Benefits of the International Residential Code's Maximum Solar Heat Gain Coefficient Requirement for Windows

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Texas adopted in its residential building energy code a maximum 0.40 solar heat gain coefficient (SHGC) for fenestration (e.g., windows, glazed doors and skylights)—a critical driver of cooling energy use, comfort and peak demand.

An analysis of the expected costs and benefits of low solar heat gain glazing, and specifically the SHGC requirement in the new Texas Residential Building Energy Code,[1] shows that the 0.40 SHGC requirement is ideal for Texas and that the benefits far outweigh the expected costs. For consumers, the requirement will increase comfort and reduce their cost of home ownership. The anticipated public benefits are also substantial – the result of full implementation can be expected to:

- Reduce cumulative statewide cooling energy use over ten years by 15 billion kWh;
- Reduce cumulative statewide electric peak demand over ten years by over 1200 MW;
- Result in cooling cost savings of more than a billion dollars; and
- Reduce cumulative statewide key air pollutants.

I. Background

The IRC energy chapter and the IECC, which is the successor to the Model Energy Code, are the first national model building codes to properly address the significant influence of fenestration solar gain on air conditioning load. The IRC and the IECC (both the 1998 and 2000 versions) establish a maximum SHGC standard of 0.40 for glazed fenestration products (windows, glass doors, skylights) in warm weather climates where mechanical cooling systems are installed. This standard is designed to reduce unwanted solar gain. Without an SHGC requirement, the energy codes would only control U-factor (or the insulating value) of fenestration, which is primarily an issue for the heating season.

Following this lead, the southern states of Arizona,[2] South Carolina, and now Texas have adopted the most current (2000) version of the IRC and/or IECC and the 0.40 SHGC requirement. A number of other states are also expected to adopt the IECC and the 0.40 SHGC requirement – for example, Georgia is well along in the process of adoption of the IECC and is expected to adopt this requirement when its code update process is completed within the next few months. In addition, while both California and Florida use their own, state-developed building energy codes, rather than the national model, both states utilize a 0.40 SHGC as the standard for fenestration in their codes. (California utilizes this requirement only in its climate zones with significant cooling requirements.

In 2001, the U.S. Department of Energy issued its official determination that the IECC would achieve greater energy efficiency than previous versions of the Model Energy Code. In its determination, DOE cited the IECC's treatment of windows, and specifically the 0.40 SHGC requirement, as "major" improvements in energy efficiency:

> The 1998 IECC limits SHGC to a maximum 0.40 for those residential buildings located in climates having fewer than 3500 annual Heating Degree Days. Setting the maximum SHGC for glazing products to 0.40 in climates below 3500 recognizes that low SHGC glazing is an effective cooling load reduction strategy in those parts of the country needing significant air conditioning. Bureau of Census data from 1992 indicates that approximately 40% of all new housing starts were in the 0-3500 HDD climate region. Therefore, this one change has the potential to positively impact a

> substantial portion of the new housing market.
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> The 2000 IECC has new, specific language that makes it clear that all replacement fenestration and fenestration in additions are subject to the SHGC requirement. This provision ensures energy efficiency improvement in residential buildings and additions in warm climates.[3]

With this determination, all states, pursuant to federal law (the Energy Policy Act of 1992), are now required to review the 2000 IECC (including, in states with significant cooling requirements, the SHGC requirement) for potential adoption. If a state determines not to adopt the IECC, then it must provide DOE with an explanation of its reasons for not doing so.

Many, often subjective, competing factors came into play in establishing the SHGC maximum level and the applicable climate range in the IRC/IECC. This requirement was not produced solely from a simple cost/benefit calculation, but instead was the result of informed judgment and thorough discussion and debate. Where appropriate, we have reproduced below some of the information that substantiated the adoption of the SHGC requirement in the IRC/IECC and explained its relevance to Texas.

II. Consumer Energy-Related Cost-Savings from the Texas Energy Code's 0.40 Maximum SHGC Requirement

It is expected that most builders will meet the new SHGC requirement through upgraded windows, glazed doors and skylights. In fact, the SHGC level and the climate range in the Texas energy code are based primarily on the energy-related cost savings from upgrading double-pane insulated glass units with low-cost, low solar gain, low-e coatings. These coatings produce cost-effective cooling savings and an increase in the insulating value of the glass. At the same time, such savings can be achieved without substantial reductions in visible light transmitted through the window and without significant tinting.

As the analysis below demonstrates, the maximum 0.40 SHGC requirement produces significant energy-related cost savings in Texas through installation of the appropriate windows. Of course, while this is the simplest course of action to meet the SHGC requirement, other options are also available and could include the use of permanent solar shading devices such as overhangs, or a combination of different measures to meet the requirement.

A. Upgrading Double Pane Insulated Glass Units to Low Solar Gain Low-E Achieves the 0.40 SHGC

The vast majority of fenestration products sold in the U.S. and Texas are insulated glass – or double-pane – units.[4] For these products, achieving a 0.40 SHGC is a relatively simple, low-cost matter. Low solar gain low-e coatings added to double-pane IG units in virtually any frame can achieve an SHGC below 0.40—the low solar gain coating is typically a spectrally-selective low-e coating with an emissivity of 0.05 or lower on surface two (the inside of the outside pane of glass).

It is important to note that there are many different types of low-e glazing and that not all will substantially reduce solar gain; as a result, the Texas energy code specifies the exact SHGC required. Moreover, the code properly requires that the SHGC be certified and labeled in accordance with the National Fenestration Rating Council's (NFRC) procedure. This is a critical point – by utilizing accurate and credible NFRC ratings, the homeowner and the state are assured that the window products will actually be of the low solar gain variety and provide the benefits that the SHGC requirement is intended to achieve.

According to the table of typical SHGC values from the *2001 ASHRAE Handbook of Fundamentals*, a metal/aluminum framed spectrally-selective low-e, low solar gain product produces an SHGC of 0.34 – 0.38 (depending upon the window style), while the wood/vinyl-framed product with the same glazing produces SHGC values in the 0.28 – 0.36 range.[5]

B. Upgrade Cost of Low Solar Gain Low-E Glazing

When the maximum SHGC requirement was first introduced in the IECC, the testimony at the ICC hearings cited S. Reilly, B. Maese & A. Ghosh, "Cost-Effective Windows for Southern Climates," *1996 ACEEE Summer Study on Energy Efficiency in Buildings -- Building Industry Trends*, Volume 10, which found that low solar gain low-e glazing was a cost-effective improvement in cooling-dominated climates.[6] This study recognized that in any reasonably mature market, the cost to builders or consumers to upgrade IG units by adding a low solar gain low-e coating was relatively low, well below $2.00 per square foot of window area. With greater competition in the market, growth in market share and the substantial existing available capacity to manufacture this product as noted below, the cost can be expected to continue to fall.[7]

Because the base window in Texas is a double-pane window, the initial, most significant cost hurdle for low solar gain low-e coated windows already has been overcome in the Texas window market. (Spectrally-selective coatings, which are used to achieve the 0.40 maximum SHGC requirement, must be applied to the inside surface of dual-pane window.) The only upgrade cost to move to a low solar product is the upgrade cost of the glass itself. In most cases, manufacturers simply substitute low solar gain low-e coated glazing for clear glazing without changing their designs and with only slight modifications to their manufacturing processes. In fact, even prior to the new code, most manufacturers that offered double-pane products also offered low solar gain low-e as a glazing option.

Each manufacturer employs different pricing strategies depending upon the market in which they sell, so it is difficult to identify an exact product upgrade cost for all low solar gain low-e glazed products. However, our experience suggests that a good estimate of the average upgrade cost for low solar gain low-e is less than a $1.50 per square foot of window area. This price has been substantiated through various studies and surveys across the U.S. and through surveys of large retailers in Texas. In fact, a review of the window products sold in various retail stores indicated a range of upgrade costs of low-e glazing much lower than $1.50/sq.ft of windows. A cost range of $0.80/sq.ft. to $1.35/sq.ft. is consistent with surveys conducted of retailers across the country. As a result, a $1.50/sq.ft. of window area upgrade cost represents a conservative estimate.

C. Substantial Consumer Cost Savings from Low Solar Gain Low-E Glazing

A simple cost-effectiveness analysis shows that at incremental costs even greater than $1.50/sq.ft., the upgrade to low solar gain low-e is cost-effective and produces substantial energy cost savings on a per-home basis in Texas.[8] In fact, considering the energy cost savings alone, the investment would be paid back in about five years. If the reduced cost of cooling equipment is factored in, the payback drops to less than four years. Moreover, the annual energy-cost savings to the homeowner would be a multiple of two to three times the additional financing or mortgage cost of the upgrade.

This cost-benefit analysis is based upon a comparison of two common window types: a double-pane window with clear glass in a metal/aluminum frame versus a double-pane window with low solar gain low-e glass in a metal/aluminum frame.[9] These two window samples were selected because Window B complies with the Texas energy code SHGC requirements, while Window A does not, and the only difference between the two is the glazing. Thus, the only real difference in price between these two products is the upgrade cost of the glass.[10]

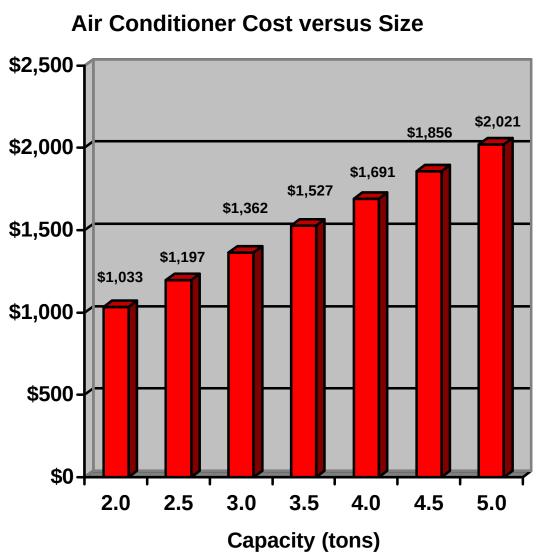
In comparing these two windows, which to the naked eye appear almost identical, there are significant differences in annual per home energy costs. The cost-effectiveness analysis compares annual energy cost savings with the incremental cost to upgrade to low-e glazing using two different payback assumptions. First, the analysis does a straight comparison (or simple payback) of the incremental glazing cost to the total energy dollars saved; and second, it compares the increased annual mortgage expense attributable to the additional glazing cost with annual energy cost savings.

In order to conduct the analysis, a new two-story home of 2000 square feet, with 300 square feet of windows, located in Dallas-Ft. Worth, was selected as the typical home. This home is assumed to be insulated to levels required by the IECC. The 300 square feet of fenestration amounts to a $450 upgrade cost (at a $1.50 sq. ft.) and results in windows equaling 15% of both floor and wall area. The glass was placed in equal amounts for each orientation.

On a per-home basis, a typical Texas home would save roughly $85 per year on cooling energy costs with the glazing upgrade. At the $1.50 per sq.ft./ $450 per home upgrade cost, this results in the incremental cost of the glass being recovered in slightly over 5 years (simple payback). These energy savings also exceed the increased mortgage cost (at 7%) to finance the glazing upgrade by over 2 ½ times (in other words, the energy savings would be more than double the increased mortgage payment each month).

This analysis depicts the savings attributable to the window and glass products, only. There are additional savings through downsized cooling equipment that would cut the simple payback period by more than a third. The total energy and cost savings, including the windows and equipment, would be more than triple the increased mortgage cost. For example, using an HVAC equipment analysis tool, the representative cooling load of a typical two-story house in the southern U.S. with clear glass is roughly 20% higher than the cooling load of the same house with low solar gain low-e glass. For a 10 SEER air conditioner unit, this reduction in cooling load could allow the a/c unit to be downsized by ½ ton or more in some cases. Through a survey of various HVAC dealers, the average savings by reducing ½ ton of air conditioning capacity is between \$150 to \$200 per unit. This amount has also been confirmed through independent resources. An excerpt from *No Regrets Remodeling* contained the following graphic of air conditioner cost versus size:

Chart 1



Note: Excerpt from HOME ENERGY MAGAZINE, *No Regrets Remodeling*, "Tips for Buying a New Air Conditioner," 1997.

D. Sufficient Low Solar Gain Low-E Glass is Available in the Market to Meet Texas Needs

Today, between one-third and one-half of the windows in the U.S. are being produced with some form of low-e glass. According to the National Fenestration Rating Council (NFRC) Certified Products Directory, over 29,000 different window products from a wide array of manufacturers are certified with SHGCs at or below 0.40. (*See* **Appendix A** for a graph produced by NFRC depicting the distribution of NFRC SHGC ratings for residential windows.) There is enormous industry capacity to produce low solar gain low-e glass that has been installed over the past few years nationwide. We estimate that are twenty-four coating facilities capable of producing low solar gain low-e glass geographically dispersed throughout the United States along with numerous insulated glass manufacturing facilities. We estimate that these coating facilities can produce between 750 million and one billion square feet of low solar gain glass annually. While some window manufacturers in Texas will, no doubt, be required to change their product mix, there is no reason why adequate low solar gain products will not be available to meet the needs of Texas.

III. Statewide Cost, Energy and Peak Demand Savings from the Texas Energy Code's 0.40 Maximum SHGC Requirement

The per-home cost-effectiveness analysis above is important, because it shows that the individual homeowner will be economically better off with the new SHGC requirement and the resulting glazing upgrade. A more macro analysis shows that the requirement is also extremely beneficial to Texas. In order to assess these macro impacts, the per-home savings can be extrapolated to the whole Dallas/Ft. Worth housing market, and to the entire Texas housing market to assess the level of utility cost, cooling energy (kWh), and electrical demand (MW) savings. When one considers the full breadth of the Texas energy code requirements for both new and existing homes (0.40 SHGC requirement for new and replacement fenestration), the annual savings attributable to low solar gain low-e glazing are enormous:[11]

Table 1

*Annual Texas Cooling Savings	Window A (Double-Pane Clear)	Window B (Low Solar Gain Low-e)	Savings
Energy	1,176,149 MWh	892,190 MWh	283,959 MWh
Cost	$ 103.5 million	$ 78.5 million	$25 million
Demand	403 MW	271 MW	132 MW

* The energy and cost savings reflected in this table are based upon the cooling savings attributable to new and replacement low solar gain low-e glazing in Dallas/Ft. Worth and do not reflect any effect on heating requirements due to reduced solar gain in the winter and/or the increased insulating value of the glass. (The total demand savings would be unaffected, since electric utility peak demands occur in the summer.) Annual savings will vary depending upon the frame type and overall fenestration product U-factor and SHGC. However, total energy and cost savings can be expected to remain substantial (the same order of magnitude), even if the effects on heating energy are included.

As a point of reference, the roughly 25% reduction in cooling energy use and **over 30% reduction in peak demand** reflected above are substantial enough to help utilities meet the mandate of the Texas utility restructuring law, Senate Bill 7, which requires each utility "to reduce Texas customers' energy consumption by at least 10% of the electric utility's annual growth in **demand** . . . [in Texas] by January 1, 2004."[12] As a result, many utilities are either planning or already have efforts underway to convert the window marketplace to high performance low solar gain low-e windows. These programs will ease the transition to upgraded windows that will meet the new Texas energy code.

From a longer-term vantage point, the potential cumulative cooling savings attributable to low solar gain low-e glazing compounded over a ten-year period are noteworthy:[13]

Table 2

Cumulative Cooling Energy and Demand Savings (10-year)		
	Dallas/Ft. Worth	**Texas (*statewide estimate*)**
Cumulative Cooling Energy Savings	5,203,845 MWh	15,617,743 MWh
Cumulative Cooling Cost Savings	$ 458 million	$ 1.374 billion
Annual Peak Demand Savings in Tenth Year	441 MW	1,324 MW

Arguably, these vast savings are understated because:

(i) these figures are based upon very conservative envelope and glazing assumptions: for example, (i) these calculations presume all existing and new houses are built to meet minimum Model Energy Code standards, which is often an incorrect, overstated assumption; (ii) the calculations presume typical shading of all windows, which in many cases, is not at all typical as it overestimates the presence of trees, interior blinds, window screens and adjacent structures; and (iii) the calculations assume a 78 degree set point for the cooling system and 15% window area, both of which are conservative assumptions;

(ii) using energy, cost and demand savings based upon the Dallas/Ft. Worth region is a conservative method for estimating savings for the entire state (this same analysis using

San Antonio as the base case ratchets up the savings by 15%); and

(iii) these savings reflect energy, costs and demand at the home site, not at the energy source (as a rule of thumb, for every 1 Btu consumed at home, an electric generating plant had to consume over 3 Btus (the equivalent of 2 Btus is lost in the entire process of generating, transmitting and distributing electricity); thus, the cooling savings indicated above represent only one-third of the real energy savings).

The electric peak demand savings identified above are particularly noteworthy. The reduced cooling loads will reduce overall electric utility peak demands, resulting in utilities requiring less power plants to meet demands at peak. As shown above, the use of low solar gain low-e glazing could reduce electric peak demand in Texas by roughly **130 MW annually**, amounting to **avoiding at least two large coal or lignite-fired power plants by the tenth year** of the implementation of the SHGC requirements.[14] Electric system reliability will also improve and there will be reduced risk of electric price spikes as a result of the reduced electric air conditioning usage during critical hot weather periods.

IV. Other Benefits from the Texas Energy Code's 0.40 Maximum SHGC Requirement

As shown above, reasonable economic analysis suggests that a maximum 0.40 SHGC is feasible, reasonable and cost-effective. Similarly, the 0.40 SHGC will conserve substantial energy and sharply reduce peak electric demand. However, these were not the only reasons for adopting this requirement in the code.

A. Comfort

Probably one of the most important benefits of reduced solar gain is the improved comfort for the homeowner. After all, windows are generally installed in the first place for comfort. As noted in the 1993 *ASHRAE Handbook of Fundamentals* at page 27.1, of the four factors designers should consider when selecting fenestration, "economic" is only one. Another important factor relevant to this issue is "thermal"– "designing for … occupant comfort and energy conservation." Occupant comfort in the summer is heavily affected by solar gain through the windows.

One answer to reducing unwanted solar gain and improving occupant comfort has traditionally been to reduce the amount of fenestration in the building and/or constrain the placement and orientation of the fenestration. These approaches are no longer the best answer – they only reduce views, daylighting and ventilation. Instead, use of energy efficient fenestration is the preferred solution, providing comfort, aesthetic appeal and economic efficiency.[15]

B. Environmental Benefits

At the same time, like other conservation approaches, the SHGC requirement will reduce consumption of non-renewable energy resources and reduce environmental impacts from electric generation, which is almost universally utilized for cooling. Applying the 0.40 SHGC requirement throughout the state would produce substantial reductions in key air pollutant emissions.

For example, the cooling savings (again using Dallas-Ft. Worth as the base case) attributable to the 0.40 SHGC (as compared to double-pane clear insulated glass windows) would reduce annual NO_X emissions by at least **550 tons**, annual SO_2 emissions by at least **475 tons**, and annual CO_2 emissions by almost **200,000 tons**. The cumulative ten-year effect of these emissions reductions is quite substantial:

Table 3

Cumulative Metric Tons of Emissions Saved in Texas (10-year): *		
NO_X	**SO_2**	**CO_2**
30,462 Tons	**26,211 Tons**	**10,696,975 Tons**

* These emissions reductions are based upon the cooling savings attributable to low solar gain low-e glazing and do not reflect any effect on heating requirements due to reduced solar gain in the winter and/or increased insulating value of the glass. Annual emissions reductions will vary depending upon the heating source used – natural gas, electric, oil, etc. However, emissions

reductions will remain substantial (same order of magnitude) even if such impacts were included.

V. Conclusion

Low solar gain low-e windows, as required by the new SHGC requirement in the energy code, are ideal for Texas. The maximum 0.40 SHGC requirement in the new Texas Residential Building Energy Code is specifically designed to reduce cooling energy use and in reality is the only code provision capable of significantly lowering electric utility peak demand. Reduced cooling energy use translates directly to improved air quality through reduced electricity production, which in turn will reduce harmful air pollutant emissions in the state. Reduced peak demand will eliminate the need to build several new power plants that would otherwise have been necessary to match growing demand, and consequently, will improve electric system reliability. In addition to these macro benefits to Texas, each consumer will benefit through lower utility bills and a much more comfortable home.

ENDNOTES

1. Through Senate Bill 5 and Senate Bill 365, the Texas Legislature adopted and Governor Perry signed legislation to implement the International Residential Code (IRC) energy chapter as the statewide residential building energy code. The IRC requires that the area-weighted average SHGC of all fenestration installed in climates up to 3,500 HDD be below 0.40. The IRC also incorporates the entire International Energy Conservation Code (IECC) as an alternative energy code. The IECC prescriptive paths also require the use of a 0.40 SHGC.

2. Arizona adopted the 2000 IECC as a voluntary statewide code and as the basis for statewide incentives for energy efficient buildings. Some local jurisdictions in Arizona, including Tucson/Pima County, have adopted the IECC as a mandatory code.

3. 66 Fed. Reg. 1964, at 1965, 1968 (January 10, 2001).

4. According to a 2001 Texas Window Initiative "Baseline Survey of Residential Windows," on average over 80% of the windows manufactured in Texas are double-pane/IG units.

5. See JOHN CARMODY, ET AL., RESIDENTIAL WINDOWS, A GUIDE TO NEW TECHNOLOGIES AND ENERGY PERFORMANCE, 2nd Ed. (2000) at 98 – 110 (for a detailed discussion of these technologies).

6. S. Reilly, B. Maese & A. Ghosh, "Cost-Effective Windows for Southern Climates," *1996 ACEEE Summer Study on Energy Efficiency in Buildings* -- *Building Industry Trends*, Volume 10, at page 10.135. According to the Reilly study at page 10.134, costs for low-e in more mature markets like California, Oregon and Washington back in 1996 were less than $2 per square foot. Similarly, a 1995 study by the Washington State Energy Office [M. Lubliner & T. Ossinger, "Pricing of Energy Efficient Windows in the Pacific Northwest"], found the cost to upgrade to low-e windows in that market to range from $1.24 to $1.65 per square foot. A 1993 Oregon study (referenced at page 13 of the WSEO study) found a $1.27 per square foot price to upgrade clear IG units to low-e with argon.

7. *See* CARMODY, n5, at 63.

8. This analysis was done using various window simulation software programs and assumptions to calculate the energy impacts for Texas, which is explained in greater detail below.

9. According to surveys by Ducker Research Co., approximately 50% of the windows for new construction in Texas are wood windows; 40% vinyl; and 10% aluminum.

10. Specifically, the analysis compares clear double pane aluminum-frame windows (0.79 U-factor and 0.68 SHGC) with low solar gain low e double pane aluminum-frame windows (0.60 U-factor and 0.38 SHGC). Adding the low solar gain low e coating has the added of benefit of somewhat reducing the U-factor in addition to substantially reducing the SHGC.

11. For 1999, which was the most current complete data available at the time of publication, the Texas Comptroller of Public Accounts (citing the U.S. Census Bureau) reported 144,258 housing starts in Texas: 36,443 housing starts in the Dallas PMSA and 11,604 in the Ft. Worth MSA for a total of 48,047 housing starts in the Dallas/Ft. Worth metropolitan area. Based upon independent market research data (F.W. Dodge, Ducker Research Co.), approximately 1/2 to 2/3 of the residential fenestration sold in the U.S. is for replacement projects in existing homes. To conservatively estimate the savings attributable to both new and existing homes in compliance with the Texas energy code requirements for new and replacement fenestration, this analysis approximates that roughly 1/2 of the fenestration sold in Texas is for existing homes.

ENDNOTES (cont.)

12. SB 7 at 164.

13. "Cumulative" in the sense that the annual low solar gain low-e savings will be reproduced each year that the technology remains in place. Thus, each year's batch of new and existing homes complying with the 0.40 SHGC requirement will produce additional savings to be added to the recurring savings originally generated in prior years. (Many low solar gain low-e glazing units carry warranties of 10 years or more, which will guarantee that the savings continue for at least the ten-year period analyzed here.)

14. It should be noted that these estimates are very conservative. First, they do not consider the effects of transmission losses, which would increase the MW of generating capacity necessary to meet these demands. Second, the estimates are based on average loads and do not reflect higher demands resulting from extreme temperatures. Third, the estimates do not reflect the need for a reserve margin, typically 15% (another 200 MW), to meet these demands.

15. *See* CARMODY, n5, at 132-139.

APPENDIX A

NFRC SHGC Product Distribution

(Residential Only)