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Selecting Residential Window Glazing for Optimum Energy Performance

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This Update discusses the results of a research project that examined the impacts of two types of high-performance window glazing (low solar heat gain and high solar heat gain) on energy consumption in residential applications.

Windows affect energy loads on houses in two ways: they allow solar energy to enter the house and also allow a significant amount of heat to escape in winter and enter in summer, as their insulating value is much lower than that of the surrounding walls. In winter this solar energy can help heat the house, whereas in summer, it contributes to excess heat, which then has to be removed or dealt with in some way.

Various research studies have shown that in a typical Canadian house with conventional double-pane clear-glass windows, solar gain typically provides from 10% to 27% of the total heating energy for the house. However, the heat loss through these same windows during the heating season may account for more than 27% of the total heat loss for the house.[1]

One way of achieving better performance is by using high-performance low-emissivity (low-e) coated glazing, which provides better thermal performance than clear glass. However, the products available on the market vary greatly when it comes to taking advantage of solar gain. They range from those with low solar heat gain (LSG), which greatly reduce the entry of solar radiation into the living space, to those with high solar heat gain (HSG), which allow greater solar gain. The LSG windows provide an advantage during cooling season while the HSG windows are beneficial during winter.

In general, Canada is a heating dominated climate—so at first glance, installing HSG glazing would be an obvious choice. But with the rising cost of electricity for summer cooling and the concerns over peak electrical loads during hot summer afternoons, the advantages of LSG glazing during cooling season are becoming more significant. Many other factors affect annual savings from low-e coated glazing, making it challenging to answer the question: Which low-e coated glazing—HSG or LSG—will provide the best energy and cost savings performance for Canadians?

Factors that influence savings

The house thermostat setting, the choice to cool or not to cool in summer, the orientation of the house, the size of windows, and the choice of shades are just a few of the factors that influence overall savings. Additionally, regional climate and the cost of the available heating fuels (electricity, oil, natural gas or propane) play an important role in determining the cost savings to be gained from using these high-performance glazing systems.

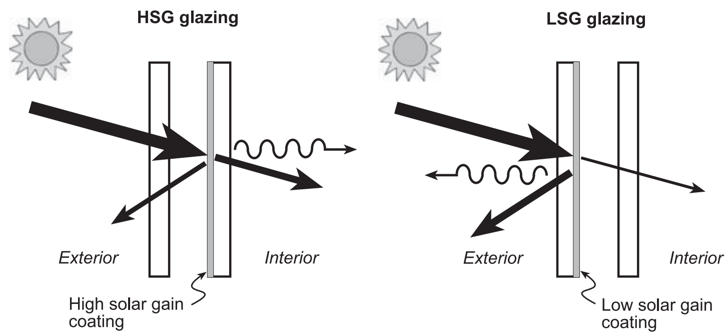

Figure 1. High solar heat gain (HSG) and low solar heat gain (LSG) glazing

Figure 2. The Canadian Centre for Housing Technology is operated as a partnership between NRC, Canada Mortgage and Housing Corporation, and Natural Resources Canada.

In order to answer this question for a specific case, researchers at the Canadian Centre for Housing Technology (CCHT) in Ottawa conducted a side-by-side, whole-house comparison of two different types of window glazing. They then used the results to calibrate a model for examining glazing performance in a number of other locations across Canada, for different circumstances.

The Experiment

In 2006, an LSG glazing and an HSG glazing were compared using the twin side-by-side houses at CCHT (Figure 2) for one month in winter and one month in summer. One house was fully glazed with the LSG glazing and the other with the HSG glazing. This allowed researchers to examine the whole-house effect of the glazing on the energy consumption for both heating and cooling, and also on the temperatures of the houses. The thermostats in both houses were set to 21°C in winter and 26°C in summer.

The results showed that the solar energy transmitted through the windows in the two houses had a large impact on energy consumption for both heating and cooling, for both houses. The impact was greatest on the sunniest days and the effect most pronounced in winter when the sun is low in the sky and solar radiation strikes the glazing more directly. Figure 3 shows transmitted solar radiation through a south-facing window for one sunny day in winter and one sunny day in summer. On the winter day, the house with the LSG glazing had to compensate for the lost solar gain by

Window features for improved energy performance

Modern windows can be equipped with a variety of features to improve energy performance. These features include double or triple glazing, warm-edge spacers, gas filling between the panes (argon, krypton or a mixture of both), and a variety of coatings on the glass. All of these features are aimed at improving the U-factor of the window, hence reducing the heat loss through the window.

Low-e coatings. A low-e coating is a thin metallic layer applied to the surface of the glazing to improve energy performance. It does so by reflecting the long-wave infrared radiation (heat) portion of the spectrum, while still allowing part of the solar spectrum to pass through it. Thus, heat is reflected back into the house in winter (or kept out in summer), and the glass remains "see-through." Only a small portion of the solar spectrum is visible light, and how the low-e coatings deal with the remaining "invisible" portion of the solar spectrum can vary. An LSG coating reflects most of the invisible solar spectrum, helping to keep solar gain to a minimum, while an HSG coating transmits most of the solar spectrum and its accompanying heat gain. The location of the coating also makes a difference: an LSG coating is typically located on the exterior pane of the window, to reflect heat out of the building; an HSG coating is typically located on the interior pane of the window, to reflect towards the inside (see Figure 1).

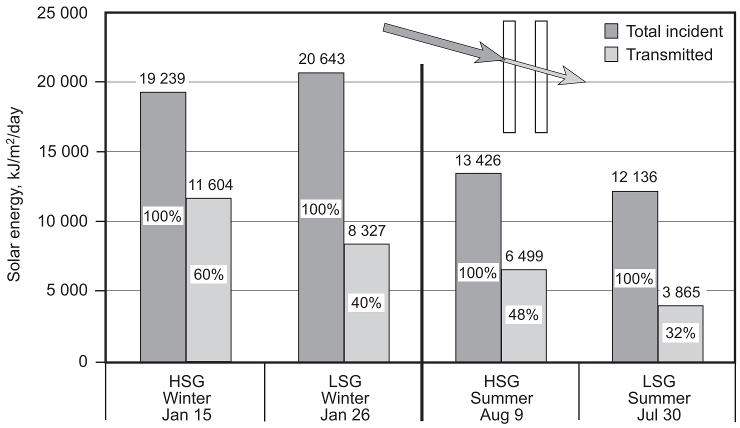

Figure 3. Measured transmitted solar energy on sunny days from the CCHT experiment

consuming on average 15% more natural gas. On the summer day, this house benefited by consuming on average 20% less electrical energy for air-conditioning.[2]

The researchers used these results to predict the energy performance of the two types of low-e window glazing for different locations across the country. In the models, the two were also compared to double-pane clear-glass air-filled (conventional) glazing.

A total of 12 locations, 10 in Canada and two in the U.S., representing different zones ranging from very cold to hot and humid climates, were selected to evaluate the effects of the three different types of glazing. Table 1 (see p. 4) provides heating degree-day data, climate zones, and the utility rates of electricity and the heating fuel used predominantly in these locations.

The properties of the three types of glazing (LSG, HSG, and conventional) are described in Table 2 (p. 4). While the LSG glazing has a lower (better) U-factor than the HSG glazing, the HSG glazing's high solar heat gain coefficient (SHGC) results in a higher energy rating (see sidebar). Based on these properties, both the LSG and HSG glazing used in the experiment qualify for the ENERGY STAR® Rating in Zones A (temperate west coast) and B (moderate heating requirements), while only the HSG glazing qualifies in Zones C and D (significant heating requirements), based on its high ER value. The conventional glazing has a higher SHGC—that is, it allows more solar gain than the low-e glazing, but it also allows much greater heat loss and thus does not meet the ENERGY STAR® criteria.

Key measures of window energy performance and the ENERGY STAR® program

The thermal performance of a window can be described in several different ways:

- **U-factor:** a measurement of the rate of heat transfer through the window. A low U-factor is desirable since it indicates low heat loss in winter and low heat gain in summer. The U-factor is the inverse of the R-value.
- **Solar Heat Gain Coefficient (SHGC):** a measurement of the fraction of incident solar radiation admitted through a window. It includes both radiation that is directly transmitted and radiation that is absorbed and subsequently released inward. The SHGC is expressed as a number between 0 and 1. The higher the window's SHGC, the more solar heat it transmits into the living space.
- **Energy Rating (ER) Value:** a measurement of the window's overall energy performance based on the thermal transmission heat loss, solar heat gain performance and heat loss due to air leakage of the window. The higher the ER value, the better the energy performance of the window during heating season.[3]

The ENERGY STAR® program in Canada is a voluntary arrangement between Natural Resources Canada's Office of Energy Efficiency and organizations that build, manufacture, sell or promote products or new homes that meet the ENERGY STAR® levels of energy performance. The ENERGY STAR® symbol helps consumers quickly and easily identify products that save energy. Windows and doors qualify for ENERGY STAR® by meeting either a maximum U-value or minimum energy rating (ER) for each of four Canadian climate zones.[4] The Canadian requirements for meeting the ENERGY STAR® rating are listed in Table 3 (p. 4). There are over 90,000 labelled window products listed in the Canadian ENERGY STAR® database that meet these requirements, of which more than 98% feature a low-e coating.

Table 1. Utility costs of natural gas and electricity (averaged for Nov 2006 – Feb 2007)

Location	Heating degree days (below 18°C)	Zone	Fuel use for space heating		Space cooling with electricity $/kWh
Canadian locations					
Halifax, NS	4367	B	0.836	$/L (oil)	0.099
Montreal, QC	4575	B	0.062	$/kWh (electricity)	0.062
Quebec City, QC	5202	B	0.062	$/kWh (electricity)	0.062
Ottawa, ON	4600	B	0.5092	$/m³ (natural gas)	0.086
Toronto, ON	4066	B	0.5092	$/m³ (natural gas)	0.092
Winnipeg, MB	5785	C	0.4931	$/m³ (natural gas)	0.061
Calgary, AB	5108	B	0.3997	$/m³ (natural gas)	0.082
Edmonton, AB	5708	C	0.3997	$/m³ (natural gas)	0.082
Vancouver, BC	2927	A	0.4781	$/m³ (natural gas)	0.062
Victoria, BC	3041	A	0.4781	$/m³ (natural gas)	0.062
U.S. locations					
New York, NY	2641		0.55	$/m³ (natural gas)	0.143
Miami, FL	83		0.55	$/m³ (natural gas)	0.086
The unit costs are represented in each country's currency (for example, for U.S. locations figures are in U.S. currency). Utility rates were obtained from the Energy Statistics Handbook[6] published quarterly in Canada and from the United States Energy Information Administration.[7]					

Table 2. Properties of windows used in experiment

Window	Window solar heat gain coefficient (SHGC)	Window U-factor W/(m²K)	Energy rating (ER value)
LSG	0.33	1.62	23.6
HSG	0.52	1.76	31.3
Conventional*	0.69	2.89	14.4
*Conventional double-pane clear-glass air-filled window (used only in modelling)			

Table 3. Canadian ENERGY STAR® requirements for windows[4]

Zone	Heating Degree Days (below 18°C)	Maximum U-factor* W/(m²K)	Minimum energy rating (ER value)*
A	<=3500 HDDs	2.0	17
B	>3500 to <=5500 HDDs	1.8	21
C	>5500 to <=8000 HDDs	1.6	25
D	>8000 HDDs	1.4	29
*Windows can qualify by either their U-factor or their ER value.			

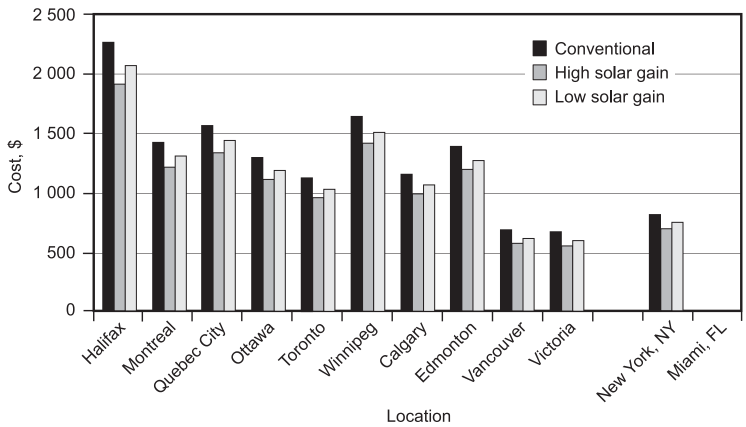

Figure 4. Annual cost of heating for North American locations (costs are represented in each country's currency)

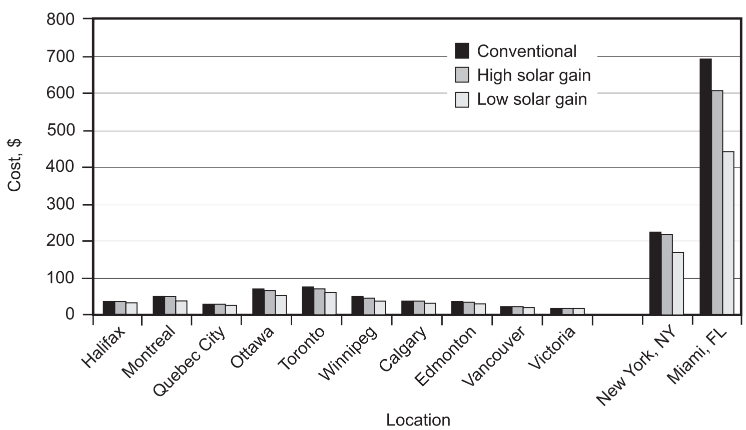

Figure 5. Annual cost of cooling for North American locations (costs are represented in each country's currency)

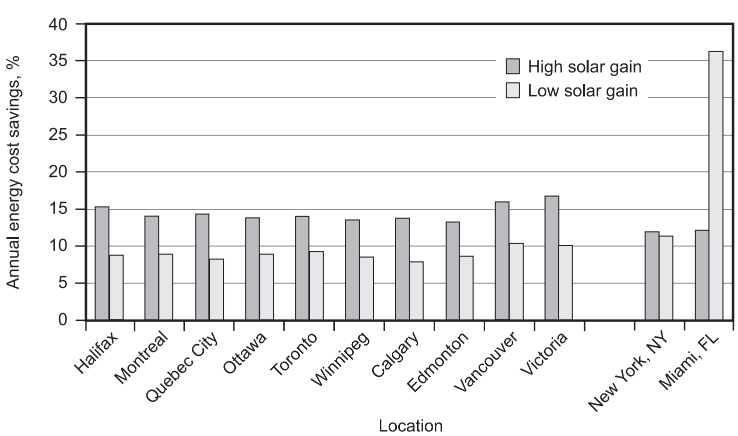

Figure 6. Annual energy cost savings compared to conventional clear glass glazing

Considerations for Selecting Window Glazing

The experiment and modelling studies resulted in a few guidelines for selecting the appropriate type of low-e coating to obtain the best possible energy performance.

HSG for heating. During heating season, both types of low-e glazing provide improved energy savings over clear glass. Since the HSG glazing allows higher solar gains than the LSG product, a house with HSG glazing requires less heating on sunny days and thereby experiences greater energy savings in the heating season. Heating costs for different locations across North America are provided in Figure 4.

LSG for cooling. During cooling season, both types of low-e glazing improve energy savings compared to clear glass. However, because LSG glazing reduces solar gain more than HSG glazing, a house with LSG glazing experiences smaller air-conditioning loads on sunny days and greater energy savings for cooling. The costs of cooling for different locations across North America are shown in Figure 5.

Since it is most unlikely that homeowners would be willing to switch from HSG to LSG glazing twice a year in order to capture the benefits from the two types of glazing, it is important to choose the type of glazing that will provide the largest year-round energy savings. This is not as simple as considering whether a climate is heating or cooling dominated, as other factors, including the house operation (see "House operation" section below) and the type of heating fuel also come into play.

Climate (heating degree days). Generally, in locations where there are more than 3000 Celsius heating degree days (encompassing almost all of Canada), HSG glazing provides the best overall energy performance; in warmer southern U.S. climates, it is the LSG glazing that does this. (See Figure 6 for savings for different locations across Canada and a few locations in the U.S.) New York City is of particular interest: here, the costs of the heating and cooling seasons offset each other—the two types of

Heating degree days

Heating degree days are a measure of the severity of winter. A degree day is the number of degrees below 18°C for a single day's mean temperature in a specific location. The total *heating degree days* for that location is calculated by taking the cumulative *degree days* for the whole year. The higher the *heating degree days*, the colder the winter and the greater the heating requirements for the location.

low-e glazing provide similar annual energy savings, and both provide savings over conventional clear glazing.

Heating fuel source. The higher the cost of heating, the greater the benefit from reducing the heating loads through the use of HSG windows. For example, although Halifax does not have the largest heating loads of all the modelled locations, it has the highest heating fuel costs and so has the most to gain from the use of HSG glazing.

In Quebec, where electricity is the fuel predominantly used for both cooling and heating, using HSG windows leads to energy savings, which translates directly into cost savings.

In places where heating energy comes from less expensive sources than electricity, the cost of heating is low compared to the cost of cooling. However, with LSG glazing, the cooling energy requirements can be minimized, resulting in savings over the year.

House operation. The temperature that the thermostat is set to (set-point), the use of free cooling (opening windows to take advantage of cool days or nights in summer) and the choice of heating and cooling systems all have an impact on savings; for example, if a house is operated without air-conditioning, only the consumption of heating energy contributes to annual energy performance. Thus, HSG glazing should be selected to increase winter solar gain and reduce heating energy consumption. In this situation, shading strategies may be necessary in summer to keep room temperatures comfortable.

House temperature. Since HSG glazing allows for greater solar gain than LSG glazing, warmer temperatures can occur in rooms with south-facing windows. In the CCHT experiment, on sunny winter days, temperatures in the south-facing rooms were up to 3.8°C warmer at mid-height in the rooms with HSG glazing than in the rooms with LSG glazing. In summer, the effect was less pronounced due to the higher position of the sun and the air-conditioning system helping to regulate temperatures: the room was up to 1.0°C warmer at mid-height. Both types of low-e glazing allowed less solar gain than clear glass. Although HSG glazing appears to contribute to the overheating of rooms (i.e., room temperature is above the set-point) in winter, room temperatures in both summer and winter are lower than those that can be expected with clear glazing.

Use of shading devices with low-e glazing. In nearly all locations across Canada, the HSG product offered the largest annual savings in energy and cost. However, the peak demand for electrical generation occurs during the summer. While trading HSG glazing for LSG glazing twice a year is not a practical option, there is still a need for methods that cut down on summer heat gain and energy consumption. For this reason, it is important to look at the combination of HSG low-e glazing and shading strategies.

Shading experiments at CCHT have shown that combining standard interior Venetian blinds with HSG glazing does not have a great influence on cooling energy consumption. However, exterior shading can reduce cooling consumption on sunny days by up to 26%.[5] This can be accomplished in a number of ways; for example, through the use of shades or shutters, well-designed architectural overhangs to shade windows in the summer and allow solar gains in the winter, or strategically placed deciduous trees.

Combinations of glazing and orientation. Although the experiment examined glazing only on a whole-house basis, different combinations of glazing could produce even greater energy savings. Generally, in a heating dominated climate, glazing with a high SHGC (i.e., HSG glazing) should be used on the south side to encourage solar gain. Glazing on the north side of the house should be selected to maximize performance in the heating season, making glazing with better thermal performance (i.e., a low U-factor) the preferred option. With more than one type of glazing, care should be taken during construction to correctly label the location and orientation of each window to ensure proper installation.

Summary

While both the LSG and HSG glazing provided energy cost savings over the conventional glazing, the use of HSG glazing produced the greatest savings for Ottawa and for all the modelled Canadian locations. The HSG glazing would be expected to produce savings of between 13% and 17% in combined heating and cooling costs for these Canadian locations, while the LSG glazing would be expected to produce savings of between 8% and 10% compared to the conventional glazing.

Savings depend largely on the type and cost of fuel used for heating, and the distribution of the window area by orientation. The higher the cost of heating, the greater the benefit of reducing the heating loads through the use of HSG glazing. However, LSG glazing was the most effective at reducing cooling loads during summer, when utilities are most likely to experience peak demands for electricity. An even more effective approach to reducing both heating and cooling energy using available window technologies may be to combine the use of HSG glazing with shading strategies to improve overall energy performance.

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