Bob Vila Talks
Solar Heat Gain Control for Windows

Before innovations in glass, films, and coatings in the past decade, a typical residential window with one or two layers of glazing allowed roughly 75-85% of the solar energy to enter a building, which has a negative impact on summertime comfort and cooling bills, especially in hot climates.

External window shading devices such as awnings, roof overhangs, shutters, and solar screens, and internal shading devices such as curtains and blinds, can control the entry of solar heat. However, shutters, solar screens, curtains, and blinds make rooms dark. Curtains and blinds also let in some of the undesirable heat. While exterior shading devices are about 50% more effective than internal devices at blocking solar heat, they may create problems with the building's aesthetics and are sometimes expensive to build. It is also impractical to construct roof overhangs to effectively shade east and west facing windows.

The following are the percentages of the radiant energy that different types of internal shading devices transmit, reflect, or absorb:

- Roller Shades: up to 25%, 15-80%, 20-65%
- Vertical Blinds: 0%, 23%, 77%
- Venetian Blinds: 5%, 40-60%, 35-55%

The weak thermal characteristics of windows became a prime target for research and development in the attempt to control indoor temperatures of buildings. This led to the development of low-emissivity or "low-e," glass and films that control heat gain and loss, reduce glare, minimize fabric fading, provide privacy, and occasionally provide added security in wind, seismic, and other high-hazard zones. New construction and window replacement applications commonly use glazing with these coatings.

Some low-e coatings and solar control films reduce solar heat gain without impairing visible light transmission excessively. These include tinted glass and spectrally selective coatings, which transmit visible light while reflecting the long-wave infrared portion of sunlight. Many spectrally selective coatings also have some low-e properties as well. Modern window glazing falls into three categories: chemically or physically altered glass, coated glass or films, and multiple-layered assemblies with or without either of the first two items.

Chemically or Physically Altered Glass

Tinting is the oldest of all the modern window technologies and, under favorable conditions, can reduce solar heat gain during the cooling season by 25% to 55%. Tinted glass is made by alteration of the chemical properties of the glass. Both glass and plastic laminate may be tinted. The tints absorb a portion of the sunlight and solar heat before it can pass all the way through the window to the room. Tinted glazings reduce the latter by 25-55%. "Heat absorbing" tinted glass maximizes its absorption across some, or all, of the solar spectrum. Unfortunately, the absorbed energy often transfers by radiation and convection to the inside.

Spectrally selective tints reduce infrared light (heat) transmission while allowing relatively more visible light to pass through (compared to bronze- or gray-tinted glass). For buildings that use daylight for lighting, a spectrally selective window is a good choice. Spectrally selective glass also absorbs much of the ultraviolet (UV) portion of the solar spectrum. In a multi-paned window, they function best as the outermost sheet of glazing. Thermal performance is increased when combined with a low-e coating. Spectrally selective coatings often have a light blue or green tint.

Coatings and Films

Low-e and reflective coatings usually consist of a layer of metal a few molecules thick. The thickness and reflectivity of the metal layer (low-e coating) and the location of the glass it is attached to directly affects the amount of solar heat gain in the room. Most window manufacturers now use one or more layers of low-e coatings in their product lines.

Any low-e coating is roughly equivalent to adding an additional pane of glass to a window. Low-e coatings reduce long-wave radiation heat transfer by 5 to 10 times. The lower the emissivity value (a measure of the amount of heat transmission through the glazing), the better the material reduces the heat transfer from the inside to the outside. Most low-e coatings also slightly reduce the amount of visible light transmitted through the glazing relative to clear glass. Here are representative emissivity values for different types of glass:

- Clear glass, uncoated: 0.84
- Glass with single hard coat low-e: 0.15
- Glass with single soft coat low-e: 0.10

A pyrolytic coating baked on at a high temperature constitutes a "hard coat" low-e coating. These are often made of a metallic oxide. One layer is about 1/10,000 the diameter of a human hair.

"Soft coat" low-e coatings are applied to the glass at lower temperatures and even thinner thicknesses than hard coatings. Both types of low-e coatings (within insulated glazing assemblies) are typically warranted for 10 to 50 years.

The only spectrally selective coatings now available are modified soft coat low-e coatings. The selective properties of the coatings are determined by modifying the coating's thickness and number of layers. A spectrally selective tinted glazing with a pyrolytic hard coat serves a similar purpose. These spectrally selective hard coats are currently under development.

"Aftermarket" films are available for application on existing windows. They are relatively easy to apply on glazing up 36 square inches (91.5 square centimeters). They are often applied to the glass with a water soluble adhesive. To reduce the possibility of bubbles and wrinkles on large windows, have the film installed professionally. Most films should be applied to the inside surface of the glass since they can be damaged easily by weather. If you plan to install the film yourself, be careful to select the appropriate film for your needs, and understand all directions before beginning. Plastic films generally last about 8 to 10 years before they start looking worn.

Performance Selection

The key measures of window performance are the U-Factor, Solar Heat Gain Coefficient, and Visible Transmittance. The air leakage rating (measure of the rate of air loss around a window under a specific pressure differential) is also important, but not addressed here.

The U-Factor is a measure of how easily heat travels through a material. The lower the value, the lower the amount of heat transfer through the window (from the interior to the exterior). Some manufacturers rate thermal performance using R-Factors. R-Factor is the inverse of the U-Factor, i.e., 1/U = R, 1/R = U. For example: a U-Factor of 0.25 is the same as an R-Factor of 4.0. The overall or "total" or "whole window" U-Factor of any window depends on the type of glazing, frame materials and size, glazing coatings, and type of gas (air, or inert argon or krypton) between the panes. Some typical U-Factor ranges for different window assemblies are:

- Single glazed: 0.91 - 1.11
- Double glazed: 0.43 - 0.57
- Triple glazed: 0.15 - 0.33

The Solar Heat Gain Coefficient (SHGC) is the fraction of solar heat that enters the window and becomes heat. This includes both directly transmitted and absorbed solar radiation. The lower the SHGC, the less solar heat that the window transmits through the glazing from the exterior to the interior, and the greater its shading ability. In general, South facing windows in houses designed for passive solar heating (with a roof overhang to shade them in the summer) should have windows with high a SHGC to allow in beneficial solar heat gain in the winter. East or West facing windows that get a lot of undesirable sun in mornings and afternoons, and windows in houses in hot climates, should have lower SHGC assemblies.

The visible transmittance (VT) refers to the percentage of the visible spectrum (380-720 nanometers) that is transmitted through the glazing. When daylight in a space is desirable, as in showrooms and studios, high VT glazing is a logical choice. However, low VT glazing such as bronze, gray, or reflective-film windows are more logical for office buildings or where reducing interior glare is desirable. A typical clear, single-pane window has a VT of 0.90, meaning it admits 90% of the visible light.

The ratio between SHGC and VT is called the light-to-solar gain ratio (LSG.) This provides a gauge of the relative efficiency of different glass types in transmitting daylight while blocking heat gains. The higher the ratio number the brighter the room is without adding excessive amounts of heat.

Here are typical values for the Total Window and Center of Glass ( ) for different types of windows:

Window and Glazing Types	SHG	VT	LSG
Single-glazed, clear	0.79 (0.86)	0.69 (0.90)	0.87 (1.04)
Double-glazed, clear	0.58 (0.76)	0.57 (0.81)	0.98 (1.07)
Double-glazed, bronze	0.48 (0.62)	0.43 (0.61)	0.89 (0.98)
Double-glazed, spectrally selective	0.31 (0.41)	0.51 (0.72)	1.65 (1.75)
Double-glazed, spectrally selective	0.26 (0.32)	0.31 (0.44)	1.19 (1.38)
Triple-glazed, new low-e	0.37 (0.49)	0.48 (0.68)	1.29 (1.39)

Factors to consider when choosing windows are: climate, building design, building orientation, and external shading. Check with manufacturers for product specifications.

Calculating Energy Savings

Energy savings from solar control glazing are difficult to accurately predict. Predictions of savings are based on many variables such as: size and orientation of the windows, solar heat gain coefficient (SHGC), and the cooling load factor (CLF; the ratio of actual total cooling compared with total steady-state cooling during the same period at constant ambient conditions.) To make this somewhat simpler, some references combine these variables into one figure: the Heat Transfer Multiplier (HTM). The HTM will vary with location, seasonal changes, time of day, shading, orientation, temperature, and building color.

There are also computer programs for sizing of heating/cooling systems. These can also be used to estimate solar heat gain from different types of windows (given the SHGC and climate). Typically, you run the same program for each choice in window type and find the dollar value of the difference in energy saved between the choices. You can then divide the purchase price by the estimated savings to determine simple payback.

Some solar control films are very costly and may have very long payback periods. In such cases it may make better sense to consider other shading devices such as awnings, overhangs, solar screens, shutters, roller shades, blinds, and draperies.