Efficient Windows Collaborative

The Efficient Windows Collaborative Multiple Benefits Fact Sheet

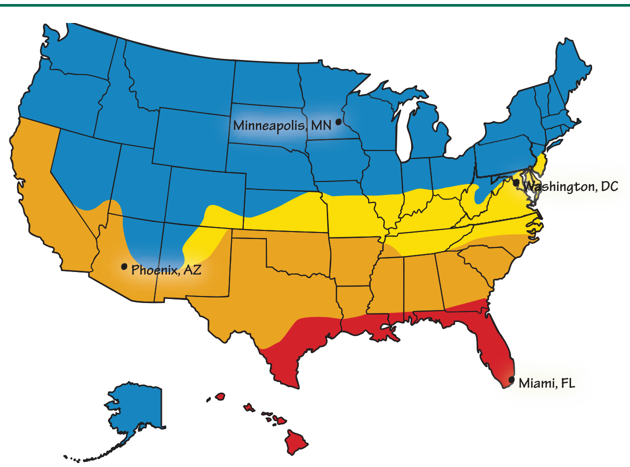
www.efficientwindows.org | September 2008

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), Phoenix, Arizona (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 34 generic window types—various glazing types combined with four 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 divided into three groups as well.



ENERGY STAR® Zones

- Northern Climate Zone (mostly heating)
- North/Central Climate Zone (heating & cooling)
- South/Central Climate Zone (heating & cooling)
- Southern Climate Zone (mostly cooling)

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

				Likely Meets		Priority				
						High	Low	High	Moderate	High
Glass	Frame	U-factor	SHGC	Energy Star	Code*	Annual Energy Cost	Electric Peak	Winter Comfort	Summer Comfort	Condensation Resistance
single, clear	aluminum	1.16	0.76	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.70	no	no	●	●	●	●	△
	vinyl/wood/clad	0.84	0.63	no	no	●	●	●	●	△
single, bronze tint	aluminum	1.16	0.65	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.59	no	no	●	△	●	●	△
	vinyl/wood/clad	0.84	0.54	no	no	●	△	●	●	△
double, clear	aluminum	0.76	0.68	no	no	●	●	●	●	●
	alum w/thermal break	0.63	0.62	np	no	△	△	●	●	△
	vinyl/wood/clad	0.49	0.56	no	no	△	△	●	●	■
	insulated	0.44	0.60	no	no	△	△	●	●	■
double, bronze tint	aluminum	0.76	0.56	no	no	●	△	●	△	●
	alum w/thermal break	0.63	0.52	no	no	△	△	●	△	△
	vinyl/wood/clad	0.49	0.47	no	no	△	△	●	△	■
	insulated	0.44	0.49	no	no	△	△	●	△	■
double, high-performance tint	aluminum	0.76	0.47	no	no	●	△	●	△	●
	alum w/thermal break	0.63	0.43	no	no	●	△	●	△	△
	vinyl/wood/clad	0.49	0.39	no	no	△	■	●	△	■
	insulated	0.44	0.41	no	no	△	■	●	△	■
double, high-solar-gain low-E	aluminum	0.61	0.64	no	no	△	△	△	●	●
	alum w/thermal break	0.50	0.58	no	no	△	△	△	●	△
	vinyl/wood/clad	0.37	0.53	yes	yes	■	△	△	●	■
	insulated	0.29	0.56	yes	yes	■	△	△	●	■
double, moderate-solar-gain low-E	aluminum	0.60	0.53	no	no	△	△	△	△	●
	alum w/thermal break	0.48	0.48	no	no	△	△	△	△	△
	vinyl/wood/clad	0.35	0.44	yes	yes	■	△	△	△	■
	insulated	0.27	0.46	yes	yes	■	△	△	△	■
double, low-solar-gain low-E	aluminum	0.59	0.37	no	no	△	■	△	■	●
	alum w/thermal break	0.47	0.33	no	no	△	■	△	■	△
	vinyl/wood/clad	0.34	0.30	yes	yes	■	■	△	■	■
	insulated	0.26	0.31	yes	yes	■	■	△	■	■
triple, high-solar-gain low-E	vinyl/wood/clad	0.29	0.38	yes	yes	■	■	■	△	■
	insulated	0.18	0.40	yes	yes	■	■	■	△	■
triple, low-solar-gain low-E	vinyl/wood/clad	0.28	0.25	yes	yes	■	■	■	■	■
	insulated	0.18	0.26	yes	yes	■	■	■	■	■

* Based on whether these generic window options are likely to meet the prescriptive requirements of the 2006 International Energy Conservation Code (IECC). The actual code requirements in a given jurisdiction may differ from those of the IECC.

● below average △ average ■ above average

Washington, DC

						Priority				
				Likely Meets		High	Moderate	High	Moderate	Moderate
Glass	Frame	U-factor	SHGC	Energy Star	Code*	Annual Energy Cost	Electric Peak	Winter Comfort	Summer Comfort	Condensation Resistance
single, clear	aluminum	1.16	0.76	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.70	no	no	●	●	●	●	△
	vinyl/wood/clad	0.84	0.63	no	no	●	●	●	●	△
single, bronze tint	aluminum	1.16	0.65	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.59	no	no	●	●	●	●	△
	vinyl/wood/clad	0.84	0.54	no	no	●	△	●	●	△
double, clear	aluminum	0.76	0.68	no	no	●	●	●	●	●
	alum w/thermal break	0.63	0.62	no	no	△	●	●	●	△
	vinyl/wood/clad	0.49	0.56	no	no	△	△	●	●	■
	insulated	0.44	0.60	no	no	■	△	●	●	■
double, bronze tint	aluminum	0.76	0.56	no	no	●	△	●	△	●
	alum w/thermal break	0.63	0.52	no	no	△	△	●	△	△
	vinyl/wood/clad	0.49	0.47	no	no	△	△	●	△	■
	insulated	0.44	0.49	no	no	△	△	●	△	■
double, high-performance tint	aluminum	0.76	0.47	no	no	●	△	●	△	●
	alum w/thermal break	0.63	0.43	no	no	●	△	●	△	△
	vinyl/wood/clad	0.49	0.39	no	no	△	■	●	△	■
	insulated	0.44	0.41	no	no	△	■	●	△	■
double, high-solar-gain low-E	aluminum	0.61	0.64	no	no	△	●	△	●	●
	alum w/thermal break	0.50	0.58	no	no	△	△	△	●	△
	vinyl/wood/clad	0.37	0.53	yes	yes	■	△	△	●	■
	insulated	0.29	0.56	yes	yes	■	△	△	●	■
double, moderate-solar-gain low-E	aluminum	0.60	0.53	no	no	△	△	△	△	●
	alum w/thermal break	0.48	0.48	no	no	△	△	△	△	△
	vinyl/wood/clad	0.35	0.44	yes	yes	■	△	△	△	■
	insulated	0.27	0.46	yes	yes	■	△	△	△	■
double, low-solar-gain low-E	aluminum	0.59	0.37	no	no	△	■	△	■	●
	alum w/thermal break	0.47	0.33	no	no	△	■	△	■	△
	vinyl/wood/clad	0.34	0.30	yes	yes	■	■	△	■	■
	insulated	0.26	0.31	yes	yes	■	■	△	■	■
triple, high-solar-gain low-E	vinyl/wood/clad	0.29	0.38	yes	yes	■	■	■	△	■
	insulated	0.18	0.40	yes	yes	■	■	■	△	■
triple, low-solar-gain low-E	vinyl/wood/clad	0.28	0.25	yes	yes	■	■	■	■	■
	insulated	0.18	0.26	yes	yes	■	■	■	■	■

* Based on whether these generic window options are likely to meet the prescriptive requirements of the 2006 International Energy Conservation Code (IECC). The actual code requirements in a given jurisdiction may differ from those of the IECC.

● below average △ average ■ above average

Phoenix, Arizona

				Likely Meets		Priority: High	Priority: High	Priority: Moderate	Priority: High	Priority: Low
Glass	**Frame**	**U-factor**	**SHGC**	**Energy Star**	**Code***	**Annual Energy Cost**	**Electric Peak**	**Winter Comfort**	**Summer Comfort**	**Condensation Resistance**
single, clear	aluminum	1.16	0.76	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.70	no	no	●	●	●	●	△
	vinyl/wood/clad	0.84	0.63	no	no	●	●	●	●	△
single, bronze tint	aluminum	1.16	0.65	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.59	no	no	●	●	●	●	△
	vinyl/wood/clad	0.84	0.54	no	no	●	●	●	●	△
double, clear	aluminum	0.76	0.68	no	no	●	●	●	●	●
	alum w/thermal break	0.63	0.62	no	no	●	△	●	●	△
	vinyl/wood/clad	0.49	0.56	no	no	△	△	●	●	■
	insulated	0.44	0.60	no	no	△	△	●	●	■
double, bronze tint	aluminum	0.76	0.56	no	no	●	△	●	△	●
	alum w/thermal break	0.63	0.52	no	no	△	△	●	△	△
	vinyl/wood/clad	0.49	0.47	no	no	△	△	●	△	■
	insulated	0.44	0.49	no	no	△	△	●	△	■
double, high-performance tint	aluminum	0.76	0.47	no	no	△	△	●	△	●
	alum w/thermal break	0.63	0.43	no	no	△	△	●	△	△
	vinyl/wood/clad	0.49	0.39	no	yes	△	△	●	△	■
	insulated	0.44	0.41	no	yes	△	■	●	△	■
double, high-solar-gain low-E	aluminum	0.61	0.64	no	no	●	△	△	●	●
	alum w/thermal break	0.50	0.58	no	no	△	△	△	●	△
	vinyl/wood/clad	0.37	0.53	no	no	△	△	△	●	■
	insulated	0.29	0.56	no	no	△	△	△	●	■
double, moderate-solar-gain low-E	aluminum	0.60	0.53	no	no	△	△	△	△	●
	alum w/thermal break	0.48	0.48	no	no	△	△	△	△	△
	vinyl/wood/clad	0.35	0.44	no	no	△	■	△	△	■
	insulated	0.27	0.46	no	no	△	■	△	△	■
double, low-solar-gain low-E	aluminum	0.59	0.37	no	yes	△	△	△	■	●
	alum w/thermal break	0.47	0.33	yes	yes	△	■	△	■	△
	vinyl/wood/clad	0.34	0.30	yes	yes	■	■	△	■	■
	insulated	0.26	0.31	yes	yes	■	■	△	■	■
triple, high-solar-gain low-E	vinyl/wood/clad	0.29	0.38	yes	yes	■	■	■	△	■
	insulated	0.18	0.40	yes	yes	■	■	■	△	■
triple, low-solar-gain low-E	vinyl/wood/clad	0.28	0.25	yes	yes	■	■	■	■	■
	insulated	0.18	0.26	yes	yes	■	■	■	■	■

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● below average △ average ■ above average

Miami, Florida

				Likely Meets		Priority				
						High	High	Low	High	Low
Glass	Frame	U-factor	SHGC	Energy Star	Code*	Annual Energy Cost	Electric Peak	Winter Comfort	Summer Comfort	Condensation Resistance
single, clear	aluminum	1.16	0.76	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.70	no	no	●	●	●	●	▲
	vinyl/wood/clad	0.84	0.63	no	no	●	●	●	●	▲
single, bronze tint	aluminum	1.16	0.65	no	no	●	●	●	●	●
	alum w/thermal break	1.00	0.59	no	no	●	●	●	●	▲
	vinyl/wood/clad	0.84	0.54	no	no	▲	▲	●	●	▲
double, clear	aluminum	0.76	0.68	no	no	●	●	●	●	●
	alum w/thermal break	0.63	0.62	no	no	●	●	●	●	▲
	vinyl/wood/clad	0.49	0.56	no	no	▲	▲	●	●	■
	insulated	0.44	0.60	no	no	●	▲	●	●	■
double, bronze tint	aluminum	0.76	0.56	no	no	▲	▲	●	▲	●
	alum w/thermal break	0.63	0.52	no	no	▲	▲	●	▲	▲
	vinyl/wood/clad	0.49	0.47	no	no	▲	▲	●	▲	■
	insulated	0.44	0.49	no	no	▲	▲	●	▲	■
double, high-performance tint	aluminum	0.76	0.47	no	no	▲	▲	●	▲	●
	alum w/thermal break	0.63	0.43	no	no	▲	▲	●	▲	▲
	vinyl/wood/clad	0.49	0.39	yes	yes	■	■	●	▲	■
	insulated	0.44	0.41	yes	yes	■	■	●	▲	■
double, high-solar-gain low-E	aluminum	0.61	0.64	no	no	●	●	▲	●	●
	alum w/thermal break	0.50	0.58	no	no	●	▲	▲	●	▲
	vinyl/wood/clad	0.37	0.53	no	no	▲	▲	▲	●	■
	insulated	0.29	0.56	no	no	▲	▲	▲	●	■
double, moderate-solar-gain low-E	aluminum	0.60	0.53	no	no	▲	▲	▲	▲	●
	alum w/thermal break	0.48	0.48	no	no	▲	▲	▲	▲	▲
	vinyl/wood/clad	0.35	0.44	no	no	▲	▲	▲	▲	■
	insulated	0.27	0.46	no	no	▲	▲	▲	▲	■
double, low-solar-gain low-E	aluminum	0.59	0.37	yes	yes	■	■	▲	■	●
	alum w/thermal break	0.47	0.33	yes	yes	■	■	▲	■	▲
	vinyl/wood/clad	0.34	0.30	yes	yes	■	■	▲	■	■
	insulated	0.26	0.31	yes	yes	■	■	▲	■	■
triple, high-solar-gain low-E	vinyl/wood/clad	0.29	0.38	yes	yes	■	■	■	▲	■
	insulated	0.18	0.40	yes	yes	■	■	■	▲	■
triple, low-solar-gain low-E	vinyl/wood/clad	0.28	0.25	yes	yes	■	■	■	■	■
	insulated	0.18	0.26	yes	yes	■	■	■	■	■

* Based on whether these generic window options are likely to meet the prescriptive requirements of the 2006 International Energy Conservation Code (IECC). The actual code requirements in a given jurisdiction may differ from those of the IECC.

● below average ▲ average ■ above average

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 choices for a typical house in four U.S. cities. The set of six windows chosen for each city varies depending on appropriateness for that climate.

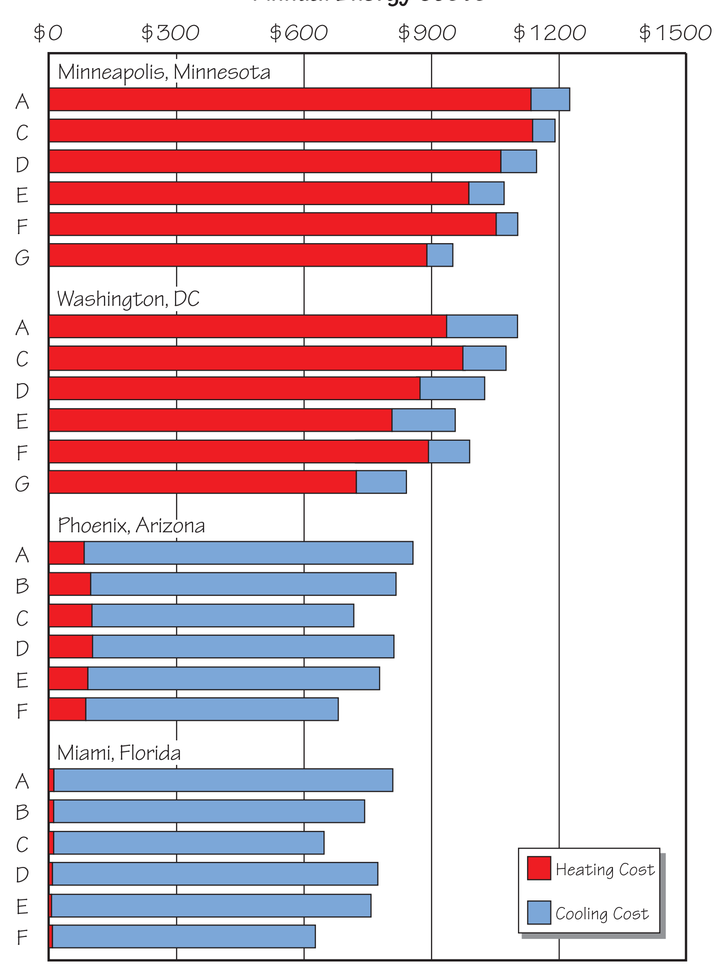
In a heating-dominated climate such as Minneapolis, Minnesota, the highest heating energy costs occur with aluminum-framed windows regardless of glazing type (Windows A and C). Within the wood/vinyl frame group, the low-E windows (E and F) have lower annual energy costs than clear double glazing (Window 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. However, this depends on how well the house is oriented to take advantage of solar gain during the heating season. During the cooling season, Window F is clearly better, making it close to Window E in total energy cost. The triple-glazed unit (Window G), with its very low U-factor, results in even greater energy savings.

Within the north/central climate zone, cities have both heating and cooling requirements, though many are more heating-dominated. The comparison in Washington, DC is similar to the northern zone locations—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 E is clearly better during the cooling season. The triple-glazed unit (Window G) results in even greater heating season savings.

Within the south/central climate zone, cities have both heating and cooling requirements. Phoenix, Arizona has a climate where cooling costs exceed heating costs regardless of frame type. The low-solar-gain low-E cases (Windows C and F) clearly have lower annual energy costs than the double clear (Window D) or the high-solar-gain low-E option (Window E). Because the cooling costs are dominant, the frame type has less influence on energy costs.

Window	Glazing	Frame	U-factor	SHGC	VT
A	double, clear	aluminum w/break	0.63	0.62	0.63
B	double, bronze tint	aluminum w/break	0.63	0.52	0.48
C	double, low-solar-gain low-E	aluminum w/break	0.47	0.33	0.55
D	double, clear	wood/vinyl	0.49	0.56	0.59
E	double, high-solar-gain low-E	wood/vinyl	0.37	0.53	0.54
F	double, low-solar-gain low-E	wood/vinyl	0.34	0.30	0.51
G	triple, moderate-solar-gain low-E	insulated vinyl	0.18	0.40	0.50

Annual Energy Costs

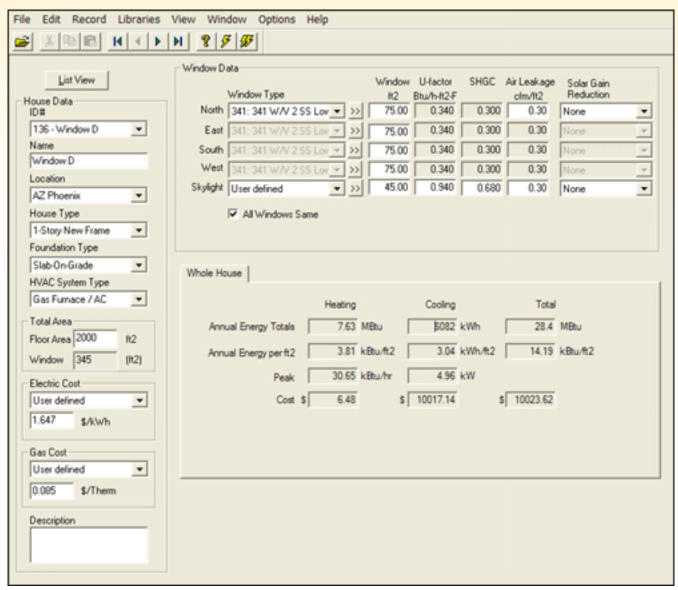


In a cooling-dominated climate such as Miami, Florida, there are significant savings in annual cooling costs by using windows with low-solar-heat gain coefficients (Windows C and F) instead of double-glazed, clear units or traditional bronze- or gray-tinted glass (Windows A, B, and D). The windows with comparable glazings but different frames show that wood and vinyl frames perform better than aluminum frames. Some of this effect is because with thicker wood and vinyl 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 (Window 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 unit (Window E) uses much more cooling energy than the low-solar-gain low-E option (Window F).

In applying these typical results to your particular situation, remember that the example is an average house (2000 square feet) with an average amount of window area (300 square feet). The windows are equally distributed on all four sides and include typical shading (interior shades, overhangs, trees, and neighboring buildings). 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 so you can base decisions on your own house design.

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 heating and cooling costs for your specific climate, 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. The program then calculates the annual energy use and cost in a matter of seconds. RESFEN provides the annual heating and cooling energy use and cost as well as peak heating and cooling loads. It is designed so that different window types can be placed on different orientations.



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

Assumptions

The annual energy performance figures were generated using RESFEN for a typical (new construction) 2000 sq ft house with 300 sq ft of window area. The windows are equally distributed on all four sides and include typical shading (interior shades, overhangs, trees, and neighboring buildings). U-factor, SHGC, and VT 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. The prices shown in the figures are average energy prices projected for the period of 2006-2030, which is the typical effective lifetime of a window installed in 2005. The bases for these prices are average state-specific 2005 prices for electricity during the cooling season and for natural gas during the heating season, adjusted by the projected difference between average national 2005 prices and average national prices between 2006 and 2030. Energy Information Administration (EIA) data (www.eia.doe.gov) is used for the 2005 prices. The 2006-2030 prices are based on EIA projections of future prices in real 2004 dollars that have been adjusted to take into account an estimated future inflation rate of 3 percent annually.

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; 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 not only saves cost but is important to ensure that the system runs smoothly and maintains comfort. Lower peak demand also benefits the electrical utilities in that load factors are reduced during the peak times in summer. Lowering the cooling demand is a goal of most electric utilities. If peak cooling loads are minimized, additional generating capacity is not required. This directly benefits the utility company, and indirectly the consumer, by keeping rates down.

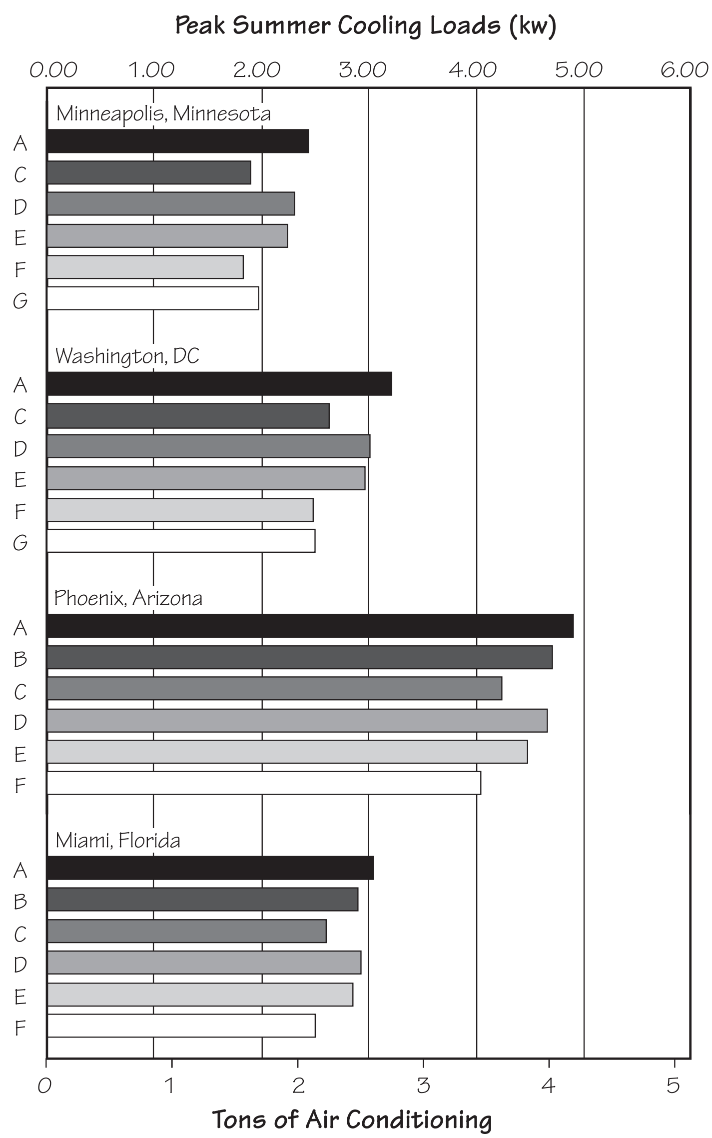
Similar to annual energy use, RESFEN was used to determine peak electricity demand for several window choices on a typical house in four U.S. cities, as shown in the Peak Summer Cooling Loads figure. Even though the northern zone is not predominantly a cooling climate, there can still be hot, humid days in summer with high peak loads. In Minneapolis, Minnesota the low-solar-gain low-E (Windows C and F) reduces the peak cooling load by 20 to 25 percent compared to clear double glazing (Window D). This difference would be higher if the windows were unshaded.

Similar to the northern climate, the same pattern occurs in a north/central climate city such as Washington, DC.

Window	Glazing	Frame	U-factor	SHGC	VT
A	double, clear	aluminum w/break	0.63	0.62	0.63
B	double, bronze tint	aluminum w/break	0.63	0.52	0.48
C	double, low-solar-gain low-E	aluminum w/break	0.47	0.33	0.55
D	double, clear	wood/vinyl	0.49	0.56	0.59
E	double, high-solar-gain low-E	wood/vinyl	0.37	0.53	0.54
F	double, low-solar-gain low-E	wood/vinyl	0.34	0.30	0.51
G	triple, moderate-solar-gain low-E	insulated vinyl	0.18	0.40	0.50

In a south/central climate such as Phoenix, Arizona 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.



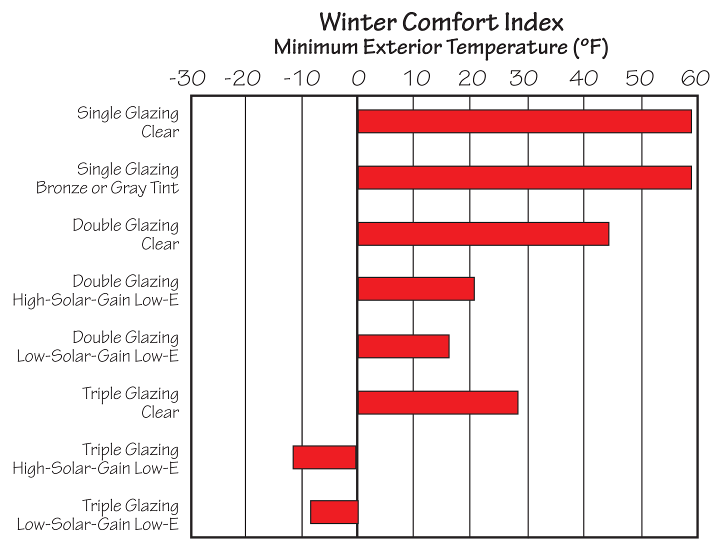
Thermal Comfort

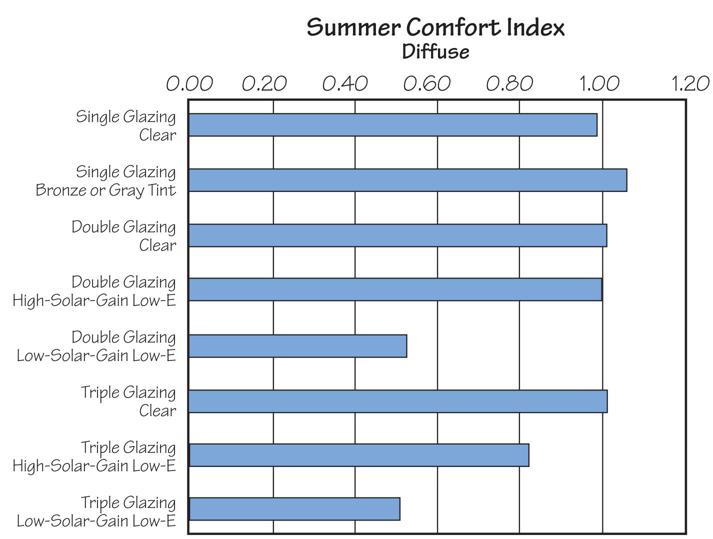
Windows affect human comfort in several ways. If people are exposed to the effects of a cold window surface, they experience significant radiant heat loss to that cold surface and they feel uncomfortable, even in the presence of comfortable room air temperatures. The fact that this heat loss occurs on one side of the body more than the other is called radiant asymmetry, and this 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 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. With tinted glass, although it helps to reduce direct solar heat gain and glare, surfaces get as hot as 140°F. These surfaces radiate heat to building occupants and can also create convection drafts of warm air that can cause discomfort.

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 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 high- or low-solar-gain low-E coatings 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 it 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. 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 low-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)
This fact sheet was produced with funding from the Windows and Glazings Program at the U.S. Department of Energy (www.eren.doe.gov) in support of the EWC. For more information, contact:

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 Biulding 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 aluminum 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 higher CR is better. The worst performance occurs with non-thermally broken aluminum frames where the CR falls in a range of 10 to 23 regardless of glazing type. The CR for aluminum frames with thermal breaks is higher—in the range of 30 to 42. The greater insulating value of wood and vinyl frames results in even better condensation performance resistance. Because the wood or vinyl 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 to 48 while with low-E glazings, the range is 40 to 60. The wide range in CR reflects differences in types of low-E coatings and spacers. Even better performance can be achieved with wood or vinyl framed triple-glazed low-E window units where a CR of 65 to 70 is possible.