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Effect of Window Insulation on Total Heating Demand in arctic dwellings

by Martin Kotol, PhD Candidate, Research Fellow
Cold Climate Housing Research Center

Windows are an important part of the building envelope. They provide buildings and occupants with daylight, views, and (when correctly designed) allow solar energy to enter the building and thereby reduce the heating demand. Windows can also provide buildings with passive ventilation in the summer, although during the heating season more advanced mechanical systems with heat recovery are recommended for better energy performance. Because windows have inferior thermal properties than walls, they are a large contributor to a building envelope's overall heat loss, especially in arctic regions with extremely cold temperatures and long periods without sun. To reduce heat loss through windows, several methods have been identified and evaluated in a previous study performed by CCHRC, *Evaluating Window Insulation for Cold Climates*.

A followup study was conducted to evaluate the effects of adding window insulation to different types of windows on the annual heating demand and thermal environment of buildings. This followup study was performed using a computational simulation called IDA ICE. In the study, the average house was modeled based on characteristics from houses built between 2006 and 2012 that meet the Alaska Housing Finance Corporation's Building Energy Efficiency Standard (BEES) requirements for Climate Zone 8 – Subarctic (which includes Fairbanks). Different window types and various insulation methods were simulated. This report presents the results of the study. Consult the original study for more background information.

Model description

The model simulates the average house as closely as possible (see Table 2 for details). The modeled house shown in Figure 1 consists of two zones - ground floor and first floor - heated by hot-water baseboards and ventilated by a heat recovery ventilator (HRV) with a 70% efficiency. The ventilation unit also has a by-pass that activates when the indoor temperature exceeds

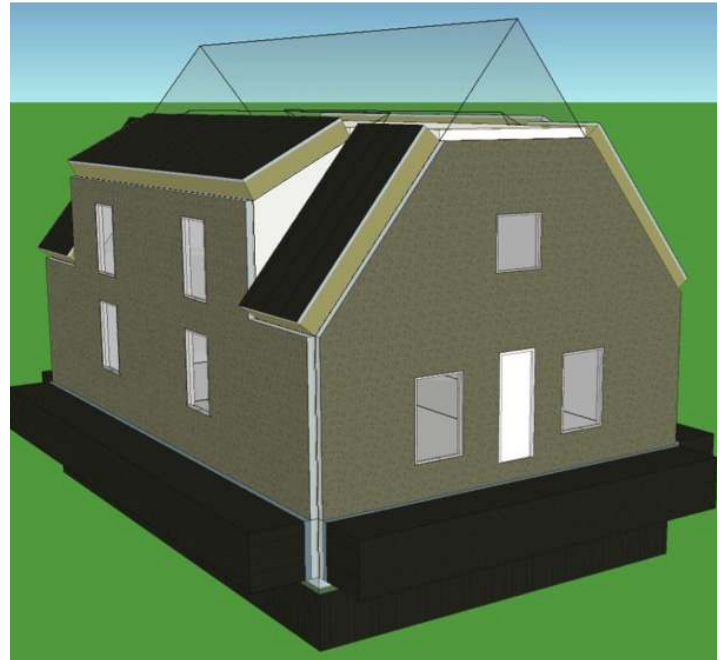


Figure 1. Model of the average house in Climate Zone 8.



Figure 2. Exterior shutters were one of eight types of window insulation tested in the original study for energy performance, condensation resistance, and other criteria.

Table 1. Insulation methods

Insulation method	R-value [h·ft ² ·°F/Btu]	Schedule
Exterior foam shutters 2"	11	Daily 9p.m.-7a.m.
Exterior mechanical shutters	1.05	Daily 9p.m.-7a.m.
Exterior storm window ¹	2.51	October 1-April 30
Interior insulated blinds	0.31	Daily 9p.m.-7a.m.
Interior storm windows	1.13	October 1-April 20
Interior Curtain	0.79	Daily 9p.m.-7a.m.
Interior plastic film	0.51	October 1-April 30

¹ The R-value of 2.51 was used in order to be consistent with the previous study. However, the realistic value would be closer to 1.5, which brings the results of the exterior storm window closer to those of an interior storm window.

77°F. Nine different types of windows were modeled with varying U-values and solar heat gain coefficients (SHGC). U-value is a measure of heat transfer (the lower the U-value of a material, the less heat is lost through it). SHGC, also referred to as solar gain, is the fraction of incident solar radiation that is admitted through a window (the higher the SHGC, the greater the heat gain).

The windows were assumed to be opened when the indoor temperature exceeds 80.6°F in order to reduce overheating. Seven insulation methods were modeled, displayed in Table 1. The work assumed that insulation was added to all the windows of the house and that the operating schedule provided in Table 1 was strictly followed. In other words, these results reflect a best-case scenario. The effect of the window insulation strategies could be skewed if only some windows were insulated and if the operation schedule were not strictly followed.

Results

The results in Figure 4 show that the higher the energy efficiency of windows, the smaller the effect of window insulation. When U-0.28 windows are used (the average for Climate Zone 8), the overall heating demand of the building can be reduced by 8% by using exterior storm windows (if installed from October to April) or by 7% if using 2-inch-thick foam exterior shutters (if shutters are closed overnight). With more efficient U-0.2 windows, the heating demand is reduced by 4% using exterior storm windows and by 5% using exterior shutters. In older windows (U-0.48 or higher) the potential for reducing annual heating demand is as high as 15% with exterior storm windows or 12% with thermal shutters.

In the case of exterior shutters, further savings can be achieved by closing them in the daytime during unoccupied hours. However, this should only be done

Table 2. Input parameters

	Climate Zone 8		
	Average house ¹	Model	Difference
U-walls [h·ft ² ·°F/Btu]	0.054	0.054	0%
U-Ceilings [h·ft ² ·°F/Btu]	0.021	0.021	1%
U-Windows [h·ft ² ·°F/Btu]	0.294	0.282	4%
Air leakage [ACH@50Pa]	1.6	1.6	0%
BG ² Walls [ft ²]	515	529	-3%
AG ³ Walls [ft ²]	1,638	1,698	-4%
Ceilings [ft ²]	1,717	1,593	7%
Floors [ft ²]	1,140	1,076	6%
Windows (South) [ft ²]	64	64	-1%
Windows (Other) [ft ²]	118	118	0%
Total floor area [ft ²]	1,906	2,152	-13%
Volume [ft ³]	24,483	23,466	4%

¹ As built between 2006 and 2012, meeting BEES requirements

² Below Ground

³Above Ground

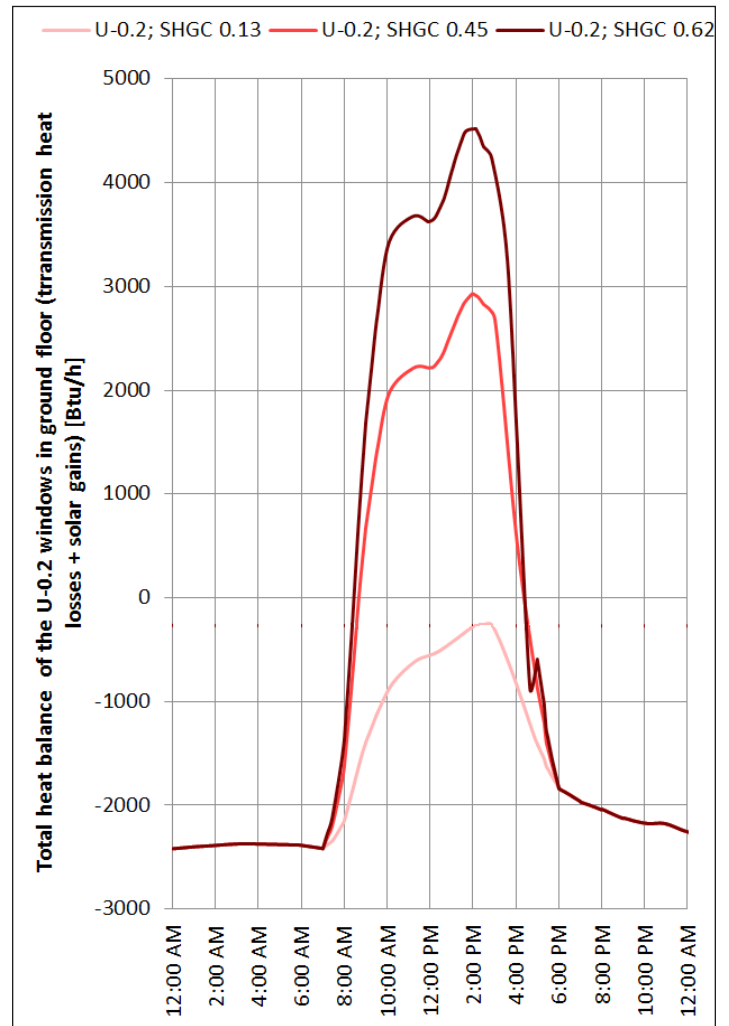


Figure 3. Heat balance of U-0.2 windows on March 1 with different SHGC.

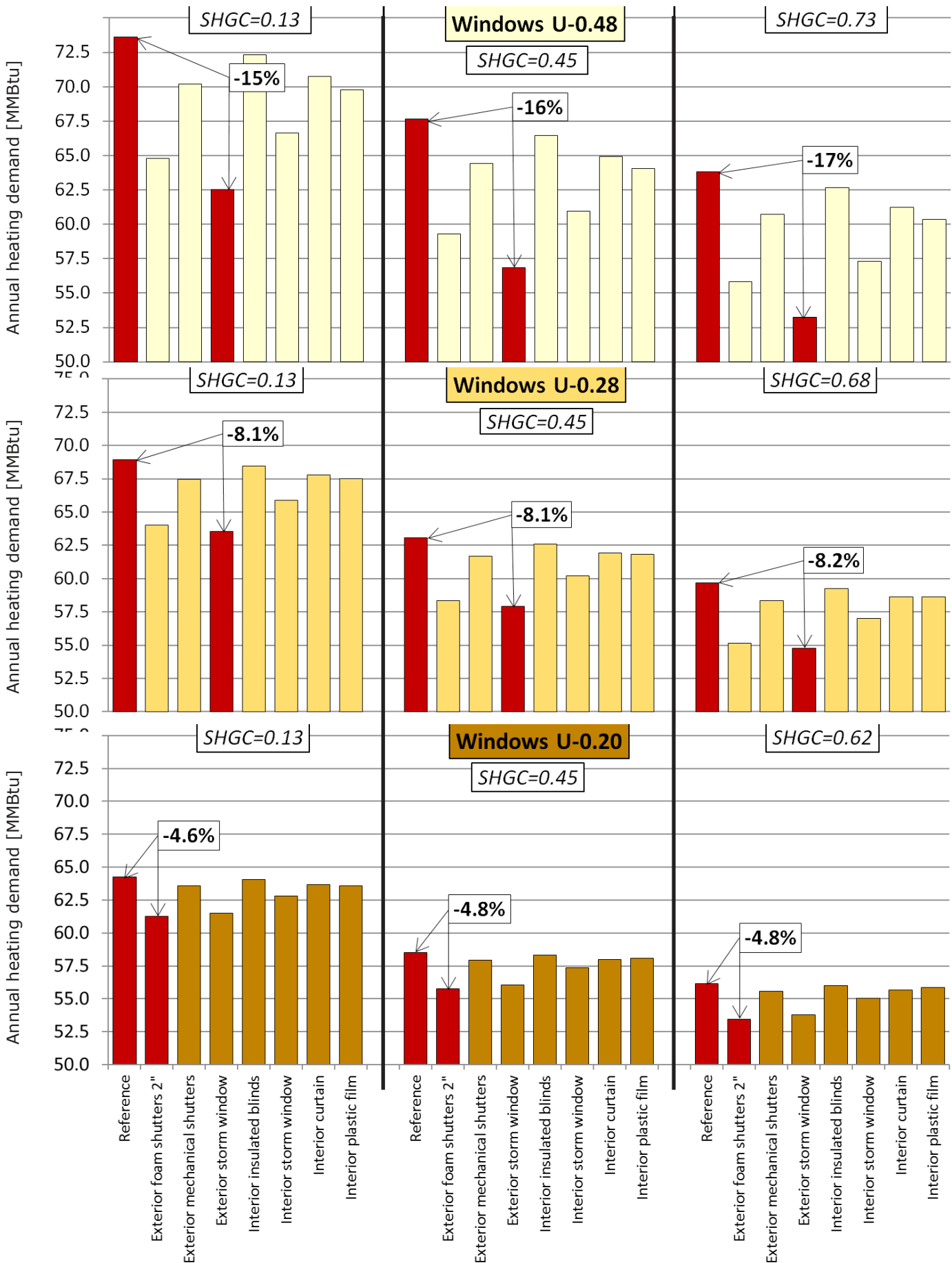


Figure 4. Simulation results. Each sector represents a different window type. The first column of each sector is a reference case (no additional insulation) followed by 7 columns representing different insulation methods. The greatest difference from reference in each sector is highlighted in red.

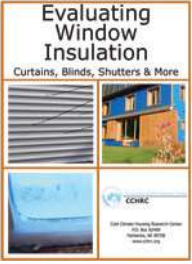
during winter months when there is no solar gain potential through windows; otherwise it would be counterproductive as the solar gain would be reduced by closed shutters. Total heating demand can be reduced by 9.4% when average U-0.28 windows are used.

The results clearly show that not only R value but also SHGC has a large effect on the total heating demand of the building. For example, U-0.28 windows with SHGC 0.68 will perform better than U-0.2 windows with SHGC 0.13 and only a little worse (2% higher total heating demand) than U-0.2 windows with SHGC 0.45. Figure 3 shows the total heat balance of windows in the ground floor during March 1 when U-0.2 windows with different SHGC are used. During night-time, there is no difference between the windows, but as the sun rises at 7 a.m. the heat balance starts to differ. By 2 p.m. the windows can together provide as much as 4,436 Btu/hour heat gain for the building or 255 Btu/hour heat loss, depending on the SHGC.

With increasing SHGC there is a bigger risk of overheating during the summer. This can be remedied by increasing ventilation through opening windows or using a mechanical ventilation system. However, ventilation rates must be very high in order to compensate for the large solar gains. This can cause draft discomfort in occupants. By using solar shading (preferably external), overheating can be reduced without introducing excessively high ventilation rates (see Figure 5).

Conclusions

This study confirmed that some window insulation methods can achieve a significant reduction in a home's annual heating demand. The reduction potential is higher in windows with poorer performance. Some of the insulation methods not only reduce the heating demand but also help reduce risks of overheating during the summer, which is more of an issue in new high-insulating windows with large Solar Heat Gain Coefficients.



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ADDITIONAL RESOURCES

For the initial report, Evaluating Window Insulation for Cold Climates, visit cchrc.org/evaluating-window-insulation

For other CCHRC publications, visit cchrc.org/publications-catalog

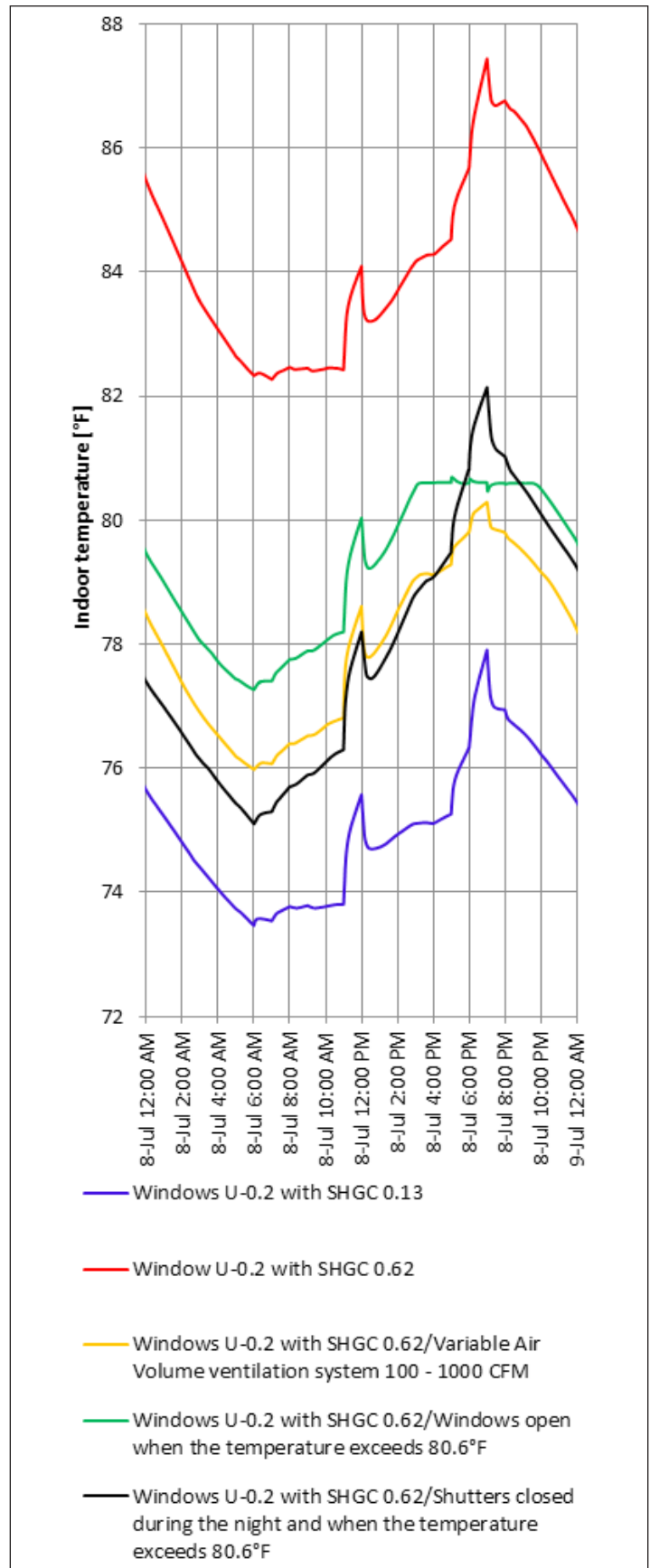


Figure 5. Indoor temperatures on July 8 when different windows and multiple passive cooling strategies were used.