Energy Impact of Windows

There are more than 90 million homes and approximately 19 billion square feet of windows in the U.S. alone. It is estimated that over half of these still have single pane glazing. Most of these homes are more than 20 years old and, as a result, the market for insulated glass units (IGUs) in replacement windows is growing rapidly. At the same time, the new construction market is growing rapidly.

Increasingly, “high performance” window options have become popular for good reason: The energy impact of windows is enormous. In a typical house, windows typically account for 20% to 25% of the total heat loss and 45% or more of the building’s designed cooling load. Some products can also reduce UV rays that cause fading damage by over 80%.

A Profusion of Choices

Since there are hundreds of window manufacturers, each with many different product offerings, it’s easy to get confused trying to sort through the trade names and marketing hype. Window options used to be limited to single-pane versus double-pane and wood frame versus aluminum frame.

Today, there are eight or more basic frame types, six or seven glass options, and three or four warm-edge technologies, not to mention argon and krypton gas fills. To make matters even more challenging, consumers have grown to expect higher performance from their windows, even when they don’t understand the technologies involved.
Comfort Is the Issue

Evaluating which type of window is best for a particular home in a particular climate begins with our previous discussion of comfort. A study commissioned by Pacific Gas and Electric discovered that the number one reason customers make energy-efficiency improvements to their homes is to increase their comfort.

Windows have a huge impact on comfort. When it is 40°F outside, the inside surface temperature of a single-pane window can be 20°F colder than the room temperature. Since our bodies radiate heat to colder surfaces, a poor insulating window can make us feel uncomfortable even if the home is well insulated.

**Heat transfer through a window:** The yellow wavy arrows indicate heat transfer by radiation, demonstrating that heat is radiating off the individual toward the cold surface of the glass. The larger arrow represents heat transfer by conduction — the heat flows from molecule to molecule through the air in the room, through the walls, and from the inside surface of the glass to the outside. In addition, there are convection losses, indicated by the curved blue arrows, due to cool air falling across the surface of the glass inside and wind blowing across the window on the outside, scavenging away heat much faster than conduction does.

High-performance technologies can make windows feel warmer during cold weather by keeping the temperature of the interior glass surface higher.

Summer performance is as important as winter performance. While we tend to evaluate windows based on what they do to reduce heating costs, it’s important to remember that the right window can also reduce air conditioning costs. Since more than 40% of existing homes and 80% of new homes have air conditioning, it makes sense to pay close attention to a window’s solar heat-gain properties as well.
NFRC Labeling

Fortunately, it’s becoming easier than ever before to compare windows and select the unit that’s right for a particular climate and set of conditions. The National Fenestration Rating Council (a collaborative effort between manufacturers, the Department of Energy, utility companies, and others) has established clear criteria for comparing windows. This information is available for most windows sold in the U.S., presented right on the window with a label. The NFRC label gives specific information about a window’s winter performance, summer performance, and the amount of light it lets in. The NFRC label lists three important numbers:

- **U-factor**: the amount of energy, in BtUs, transferred via conduction through a window
- **SHGC (solar heat gain coefficient)**: the amount of solar heat that gets through
- **VLT (visible light transmittance)**: a measure of how much visible light comes through

These ratings are for the total window unit, not just the glass.

The NFRC label, found on most windows, makes it easy to assess a window’s energy performance. Whether higher or lower U-factor and solar heat gain coefficient ratings are better depends on the climate where the window will be installed.

**U-factor.** The U-factor is the inverse of the more common R-value measurement. The lower the U-factor of a window, the higher its R-value. Specifically, the U-factor measures the rate of non-solar heat transfer from one side of the window to the other. Heat transfer implies both heat loss out of a living space during cold winter weather and non-solar heat gain into a living space during hot summer weather. As a point of reference, a single pane of glass has a U-factor of 1.9 (Btu per sq. ft. per degree F). As U-factors fall towards 0, they indicate better performance.
**Solar heat gain coefficient.** The SHGC measures the amount of solar heat that gets through a window. An SHGC of .78 indicates that approximately 78% of the solar heat that strikes a window actually passes through it. A single pane of glass has a center-of-glass SHGC of around .9 (total window = .74), while for regular double-pane glass, it falls off to around .8 (total window = .63). The lower the SHGC, the better a window is at reducing heat gain and associated cooling costs.

**Visible light transmittance** (VLT) is a measure of how much visible light comes through the entire window. The higher the number, the more visible light that gets in. A single pane of glass transmits about 92% of available visible light. However, NFRC rates the entire window, including the frame, so the VLT of a typical single-pane aluminum window is about .70.

A window’s VLT rating can be somewhat misleading because the whole window is taken into account. For example, a double-pane wood/vinyl window has a total product visible light transmission of .57. A double pane aluminum window has .62. This means that windows with wider frames end up with slightly lower VLT ratings.

Use the VLT when comparing the energy performance characteristics of windows to make sure you’re not sacrificing any more light than is necessary for a desired energy performance.

**Optional ratings.** Two optional ratings that may appear on the NFRC label include Air Leakage (AL) and Condensation Resistance (CR).

*Air Leakage* is expressed as the equivalent cubic feet of air passing through a square foot of window area (cfm/sq. ft.). Heat loss and gain occur by infiltration through cracks in the window assembly. The lower the AL, the less air will pass through cracks in the window assembly.

*Condensation Resistance* measures the ability of a window to resist the formation of condensation on the interior surface. The higher the CR rating, the better that product is at resisting condensation formation. While this rating cannot predict condensation, it can provide a credible method of comparing the potential of various products for condensation formation. CR is expressed as a number between 0 and 100.

**Energy Star Label**

In addition to the NFRC label, many windows also have an Energy Star label, which makes it easy to tell whether a given window is right for your climate. The Energy Star rating is based on minimum Department of Energy (DOE) performance specifications by region.

In the absence of an Energy Star label, look for a maximum U-factor of .35 for cold (heating) climates. In hot (cooling) climates, look for a maximum .75 U-factor and an SHGC of .40 or less. In mixed climates, aim for a U-factor of .40 and an SHGC of .40. When relying on passive solar gains to help heat a home in a cold or mixed climate, an SHGC of .55 is a good compromise.
Building Design and Orientation

It’s also important to understand that a building’s orientation has a big impact on its energy performance. Any window salesperson that guarantees energy savings without really understanding the home in terms of the orientation and the square footage of glass is not to be believed. If a house has a lot of windows on one or more walls, the direction those windows face will have enormous impact on the energy load of the house; you’re going to have a lot more heat load on the structure for this much glass facing west than you would if the glass was facing north.

Similarly, the design structure has a big impact on its energy efficiency. Overhangs, awnings, and trees all make a difference in the amount of solar heat gain, which can make a difference in both heating and cooling climates.

Review: Essential Concepts in Heat Transfer

Heat always behaves in predictable ways:

- Heat always moves from warmer areas to colder areas. An easy way to remember this is that the sun always heats the earth; the earth does not cool the sun.

- The greater the temperature difference (sometimes referred to as a temperature gradient), the faster heat flows. So, for example, when you go outside on a day when it’s 69°F outside, you don’t experience much discomfort because there’s not much heat transfer. If it’s 70°F inside and 70°F outside, is there any heat transfer? No. But, if it’s 70°F inside and 0°F outside, there is a lot of heat flow, which is immediately noticeable.

- In a home, higher levels of heat flow results in higher energy costs.

- Air contains moisture, so when air moves from warmer to colder along a temperature gradient, it carries moisture. This can have an impact on building durability if the air cools sufficiently to cause the moisture to condense on a surface in the home.

- Heat moves through building assemblies in three ways — by conduction, convection, and radiation.

1. **Conduction**: The process whereby heat is transferred directly through solid materials from molecule to molecule. No movement of the material plays a role in the heat transfer.

2. **Convection**: The process in which heat moves with the movement of a fluid, such as air. The transfer of heat occurs by physically moving the molecules from one place to another. Examples: hot air rises and forced-air heating systems work by moving hot air from one place to another.
3. **Radiation**: The movement of heat away from an object by means of electromagnetic waves. Radiation is not affected by the air, so a campfire emits heat, even when the wind is blowing. Radiated heat moves at the speed of light through the air without heating the space between the surfaces. An example is the warmth you feel on your skin from the sun, even though the space between the sun and the earth is still extremely cold.