market share and number of companies in each tier:

Table C-1: Distribution of Window Manufacturers Researched

Market Tier	Share of Market Represented (%)	Number of Companies Researched
Top 20 Manufacturers	63	17
Top 21-100 Manufacturers	20	25
Remaining Manufacturers	17	20

Source: D&R International, Ltd., 2008. Analysis of 62 window manufacturers from 2008 Top 100 Manufacturers from *Window & Door Magazine* (February 2008) and ENERGY STAR Windows, Doors, and Skylights partners.

5. Recorded technical specifications of windows for sale on each company's website. Focused on double-hung and single-hung windows as the reference operator type for ENERGY STAR. Limited the sample to windows that already qualify for the strictest U-factor in current ENERGY STAR criteria (0.35 or lower) as the windows most likely to undergo modifications to proposed criteria levels.
6. If no window specifications were available, substituted the next available company from immediate market tier or, when necessary, from the following tier.
7. Calculated mean, median, and standard deviation for U-factor and SHGC of all records to match corresponding results from the NFRC Certified Product Directory.
8. Graphically represented the range of technical performance for these windows for comparison with a graph of similar windows listed in NFRC's Certified Product Directory.

[2] D&R International, Ltd., 2008. Sample size determined according to methodology in Cohen, Jacob. *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, NJ: Lawrence Earlbaum Associates, 1988.