The Efficient Windows Collaborative Multiple Benefits Fact Sheet

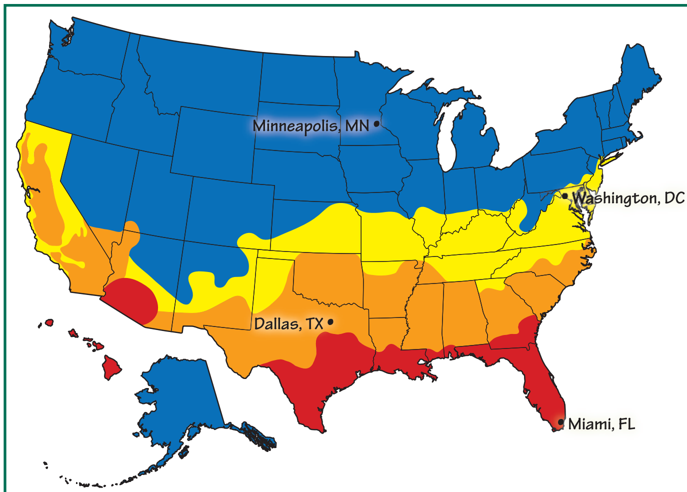
www.efficientwindows.org January 2010

Selecting a window or skylight involves many considerations such as appearance, energy performance, human factor issues, technical performance, and cost. This fact sheet combines several measurable attributes (annual energy cost, peak demand, winter and summer thermal comfort, and condensation) to assist in the selection process.

Making purchasing decisions based on one attribute, such as energy performance, may not always lead to a completely balanced outcome. For example, two windows that are similar in their effect on annual energy use may be very different in their condensation resistance or in the comfort they provide at extreme temperatures.

To assist in decision-making, tables showing multiple attributes of windows, representing each of the four ENERGY STAR climate zones, are shown on the following pages. The representative cities are Minneapolis, Minnesota (northern), Washington, DC (north/central), Dallas, Texas (south/central), and Miami, Florida (southern). On each table, a rating of below average, average, and above average is given for the five attributes: annual energy cost, electricity peak, winter comfort, summer comfort, and condensation resistance. There are 29 generic window types—various glazing types combined with three frame types—shown for each climate. It is important to note that not all of the attributes have the same priority and this varies by region. For example, winter comfort and condensation are less important in a southern climate zone.

Annual energy costs and peak demand are simulated using the computer program, RESFEN. The range of results for a given city are divided into three groups designated as below average, average, and above average. Similarly, results of the Winter and Summer Thermal Comfort Index developed at the University of California, Berkeley, and the National Fenestration Rating Council's (NFRC) condensation rating (CR) are also divided into three groups.



Multiple Benefits Fact Sheet Contents

Visit www.efficientwindows.org for more information on the benefits of efficient windows, how windows work, how to select an efficient window, and what manufacturers provide efficient windows.

Minneapolis, Minnesota

● below average ▲ average ■ above average

						Priority				
						High	Low	High	Moderate	High
Glass	Frame[1]	U-factor[2]	SHGC[2]	Energy Star	Tax Credit[3]	Annual Energy Cost	Electric Peak	Winter Comfort	Summer Comfort	Condensation Resistance
single, clear	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	>0.60	no	no	●	●	●	●	▲
single, bronze tint	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	0.41–0.60	no	no	●	●	●	●	▲
double, clear	metal	0.71–0.99	>0.60	no	no	●	●	●	●	●
	metal w/thermal break	0.56–0.70	>0.60	no	no	●	●	●	●	▲
	non-metal	0.41–0.55	0.41–0.60	no	no	▲	▲	●	●	▲
double, bronze tint	metal	0.71–0.99	0.41–0.60	no	no	●	▲	●	▲	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	●	▲	●	▲	▲
	non-metal	0.41–0.55	0.41–0.60	no	no	▲	▲	●	▲	▲
double, high-performance tint	metal	0.71–0.99	0.41–0.60	no	no	●	▲	●	▲	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	●	▲	●	▲	▲
	non-metal	0.41–0.55	0.26–0.40	no	no	▲	▲	●	▲	▲
double, high-solar-gain low-E	metal	0.56–0.70	>0.60	no	no	●	●	●	●	●
	metal w/thermal break	0.41–0.55	0.41–0.60	no	no	▲	▲	▲	●	▲
	non-metal	0.31–0.40	0.41–0.60	maybe	no	▲	▲	▲	●	■
double, moderate-solar-gain low-E	metal	0.56–0.70	0.26–0.40	no	no	●	■	●	▲	●
	metal w/thermal break	0.41–0.55	0.26–0.40	no	no	▲	■	▲	▲	▲
	non-metal	0.31–0.40	0.26–0.40	maybe	no	▲	■	▲	▲	■
double, low-solar-gain low-E	metal	0.56–0.70	≤0.25	no	no	●	■	●	■	●
	metal w/thermal break	0.41–0.55	≤0.25	no	no	▲	■	▲	■	▲
	non-metal	0.31–0.40	≤0.25	no	no	▲	■	▲	■	■
triple, high-solar-gain low-E	non-metal	0.21–0.25	0.26–0.40	yes	maybe	■	▲	■	▲	■
triple, low-solar-gain low-E	non-metal	0.21–0.25	≤0.25	yes	yes	■	■	■	■	■
thermally improved[4]										
double, high-solar-gain low-E	non-metal,	0.26–0.30	0.41–0.60	yes	no	■	▲	■	●	■
double, moderate-solar-gain low-E	non-metal,	0.26–0.30	0.26–0.40	yes	maybe	■	■	■	▲	■
double, low-solar-gain low-E	non-metal,	0.26–0.30	≤0.25	yes	yes	■	■	■	■	■
triple, high-solar-gain low-E	non-metal,	≤0.20	0.26–0.40	yes	maybe	■	▲	■	▲	■
triple, low-solar-gain low-E	non-metal,	≤0.20	≤0.25	yes	yes	■	■	■	■	■

[1]Metal-frames are typically made of aluminum and may be thermally broken into separate interior and exterior parts joined by a less conductive material. Typical non-metal frames are made of wood, vinyl, fiberglass, composite materials or hybrid designs combining multiple materials.

[2]The U-factor and Solar Heat Gain Coefficient (SHGC) ranges shown are typical for these generic glass and frame combinations. The U-factor and SHGC of specific products may differ from these ranges. Accurate information on window energy performance is provided by the National Fenestration Rating Council (NFRC) and can be viewed on the NFRC labels applied to windows. For more information, see www.nfrc.org.

[3]A federal tax credit, covering 30% and up to $1,500 of the cost of replacement windows is available for qualifying windows installed in 2009 or 2010. In order to qualify, windows must have a U-factor and SHGC of no more than 0.30. For more information, see www.efficientwindows.org/taxcredit/taxcredit.cfm.

[4]Thermally improved may include a combination of features resulting in a lower U-factor such as high-performance frame design, warm-edge spacer technology, low-conductance gas fill, and high-performance glazing.

Washington, DC

● below average △ average ■ above average

						Priority				
						High	Moderate	High	Moderate	Moderate
Glass	Frame[1]	U-factor[2]	SHGC[2]	Energy Star	Tax Credit[3]	Annual Energy Cost	Electric Peak	Winter Comfort	Summer Comfort	Condensation Resistance
single, clear	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	>0.60	no	no	●	●	●	●	△
single, bronze tint	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	0.41–0.60	no	no	●	●	●	●	△
double, clear	metal	0.71–0.99	>0.60	no	no	●	●	●	●	●
	metal w/thermal break	0.56–0.70	>0.60	no	no	●	●	●	●	△
	non-metal	0.41–0.55	0.41–0.60	no	no	△	●	●	●	△
double, bronze tint	metal	0.71–0.99	0.41–0.60	no	no	●	●	●	△	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	●	△	●	△	△
	non-metal	0.41–0.55	0.41–0.60	no	no	△	△	●	△	△
double, high-performance tint	metal	0.71–0.99	0.41–0.60	no	no	●	△	●	△	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	●	△	●	△	△
	non-metal	0.41–0.55	0.26–0.40	no	no	△	△	●	△	△
double, high-solar-gain low-E	metal	0.56–0.70	>0.60	no	no	●	●	●	●	●
	metal w/thermal break	0.41–0.55	0.41–0.60	no	no	△	△	△	●	△
	non-metal	0.31–0.40	0.41–0.60	no	no	△	△	△	●	■
double, moderate-solar-gain low-E	metal	0.56–0.70	0.26–0.40	no	no	●	■	●	△	●
	metal w/thermal break	0.41–0.55	0.26–0.40	no	no	△	■	△	△	△
	non-metal	0.31–0.40	0.26–0.40	maybe	no	△	■	△	△	■
double, low-solar-gain low-E	metal	0.56–0.70	≤0.25	no	no	●	■	●	■	●
	metal w/thermal break	0.41–0.55	≤0.25	no	no	△	■	△	■	△
	non-metal	0.31–0.40	≤0.25	maybe	no	△	■	△	■	■
triple, high-solar-gain low-E	non-metal	0.21–0.25	0.26–0.40	yes	maybe	■	△	■	△	■
triple, low-solar-gain low-E	non-metal	0.21–0.25	≤0.25	yes	yes	■	■	■	■	■
thermally improved[4]										
double, high-solar-gain low-E	non-metal,	0.26–0.30	0.41–0.60	no	no	△	△	■	●	■
double, moderate-solar-gain low-E	non-metal,	0.26–0.30	0.26–0.40	yes	maybe	■	■	■	△	■
double, low-solar-gain low-E	non-metal,	0.26–0.30	≤0.25	yes	yes	■	■	■	■	■
triple, high-solar-gain low-E	non-metal,	≤0.20	0.26–0.40	yes	maybe	■	■	■	△	■
triple, low-solar-gain low-E	non-metal,	≤0.20	≤0.25	yes	yes	■	■	■	■	■

[1]Metal-frames are typically made of aluminum and may be thermally broken into separate interior and exterior parts joined by a less conductive material. Typical non-metal frames are made of wood, vinyl, fiberglass, composite materials or hybrid designs combining multiple materials.

[2]The U-factor and Solar Heat Gain Coefficient (SHGC) ranges shown are typical for these generic glass and frame combinations. The U-factor and SHGC of specific products may differ from these ranges. Accurate information on window energy performance is provided by the National Fenestration Rating Council (NFRC) and can be viewed on the NFRC labels applied to windows. For more information, see www.nfrc.org.

[3]A federal tax credit, covering 30% and up to $1,500 of the cost of replacement windows is available for qualifying windows installed in 2009 or 2010. In order to qualify, windows must have a U-factor and SHGC of no more than 0.30. For more information, see www.efficientwindows.org/taxcredit/taxcredit.cfm.

[4]Thermally improved may include a combination of features resulting in a lower U-factor such as high-performance frame design, warm-edge spacer technology, low-conductance gas fill, and high-performance glazing.

Dallas, Texas

● below average ▲ average ■ above average

Glass	Frame[1]	U-factor[2]	SHGC[2]	Energy Star	Tax Credit[3]	Annual Energy Cost	Electric Peak	Winter Comfort	Summer Comfort	Condensation Resistance
					Priority	High	High	Moderate	High	Low
single, clear	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	>0.60	no	no	●	●	●	●	▲
single, bronze tint	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	0.41–0.60	no	no	●	●	●	●	▲
double, clear	metal	0.71–0.99	>0.60	no	no	●	●	●	●	●
	metal w/thermal break	0.56–0.70	>0.60	np	no	●	●	●	●	▲
	non-metal	0.41–0.55	0.41–0.60	no	no	●	▲	●	●	▲
double, bronze tint	metal	0.71–0.99	0.41–0.60	no	no	●	▲	●	●	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	●	▲	●	●	▲
	non-metal	0.41–0.55	0.41–0.60	no	no	▲	▲	●	●	▲
double, high-performance tint	metal	0.71–0.99	0.41–0.60	no	no	●	▲	●	▲	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	●	▲	●	▲	▲
	non-metal	0.41–0.55	0.26–0.40	no	no	▲	▲	●	▲	▲
double, high-solar-gain low-E	metal	0.56–0.70	>0.60	no	no	●	●	●	●	●
	metal w/thermal break	0.41–0.55	0.41–0.60	no	no	●	▲	▲	●	▲
	non-metal	0.31–0.40	0.41–0.60	no	no	▲	▲	▲	●	■
double, moderate-solar-gain low-E	metal	0.56–0.70	0.26–0.40	no	no	●	■	●	▲	●
	metal w/thermal break	0.41–0.55	0.26–0.40	no	no	▲	■	▲	▲	▲
	non-metal	0.31–0.40	0.26–0.40	maybe	no	■	■	▲	▲	■
double, low-solar-gain low-E	metal	0.56–0.70	≤0.25	no	no	▲	■	▲	■	●
	metal w/thermal break	0.41–0.55	≤0.25	no	no	▲	■	▲	■	▲
	non-metal	0.31–0.40	≤0.25	maybe	no	■	■	▲	■	■
triple, high-solar-gain low-E	non-metal	0.21–0.25	0.26–0.40	maybe	maybe	■	▲	■	▲	■
triple, low-solar-gain low-E	non-metal	0.21–0.25	≤0.25	yes	yes	■	■	■	■	■
thermally improved[4]										
double, high-solar-gain low-E	non-metal,	0.26–0.30	0.41–0.60	no	no	▲	▲	■	●	■
double, moderate-solar-gain low-E	non-metal,	0.26–0.30	0.26–0.40	maybe	maybe	■	■	■	▲	■
double, low-solar-gain low-E	non-metal,	0.26–0.30	≤0.25	yes	yes	■	■	■	■	■
triple, high-solar-gain low-E	non-metal,	≤0.20	0.26–0.40	maybe	maybe	■	■	■	▲	■
triple, low-solar-gain low-E	non-metal,	≤0.20	≤0.25	yes	yes	■	■	■	■	■

[1]Metal-frames are typically made of aluminum and may be thermally broken into separate interior and exterior parts joined by a less conductive material. Typical non-metal frames are made of wood, vinyl, fiberglass, composite materials or hybrid designs combining multiple materials.

[2]The U-factor and Solar Heat Gain Coefficient (SHGC) ranges shown are typical for these generic glass and frame combinations. The U-factor and SHGC of specific products may differ from these ranges. Accurate information on window energy performance is provided by the National Fenestration Rating Council (NFRC) and can be viewed on the NFRC labels applied to windows. For more information, see www.nfrc.org.

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[4]Thermally improved may include a combination of features resulting in a lower U-factor such as high-performance frame design, warm-edge spacer technology, low-conductance gas fill, and high-performance glazing.

Miami, Florida

● below average ▲ average ■ above average

						Priority				
						High	High	Low	High	Low
Glass	Frame[1]	U-factor[2]	SHGC[2]	Energy Star	Tax Credit[3]	Annual Energy Cost	Electric Peak	Winter Comfort	Summer Comfort	Condensation Resistance
single, clear	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	>0.60	no	no	●	●	●	●	▲
single, bronze tint	metal	≥1.00	>0.60	no	no	●	●	●	●	●
	non-metal	0.71–0.99	0.41–0.60	no	no	●	●	●	●	▲
double, clear	metal	0.71–0.99	>0.60	no	no	●	●	●	●	●
	metal w/thermal break	0.56–0.70	>0.60	no	no	●	●	●	●	▲
	non-metal	0.41–0.55	0.41–0.60	no	no	●	●	●	●	▲
double, bronze tint	metal	0.71–0.99	0.41–0.60	no	no	●	●	●	▲	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	●	▲	●	▲	▲
	non-metal	0.41–0.55	0.41–0.60	no	no	●	▲	●	▲	▲
double, high-performance tint	metal	0.71–0.99	0.41–0.60	no	no	●	▲	●	▲	●
	metal w/thermal break	0.56–0.70	0.41–0.60	no	no	▲	▲	●	▲	▲
	non-metal	0.41–0.55	0.26–0.40	maybe	no	▲	▲	●	▲	▲
double, high-solar-gain low-E	metal	0.56–0.70	>0.60	no	no	●	●	▲	●	●
	metal w/thermal break	0.41–0.55	0.41–0.60	no	no	●	▲	▲	●	▲
	non-metal	0.31–0.40	0.41–0.60	no	no	●	▲	▲	●	■
double, moderate-solar-gain low-E	metal	0.56–0.70	0.26–0.40	maybe	no	▲	▲	▲	▲	●
	metal w/thermal break	0.41–0.55	0.26–0.40	maybe	no	▲	■	▲	▲	▲
	non-metal	0.31–0.40	0.26–0.40	maybe	no	▲	■	▲	▲	■
double, low-solar-gain low-E	metal	0.56–0.70	≤0.25	maybe	no	■	■	▲	■	●
	metal w/thermal break	0.41–0.55	≤0.25	yes	no	■	■	▲	■	▲
	non-metal	0.31–0.40	≤0.25	yes	no	■	■	▲	■	■
triple, high-solar-gain low-E	non-metal	0.21–0.25	0.26–0.40	maybe	maybe	▲	▲	■	▲	■
triple, low-solar-gain low-E	non-metal	0.21–0.25	≤0.25	yes	yes	■	■	■	■	■
thermally improved[4]										
double, high-solar-gain low-E	non-metal,	0.26–0.30	0.41–0.60	no	no	●	▲	■	●	■
double, moderate-solar-gain low-E	non-metal,	0.26–0.30	0.26–0.40	maybe	maybe	▲	■	■	▲	■
double, low-solar-gain low-E	non-metal,	0.26–0.30	≤0.25	yes	yes	■	■	■	■	■
triple, high-solar-gain low-E	non-metal,	≤0.20	0.26–0.40	maybe	maybe	▲	▲	■	▲	■
triple, low-solar-gain low-E	non-metal,	≤0.20	≤0.25	yess	yes	■	■	■	■	■

[1]Metal-frames are typically made of aluminum and may be thermally broken into separate interior and exterior parts joined by a less conductive material. Typical non-metal frames are made of wood, vinyl, fiberglass, composite materials or hybrid designs combining multiple materials.

[2]The U-factor and Solar Heat Gain Coefficient (SHGC) ranges shown are typical for these generic glass and frame combinations. The U-factor and SHGC of specific products may differ from these ranges. Accurate information on window energy performance is provided by the National Fenestration Rating Council (NFRC) and can be viewed on the NFRC labels applied to windows. For more information, see www.nfrc.org.

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[4]Thermally improved may include a combination of features resulting in a lower U-factor such as high-performance frame design, warm-edge spacer technology, low-conductance gas fill, and high-performance glazing.

Annual Energy Use

The annual energy use of a house can be calculated using a simulation program such as RESFEN. The Annual Energy Costs figure shows the energy use for several window types for a typical house in four U.S. cities. This typical house is 2250 square feet with a 15% ratio of window to floor area. Windows are equally distributed on all four sides and include typical shading conditions.

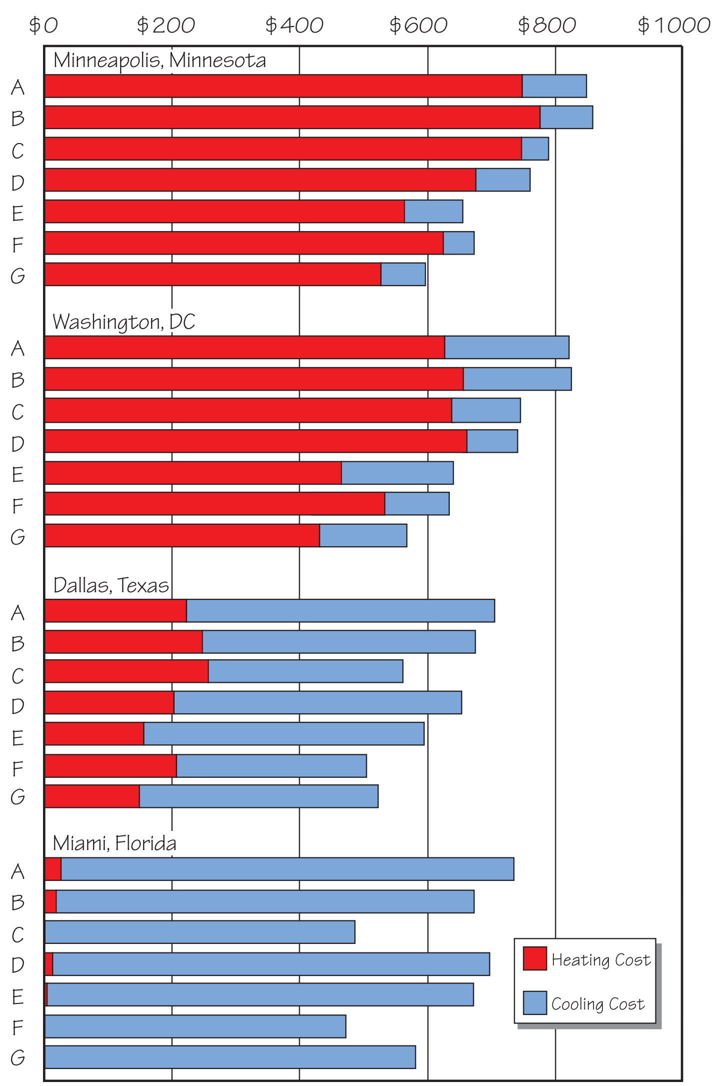
In a heating-dominated climate such as Minneapolis, Minnesota, the highest heating energy costs occur with metal-framed windows regardless of glazing type (Windows A and C). Within the non-metal frame group, the low-E windows (E and F) have lower annual energy costs than clear double glazing (Window D). On average, the high-solar-gain low-E unit (Window E) is better than the low-solar-gain low-E unit (Window F) in heating season performance because it allows more passive solar gain when oriented towards the sun. During the cooling season, Window F is clearly better, with total energy costs, making it close to Window E. The triple-glazed unit (Window G), with its very low U-factor, results in even greater energy savings.

Cities within the north/central climate zone have both heating and cooling requirements, though in many, heating dominates. The comparison in Washington, DC is similar to the northern zone—there are savings in annual heating costs using windows with low-E coatings (Windows E and F) instead of double-glazed, clear units (Windows A and D). As with the northern cities, the high-solar-gain low-E unit (Window E) is better than the low-solar-gain low-E unit (Window F) in heating season performance, but Window F is better during the cooling season. The triple-glazed unit (Window G) results in even greater heating season savings.

Cities within the north/central climate zone have both heating and cooling requirements, though heating dominates in many. The comparison in Washington, DC is similar to the northern zone—there are savings in annual heating costs using windows with low-E coatings (Windows E and F) instead of double-glazed, clear units (Windows A and D). As with the northern cities, the high-solar-gain low-E unit (Window E) is better

Window	Glazing	Frame	U-factor	SHGC	VT
A	double, clear	metal w/break	0.56–0.70	>0.60	>0.60
B	double, bronze tint	metal w/break	0.56–0.70	0.41–0.60	0.40–0.50
C	double, low-solar-gain low-E	metal w/break	0.41–0.55	≤0.25	0.51–0.60
D	double, clear	non-metal	0.41–0.55	0.41–0.60	0.51–0.60
thermally improved					
E	double, high-solar-gain low-E	non-metal	0.26–0.30	0.41–0.60	0.51–0.60
F	double, low-solar-gain low-E	non-metal	0.26–0.30	≤0.25	0.41–0.50
G	triple, high-solar-gain low-E	non-metal	≤0.20	0.26–0.40	0.41–0.50

Annual Energy Costs



than the low-solar-gain low-E unit (Window F) in heating season performance, but Window F is better during the cooling season. The triple-glazed unit (Window G) results in even greater heating season savings.

In a cooling-dominated climate such as Miami, Florida, there are significant savings in annual cooling costs by using windows with low solar heat gain coefficients (Windows C and F) instead of double-glazed, clear units or traditional bronze- or gray-tinted glass (Windows A, B, and D). The windows with comparable glazings but different frames show that non-metal frames perform better than metal frames. Some of this effect is because with thicker non-metal frames, there is less glazing area and thus less total solar heat gain in the same size window opening. It is important to note that in cooling-dominated climates, high-solar-gain low-E units (Window E) do not perform as well as low-solar-gain low-E units (Windows C and F)—all low-E windows are not the same. In Miami, the energy penalty from choosing the wrong kind of low-E glazing is apparent. The high-solar-gain low-E option (Window E) results in much more cooling energy use than the low-solar-gain low-E option (Windows C and F).

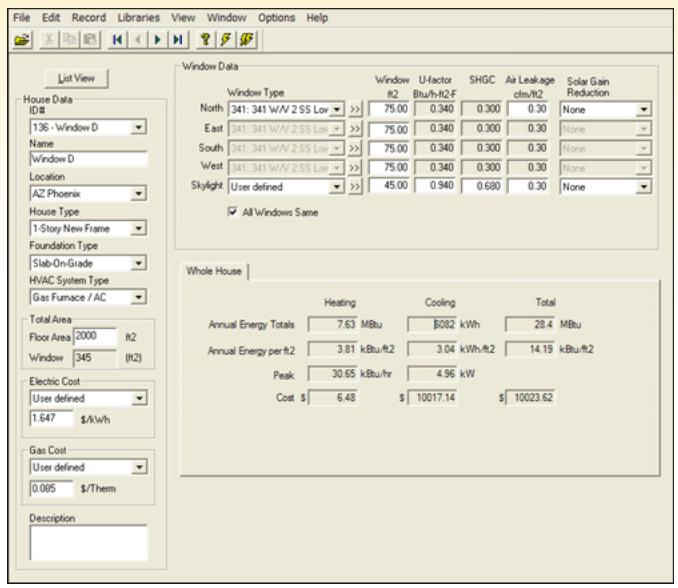
In applying these typical results to your particular situation, remember that the example is an average house . Instead of drawing conclusions from average conditions such as these, the best way to compare different windows is by using a simulation tool such as RESFEN and base decisions on your own house design.

Assumptions

The annual energy performance figures shown here were generated with regression expressions provided by Lawrence Berkeley National Laboratory (windows.lbl.gov/EStar2008). Results assume a typical (new construction: 2250 sq ft / existing construction: 2150 sq ft) house with 15% window-to-floor area. The windows are equally distributed on all four sides and include typical shading (interior shades, overhangs, trees, and neighboring buildings). U-factor and SHGC are for the total window including frame. The costs shown here are annual costs for space heating and space cooling only and thus will be less than total utility bills. Costs for lights, appliances, hot water, cooking, and other uses are not included in these figures. The mechanical system uses a gas furnace for heating and air conditioning for cooling. Natural gas prices used are projections of the average natural gas price for the heating seasons of 2010-2020 in real 2009 dollars. Projections are based on state-specific natural gas retail price data by the Energy Information Administration (EIA) for the heating seasons of 2006-08 and are adjusted based on EIA projections of national natural gas price trends for 2010-2020. Electricity prices used are projections of the average electricity price for the cooling seasons of 2010-2020 in real 2009 dollars. Projections are based on state-specific electricity retail price data by the Energy Information Administration (EIA) for the cooling seasons of 2006-08 and are adjusted based on EIA projections of national electricity price trends for 2010-2020 (www.eia.doe.gov).

More About RESFEN

Using a computer program such as RESFEN to compare the performance of window and skylight options allows you to customize the calculation by adding fuel costs for your specific location, house design options, and utility rates. The user defines the house with a series of selections from a menu: location, heating and cooling system type and efficiency, utility rates, floor area, window area, window orientation, interior/exterior shading, etc. A specific window or set of windows for each orientation is selected and specified by their U-factor, SHGC, and air leakage rate. It is designed so that different window types can be placed on different orientations. RESFEN then calculates the annual energy use and cost as well as peak heating and cooling loads.



RESFEN
Windows and Daylighting Group
Lawrence Berkeley National Laboratory (LBNL)
windows.lbl.gov/software/resfen/resfen.html

Sources

Carmody, J., S. Selkowitz, D. Arasteh, L. Heschong. Residential Windows: A Guide to New Technologies and Energy Performance, 3rd Edition. W.W. Norton, New York, 2007.

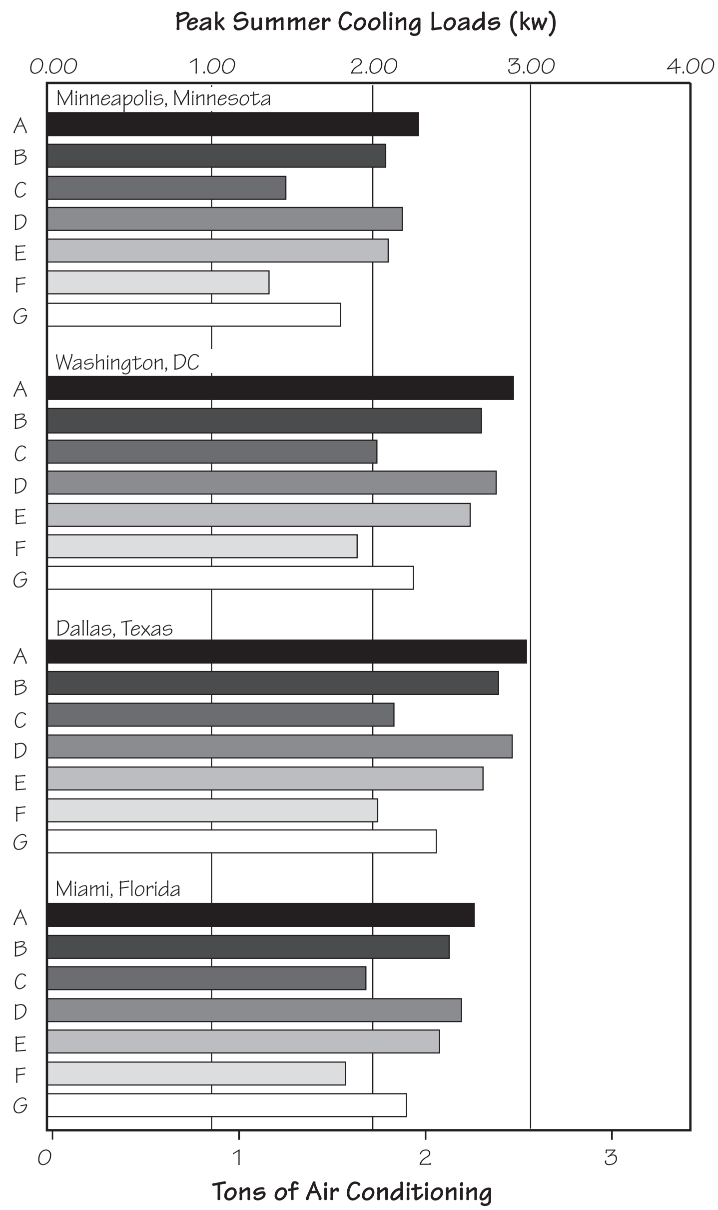
Huizenga, C., H. Zhang, P. Mattelaer, T. Yu, and E. Arens. “Window Performance for Human Thermal Comfort.” Final Report to the National Fenestration Rating Council. Center for the Built Environment, University of California, Berkeley, 2006.

Peak Demand

High-performance windows not only provide reduced annual heating and cooling bills but they reduce the peak heating and cooling loads as well. This has benefits for the homeowner in that the size of the heating or cooling system may be reduced. Taking advantage of opportunities to downsize equipment saves cost and is important to ensure that the system runs smoothly and maintains comfort. Lower peak demand also benefits the electrical utilities by reducing load during the peak times in summer. If peak cooling loads are minimized, additional generating capacity is not required. This also benefits the consumer by keeping rates down.

RESFEN was used to determine peak electricity demand with several window choices for a typical house in four U.S. cities, as shown in the Peak Summer Cooling Loads figure. Even though the northern zone is not predominantly a cooling climate, there can still be hot, humid days in summer with high peak loads. In Minneapolis, Minnesota low-solar-gain low-E glazing (Windows C and F) reduces the peak cooling load 30-40 percent compared to clear double glazing (Window D). Similar results occur in the north/central climate represented by Washington, D.C. This difference would be higher if the windows were unshaded. In a south/central climate such as Dallas, Texas or southern climate such as Miami, Florida, tinted glazing (Window B) only moderately lowers peak cooling loads while low-solar-gain low-E (Windows C and F) has a significant impact. Apart from the window type, the window orientation also has a strong impact on peak demand. For example, west-facing windows may contribute more than twice as much to peak demand as windows facing in other directions. The impact of orientation is bigger with high-solar-gain windows than with low-solar-gain windows.

Window	Glazing	Frame	U-factor	SHGC	VT
A	double, clear	metal w/break	0.56–0.70	>0.60	>0.60
B	double, bronze tint	metal w/break	0.56–0.70	0.41–0.60	0.40–0.50
C	double, low-solar-gain low-E	metal w/break	0.41–0.55	≤0.25	0.51–0.60
D	double, clear	non-metal	0.41–0.55	0.41–0.60	0.51–0.60
thermally improved					
E	double, high-solar-gain low-E	non-metal	0.26–0.30	0.41–0.60	0.51–0.60
F	double, low-solar-gain low-E	non-metal	0.26–0.30	≤0.25	0.41–0.50
G	triple, high-solar-gain low-E	non-metal	≤0.20	0.26–0.40	0.41–0.50



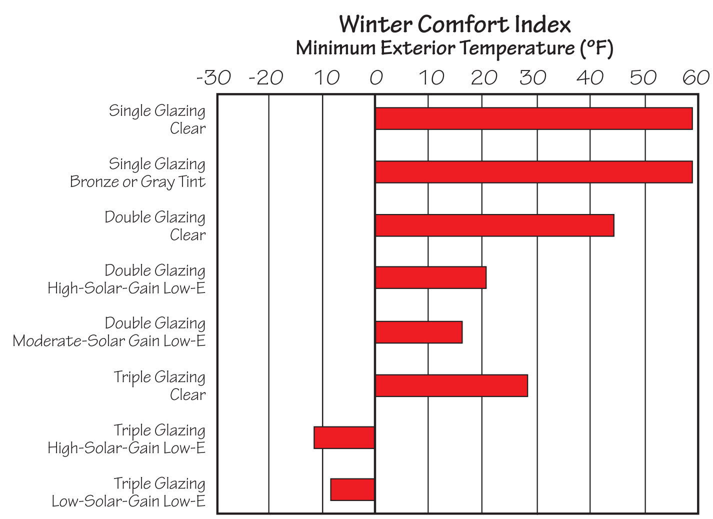
Thermal Comfort

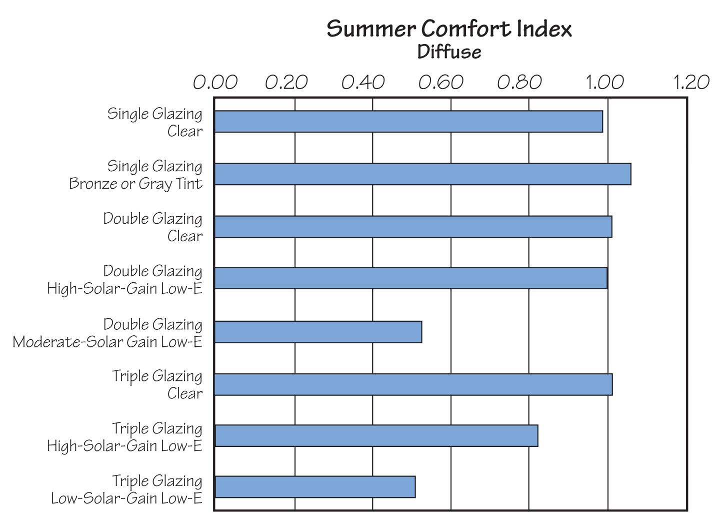
Windows affect human comfort in several ways. If people are exposed to the effects of a cold window surface, they experience significant radiant heat loss to that cold surface and they feel uncomfortable, even in the presence of comfortable room air temperatures. The fact that this heat loss occurs on one side of the body more than the other is called radiant asymmetry which leads to further discomfort. Drafts near windows are the second major source of winter discomfort. Many people falsely attribute drafts to leaky windows when in fact they are often the result of cold air patterns initiated by cold window surfaces. Drafts, of course, can also be caused by leaky windows.

Directly transmitted solar radiation has fairly obvious impacts on thermal comfort as well. During cold periods, solar radiation (within limits) can be a pleasant sensation. During warm weather, however, it is invariably a significant detractor to comfort. In addition, solar radiation will increase the surface temperature of the glass. How much the surface temperature increases depends on the absorptance of the glass and the environmental conditions. Typical clear glass windows do not absorb enough solar radiation to make a significant difference in their temperature. Although tinted glass helps to reduce direct solar heat gain and glare, its surface can get as hot as 140°F. This can cause discomfort by radiating heat to building occupants and creating convection drafts of warm air.

The importance of any measure of thermal comfort must be put into perspective. The climate will determine to what extent either winter or summer comfort will be a priority. In addition, thermal comfort will matter more in situations where window areas are larger and when people will be seated close to the windows.

To enable comparisons between windows, the Center for the Built Environment at University of California, Berkeley has proposed a method for determining a Winter and Summer Thermal Comfort Index (Huizenga et al. 2006). The Winter Comfort Index represents the minimum exterior temperature that will provide comfort for a person sitting close to a given window. As shown in the Winter Comfort Index figure, the index is nearly 60°F for single glazing (U=1.02). This means that the window has the potential to be uncomfortable at outdoor temperatures below this level. The index for double glazing (U=0.48) is reduced to 44.2°F and clear triple glazing (U=0.30) is reduced to 28.2°F. Double glazing with either a high- or moderate-solar-gain low-E coating further reduces the Winter Comfort Index to 20.8°F and 16.7°F. Triple glazed low-E options perform the best with Winter Comfort Indices of -18.4 to -21.5°F meaning that they remain comfortable even to people sitting close to them as long as the exterior is above these subzero temperatures.





The Summer Comfort Index developed by the Center for the Built Environment can be determined in two ways. The first approach only includes diffuse solar radiation, assuming a person in direct sunlight would either move or adjust the shades in the room. The second approach includes direct, as well as diffuse, solar radiation. The diffuse rating is shown and discussed here. As shown in the Summer Comfort Index figure, the Summer Comfort Index is around 1.00 for clear glazings whether they are single-, double- or triple-glazed units. Bronze-tinted single-glazing actually has a worse Summer Comfort Index (1.06) than the clear glazings because of its increased heat absorption and surface temperature of the glass. Different types of low-E coatings perform very differently in terms of summer comfort. Double-glazing with a high-solar-gain low-E coating has a Summer Comfort Index of 1.00 while a double-glazed unit with a moderate-solar-gain low-E coating has a much lower Summer Comfort Index of 0.53. In triple-glazed units, the high-solar-gain low-E unit improves to a Summer Comfort Index of 0.82 but is still well above the 0.51 index for low-solar-gain low-E.

Efficient Windows Collaborative (EWC)
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EWC / Alliance to Save Energy
1850 M Street NW, Suite 600
Washington, D.C. 20036
phone: 202-530-2254 / fax: 202-331-9588
www.efficientwindows.org / www.ase.org

National Fenestration Rating Council (NFRC)
www.nfrc.org

Center for the Built Environment (CBE)
University of California, Berkeley
www.cbe.berkeley.edu

Center for Sustainable Building Research (CSBR)
College of Design, University of Minnesota
www.csbr.umn.edu

Condensation Resistance

Condensation has been a persistent problem associated with windows. Excessive condensation can contribute to the growth of mold or mildew, damage painted surfaces, and eventually rot wood trim. Since the interior humidity level is a contributing factor, reducing interior humidity is an important component of controlling condensation. Condensation can also be a problem on the interior surfaces of window frames. Metal frames, in particular, conduct heat very quickly, and will "sweat" or frost up in cold weather. Solving this condensation problem was a major motivation for the development of thermal breaks for metal windows.

The National Fenestration Rating Council (NFRC) has developed a system for rating the condensation resistance (CR) of fenestration products. The Condensation Resistance figure shows the CR for a range of double-glazed windows. The CR is a function of the frame, spacer and glazing type—a high CR is better. The worst performance occurs with non-thermally broken metal frames where the CR falls in a range of 10–23 regardless of glazing type. The CR for metal frames with thermal breaks is higher—in the range of 30–42. The greater insulating value of non-metal frames results in better condensation performance resistance. Because the non-metal frame is no longer the dominant factor, the glazing type affects the CR to a greater degree. With clear glass, the CR range is 35–48. With low-E glazings, the range is 40–60. The wide range in CR reflects differences in types of low-E coatings and spacers. Low-conductance spacers are often used in combination with low-E glazings, increasing the condensation resistance. Even better performance can be achieved with non-metal framed, triple-glazed, low-E window units where there is a CR of 65–70.