An Evaluation of Alternative Qualifying Criteria for Energy Star Windows: February, 2003

U.S. Department of Energy
Office of Building Technology, State and Community Programs

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1.0 Background/Objectives

1.1 Energy Star Program

ENERGY STAR is a voluntary partnership among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and industry. ENERGY STAR, at both DOE and EPA, is based on legislative mandates to implement voluntary, non-regulatory programs to promote products that are substantially more efficient than required by Federal standards (the DOE ENERGY STAR program originated with Section 127 of the Energy Policy Act of 1992 [EPACT], and the EPA ENERGY STAR program originated with Section 103 of the Clean Air Act amendments of 1990). The base criteria under EPACT required DOE to establish voluntary energy efficiency product programs that serve to increase the technical energy performance potential of products, are cost-effective for the consumer, save energy, and thus reduce green house gas emissions. Criteria used by EPA under the Clean Air Act are similar but reflect a greater emphasis on reducing green house gas emissions.

The primary objective of the partnership is to expand the market for energy-efficient products. EPA and DOE use the ENERGY STAR label to recognize and promote the most energy-efficient subset of the market. The label is a simple mechanism allowing consumers to easily identify the most energy-efficient products in the marketplace. In developing criteria for the Energy Star label, EPA and DOE consider several key factors, including:

- Energy and environmental savings based on unit sales aggregated at the national level;
- Assurance that the efficient product offers the same or better overall performance as a less efficient product; and
- Assurances that the technologies or processes required for a more efficient product are commercially available and nonproprietary.

1.2 Energy Star Windows

The ENERGY STAR windows program has, since its inception in 1998, successfully promoted the increased use of efficient residential windows in the United States. As a percentage of overall national residential window sales, the number of ENERGY STAR - qualifying windows rose from less than 5 percent in 1997 to 15 percent in 1999, reaching an estimated 35 percent level in 2002. These numbers are based on sales and shipment data provided by partners as part of their ENERGY STAR agreement.

The program defines efficient residential windows by setting constraints on their U-factors and Solar Heat Gain Coefficients (SHGCs). A lower U-factor means a window is a better insulator, and a lower SHGC means the window blocks more of the sun's heat. The lower a window's U-factor and the higher its SHGC, the more it lowers a building's heating energy use. The lower a window's SHGC, the more it lowers the building's cooling energy use, including peak power electricity use. U-factors have minimal impact on cooling.

1.3 Goals and Changes from May 8, 2002 Report

This report evaluates alternative amendments to the Department of Energy's ENERGY STAR Windows Program criteria. One of the Department of Energy's alternatives is based on its potential code change submittal to the International Energy Conservation Code (IECC)[1],

[1] DOE's code change proposal was released for public comment and can be obtained from http://www.energycodes.gov/implement/doe_2004_proposals.stm. DOE is currently still evaluating whether to submit the code change proposal to the IECC for its consideration.

termed the Residential IECC Code Change (RICC) (Four-Zone) Alternative and the original May 8, 2002, (Three-Zone) Alternative. The previous version of this report (May 8, 2002) analyzed the current program, the October, 2001 Proposed Energy Star criteria and seven other sets of criteria. Additionally, an economic evaluation has been added to discuss potential consumer savings.

Specifically, for each alternative we assessed:

- Potential national and regional energy savings;
- Consumer economics;
- Impact on product availability;
- Consistency with energy codes; and
- Energy-related impacts (i.e., on electricity reliability and supply, pollution) within the Central Region of the United States.

Table 1 shows the Energy Star criteria requirements by Heating Degree-Days (HDDs), and in the case of the Four-Zone Alternative, in either/or HDD or Cooling Degree-Days (CDDs). Currently, the IECC sets window efficiency requirements by dividing the United States into climatic regions based on HDDs, while the Four-Zone Alternative considers both heating and cooling.

Table 1: Energy Star Alternatives and Reference Cases Approximate HDD Climate Zones

Reference/ Proposals	<2000 HDD	2000–3499	3500–5999	6000+
2000 IECC	U≤0.75 SHGC≤0.4	U≤0.5 SHGC≤0.4	U<.4 (U≤0.5 3500 to 3999	U < .35 SHGC – Any
Current Energy Star	U≤0.75 SHGC≤0.4		U≤0.4 SHGC≤0.55	U≤0.35 SHGC- Any
Three-Zone Alternative	U≤0.65 SHGC≤0.4	U≤0.4 SHGC≤0.4		U≤0.35 SHGC - Any
	CDD > 6300	**6300- 4500 CDD**	**3600–5400 HDD**	**5400+ HDD**
Four-Zone Alternative	U≤0.65 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.4 SHGC≤0.55	U≤0.35 SHGC – Any

Notes on References/Alternative:
2000 IECC (Reference) represents current code requirements for replacement windows
Current Energy Star Program (Reference) does not precisely fit the climate zones zone in Table 1. The Current Energy Star Program was modeled using the current map.
Three-Zone Alternative was developed by DOE after the discussions and comments from the March 20, 2002 workshop.
The Four-Zone Alternative was developed to be consistent with the new climate regions DOE is considering to propose to the IECC. The CDD are base 50°F.

Figure 1 shows the map for the Three-Zone Energy Star Alternative. The map divides the country in three regions: Northern, Central, and Southern, the same three zone concept of the current programs regions. Figure 2 shows the map for the Four-Zone Energy Star Alternative to match the RICC based program. The Four-Zone Alternative is intended to match and/or combine some of the new DOE proposed climate zones for IECC. To simplify the ENERGY STAR for the average consumer, the zones shown in Figures 1 and 2 deviate from the precise HDD and/or CDD contours to create continuous zones, similar to Current ENERGY STAR Windows criteria. Thus, the HDD descriptions in Table 1 are illustrative—not absolute—for all proposals under study. The IECC reference case in contrast, strictly follows HDD contours.

Figure 1: Three-Zone Energy Star Alternative Map

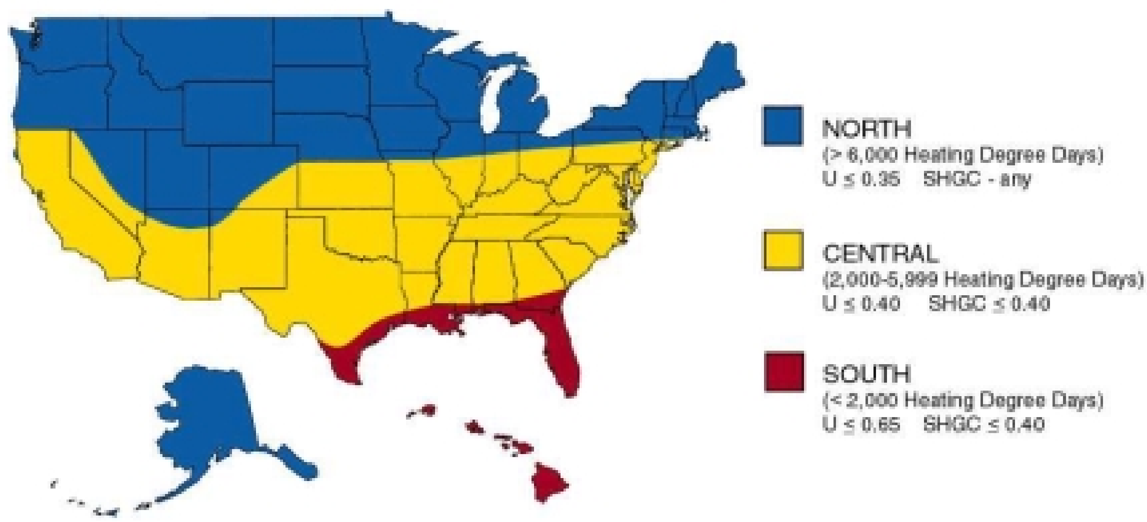
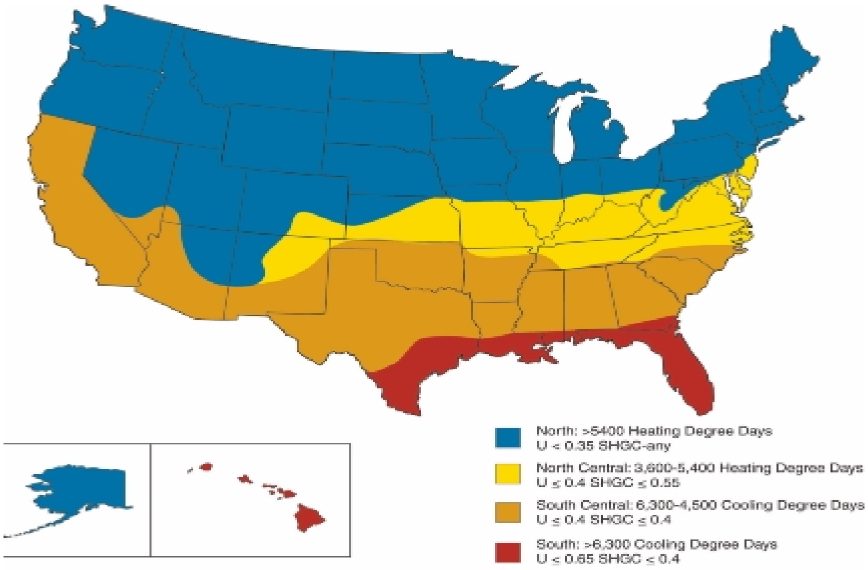


Figure 2: Four-Zone Energy Star Alternative Map



The Four-Zone map builds on the work performed by the Department of Energy in support of a range of program, including building codes, Building America and Energy Smart Schools, to more accurately define and represent climate regions in the United States. The new climate zones were developed based on a traditional system of climate classification used in many other disciplines. That classification provided quantitative definitions for three major climate types--humid climates, dry climates, and marine climates. These major climate types are important for buildings because they affect solar loads, humidity, daily temperatures ranges, and whether heating and cooling seasons are short and intense or long and mild. These are all aspects of climate that cannot be addressed simply by looking at HDDs--the primary basis for the current zones.

The new zones come from the Department's experience with what works and what does not work for building codes, and from the results of test houses and significant numbers of houses constructed by builder partners of the Building America program. The climate zones have proven excellent for defining the mechanical and envelope, which windows are a component, requirements for today's homes.

2.0 Energy Savings

The energy impacts of windows vary with climate and application, so any efficiency-marketing program must take account of these variations. At the same time, simplicity is fundamental to ENERGY STAR'S effectiveness as a marketing program for energy efficiency. This is primarily reflected in the number of climate zones the program employs. Energy Star has been using a three-zone program. However, as our analysis shows, increased energy savings can result from a slightly more complex four-zone program.

Particular areas for discussion, relative to the alternative criteria are:

- National energy savings;
- Impact of Solar Heat Gain Coefficient on Savings/Differences in the Central Zone;
- Impacts on New Construction Versus Existing Buildings; and
- Energy Supply Issues.

2.1 National Energy Savings

The national energy savings potentials of the alternative criteria, as well as the current IECC code, were estimated separately for new construction and replacement markets, and then totaled to create an expected annual energy savings potential based on annual window sales. The two calculations and summation are an attempt to account for the relative equality, in terms of window sales, between new construction and replacements. By most estimates, new construction accounts for 45 to 50 percent of all residential window sales (in 2000, 25.9 million windows were sold into new construction and 29.3 million were sold for remodeling and replacement)[2].

The national energy impacts and savings potentials were determined using a methodology originally developed for a similar study in 1999.[3] This procedure is based on DOE-2 building energy simulation program estimates of energy savings from windows in typical houses in 48 U.S. cities. In conducting this analysis, a couple of basic assumptions were made:

- It is assumed all window sales move from today's efficiency distribution to the defined minimum ENERGY STAR criteria for each zone(s) in each alternative. This is referred to as the "technical potential."
- Energy calculations for each of the 48 cities from the NFRC 900 database[4] were averaged according to climate zones/census regions, with the average consumption and savings serving as a proxy for that climate zone/census region.

This analysis represents a relative order of merit in terms of energy savings, but is not an absolute saving estimate for ENERGY STAR windows. Absolute savings will depend on many variables, such as market penetration, installed performance, future consumer energy use habits, etc.

[2] Department of Energy, Office of Building Technologies, State and Community Programs, 2001 BTS Core Databook, July 13, 2001
[3] Arasteh, D., Lawrence Berkeley National Laboratory, E. Barbour, Arthur D. Little, Inc. "An Evaluation of Alternative Qualifying Criteria for Energy Star Windows," May 12, 1999
[4] Arasteh, D., J. Huang, R. Mitchell, R. Clear, C. Kohler., "A Database of Window Annual Energy Use in Typical North American Residences." Presented at the 2000 ASHRAE Winter Meeting, February 5–9, 2000, Dallas, TX, July 1999

Details on the assumptions and methodology are located in Appendix A for existing buildings and Appendix B for new construction. The accompanying spreadsheet (Appendix C) includes the assumed window characteristic and energy calculation results for the 48 cities and each proposal. Table 2 presents the results of these calculations using the regional estimated average efficiency of windows sold today as the baseline and estimating annual energy savings potential from the various alternatives and reference cases considered.

Table 2: Total Annual Energy Savings Potential (relative to current sales, technical potential in trillion Btus per year)

Scenario	Heating Savings	Cooling Savings	Total
IECC 2000	(1.5)	7.8	6.3
Current Energy Star	1.3	6.6	7.9
Three-Zone Alternative	1.0	9.3	10.3
Four-Zone Alternative	4.1	7.9	12.0

(Components may not add to totals because of rounding)

The estimated savings show greater potential with cooling than heating for all of the alternatives. This is because national window sales, except in the South, have already evolved from single pane to dual pane technology or insulating glass units (IGUs). By definition, IGUs reduce heating loads due to the lowering of thermal transmittance through the two panes of glass. Thus, an incremental change in U-factor in any of the proposals will reflect lower gains in heating energy reduction than a change in SHGC, which indicates much greater cooling energy savings. This is particularly true in southern climates, where there is a large amount of cooling energy savings potential. Air pollution impacts are also a factor to be considered in relation to ENERGY STAR requirements. Typically, saving on electricity (cooling) reduces air pollution impacts more than savings on gas (heating)[5].

2.2 Impact of Solar Heat Gain Coefficient on Savings/Central Zone

One of the major differences in the various alternatives is the SHGC requirement for various zones. Primarily, the discussion centers on how far to the north and at what level do you extend the maximum SHGC requirement. In order to evaluate what impact this has, we used the NFRC 900 database to estimate the relative energy consumption for a new and existing home using windows with a U-factor of 0.35 and either 0.4 SHGC or 0.55 SHGC throughout the country. Below are the results of this analysis.

[5] Typical primary emissions for Natural Gas and Electricity, in million metric tons of carbon per quad, are 14.4 and 16.03 respectively. Source: 2002 Buildings Energy Databook, http://buildingsdatabook.eren.doe.gov/

Figure 3: Impact of SHGC on Energy Savings, (MMBtus/yr.)

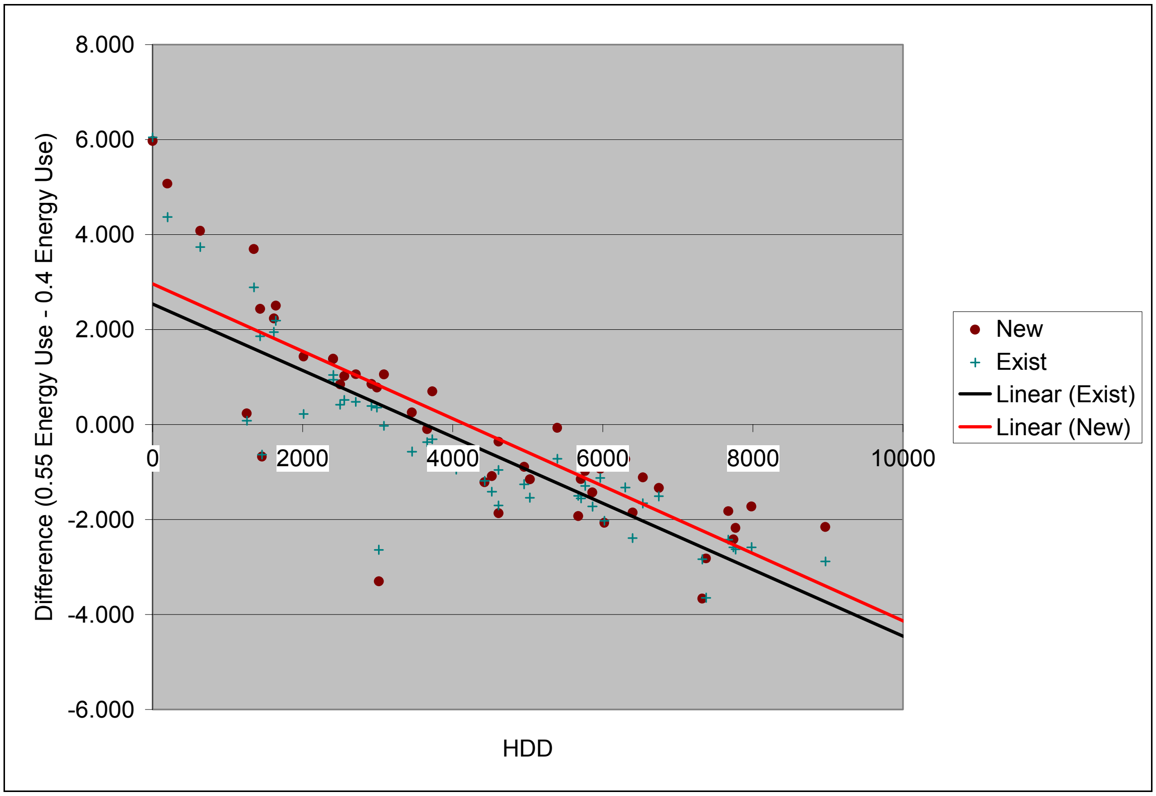


Figure 3 shows the relative difference in energy consumption, annual heating and cooling combined, between homes using two different SHGCs. At approximately 4000 HDD, the relative savings shifts from the low SHGC window to the higher SHGC window. This indicates the potential importance of increasing SHGC requirements in the northern climates, while still focusing on reducing U-factor of windows to provide energy savings. For the northern climates, reduction in U-factor will still provide the largest portion of potential savings. However, it does not take into account other considerations when developing ENERGY STAR criteria, such as peak energy savings and trade-offs between U-factor and SHGC for entire climate regions. Also, it should be noted, both of these windows will save heating and cooling energy over current sales.

2.3 New Construction Versus Existing Buildings

As stated before, the market for window sales is almost evenly split between new construction and retrofit applications. The results presented are a combination of savings from new construction and existing homes. There are a couple of differences in the estimates for new and retrofit, due to differences in each of these markets. These differences are:

- Air conditioning represents a greater percentage of total energy use in the new construction market due to increased use of insulation. The increased insulation reduces the heating load more than it reduces the cooling load. Also, new homes are far more likely to have air conditioning.
- As a national trend, new homes are located farther south than existing homes. The increased emphasis on new construction in the South has also increased related

cooling consumption. In 2000, the South represented 46 percent all new homes built in the United States. Given new homes represent approximately one-half of all window sales, cooling savings and lower SHGC will be important in staving off increases in energy consumption in those regions.

In short, and all else being equal, the new construction market will show greater energy savings for technologies that lower the cooling load. Similarly, in the existing market, technologies that lower the heating load will provide more savings.

2.4 Energy Supply Issues

Electricity reliability and gas pricing in times of high demand should also be considered in the decision making process about ENERGY STAR requirements although these issues are often regional and temporal. Taking these factors into account consistently requires clarifying the perspective upon which the ENERGY STAR criteria is or should be based. Solar heat gain through windows is a large component of residential cooling loads; therefore, reducing the SHGC of windows will reduce peak-cooling loads dramatically, which in turn reduces electricity consumption, utility bills, and power-plant pollution emissions.

Since the two alternatives examined were mostly similar except for the 3,600 HDD to 5,400 HDD region, an evaluation was made for that zone where the SHGC varied significantly between proposals. For this analysis, we examined the zone with HDD more than 3,600 but less than 5,400, and calculating with the different levels of SHGC, using either a maximum of 0.4 or a maximum of 0.55. Previous studies, such as *Energy Savings and Pollution Prevention Benefits of Solar Heat Gain Standards in the International Energy Conservation Code*[6] examined the peak impacts of adopting a 0.4 SHGC in the warmer climates (less than 3,500 HDD).

To examine this zone, we used the NFRC 900 database to calculate the average reduction in peak demand between windows with SHGCs of 0.55 and 0.4, the same levels used to evaluate the energy savings of the two sets of criteria. Using the assumption that when windows were replaced, the two options available to the homeowner would be windows whose SHGCs were either 0.4 or 0.55, we calculated a maximum net total potential peak reduction between these two options. The savings are based on the selection of windows with a 0.4 SHGC instead of windows with a SHGC of 0.55. Also, it was assumed the entire stock of windows would be replaced in 40 years. The results of this calculation are as follows:

[6] Prindle, Bill and Dariush Arasteh, "Energy Savings and Pollution Prevention Benefits of Solar Heat Gain Standards in the International Energy Conservation Code," May 2001

Table 3: Comparison of Three-Zone and Four-Zone Alternatives for Annual Peak Reduction

Climate Zone (3,600 to 5,400 HDD)	
Average Peak Reduction per Home	0.25 kW
Number of Homes With Cooling	18.45 Million[7]
Total Reduction	4,612 MW
Typical Lifetime of Windows	40 years[8]
Annual Avoided Capacity (Three-Zone over Four-Zone)	115 MW[9]

The 4,612 MW total reduction represents the total potential reduction in peak load for existing homes using cooling in this climate zone. Assuming that windows are replaced every 40 years, this would equal the equivalent of displacing one 115-MW power plant every year; for comparison the average size of coal plants operating in 1998 is 272 MW[10].

One would expect the Three-Zone Alternative would potentially reduce peak load over the Four-Zone Alternative due to the larger potential savings in cooling energy and the direct correlation to electricity use, thus providing benefits beyond energy savings. Peak energy savings have other impacts beyond the need for new power plants. Peak reduction has the potential to impact, positively, energy prices and electric system reliability.

3.0 Consumer Economics

The Department is interested in examining how the ENERGY STAR Windows program affects consumer economics. The economic evaluation looked at the average annual energy cost savings expected for a typical household. The analysis looked at the impact the window would have on the actual heating and cooling cost. The benefit of the ENERGY STAR windows purchase for individual consumers includes a change in the operating expense (usually decreased) and a change in the purchase price (usually increased). Manufacturing a more efficient window will potentially cost more, but due to the complexity and number of windows on the market (over 100,000 in the NFRC database) this analysis does not attempt to address incremental first cost.

Performance, as related by U-factor and SHGC, is only one of many attributes impacting cost; with the choice of frame (vinyl, wood and metal) the most significant factor affecting incremental cost of an ENERGY STAR window versus a standard option. Variations in frame price may mask differences in glazing costs/pricing, making it difficult to create a correlation of cost vs. efficiency. Additionally, window costs vary widely by region depending on whether the market for energy efficient windows is mature or not. Mature market costs are very low, while in emerging markets they are higher. ENERGY STAR is a good vehicle to move markets from emerging to mature, thereby helping out consumers over time.

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[7] Energy Information Administration, 1997 Residential Energy Consumption Survey, http://www.eia.doe.gov/residential.html
[8] Average window life span is 35 to 45 years, BTS Core Databook, 2001
[9] For comparison, the previous study cited in footnote 2 noted savings of 466 MW annually for new and existing window sales through adoption of the IECC in 10 southern states.
[10] Energy Information Administration, Inventory of Power Plants in the United States 1999, November 1999

The economic evaluation used average data from the Residential Energy Consumption Survey for natural gas, oil and electric costs, shown in Table 4.

Table 4: Average Fuel Costs

Climate Zone	Cost, $/MMBtus		
	Gas	Electric	Oil
<2,000 HDD	$7.74	$8.18	$7.29
2,000–3,499 HDD	$7.29	$7.58	$7.28
3,500–5,999	$8.74	$7.13	$6.01
6,000–7,000	$6.45	$8.29	$7.22
7,000 +	$5.87	$6.98	$6.94

Source: 1997 Residential Energy Consumption Survey

Given the baseline windows inputs for each city, the energy analysis (see Appendices A and B) calculates the heating and cooling energy consumption of a typical residence. Next, the window performance criteria of the current program or one of the alternatives is input for each city, and the spreadsheet recalculates the energy consumption for the same house.

The economic analysis used the above results and the EIA energy cost data to calculate the cost impact of each city, relative to the base assumed sales information. This provided cost impacts for the typical residence in each of the 48 cities. Below is the average savings across all 48 cities in the NFRC 900 database.

Table 5 Annual Energy Cost Savings ($/household)

Scenario	Average Savings
Current Energy Star	$23.41
Three-Zone Alternative	$28.32
Four-Zone Alternative	$30.19

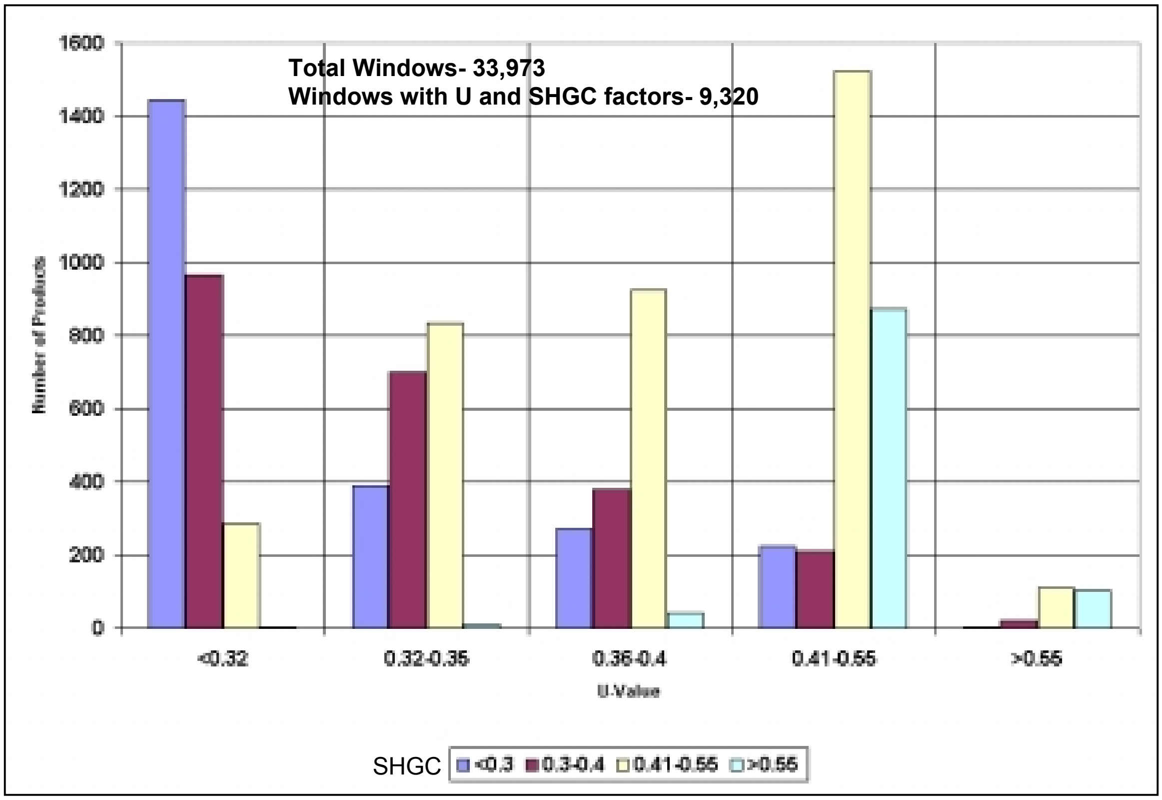
Each alternative shows savings over current typically sold and installed windows, with the Four-Zone Alternative providing slight savings over the Three-Zone Alternative. Other widely recognized benefits of ENERGY STAR windows are improved comfort and reduced condensation. These are potentially much more significant to the average homeowner than $20-30/yr. Both proposals would provide improved comfort and reduced condensation.

4.0 Impact on Manufacturing

Window manufacturers and consumers value the ENERGY STAR label for identifying efficiency and comfort. Thus, the label's requirement affect window manufacturers' decisions about window components and consumers' decisions about which products to purchase. The impacts of program requirements on participants in the window market should therefore be well-understood and included as part of the final decision-making process regarding program requirements.

We reviewed a subset of the NFRC database of products (approximately 33,973 windows within certain product categories of the entire NFRC database representing over 100,000 products) to ensure that commercially available products were available for the criteria levels included in the various proposals. The products were chosen to represent the more common residential window types. This review did not address product cost, geographical availability, or manufacturing volume. In terms of number of products available, product availability is not an issue.

Figure 4: Availability of Windows by U-Factor and SHGC



Total number of evaluated windows with U-factors: 33,973
Total number of evaluated windows with U-factors and known SHGC factors: 9320 or 27 percent of the windows with U-factors
Windows evaluated include: Vertical Sliders, Casements, Horizontal Sliders, and Fixed Operable.
Source: NFRC Product Directory, 10th Edition, 2001 (web: www.nfrc.org)

There are two manufacturing sectors within the window industry where significant investments have been made and where there may be significant impacts caused by ENERGY STAR. The impacts of ENERGY STAR on these two sectors are:

- Aluminum frames in the southern zone; and
- Types of low-emissivity (low-e) coatings for Middle and Northern zones

4.1 Aluminum Frames

Aluminum-framed residential windows once represented a significant portion of the market (30 percent or more during the 1970s but now it is less than 13 percent). Because of the relative lower energy efficiency and lower condensation resistance of these windows in central and northern states, they are no longer acceptable under many energy codes, and consumers have moved away from these products. The lower market share of aluminum frames has been hastened by the emergence of vinyl as a cost-effective and thermally efficient replacement. The decreased market share of aluminum windows has hurt aluminum extruders more than window manufacturers; manufacturers switched to vinyl extrusions and continued to sell windows while aluminum extruders have been left without a market.

However, in several significant southern markets (Florida, the Gulf Coast States, and parts of Texas,) aluminum frames predominate. In some of these geographical regions, heating energy issues are minimal, and other non-energy issues favor aluminum products. In its ENERGY STAR Windows program, DOE has attempted to take into account the prevalence and benefits of aluminum frames in southern markets, such as disaster resistance and traditionally lower cost.

For the approximate <2000 HDD zone, all proposals examined had a SHGC of a 0.4 maximum; this does not affect the use of aluminum frames. A requirement of the U-factor less than or equal to 0.65 may require some manufacturers to switch from narrow IG gaps (typical of southern climates) to wider ½” gaps (typically used in more insulating window products); such a change requires manufacturing changes but does not preclude the use of aluminum as a framing material. A lower U-factor requirement could be set if the program wanted to require thermally broken aluminum frames which reduce heat transfer by breaking the conductive path of a solid aluminum frame with a more insulating material.

With the new NFRC modeling procedures being implemented in April 2003 resulting in slightly lower (by up to 0.08) U-factors for aluminum windows, this makes the 0.65 an easier target for the industry to meet with current products.

4.2 Low-e Coatings

Low-emissivity or low-e coatings are the key component used to create an efficient window or ENERGY STAR window product. Low-e coatings are invisible, microscopically thin, metal or metallic oxide layers deposited on glass during manufacturing or soon after manufacturing. Emissivity relates to the rate of long-wave radiative heat transfer between glazing layers in a double glazed window (the lower the emissivity, the less heat transfer). This leads to decreased window U-factors (compared to uncoated clear glass) from the use of any low-e coating. Low-e coatings are all but required for an ENERGY STAR product, so the way in which ENERGY STAR addresses the different types of low-e coatings is critical for the low-e coating industry.

There are two manufacturing processes for low-e coatings, with each process producing a different product. Both products lead to significantly lower window U-factors but they differ in how they impact a window's Solar Heat Gain Coefficient (SHGC) – the fraction of incident solar radiation transmitted by the window. The products are summarized below:

- Pyrolitic (sometimes called hard) low-e coatings are deposited on the glass while it is being manufactured. These coatings transmit a higher level of sunlight, providing for added warmth in the winter but they do not reduce summer cooling loads compared to glass with lower SHGC.
- Spectrally selective coatings (sometimes called soft) are applied to glass after it is manufactured using sputtering equipment. These coatings reflect the invisible part of sunlight (the solar-infrared) while still transmitting visible light. This results in "clear" looking glass with significantly reduced summer cooling loads. However, "free solar heating" during the winter is also reduced.

Spectrally selective products have become quite popular because they meet maximum U-factor requirements (for northern climates) and also maximum SHGC requirements (for southern climates). Window manufacturers find this combination appealing because they only need to stock one product that can meet or beat codes or Energy Star requirements anywhere in the U.S. Until a few years ago, several national manufacturers offered a "northern" low-e (pyrolitic) and a "southern" low-e (spectrally selective) product; these dual products have almost all been eliminated in recent years.

In central climates (the approximate 3,500–6,000 HDD zone), both products save significant energy compared to clear uncoated double-glazing. In general in this region of the country, heating outweighs cooling energy use in the residential sector, but often the decision about which type of low-e product to use depends primarily on local climate and specifics of the application. However, in a good number of applications, air conditioning may be critical to energy use and comfort. In this zone we note the maximum SHGC of 0.40 in the 3,500-6,000 HDD zone could not be met by the pyrolitic low-e industry.

5.0 Consistency With Codes

Other factors influencing the selection of ENERGY STAR qualifying criteria are external to the program. Of these factors, building codes were identified as the most important. Building codes need to be examined to see where ENERGY STAR 's requirements fall relative to the requirements in a jurisdiction. IECC 2000 and California's Title 24 Energy Code were selected as the two most important codes for comparison with the ENERGY STAR program. This comparison was the primary factor behind DOE's efforts in 2001 to revise the ENERGY STAR program's criteria.

To date, sixteen states and the District of Columbia have adopted or are in the process of adopting the 2000 IECC or equivalent. Table 5 presents each ENERGY STAR proposal in relation to 2000 IECC standards.

Table 6: Current IECC Window Code Requirements and Comparisons with Alternatives[11]

Reference/ Proposals	<2000 HDD	2,000–3,499 (includes CA Central Valley)	3,500–5,999	6,000+
Current Energy Star	U≤0.75 SHGC≤0.4	U≤0.75 SHGC≤0.4	U≤0.4 SHGC≤0.55	U≤0.35 SHGC- Any
IECC	U≤0.75 SHGC≤0.4	U≤0.5 SHGC≤0.4	U ≤0.4 (U≤0.5 to 3999	U ≤0.35 SHGC – Any
Three-Zone Alternative	U≤0.65 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.35 SHGC - Any
Four-Zone Alternative	U≤0.65 SHGC≤0.4	U≤0.4 SHGC≤0.4	U ≤0.4 SHGC ≤0.55	U ≤0.35 SHGC – Any

Exceeds IECC Code   Meets IECC Code   Doesn't meet

Note: The four-zone alternative proposal's zones greater than 3,500 HDD do not directly match the current IECC HDD. Specifically, the northern most zone, originally designated as 6,000+ HDD moves farther south to 5,400+ HDD, increasing efficiency between 5,400 and 6,000 HDD.

5.1 General Discussion of Building Codes

The 2000 IECC requirements in Table 6 apply to replacement windows. Generally, replacement values are slightly more stringent than new construction requirements. For new construction, requirements vary more widely by region. Moreover, in new construction, window U-factor requirements can be traded off against high-efficiency heating, ventilation, and air conditioning (HVAC) equipment or other energy-saving features. Code requirements for new construction also vary based on the amount of window area in the design. A true comparison of codes is therefore very complex. However, given that approximately half the products sold are for retrofits and that a large number of new construction applications would be consistent with the values presented, the quantification of current codes in Table 6 is reasonable.

A significant issue is that the IECC code has only been adopted for new construction in a few states so far; states are even less likely to adopt it for replacement windows, which are typically not regulated. Although the calculated energy savings between ENERGY STAR and the IECC code appear small, the differences between current sales and ENERGY STAR are, in fact, significant because the IECC code is far from being widely adopted

Additionally, the Four-Zone Alternative levels are consistent with the proposal the Department is considering for the IECC 2003 code change cycle, which was offered for

[11] IECC does not address SHGC for areas above 3,500 HDD. Proposals that include SHGC requirements above 3,500 with equivalent IECC U-factor are shown not to exceed code. Additionally, the RICC based proposal evaluation represents an approximation mapping of requirements for the new climate zones to those in the 2000 IECC

comment to industry on September 2002. The Department is continuing to review the proposed climate zone change, and may or may not submit it depending on the outcome of its review, as well as comments from stakeholders. Depending on the outcome of the Department's review of this potential code submittal, it is the Department's goal to create an integrated program through coordination of the research and development, market deployment and codes and standards. Below is the new map and windows code change submittal in the RICC.

Figure 5: Climate Map for RICC

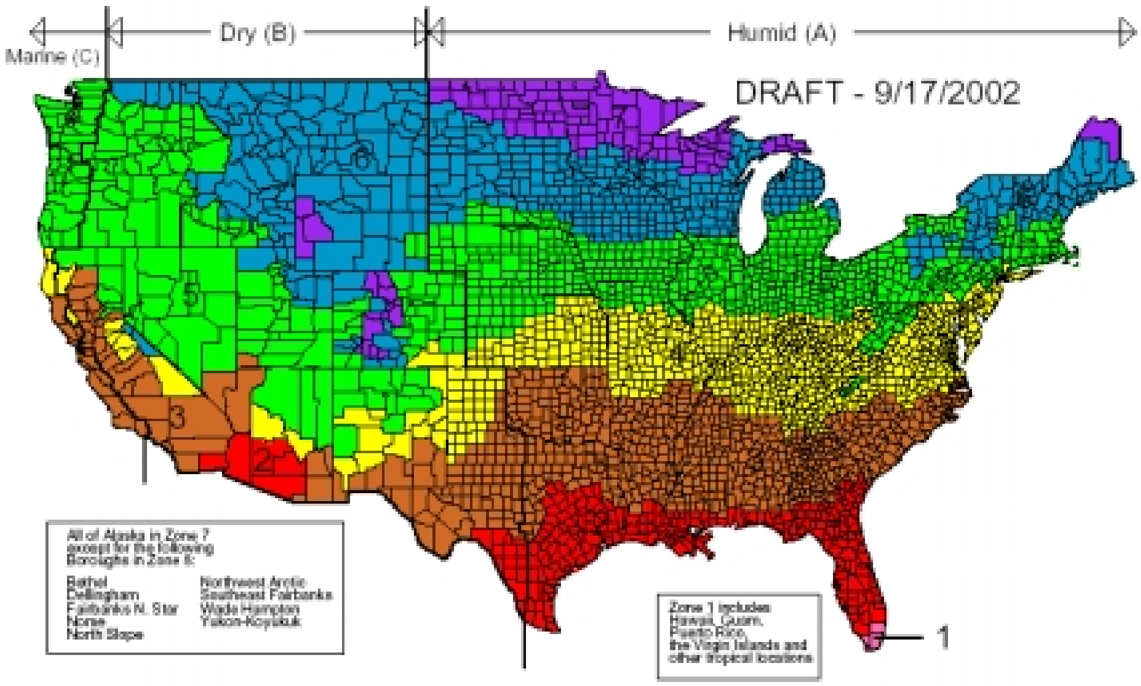


Table 7 Potential Proposed U-factors and SHGC for RICC

Climate Zone	Fenestration U-Factor	Fenestration SHGC
1	1.20	0.40
2	0.80	0.40
3	0.65	0.40
4	0.4	None
5	0.35	None
6	0.35	None
7 and 8	0.35	None

DOE's new climate zones is the culmination of a nearly two-year process involving numerous discussions, several meetings at national conferences, a white paper, and several months of technical work at Pacific Northwest National Laboratory (PNNL). The map also builds on the research conducted in Building America and Energy Smart Schools programs.

Regional issues and state policies affect codes. In states with similar climates, significant differences in codes may exist because of local policies. In addition, the penetration of ENERGY STAR windows varies from area to area—it is, for example, much greater in the north than in the south, so the effort required to move a significant portion of sales to an ENERGY STAR level in some portions of the country will vary.

6.0 Conclusions

Several, often conflicting, issues need to be addressed in the development of an updated ENERGY STAR windows program. This report notes these issues and the tradeoffs among them.

These issues are:

- Energy savings from the program;
- Consumer economic savings;
- Simplicity of the program;
- Consistency of the program with IECC Codes and regional issues;
- Impacts of the program on specific manufacturing sectors; and
- Impacts of the program on energy supply

The following table summarizes the advantages and disadvantages of the two alternatives considered, given the above list of issues.

Table 8: Summary Evaluation of Proposals

Alternative	Advantages	Disadvantages
Three-Zone	• Maintains relative simplicity of the existing system (3 zones) • Summer peak demand savings (eliminating the need for construction of some new power plants) • Provides energy savings over IECC codes and current Energy Star • Accounts for new NFRC calculation procedures', potentially not negatively impacting Aluminum frame windows qualification	• Affects two manufacturing sector (pyrolitic low-e and Aluminum frame) • Leaves some energy savings unrealized
Four-Zone	• Provides energy savings over IECC codes and current Energy Star • Adds fourth zone, which allows for consistency with 4 IECC zones • Accounts for new NFRC calculation procedures', potentially not negatively impacting Aluminum frame windows qualification.	• Adds fourth zone, which increases complexity • Leaves some peak savings unrealized • Affects Aluminum frame manufacturers

APPENDIX A

Existing Building Methodology and Results

Data from the NFRC 900 database of DOE-2 runs for 48 U.S. climates was regressed against U and SHGC [Arasteh, D., J. Huang, R. Mitchell, R. Clear, C. Kohler. July 1999. "A Database of Window Annual Energy Use in Typical North American Residences." Presented at the 2000 ASHRAE Winter Meeting, February 5-9, 2000, Dallas TX and published in the proceedings.] A specific regression was developed for each climate. These regression expressions allowed estimates of the annual energy impacts from small changes to ENERGY STAR window properties. Heating Loads reported by DOE-2 were translated into electric resistance heating energy using an efficiency of 1.0 and into heat pump energy using an approximate coefficient of performance (COP) of 2.0. Given the baseline windows inputs for each city, the spreadsheet calculates the heating and cooling energy consumption of a typical residence. Next, the window performance criteria of the current program or one of the proposals is input for each city, and the spreadsheet recalculates the energy consumption for the same house. The ratio of the energy consumption under the proposal to that under the baseline indicates the energy savings realized for both heating and cooling.

A correction factor was applied to the savings estimates to account for the fact that the regression expression developed above was developed for windows applied to typical new construction, as opposed to typical existing construction. This correction factor varied with climate, but typically reduced heating energy savings 20–30 percent and typically reduced cooling energy savings 10 percent. This correction factor accounts for the estimated decreased levels of insulation and air-sealing in the envelope of existing buildings. Note the absolute energy savings from windows are generally higher in retrofit applications but the fractional savings (window to whole house) are less since the absolute energy savings in existing houses is proportionally greater than energy use in typical new houses. This correction factor was determined by comparing two databases on energy impacts of windows, one for typical new and one for typical existing homes developed for the NFRC Annual Energy Rating Subcommittee (see http://windows.lbl.gov/AEP/database.htm).

For each of the proposal climate zones, heating and cooling energy use for the proposed ENERGY STAR criteria were determined using weighting factors for space heating and cooling based on a comparison of RECS space heating and cooling energy by HDD zones to NFRC 900 data. Shares of electricity, natural gas, and oil demand were determined from RECS, which provides household gas and electric heating and cooling consumption data for each climate zone. The national energy consumption data are provided in the following table. The correction factors developed were used to provide a savings estimate, in percentage reduction, for heating and cooling of existing buildings. This percentage reduction for each of the climate zones was then multiplied by the actual estimated RECS heating and cooling energy use.

Table A.1: RECS Annual Energy Consumption

Energy Use (Quads)				
Climate Zone	Heating			Cooling
	Gas	Electric	Oil	Electric
<2,000 HDD	0.22	0.17	—	0.55
2,000–3,499 HDD	0.41	0.23	0.02	0.30
3,500–5,999	1.30	0.67	0.52	0.36
6,000–7,000	1.23	0.17	0.22	0.09
7,000 +	0.62	0.06	0.26	0.04

Source: 1997 Residential Energy Consumption Survey

The Existing Buildings results were converted to annual savings, relative to current sales by assuming 40-year lifetime for windows. Below are the results of this analysis:

Table A.2: NFRC 900—RECS Results (relative to current typical sales, technical Potential in trillion Btus/year)

Scenario	Heating Savings	Cooling Savings	Total
IECC	(1.08)	4.00	2.92
Current Energy Star	0.33	3.55	3.88
Three-Zone Alternative	0.73	4.95	5.69
Four-Zone Alternative	2.64	4.14	6.78

(Components may not add to totals because of rounding)

Appendix B

New Construction

Data from the NFRC 900 database of DOE-2 runs for 48 U.S. climates was regressed against U and SHGC [Arasteh, D., J. Huang, R. Mitchell, R. Clear, C. Kohler. July 1999. "A Database of Window Annual Energy Use in Typical North American Residences." Presented at the 2000 ASHRAE Winter Meeting, February 5-9, 2000, Dallas TX and published in the proceedings.] A specific regression was developed for each climate. These regression expressions allowed us to estimate the annual energy impacts from small changes to Energy Star window properties. Heating Loads reported by DOE-2 were translated into electric resistance heating energy using an efficiency of 1.0 and into heat pump energy using an approximate coefficient of performance (COP) of 2.0. Given the baseline windows inputs for each city, the spreadsheet calculates the heating and cooling energy consumption of a typical residence. Next, the window performance criteria of the current program or one of the proposals is input for each city, and the spreadsheet recalculates the energy consumption for the same house. The ratio of the energy consumption under the proposal to that under the baseline indicates the energy savings realized for both heating and cooling.

Using the heating and cooling loads developed from the NFRC 900 database; the average consumption from each census region was multiplied by the number of homes built per census region. This provides a total expected consumption under each scenario. Table B.1 shows are the numbers of single-family homes built in 2000.

Table B.1: Number of New Homes Built in 2000

Census Region	Number of Homes Built, (000s)
New England	38.7
MidAtlantic	83.6
East North Central	173.2
West North Central	72.2
South Atlantic	331.5
East South Central	60.7
West South Central	137.6
Mountain	148.7
Pacific	152.0

Source: US Census Bureau

The heating results are weighted relative to the current penetration of natural gas, fuel oil, and electrically heated new homes. This data are shown below:

Table B.2: Type of Heating Fuel in New One-Family Houses in 2000

Census Region	Natural Gas (%)	Oil (%)	Electric (%)
Northeast	65	28	6
Midwest	92	—	7
South	50	—	50
West	91	—	8

Source: U.S. Census Bureau (components may not add to 100% because of rounding)

This type of analysis is heavily dependent on the quality and type of data used to develop the energy savings. Unfortunately, the U.S. Census Bureau does not report new construction statistics by climate regions, reporting instead by Census Regions. Aggregating the results to nine census regions leads to averaging multiple climate zones into one region. Such aggregation leads to a larger uncertainty for the new construction analysis compared to the previous existing building's analysis, which was based on RECS.

The one change in methodology from the existing building calculation is: instead of applying these results to RECS data, the average savings for each proposal from the NFRC 900 database for each census region was applied to the annual total number of residential single-family sales in each region. Table B.3 presents the results, compared to the current typical sales.

Table B.3: NFRC 900—New Construction Results (relative to current sales, technical potential in trillion Btus)

Scenario	Heating Savings	Cooling Savings	Total
IECC	-0.38	3.76	3.38
Current Energy Star	0.94	3.08	4.02
Three-Zone Alternative	0.28	4.32	4.61
Four-Zone Alternative	1.51	3.72	5.23

(Components may not add to totals because of rounding)

Appendix C

The accompanying spreadsheet serves as Appendix C for the analysis. Some notes on Inputs/Tables in the spreadsheet:

- Heating Energy is expressed in MMBtu/yr.
- Cooling Energy is expressed in kWh/yr.
- Sales Scenario estimated using the report *The National Energy Requirements of Residential Windows in the U.S.: Today and Tomorrow*, Frost K., Eto J., Arasteh D., and Yazdanian M., March 1996 ACEEE 1996 Summer Study on Energy Efficiency in Buildings: "Profiting from Energy Efficiency," August 25-31. 1996, Asilomar, Pacific Grove, CA.