Efficient Windows™ Collaborative

Window Design Guidance for New Homes in a Mixed 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 Washington, DC. 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 and shading strategies, these differences can be considerably less.

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

Shading Condition: On south-facing homes, overhangs can be effective to block the hot summer sun while allowing for passive solar gain in winter months. Shading devices have less impact when using high-performance windows with low-solar-gain glazing.

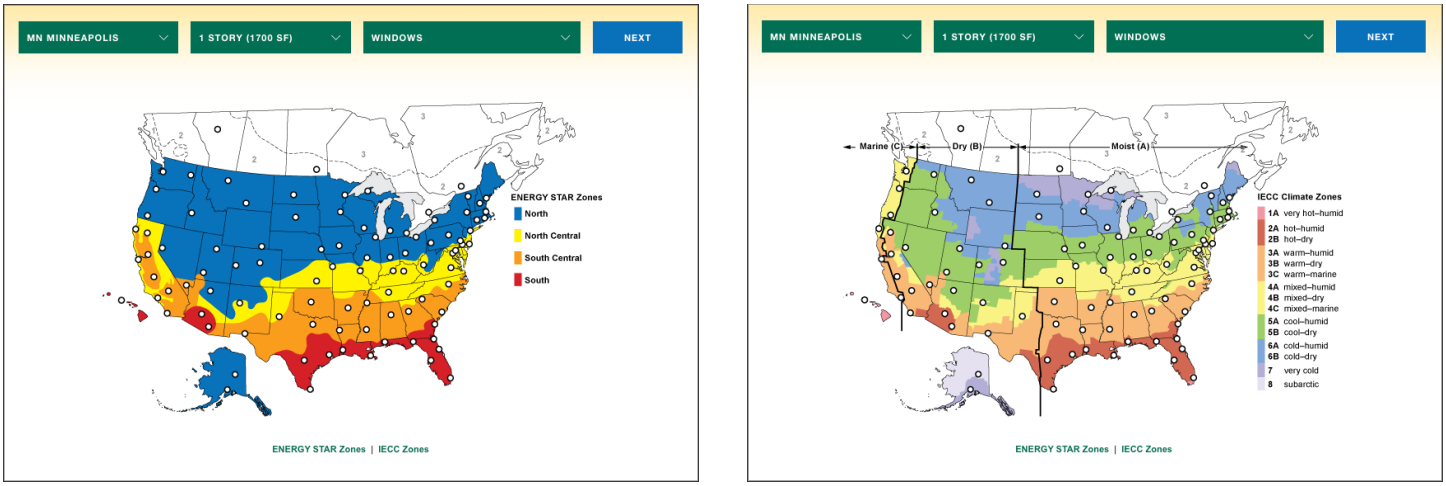

Figure 1. Opening screen of the Window Selection Tool showing the cities, house type, and window type available for selection. You can choose to see the map with the ENERGY STAR® zones or the IECC zones. The Window Selection Tool has options for new or replacement windows, 98 cities, 1- or 2-story home,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

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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.
- Under certain conditions, low energy use can be achieved with any orientation.
- West-facing designs use the most energy.
- South-facing designs use the least energy.
- Orientation has a reduced impact on energy performance when high-performance windows are used (windows 16–20).

In a mixed climate, it is necessary to reduce solar heat gain in the cooling months and it may be beneficial to take advantage of the passive solar heat gain in the heating months. In warm climates facing windows to the south where overhangs can be designed to keep out most of the hot summer sun and allow for passive solar access when the sun is lower during the winter months is an effective strategy. West windows are subject to the full force of the strong afternoon sun, at a time of day when temperatures generally climb to their peak. East windows have the same problem in the morning hours, but air temperatures tend to be cooler.

In spite of energy concerns, a house may have a spectacular view or other amenity to a direction other than south. Fortunately, the traditional patterns of avoiding east- and west-facing windows are not as critical when high-performance windows are used.

Figure 3 illustrates the impact of 5 different window orientations on annual energy costs in Washington, DC. In all cases, the windows have typical shading. As expected, orientation has a negative impact when clear, double-glazed windows are used. When high-performance windows with a low-solar-gain (LSG) low-E coatings are used, the window orientation has a diminished impact on cooling energy use.

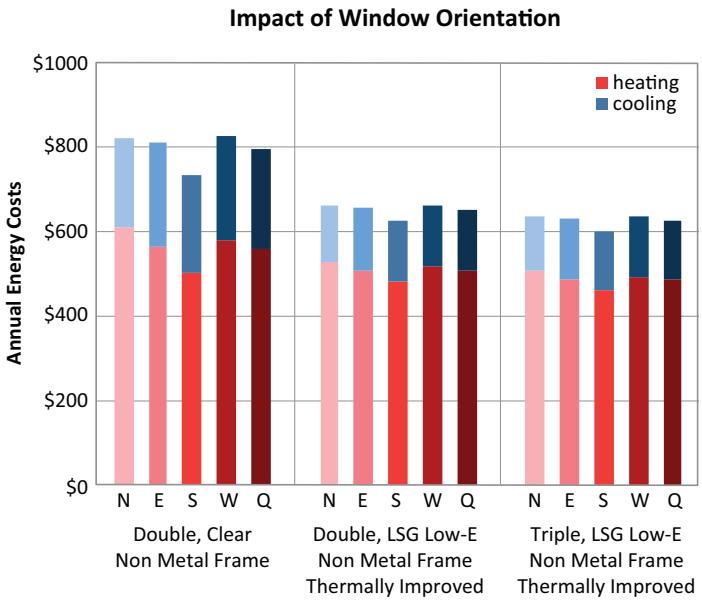

Figure 3. Impact of orientation for 3 windows in Washington, DC. The results are for 15% window area with typical shading.

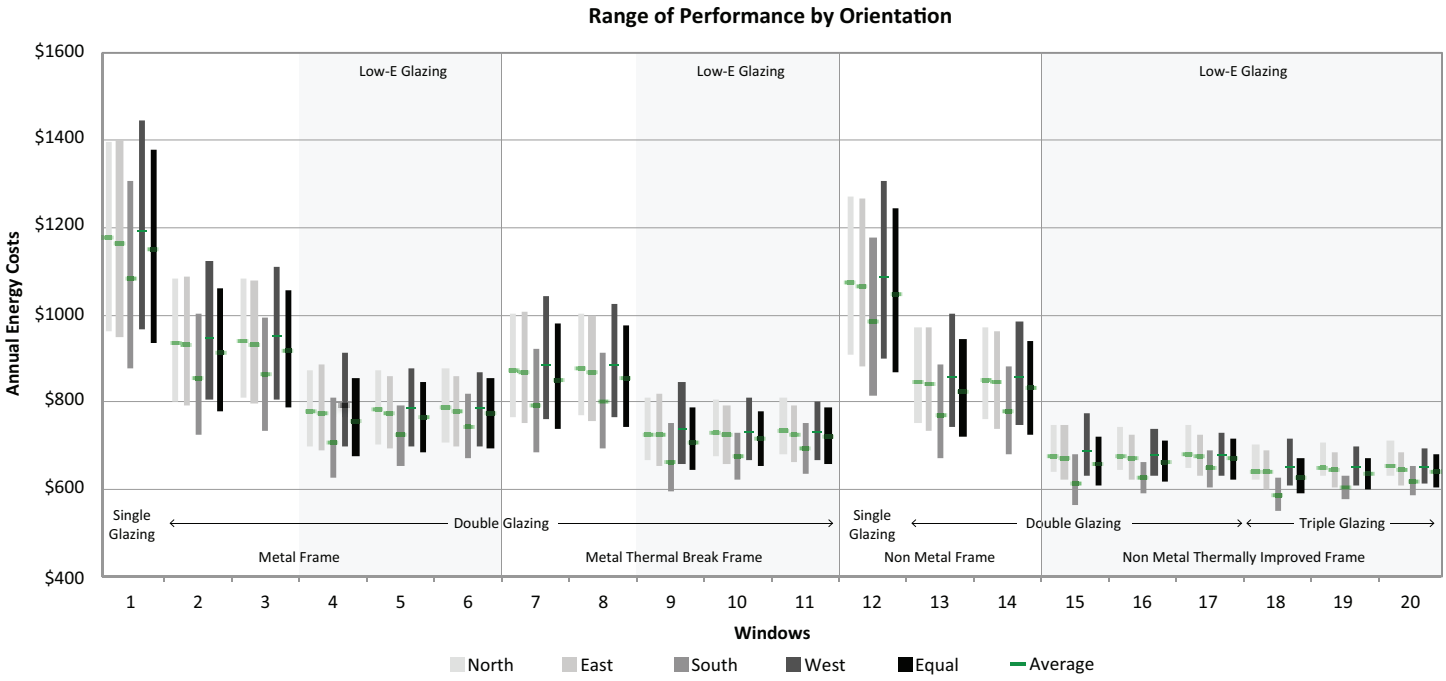

Figure 2. Annual energy costs (heating & cooling) for all window design variations by orientation in Washington, DC.

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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.
- Under certain conditions, low energy use can be achieved with any window area when using windows with a low-E coating.
- Larger window areas can have much worse performance when using windows with clear glazing.
- High-performance windows (windows 10–11, 16–20) have little heating and cooling penalty with an increase in window area.

Another traditional guideline to reduce solar heat gain is to reduce the home's total glazing area. This can be effective with any type of window, but it is particularly important when less efficient windows are used. Because of the need for daylighting, views, and natural ventilation, significantly 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 Washington, DC. In all cases, the windows are equally distributed on the four orientations with typical shading. With double clear glazing, increasing the glazing area has a significant impact on both the heating and cooling load. The annual energy use for a house with low-solar-gain (LSG) low-E glazing exhibits a similar pattern of increasing heating and cooling loads as the window area increases, but the differences are minimal.

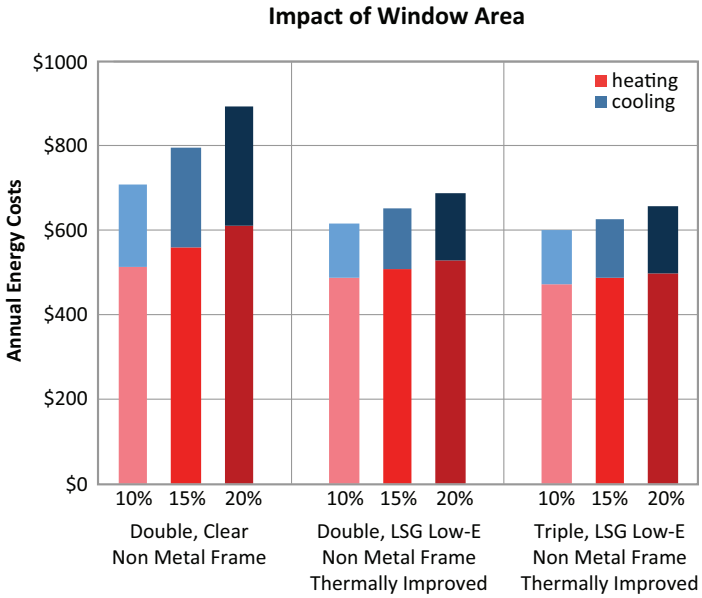

Figure 5. Impact of window for 3 windows in Washington, DC. The results are for equal orientation with typical shading.

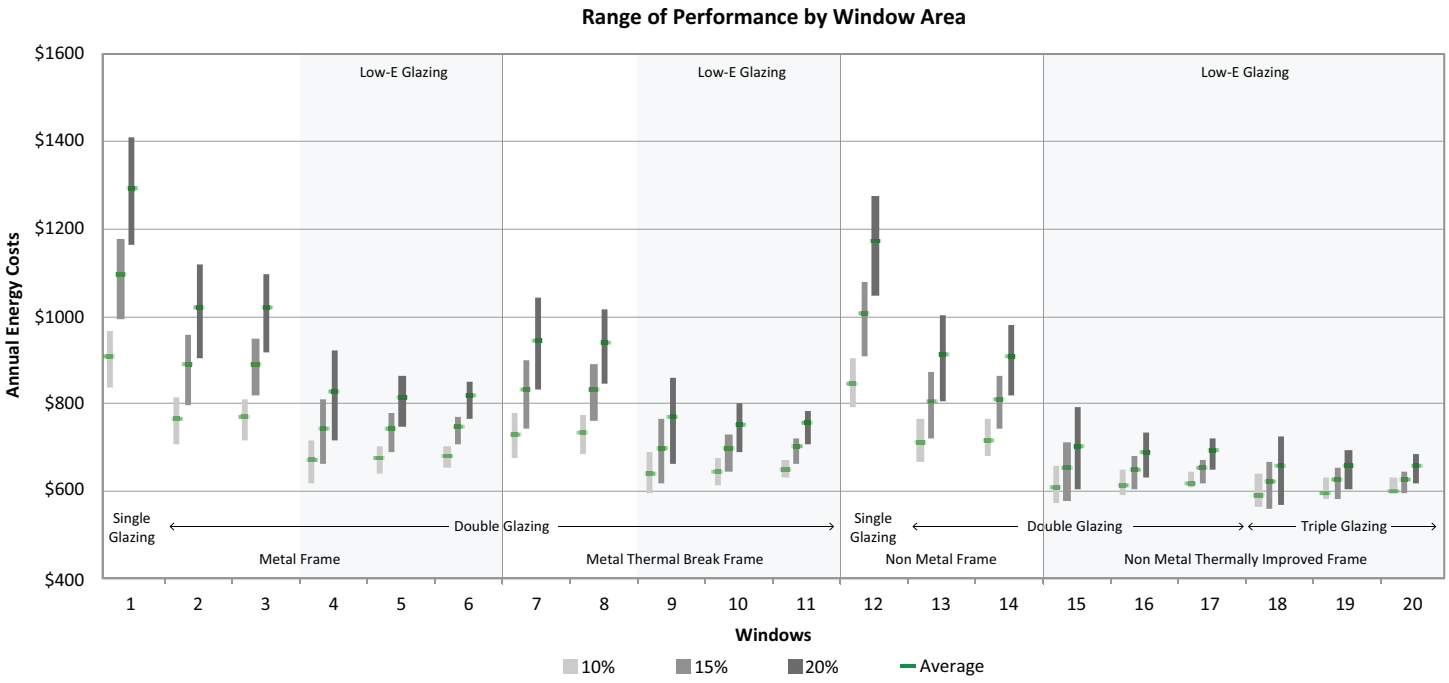

Figure 4. Annual energy costs (heating & cooling) for all window design variations by window area in Washington, DC.

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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, low energy use can be achieved with any shading strategy on any orientation.
- Windows with no shading and with overhangs perform the worst.
- The impact of shading strategies on energy performance is reduced when using high-performance windows (windows 16–20).

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 block out much of the summer sun. Overhangs have the advantage of reducing heat gain and glare without diminishing the view. Other exterior devices include grills, awnings, shutters, roll-down shades/ shutters, and canopies. 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.

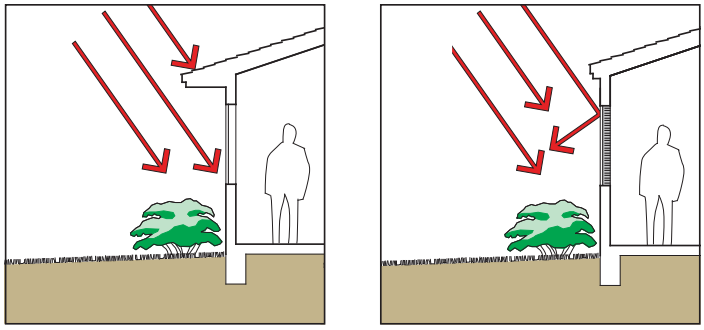

Figure 7. Shading strategies can reduce the solar heat gain that enters through the window.

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. To most effectively reduce solar heat gain, the drapery used to block the sunlight should have high reflectance and low transmittance. The impact of drapery on the solar heat gain is proportionally lessened as the window is shaded by other methods, such as exterior shading or reflective glass. 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.

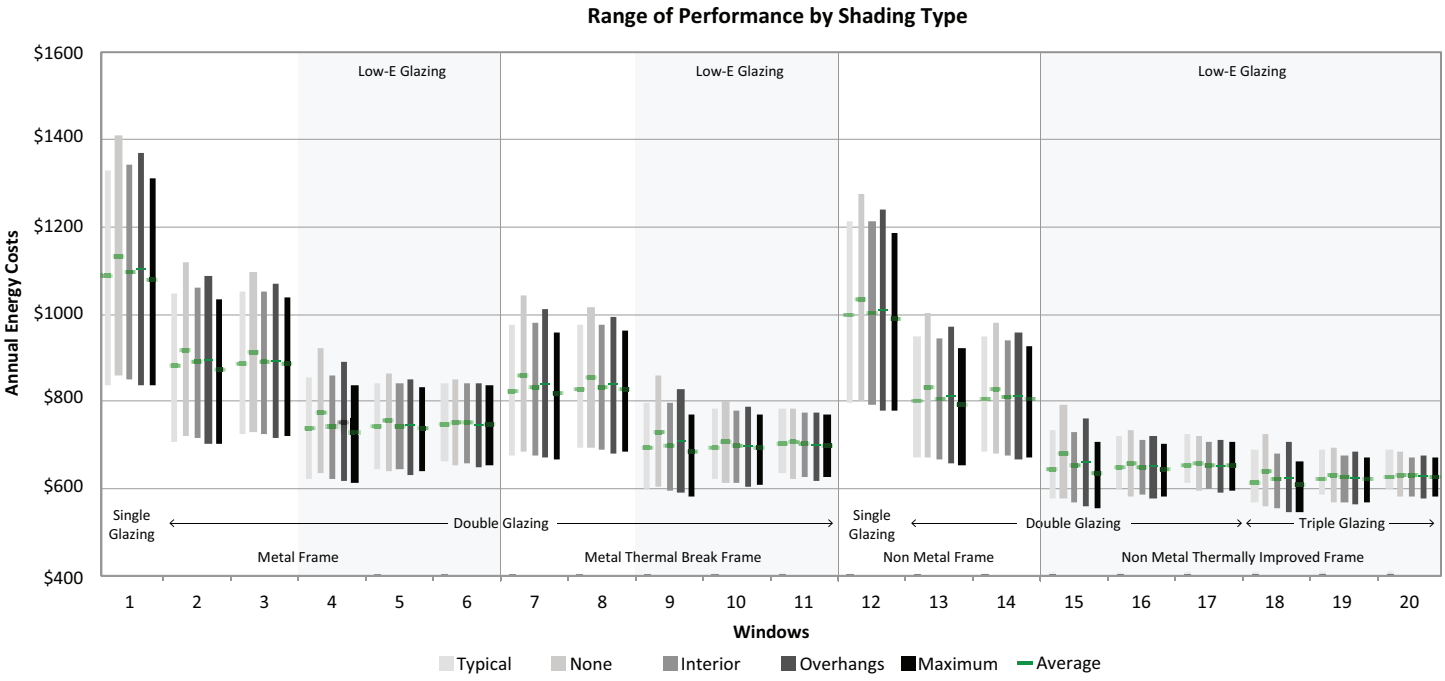

Figure 6. Annual energy costs (heating & cooling) for all window design variations by shading type in Washington, DC.

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Blinds and shades primarily provide light and privacy control but they also can have an impact on controlling solar heat gain. These include horizontal Venetian blinds, miniblinds, vertical slatted blinds, pleated and honeycomb shades, and roll-down shades—all of which can be made of various materials. Unlike other strategies to reduce heat gain, 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 cooling energy use, or you live in a house without air-conditioning in a hot climate, then the combination of good shade management with low-solar-heat-gain (LSG) 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.

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 Washington, DC. In all cases, the windows are equally distributed on the four orientations with a moderate window area. With double clear glazing, using no shading takes advantage of passive heating but significantly impacts the cooling load. Overhangs are much less effective on equal orientation, as seen earlier they are 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 low-solar-heat-gain (LSG) glazing systems are used.

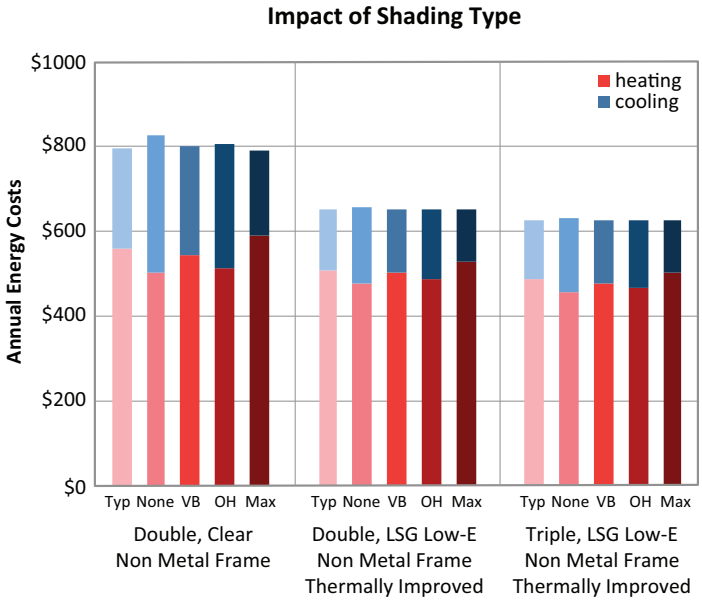

Figure 8. Impact of window for 3 windows in Washington, DC. The results are for equal orientation with typical shading.

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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.

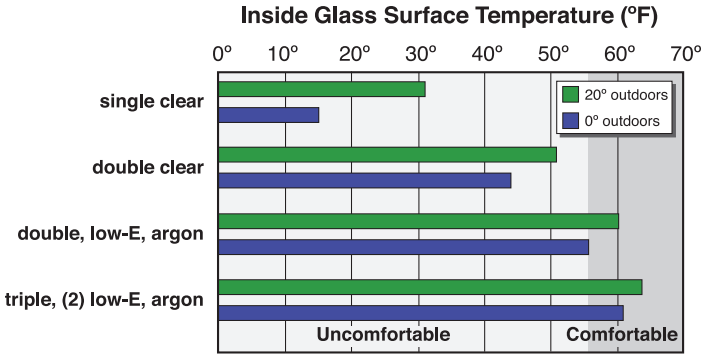

Figure 9. Window uncomfortable-comfortable threshold of a partial EWC window set.

Direct sun has obvious impacts on thermal comfort. During cold periods, limited solar radiation can be a pleasant sensation. But during warm or hot weather, it invariably causes discomfort. Just as people turn up the heat to compensate for cold windows in winter, they may use more air-conditioning to counter the effects of warm window surfaces and sunlight in summer.

To take into account the effect of solar radiation, Researchers Peter Lyons and Dariush Arasteh adapted the estimation of Percent People Dissatisfied (PPD) when direct solar radiation was present (Figure 11). The PPD is calculated from the net Predicted Mean Vote (PMV).

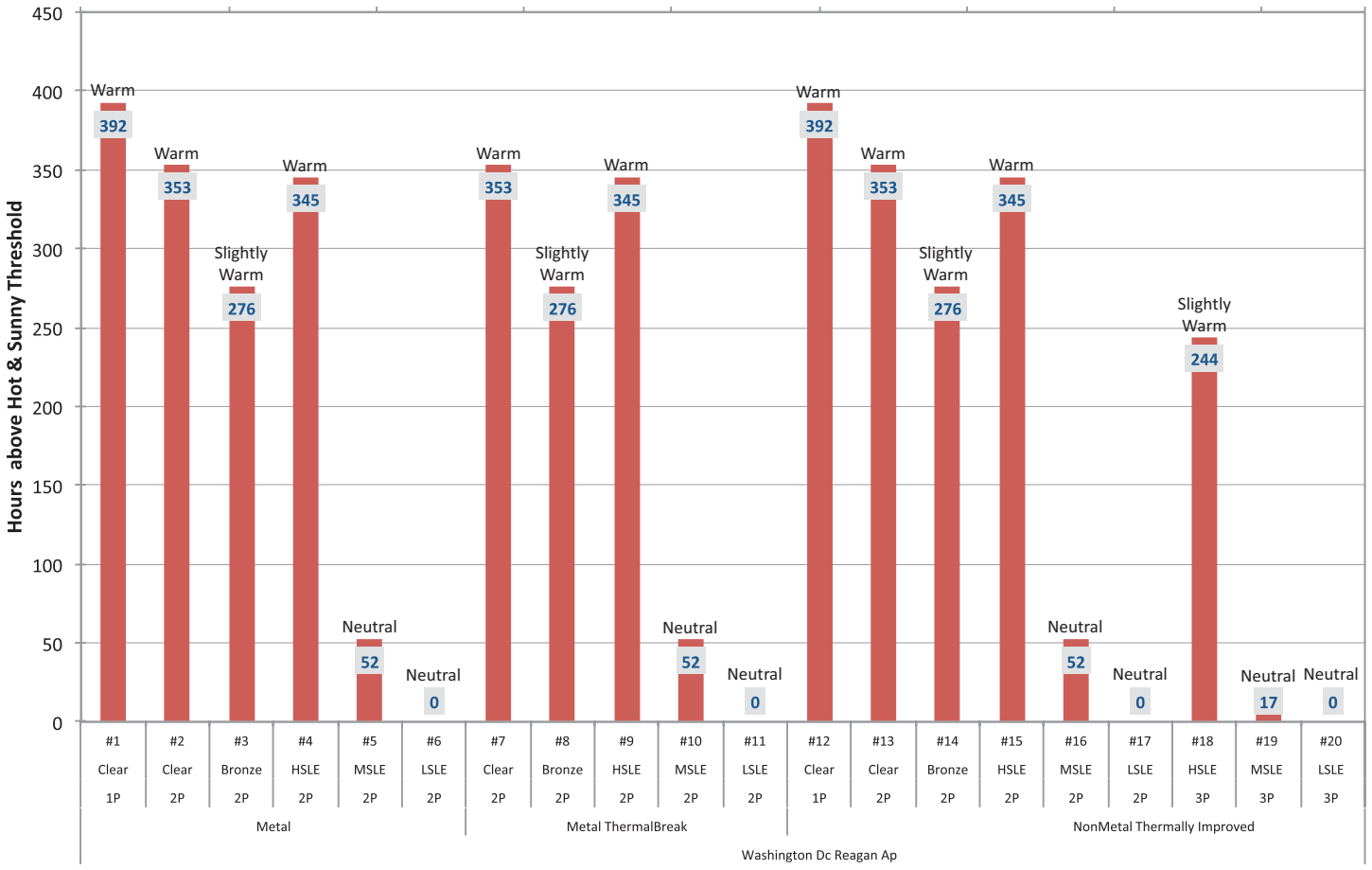

Figure 10. Summer comfort rankings for 20 windows in Washington, DC..

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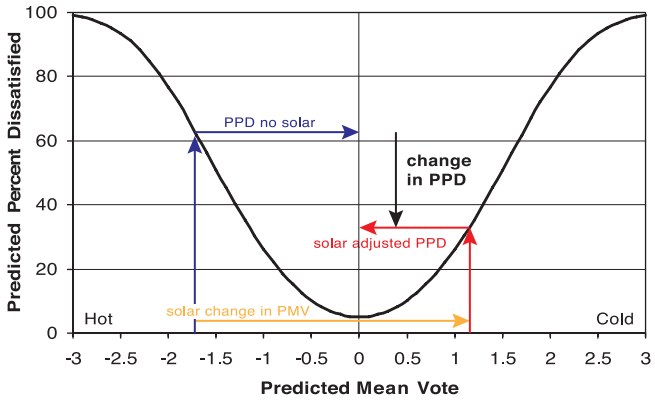

Figure 10. Fanger PPD-PMV relationship showing adjustment for solar load (Lyons and Arasteh, 1999) and incorporated into the EWC Comfort Metric.

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 10 illustrates hours summer discomfort for each of the 20 windows in Washington, DC. 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. 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.

The Figure 12 illustrates hours winter discomfort for each of the 20 windows in Washington, DC. The winter ranking levels show the windows that meet the energy code (windows 15–20) all as "Neutral." Note that the dual pane options in a metal frame (windows 9–11) return a "Slightly Cool" ranking.

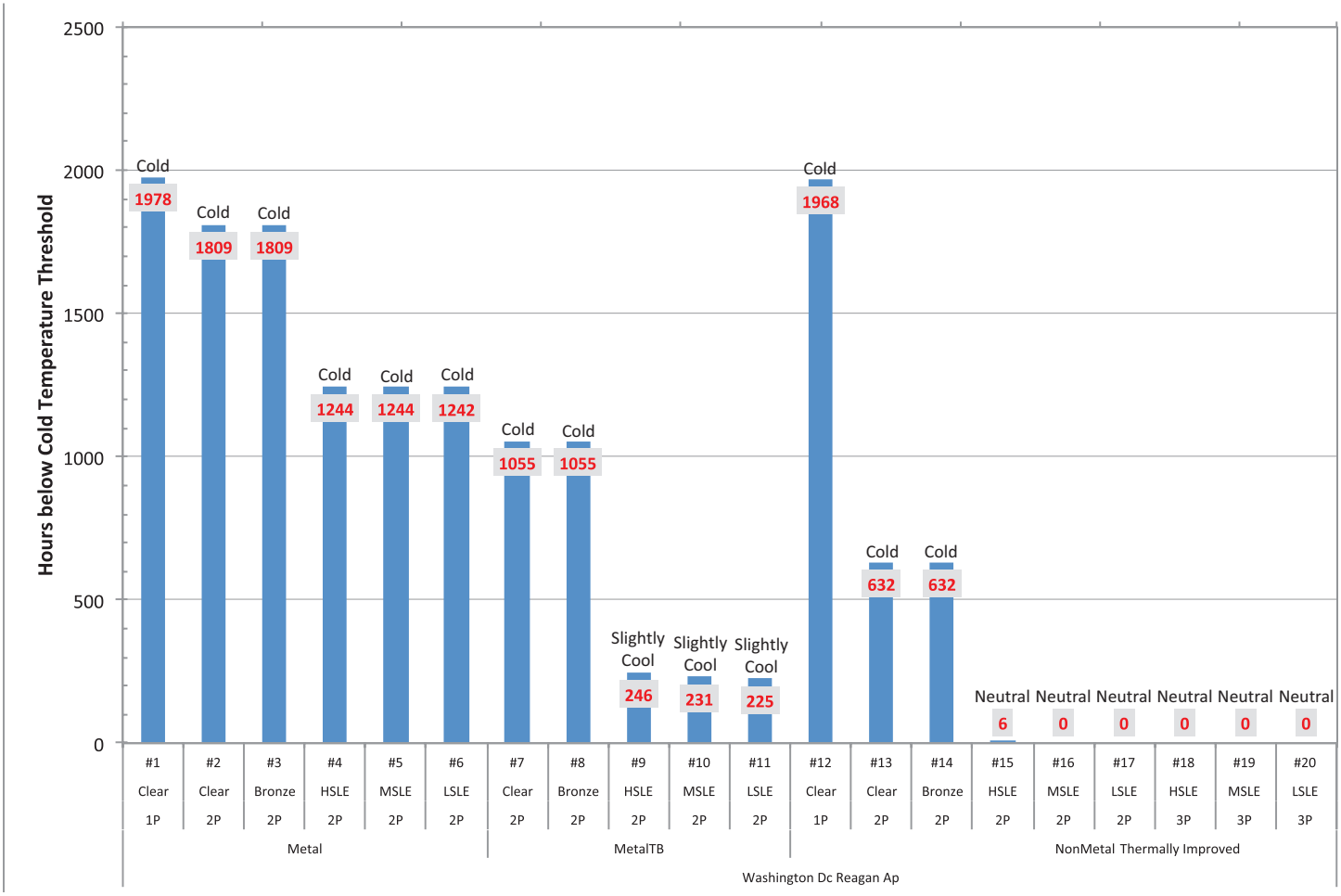

Figure 12. Winter comfort rankings for 20 windows in Washington, DC.

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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 R13 walls and R30 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**.

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For More Information

Visit the **Efficient Windows Collaborative** (EWC) for more information. The EWC web site provides unbiased information on:

- Benefits of efficient windows and how windows work;
- How to select an efficient window using the Window Selection Tool
- EWC members that provide efficient windows.

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