

# Solar Heat Gain Ignorance: A Comparison of Window Energy Rating Systems

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*ATOFINA Chemicals, Inc. is pleased to announce that since the publication of the following article, the U.S. Department of Energy has adopted a four-zone approach for the Energy Star for Windows program. This approach divides the country into more appropriate climate regions, and provides greater national energy savings than the original proposal discussed in the article. Although these criteria continue to ignore the benefits of high solar gain in northern climates, the Department is in the process of developing performance-based criteria, which will properly take into account the effects of both U-factor and solar heat gain on overall energy performance.*

**T**he technology for energy efficient residential windows has progressed significantly. Witness the development of improved frame materials and designs, insulated glass units with argon and krypton gas fills, warm edge spacers, and low emissivity coatings. Governments have a clear interest in encouraging the use of more advanced window systems to promote national energy savings, and manufacturers are motivated to provide these higher value-added products.

In the early days, there was no need for detailed window energy rating systems – it was enough to promote the use of double glazing over traditional single pane glass. As the technology developed, fair comparisons between competitive window designs became difficult and led to the development of standard methods for measuring window thermal and optical properties. These properties are in turn used in either prescriptive or performance based rating systems in

mandatory building codes and voluntary promotional labeling programmes. In this article, we compare several rating systems from around the world used to compare and promote energy efficient residential windows. In particular, the drastic shortcomings of the U.S. Energy Star programme are compared to the much more advanced systems used or being developed in other countries.

## Window Properties

**The primary window properties which impact energy performance are the overall heat transfer coefficient (U) and the solar heat gain coefficient (SHGC or g).** Air infiltration also affects energy performance to a lesser degree, but it can be shown that this effect

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is negligible as long as basic window installation requirements are met. The U-factor is a measure of the insulating value of the window against heat losses from conduction, convection, and radiation. A lower U-factor will provide better energy performance in all climates, although the savings will generally be larger in colder climates. Because of its relative simplicity, there has been a strong tendency to compare only the U-factor for different windows and glazing options, just as you would for wall insulation. However, it is inaccurate and simply wrong to treat a window as if it were an opaque wall, ignoring the effect of sunlight coming through the window. To accurately evaluate window performance, the solar heat gain must also be

considered, as its impact on energy consumption can be the same or even larger than that due to the U-factor.

**The solar heat gain coefficient reflects the fraction of incident solar energy that enters the home through the window.** This free solar energy is either beneficial or detrimental depending on the location of the home. In warm climates where energy consumption is dominated by air conditioning, windows with reduced solar heat gain are preferable. In colder, heating-dominated climates such as the upper half of the U.S. and the majority of Europe, high solar gain windows are preferable, as they let in the free energy of the sun to greatly reduce heating fuel consumption. In temperate or mixed climates, high solar heat gain in the winter and low solar heat gain in the summer would be ideal.

**Other factors also affect the overall solar heat gain, such as internal blinds, overhangs, shutters, awnings, shade trees, etc.** For example, a recent project

from the Building America programme in conjunction with the U.S. National Renewable Energy Laboratory compared the utility bills for hundreds of homes in Las Vegas with the same floor plan but different energy efficient features, including low SHGC low-e windows.<sup>1</sup> Even in this cooling dominated city, homes with low SHGC low-e windows did not show the expected savings in air conditioning costs relative to homes with standard clear windows, simply because the homeowners used their drapes to reduce the incoming sunlight when needed. These extra factors have an important implication on the choice between low and high SHGC windows in areas with mixed heating and cooling

demands. High SHGC low-e windows are “tunable” to optimize seasonal comfort and energy performance, and the ideal of high solar heating in winter and low solar heating in the summer can be achieved. In the winter, high solar gain low-e windows allow the sun’s heat in to help maintain warmth and comfort level in a home while reducing heating demand. In the summer, the solar heat gain of these same windows can always be temporarily lowered to increase comfort and reduce cooling demand through the use of blinds, solar screens, or deciduous shade trees. On the other hand, low solar gain products are in a fixed state, and the solar heat gain can never be increased to take advantage of solar heating in the wintertime.

### **Energy Rating Programmes – The Right Approach**

To properly assess window energy performance, both U and SHGC must be considered in the complete heat transfer energy balance. This concept is nothing new, and all modern building analysis tools such as the U.S. Department of Energy’s dynamic thermal simulation package DOE2.1E include both the impact of U and SHGC on energy consumption. These sophisticated simulation tools have been validated by extensive physical testing, and are readily available. While many countries are developing comprehensive performance-based energy rating programmes that include the effects of both U and SHGC, others, such as the U.S. have unjustifiably ignored the complete effects of solar heat gain.

**Australia and New Zealand have developed perhaps the most complete performance-based energy rating system, WERS or “Window Energy Rating Scheme.”** In this system, a residential window is rated with one to five stars based upon its heating and cooling performance relative to a single pane clear window in an unbroken aluminum frame. This performance is determined through a complete building dynamic

energy analysis using a typical model house and regional weather data.

Modern software tools enable this analysis to be scientifically complete including the effects of both U and SHGC, yet easy to perform.

**Canada, the United Kingdom, and Denmark have all developed performance-based energy ratings based upon a simplified energy balance of the form:**

$$ER = A \times SHGC - B \times U - C \times L$$

In the equation above L is an air leakage rate under specified conditions. A, B, and C are constants which vary by country. The ER reflects the overall heat loss or gain through a window in a typical house, averaged over the heating season. The first term captures the beneficial impact of passive solar heat gain on energy performance, whereas the second and third terms represent the energy

true in the majority of the European building codes, but there is now recognition that true energy performance can only be assessed by including both U and solar heat gain. The “European Window Energy Rating Scheme” or EWERS is being developed with the stated intention to “provide a basis for rating windows by energy performance that represents a significant improvement on rating by U-value alone.”<sup>2</sup> This programme will label products with an A to G rating according to the window annual energy loss or gain in a typical model house for specific European climates.

### **Energy Rating Programmes – The Wrong Approach**

On the other hand, in the United States, the Department of Energy has produced a rating system for residential windows, Energy Star, which is archaic and scientifically incomplete in comparison to the performance-based energy rating systems described above.

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losses due to conductive, convective, and radiative heat transfer and air leakage. The specific numbers for A, B, and C were generated from a regression on detailed building simulations using a typical model home and regional weather data. Each of these countries can be reasonably represented by one heating-dominated climate zone, but multiple equations could be developed for multiple climate zones. In this type of system, higher performance is reflected by a higher ER number. A minimum ER is specified either in the building codes and/or voluntary labeling programmes such as the Canadian Energy Star programme under development.

**In Europe, the focus was previously on only the U factor, and solar heat gain was largely ignored.** This is still

**The U.S. programme does not set criteria on actual energy performance, but rather specifies maximum U factors in three regions, as well as maximum SHGC values in the southern and central regions.** SHGC is completely ignored in the northern zone, meaning that windows that block out the warmth of the sun can get an energy star in the north! By ignoring the benefits of passive solar heat gain in mixed and heating-dominated climates, the U.S. Department of Energy has developed a system which lacks technical merit, fails to maximize energy savings, and has an anticompetitive impact on the marketplace.

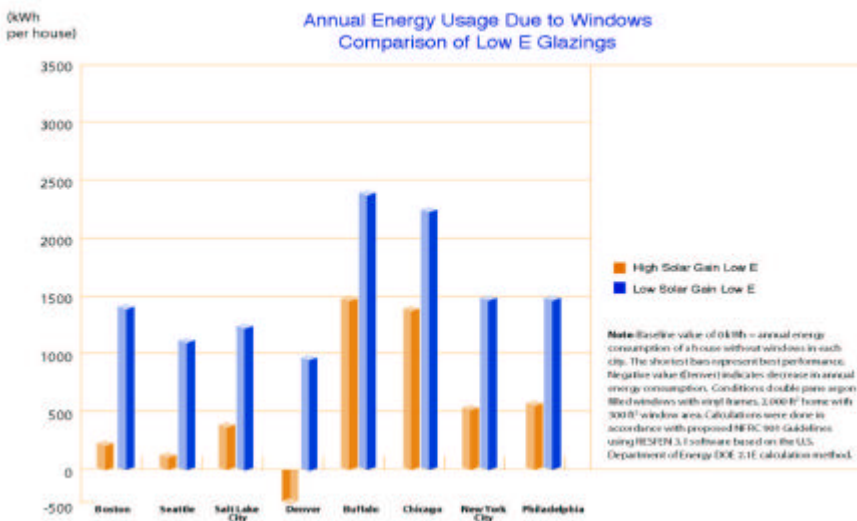
By performing single house energy performance calculations in accordance with NFRC 901 proposed guidelines based

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upon the Department of Energy's own DOE2.1E calculation tool, it can be clearly demonstrated that annual energy performance is maximized by using high solar heat gain low-e products for cities above approximately 3600 HDD65°F (heating degree days at a base 65°F, approximately equivalent to 2000 HDD18°C). As shown in Figure 1, window energy usage is reduced by using low-e windows with

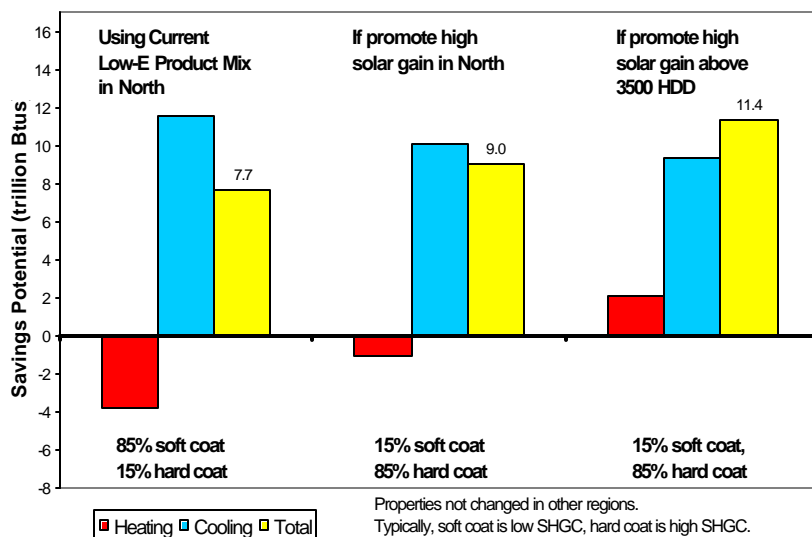
high solar heat gain, reducing the cost to consumers for heating homes in cold climates.<sup>3</sup> However, the benefit of high SHGC and passive solar heating (a free, renewable energy source) is ignored in the Energy Star programme. (Figure 1)

**Additionally, overall national energy savings would be increased through the promotion of high SHGC low-e products in northern regions.** We have examined the effect of SHGC on potential national energy heating and cooling savings relative to current sales using the model developed by Barbour.<sup>4</sup> As shown in Figure 2, if the actual current low-e product mix in the north is used in the model (85% soft coat with typical  $U = 1.8 \text{ W/m}^2\text{K}$  and  $\text{SHGC} = 0.31$ , 15% hard coat with  $U = 2.0 \text{ W/m}^2\text{K}$  and  $\text{SHGC} = 0.51$ ), the total savings potential is only 8 trillion Btus, and the heating savings are actually negative. On the other hand, with an enlightened Energy Star programme that promoted the most energy efficient products in these regions (high SHGC low-e), the savings can be dramatically increased by over 45%. It only makes sense to use the sun's energy to decrease energy usage in cold climates, but again, the U.S. Department of Energy has chosen to ignore these potential energy savings. (Figure 2)



**Figure 1: Window Annual Energy Usage in a Single Family Home**

Note: Baseline value of  $0 \text{ kWh}$  = annual energy consumption of a house without windows in each city. The shortest bars represent best performance. Negative value (Denver) indicates decrease in annual energy consumption. Conditions double pane argon filled windows with vinyl frames, 2,000 sq. ft. home with 300 sq. ft. windows are a. Calculations were done in accordance with proposed NFRC 901 Guidelines using RESFEN 3.1 software based on the U.S. Department of Energy DOE 2.1E calculation method.



**Figure 2: National Energy Savings Potential – U.S. Residential Market**

**In 2001-2002, the U.S. Department of Energy continued its mistakes by proposing to move the maximum SHGC requirement further north beyond 3600 HDD65°F (2000 HDD18°C), ignoring the benefit of high solar heat gain in the north.** After it was demonstrated this would actually *hurt* energy efficiency in these climate regions, the Department withdrew its proposal. However, the U.S. Department of Energy has recently reissued the same flawed proposal without performing any new analysis regarding solar heat gain, nor providing any further justification. Even worse, the U.S. Department of Energy ignored its own technical experts at Pacific Northwest National Laboratory, whose recent analysis disputes this proposal's technical merit, showing that the potential "economic benefits of lowering the SHGC in climate zone 4 (or above) do

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not justify the extension of this requirement into these climate zones.”<sup>6</sup>

Furthermore, the prescriptive requirements have an anticompetitive impact on the U.S. marketplace. In both the current and proposed Energy Star programme, products with an equivalent or superior performance are being excluded in the northern zone, such as products with U somewhat above 2.0 W/m<sup>2</sup>K but with high SHGC. An example of this is seen in the recent case study by Mattinson, DePaola, and Arasteh evaluating window retrofit options in Madison, Wisconsin.<sup>5</sup> In their analysis, a window with U = 2.3 W/m<sup>2</sup>K and SHGC = 0.54 would have the same impact on energy costs as a window with U = 1.9 W/m<sup>2</sup>K and SHGC = 0.34. Despite equal energy performance, the first window would not meet existing Energy Star or IECC prescriptive criteria. Similarly, the Efficient Windows Collaborative website ([www. efficientwindows.org](http://www.efficientwindows.org)) has numerous examples of windows which are denied an Energy Star label but have superior energy performance. By endorsing one window as energy efficient and not the other, the U.S. Department of Energy has established an anticompetitive environment in the marketplace, favoring one technology over its competition. It is wrong to create and to continue to support an environment where equal performance does not receive equal treatment.

**In conclusion, window energy rating systems can be a useful tool for promoting the use of high efficiency products, benefiting consumers, manufacturers, and government interests.** However, to be scientifically complete, these programmes must include the effects of both U and solar heat gain upon energy performance. While several countries around the globe have established strong performance-based programmes, the U.S. Department of Energy’s Energy Star programme for residential windows falls short.

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### *Resources:*

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