Efficient Windows™ Collaborative

Window Design Guidance for New Homes in a Cold Climate

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Introduction

The energy impact due to windows in a home depends on several design decisions—climate, window orientation, window area, shading conditions, and window (frame and glazing) type. Homeowners and designers need to know the answers to the following questions. What is the best window type to reduce energy use in a particular location? Does window area and orientation affect energy use? Are shading devices effective in saving energy?

Unfortunately, the answers to these questions are not quite as simple as they seem. For example, there is a general perception that homes with larger window areas use more energy than homes with smaller window areas. This may be true for windows with conventional clear glazing, however, with high-performance windows, a home with a large window area can use the same amount of energy or even less energy than a space with a small window area. The best option is not always obvious, so it is important for homeowners and designers to be aware of the available advanced technologies and to use calculation tools to optimize design choices for energy-efficient performance.

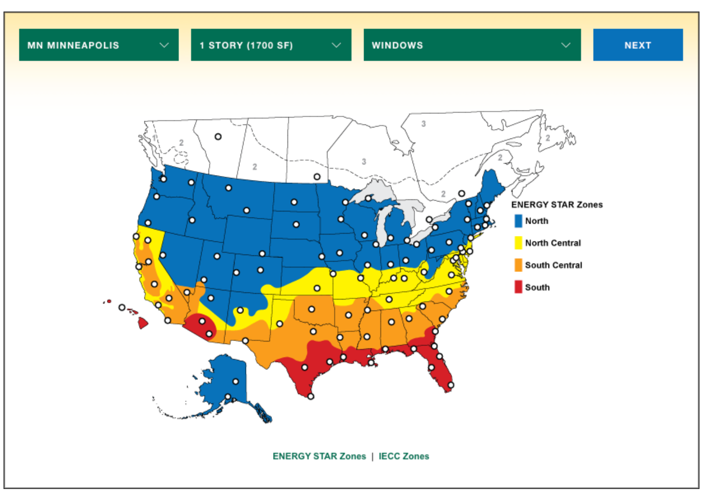
To provide guidance, the following pages examine the energy use impacts due to orientation, window area, and shading strategies for homes in Minneapolis, Minnesota. The energy use was calculated for many window design variations including 5 orientations, 3 glazing areas, 5 shading types, and 20 window types. The assumptions for these variations are shown on the last page. All simulations were performed using RESFEN and analysis was done using the EWC's Window Selection Tool. To determine actual impact of window design variations on a specific project, use the **Window Selection Tool** or **download RESFEN**.

KEY ISSUES

Orientation: Homes with windows facing predominately south use less energy than homes facing north, east, or west. With high-performance windows, these differences can be considerably less.

Window Area: Energy use increases with window area using windows with clear glazing or a poor performing frame. With high-performance windows, energy use may not increase at all when using a larger window area.

Shading Condition: In a cold climate, shading devices may have little impact. On south-facing homes, overhangs can be effective to block the hot summer sun and allow for passive winter heat. Shading devices have less impact when using high-performance windows with low-E glazing.



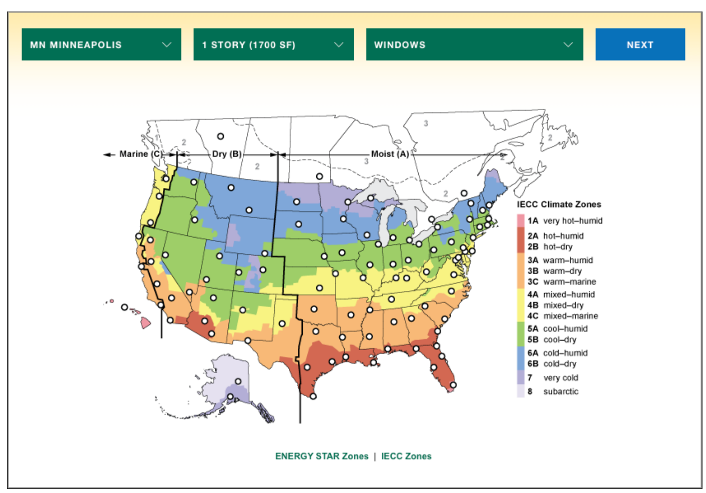


Figure 1. Opening screen of the Window Selection Tool showing the cities, house type, and window type available for selection. You can choose to see the map with the ENERGY STAR® zones or the IECC zones. The Window Selection Tool has options for new or replacement windows, 98 cities, 1- or 2-story home, and windows or skylights.

Orientation

Figure 2 shows the range of possible annual energy costs for the design variations grouped by orientation. This figure shows:

- The impact of orientation on energy use is not the same for all windows.
- South orientation performs the best.
- Orientation has a reduced impact on energy performance when high-performance windows are used (windows 15–20).

Strategies to capture winter solar heat have a long history in design. Generally, passive strategies and systems have been based on the principle that solar gain will be maximized by placing more glazing toward the south and less glazing in other directions. Simply increasing south-facing window area is not necessarily better. In order for passive solar designs to be useful, solar heat admitted through windows must be stored in thermal mass within the house, to be released later in the afternoon and at night. An inadequate ratio of mass to glass area may result in overheating during winter days or less useful solar gain than expected. Also, large windows must be carefully protected during the cooling season to avoid increased cooling costs.

Orienting the majority of windows to the south will result in greater solar gain and less heating energy use. But, it is not always feasible to do so. Window orientation in a house is often dictated by views and factors other than optimal solar gain. With high-performance windows, any orientation can result in an energy-efficient house.

Figure 3 illustrates the impact of 5 different window orientations (north, east, south, west, and equal) on annual energy costs in Minneapolis, Minnesota. In all cases, the windows have typical shading. As expected, there is a difference between orientations and south-oriented windows perform best. The difference between orientations is more notable when clear double-glazed windows are used but is diminished when higher-performance windows with lower U-factors are used.

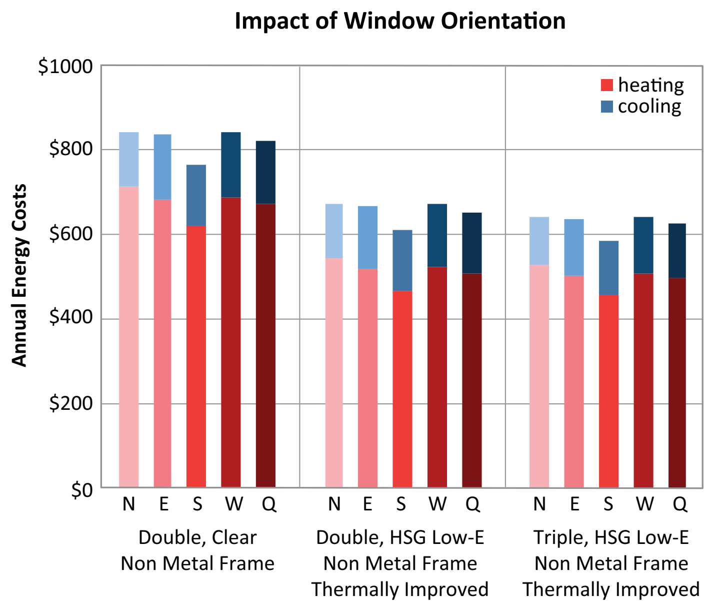


Figure 3. Impact of orientation for 3 windows in Minneapolis, MN. The results are for 15% window area with typical shading.

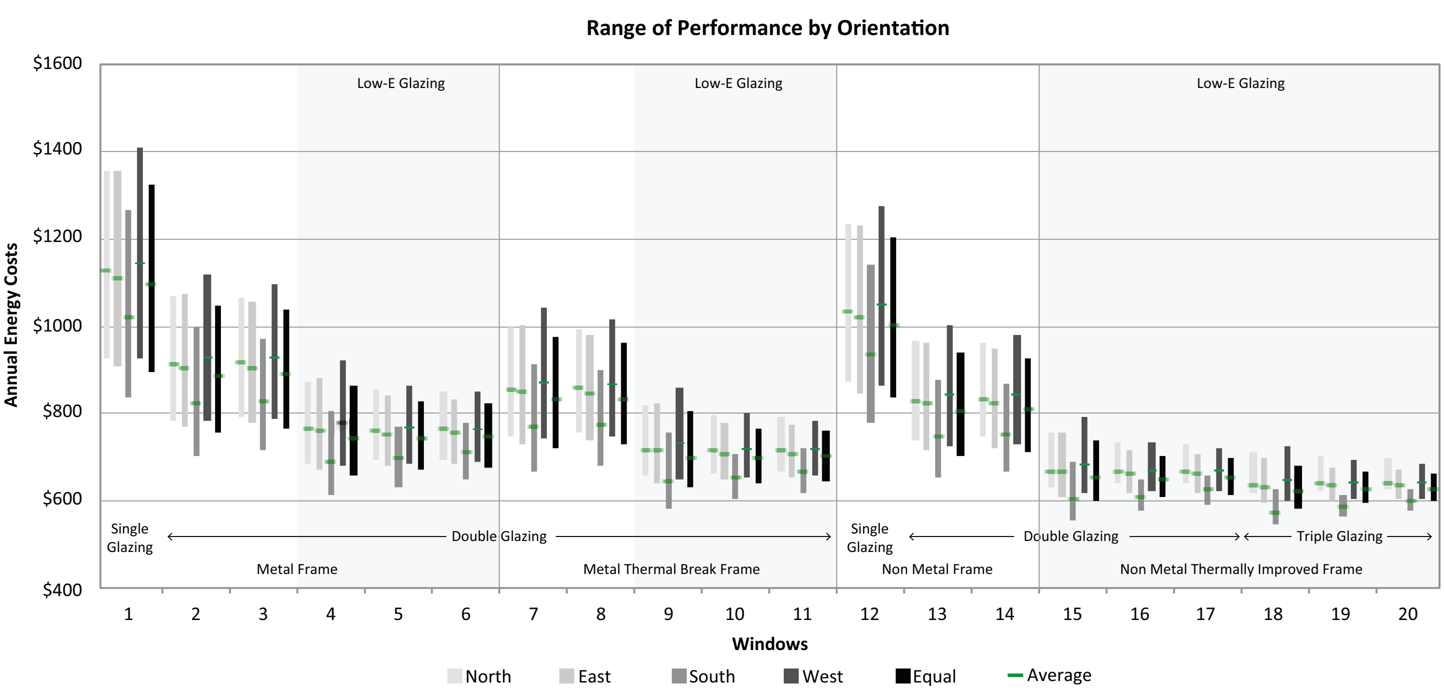


Figure 2. Annual energy costs (heating & cooling) for all window design variations by orientation in Minneapolis, MN.

Window Area

Figure 4 shows the range of possible annual energy costs for the design variations grouped by window area. This figure shows:

- The impact of window area on energy use is not the same for all windows.
- Low energy use can be achieved with any window area when using windows with a low-E coating.
- Large window areas have the worst performance when using windows with clear or tinted glazing.
- Window area has a significant less of an impact when high-performance windows are used (windows 15–20).

Another traditional guideline to reduce heat loss is to reduce the home's total window area. This is particularly important when less efficient windows are used. Because of the need for daylighting, views, and natural ventilation, reducing window area may not be a realistic or desirable strategy. As windows have improved considerably, high-performance windows can equal the performance of an insulated wall during a winter heating season. Consequently, the strategy of reducing window area to reduce energy use is no longer significant if highly efficient windows are used.

Figure 5 illustrates the impact of 3 different glazing areas (small-10%, moderate-15%, large-20%) on the annual energy costs for a house in Minneapolis, Minnesota. In all cases, the windows are equally distributed on the four orientations with typical shading. Window area has a significant impact on heating energy use when clear, double-glazed windows are used. This difference diminishes with double- and triple-glazed high-solar-gain (HSG) low-E windows—indicating the benefit of more passive solar gain exceeds any losses from more glazing area. Depending on the U-factor, solar heat gain coefficient (SHGC), house design, and climate, energy gains of the HSG low-E in the heating season may be offset by losses in the cooling season.

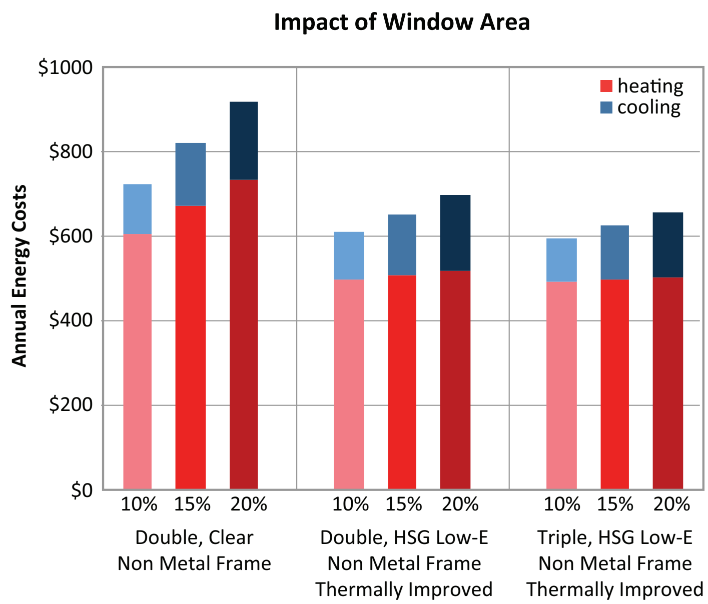


Figure 5. Impact of window for 3 windows in Minneapolis, MN. The results are for equal orientation with typical shading.

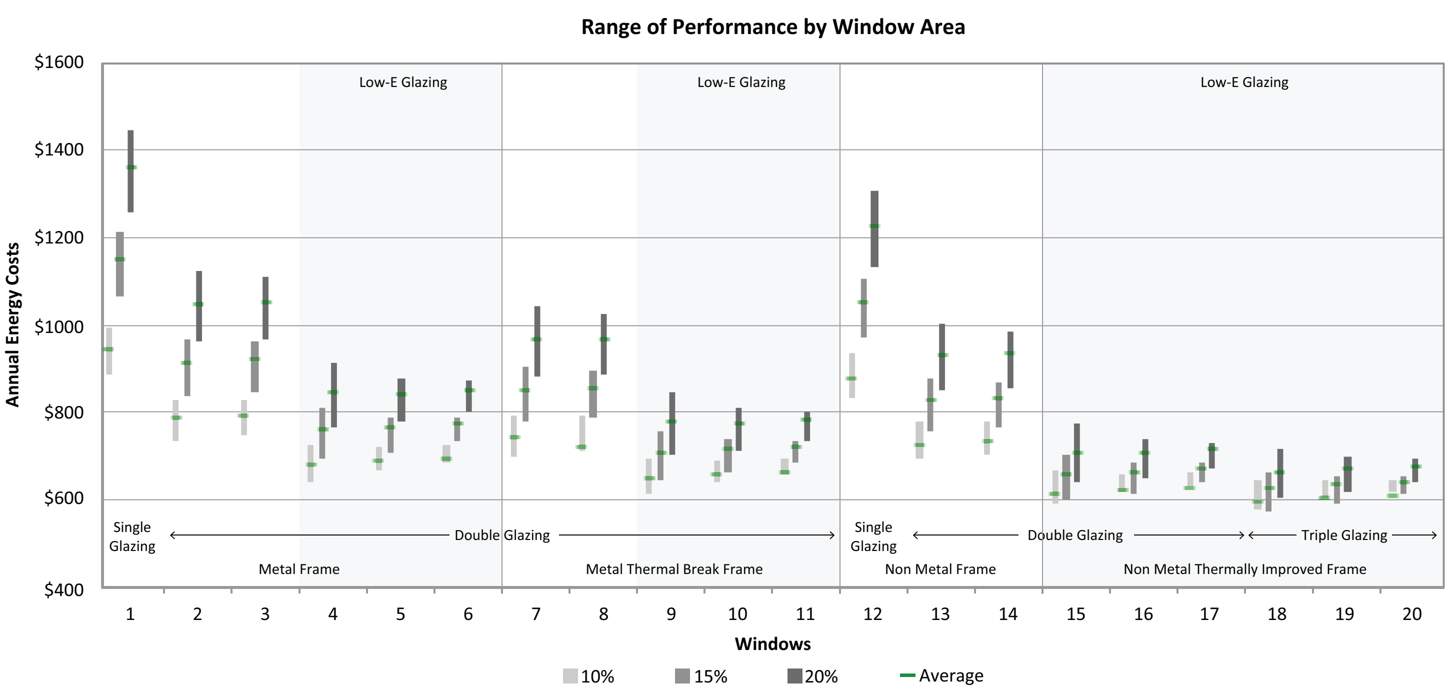


Figure 4. Annual energy costs (heating & cooling) for all window design variations by window area in Minneapolis, MN.

Shading

Figure 6 shows the range of possible energy costs for the design variations grouped by shading condition. This figure shows:

- The impact of shading strategies on energy use is not the same for all windows.
- Under certain conditions, very low energy use can be achieved with any shading strategy on any orientation while using low-E glazing options.
- Windows with no shading and clear glazing perform the worst.
- The impact of shading strategies on energy performance is significantly reduced when using high-performance windows (windows 15–20).

Any effort to shade traditional windows has had great benefits in terms of comfort and energy use. The best place to shade a window is on the outside, before the sun strikes the window. Exterior shading devices have long been considered the most effective way to reduce solar heat gain into a home. The most common approach is the fixed overhang. For south-facing windows, overhangs can be sized to permit low-angled winter sun to penetrate into the home while still blocking much of the higher-angled summer sun. Most other external and internal shading devices such as awnings, shutters, or exterior shades are operable and can be adjusted seasonally or daily to maximize solar gain in winter. The choice of shading strategy is often distinctly regional, based on local traditions. The drawback of some shading devices is that they block light and view.

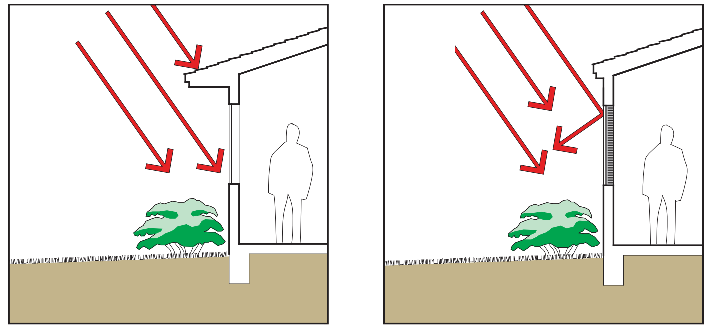


Figure 7. Shading strategies can reduce the solar heat gain that enters through the window.

Most homeowners use some form of interior window treatment such as drapes, blinds, or shades on their windows. In addition to their decorative aspects, drapes and curtains are used by homeowners to control privacy and daylight, provide protection from overheating, and reduce the fading of fabrics. The main disadvantage of drapes and other interior devices as solar control measures is that once the solar energy has entered the room through a window, a large proportion of the energy absorbed by the shading system will remain inside the house as heat gain.

Blinds and shades primarily provide light and privacy control but they also can have an impact on controlling heat loss by providing a radiant barrier. These include horizontal Venetian blinds, miniblinds, vertical slatted blinds, pleated and honeycomb shades, and roll-down shades—all of which can

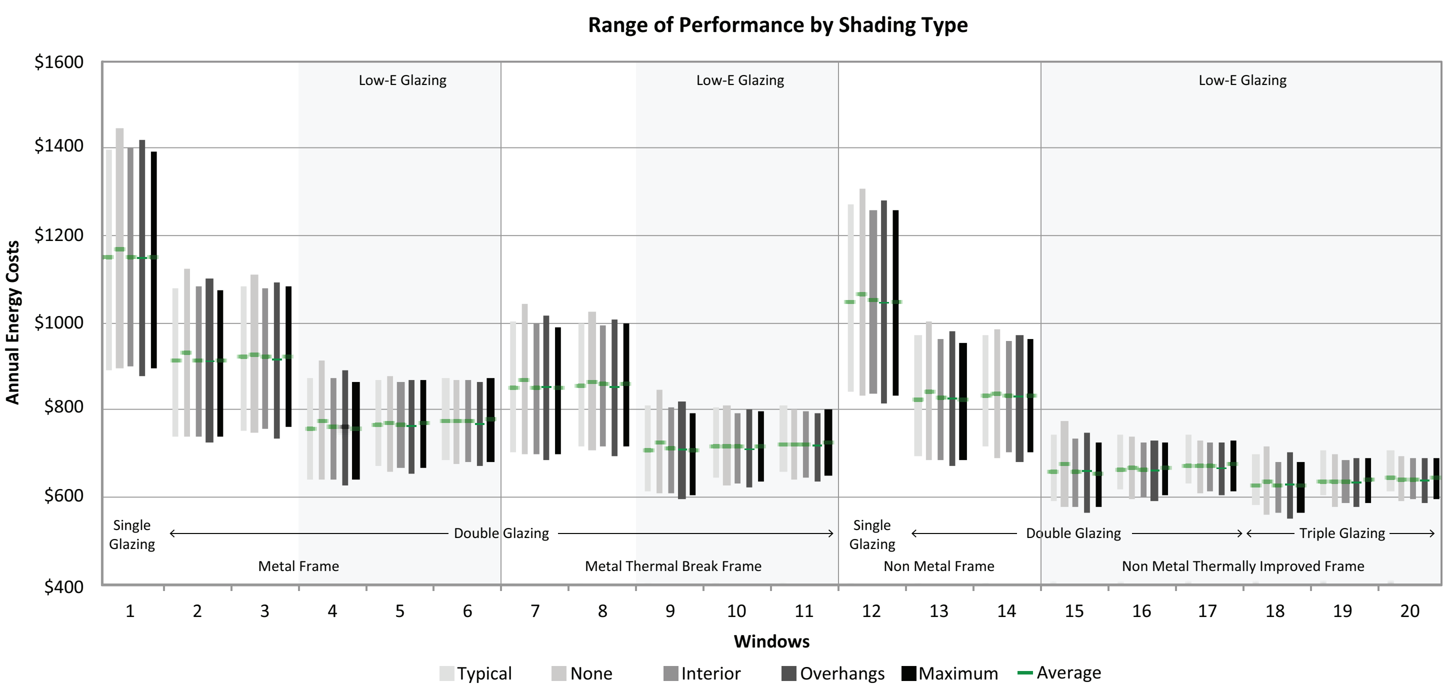


Figure 6. Annual energy costs (heating & cooling) for all window design variations by shading type in Minneapolis, MN.

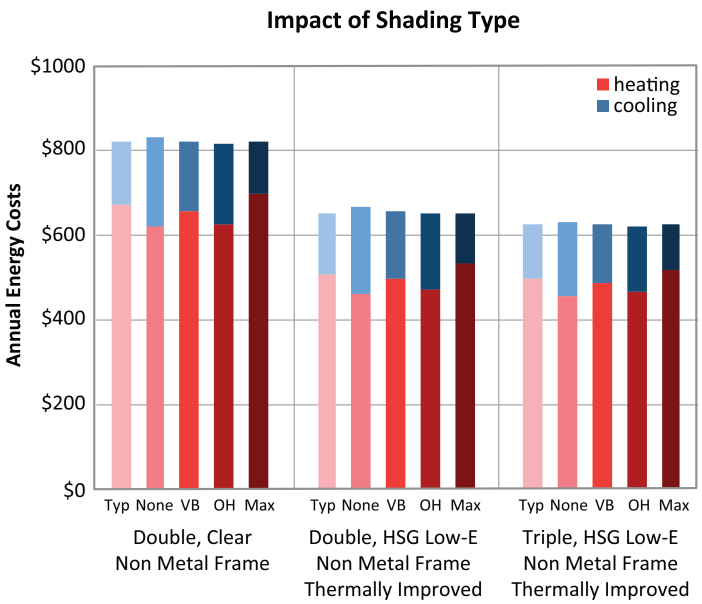


Figure 8. Impact of window for 3 windows in Minneapolis, MN. The results are for equal orientation with typical shading.

be made of various materials. Unlike other shading strategies, such as overhangs, interior shades generally require consistent, active operation by the occupant. Unfortunately, when shades are down, daylight and view are diminished or excluded completely. It is unlikely that anyone would operate all shades in a consistent, optimal pattern as they are often assumed to be operated in computer simulations. Motorized and automated shading systems are widely available to solve these operational problems. The control systems can be automated using sensors, time clocks, mobile apps, or a home automation system. They can also be directly controlled by the occupants.

By using high-performance windows to provide the necessary solar control, there are two important benefits: there is less need for operating the shades, and the window is covered less of the time, resulting in increased daylight and unobstructed views. If your goal is to minimize heat loss, then the combination of good shade management with high-performance windows will be the best strategy.

A broad-leafed tree is good at providing cool shade in the summer. In addition to shading the building from direct sun, trees have been found to reduce the temperature of air immediately around them by as much as 10˚F (5˚C) below the temperature of the surrounding air due to evaporation of moisture. A window shaded with vegetation can have full shade in the summer, while enhancing the view and perhaps the ventilation. Trees and bushes can provide strategic shade from low east or west sun angles that are extremely difficult to shade architecturally. The advantage to using deciduous vegetation for shading is that its cycle generally follows the local climate. Trees leaf out in the spring, when the weather warms up, just in time to provide shading. They drop their leaves when the cold weather appears, allowing the sun's heat to penetrate and warm the home.

Figure 8 illustrates the impact of 5 different shading strategies (typical, none, interior blinds, overhangs, maximum) on the annual energy costs for a house in Minneapolis, Minnesota. In all cases, the windows are equally distributed on the four orientations with a moderate window area. With all 3 windows, no shading has the best heating performance due to the passive solar gain, but no shading allows for a higher cooling load. Overhangs are much less effective against the lower angles of the east and west sun, but can be quite effective on the south orientation. Reliance on any form of shading is not nearly as important, however, when windows with high-solar-heat-gain (HSG) coefficients are used. Shading makes little difference in energy costs in a heating-dominated climate like Minneapolis, there are still summer comfort and glare control benefits. If the relative cost of cooling increases in comparison to heating, then the cost advantage of shading will become greater.

It should be noted that new homes designed for a northern climate must use proper passive solar strategies if using high-solar-gain (HSG) low-E glazing systems. These strategies include and are not limited to the home orientation, thermal mass for heat storage, and properly sized overhangs. If your home is not designed for passive solar heating, overheating can occur which may lead to comfort issues as well as increased HVAC system use. If your new home has large amounts of south- or west-facing windows and no passive design strategies will be implemented, it is recommended that the high-performance windows you choose are made up of moderate-solar-gain (MSG) or low-solar-gain (LSG) low-E glazing.

Comfort

Thermal comfort is that condition of mind that expresses satisfaction with the thermal environment. There are large variations, both physiologically and psychologically, from person to person, so it is difficult to satisfy everyone in a space.

Windows generally do not insulate as well as opaque wall elements. In winter when outdoor temperatures are cold, window roomside surfaces will be cooler than the adjacent wall. . Cold glass can also create uncomfortable drafts as air next to the window is cooled and drops to the floor—creating an air movement pattern that feels drafty. Figure 9 illustrates that 56°F is the threshold between comfort and uncomfortable due to the cold surface temperature of the glass. High performance windows with lower U-factors will result in a higher interior window temperature in winter and thus greater comfort.

The Efficient Window Collaborative has a Comfort Metric as part of it's online **Window Selection Tool** and it is unique and innovative for it is the first quantitative comfort metric for windows. This Comfort Metric is limited to a worst-case scenario of a large west-facing window and summer day and winter night conditions. Windows below a level of 88 discomfort hours received a "Neutral" rating—which is good rating. The neutral level is approximately 1% of the hours in a year. HVAC equipment sizing also use the 1% thresholds on weather conditions.

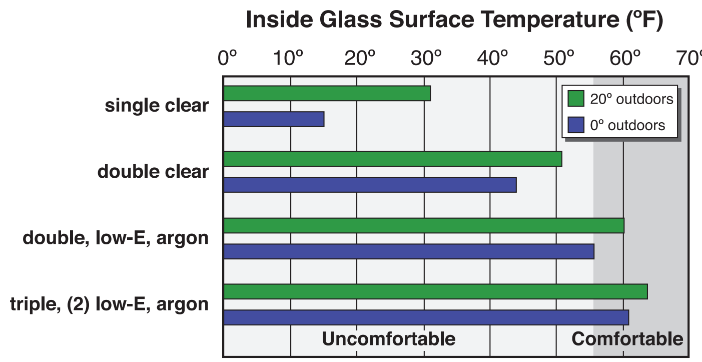


Figure 9. Window uncomfortable-comfortable threshold of 4 windows from the EWC window set.

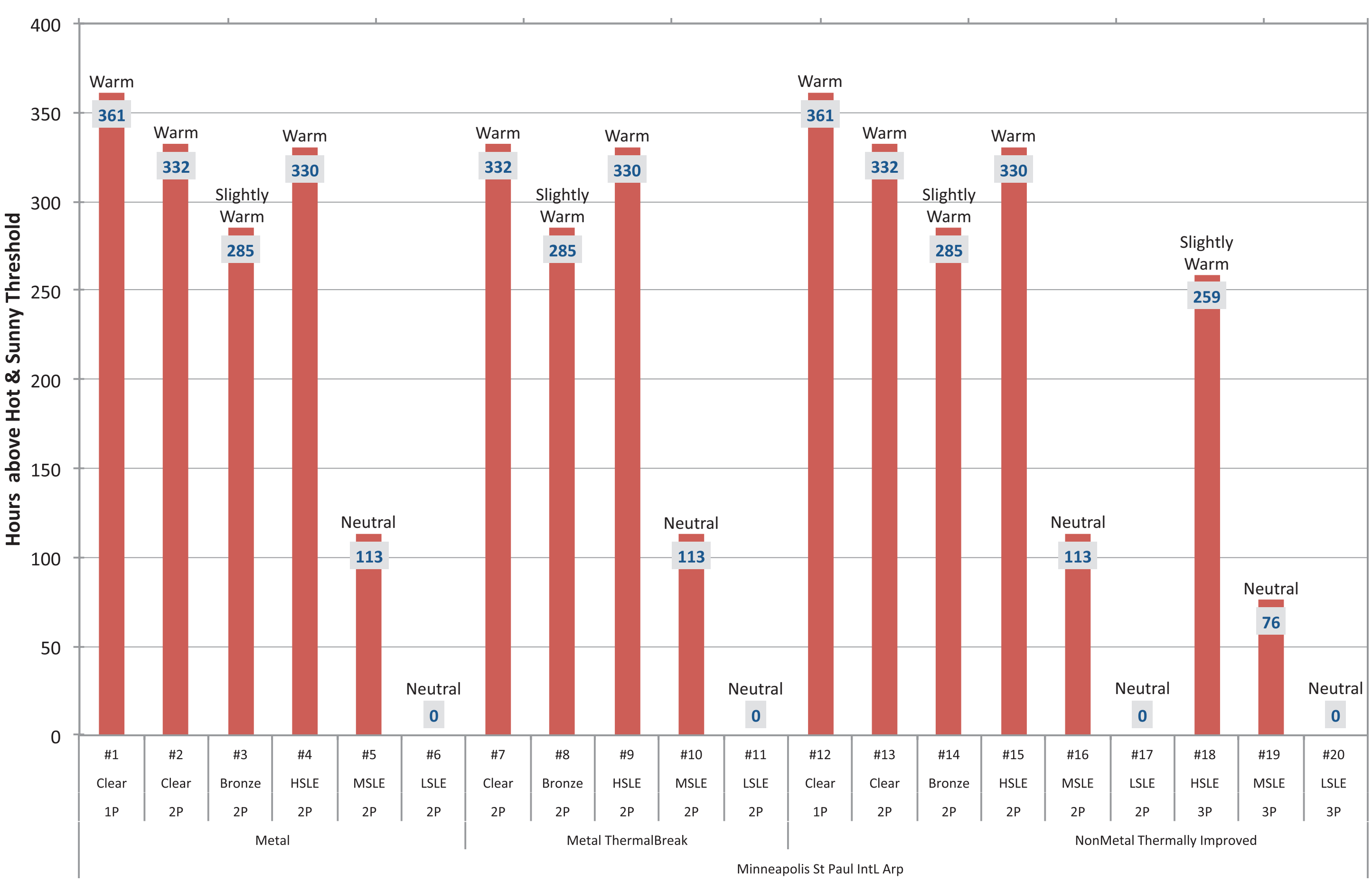


Figure 10. Summer comfort rankings for 20 windows in Minneapolis, Minnesota.

Figure 10 illustrates hours summer discomfort for each of the 20 windows in Minneapolis, Minnesota. The summer ranking levels match up well with type of low-E used in the glazing systems. An low-solar-gain (LSG) below 0.25 will be neutral and high-solar-gain (HSG) greater than 0.50 will be hot. It should be noted that in a northern climate, if passive design strategies are not implemented, this figure illustrates that even a high-performance window (windows 15 and 18) can possibly lead to comfort issues and increase HVAC system use. It is recommended that if no passive design strategies are used then a LSG or MSG windows system is chosen—even in a northern climate—otherwise overheating in the summer months may occur and there will be comfort issues.

The Figure 11 illustrates hours winter discomfort for each of the 20 windows in Minneapolis, Minnesota. The winter ranking levels show the dual pane windows that meet the energy code (windows 15–17) as "Cool" and the triple pane products (windows 18–20) as "Neutral." Note also how the cool glass options (windows 15–17) in a non-metal frame turn deliver a cold rank in a metal frame (windows 9–11).

When choosing windows for your particular climate, make sure that you take into account, not only the design of your home, but also the thermal impacts of both the heating and the cooling seasons. For comfort issues may occur as a result of either of those situations.

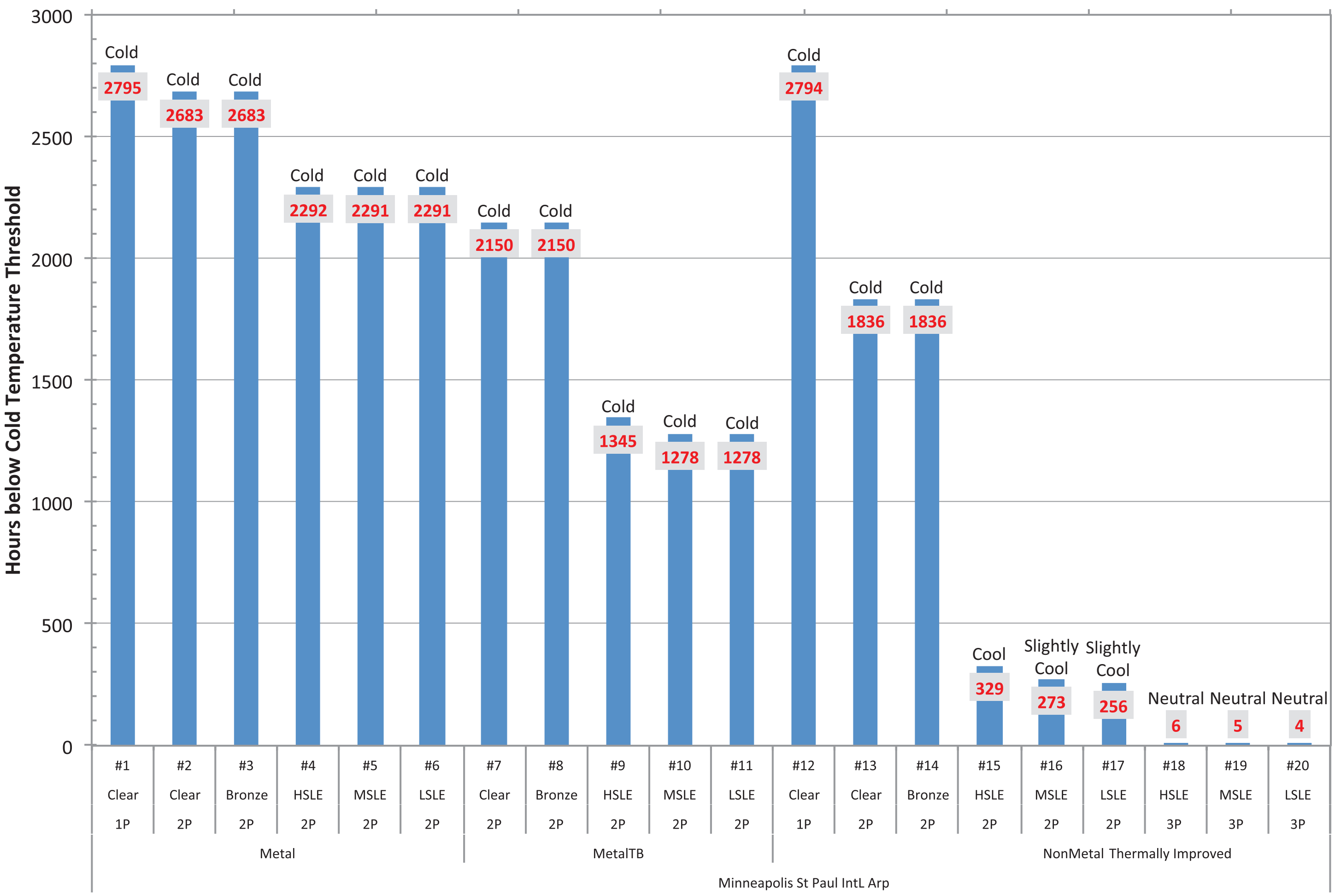


Figure 11. Winter comfort rankings for 20 windows in Minneapolis, Minnesota.

Assumptions

The following assumptions are used in the Window Selection Tool for all energy use calculations presented in this design guide. The annual energy performance figures were generated with **RESFEN6** provided by Lawrence Berkeley National Laboratory. The annual costs are 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. Natural gas prices are based on state-specific average natural gas retail price data for the heating season (November–March) for the years 2013–2015. Electricity prices are based on average state-specific electricity retail price data for the cooling seasons (May–September) of 2013–2015. All price data is from the **Energy Information Administration** (EIA).

The House

The house used in the simulations for this guide is a 2600 square foot, two-story new house. The mechanical system uses a gas furnace for heating and electric air conditioning for cooling. The foundation includes a basement. The building envelope consists of R19 walls and R49 roof.

House Orientation

Orientation of the windows of the house are available in equal(the windows are equally distributed on all 4 sides), north, east, south and west (55% of the window area is on the dominant orientation with 15% on remaining 3 orientations).

Window-to-Floor Ratio

Window sizes were modeled with a fenestration window-to-floor area ratio (which includes the area of the whole window with frame). Window-to-floor ratios include 10% (260 square feet of window area), 15% (390 square feet of window area), and 20% (520 square feet of window area).

Shading Systems

Overhangs were mounted directly above the window frame with a 2-foot projection and extend the entire width of the window. Interior Venetian blinds were simulated so that the slats would have a seasonal SHGC multiplier (summer=0.80, winter=0.90). Typical shading represents a statistically average solar gain reduction which includes interior shades, 1-foot overhang, adjacent buildings 20 feet away, and other sources of heat gain reduction such as insect screens and trees. Maximum shading takes into account interior shades, 2-foot overhangs and obstructions that represent adjacent buildings and vegetation.

Window System

There are hundreds of glazing systems available in the market today, with varying combinations of glass panes, special coatings, and tints. The Window Selection Tool models the performance of 23 window systems (20 of which are represented in this document), representative of the breadth of options available. U-factor and solar heat gain coefficient (SHGC) are for the total window including frame. For ease of comparing the performance of glass features, all high-performance glazing systems in the Window Selection Tool are modeled with an argon fill. All specific simulation assumptions for this document can be found on the EWC web site as part of the **Window Selection Tool**.