Chapter 6

Windows and Doors

Windows and doors are often the architectural focal point of residential designs, yet they typically provide the lowest insulating value in the building envelope. Although recent developments in energy efficient products have markedly improved the efficiency of windows and doors, they still pose a major energy liability.

Windows

Windows connect the interior of a house to the outdoors, provide ventilation and daylight, and are key aesthetic elements. In passive solar homes, windows can provide a significant amount of heat for the homes during the winter.

The type, size, and location of windows greatly affect heating and cooling costs. Select high quality windows, but shop wisely for the best combination of price and performance. Many home construction budgets have been exceeded by spending thousands of additional dollars on premium windows with marginal energy savings. Good windows do not have to be expensive.

In general, windows need to be double-glazed, low-e, well-built, and have good weather stripping in order to meet the provisions of the building code. Carefully evaluate added features, such as inert gas fill between glazing layers and tinted or reflective units – they may provide additional energy savings at relatively low extra cost.

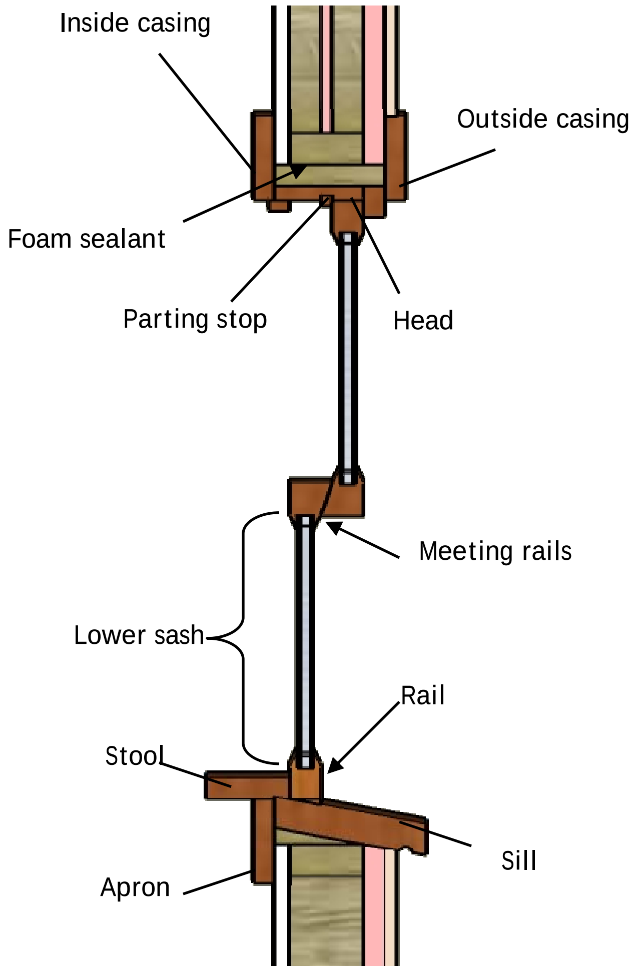
Table 6-1
Economics of Energy Conserving Windows and Doors

Type of Treatment	Energy Savings ($/yr)	Extra Costs ($)*	Rate of Return	Extra Annual Mortgage ($/yr)**
Windows (compared to single-glazed windows)				
Double-glazed (R-1.8)	116	660	19%	53
Double-glazed with low-e coating (R-2.4)	157	1,110	16%	89
Double-glazed with low-e coating and inert gas fill (R-2.7)	186	1,260	17%	101
Triple-glazed, low-e coating, inert gas fill (R-3.2)	235	1,710	15%	138
Quadruple-glazed, low-e coating, inert gas fill (R-5)	245	2,900	8%	232
Doors (compared to solid wood doors)				
Foam-insulated doors (R-5)	5	20	26%	2
Storm doors over wood doors (R-3.2)	3	90	n/a	9

*Savings and costs are for a home with 300 square feet of windows and 2 exterior doors located in Baton Rouge, LA

**Extra annual mortgage for 30 year loan @ 7% annually.

Figure 6-1
Window Anatomy



To understand window technologies, it is helpful to know how they lose and gain heat. See the following list of ways that heat is moved through windows:

- Conduction through the glass, center and edge of glazing unit, and frame
- Convection across the air space in double- and triple-glazed units
- Air leakage around the sashes and the frame
- Radiant energy from the sun transmitted through the glazing
- Radiant energy from inside emitted to the to the cold winter air

Figure 6-2
Winter Heat Loss in a Typical Double-glazed Window

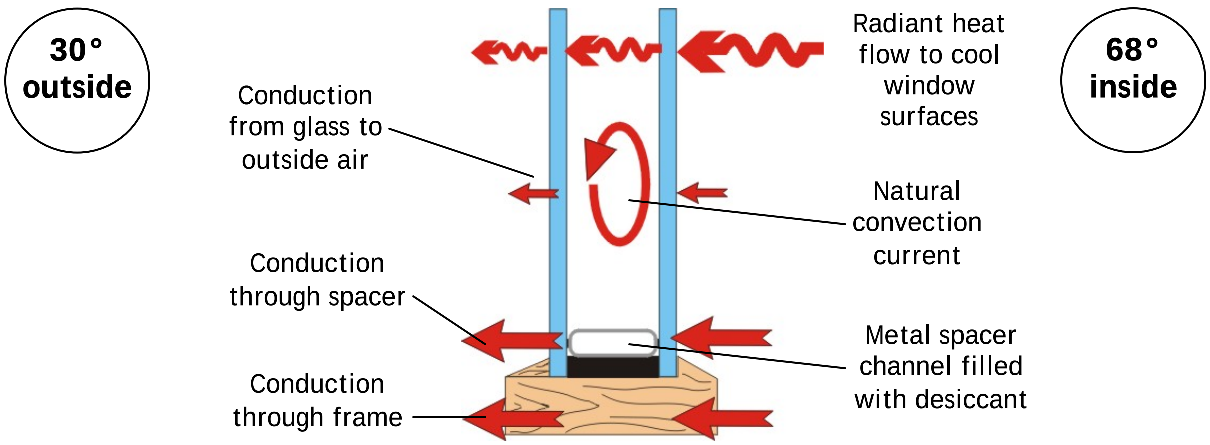
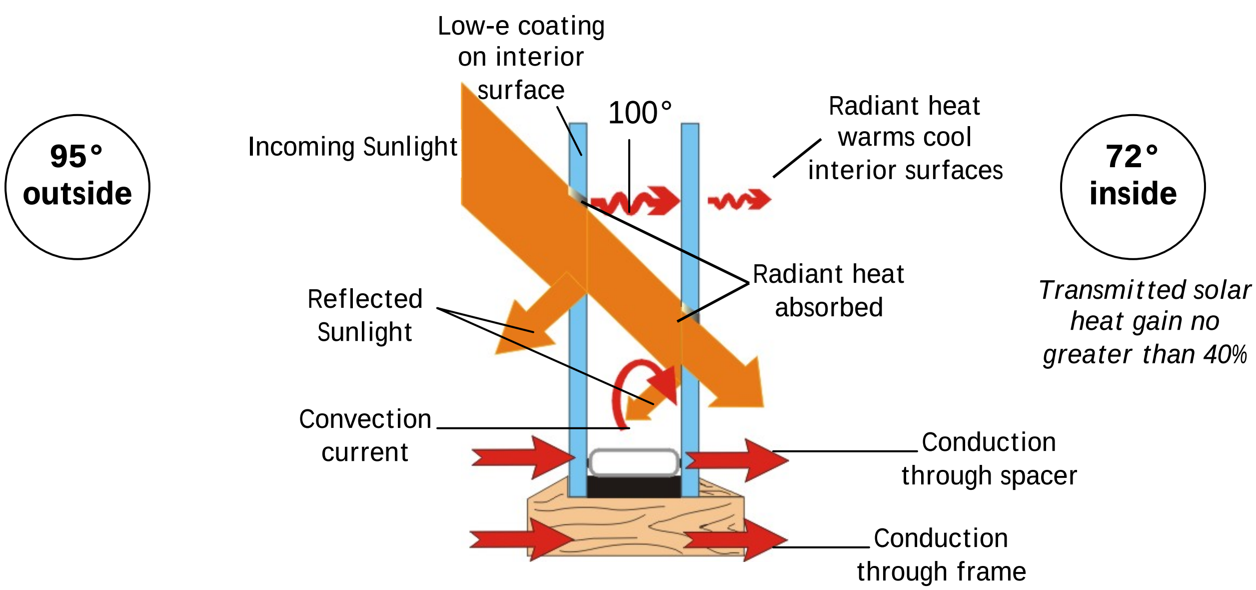


Figure 6-3
Summer Heat Gain in a Typical Double-glazed, Low-e Window



Goals of Efficient Windows:

- Low U-values – a minimum of double-glazed glass (U-0.65) with thermal breaks in metal-framed units.
- Low air leakage rates
    - Less than 0.25 cfm per linear foot of sash opening for double hung windows
    - Less than 0.10 cfm per linear foot for casement, awning, and fixed windows
- Moderate to high transmission of visible light (Visible Transmittance of 50% to 80%)
- Low transmission rates of ultraviolet and infrared light

Measurements of Window Performance

When shopping for windows, it is useful to know some of the following basic window terminology:

NFRC - The National Fenestration Rating Council is a national nonprofit organization that publishes a directory of windows that have been tested according to their criteria. The NFRC rating system is described later in the chapter. Builders should use windows with an NFRC label, as their listed insulating values and air tightness have been verified by independent laboratories.

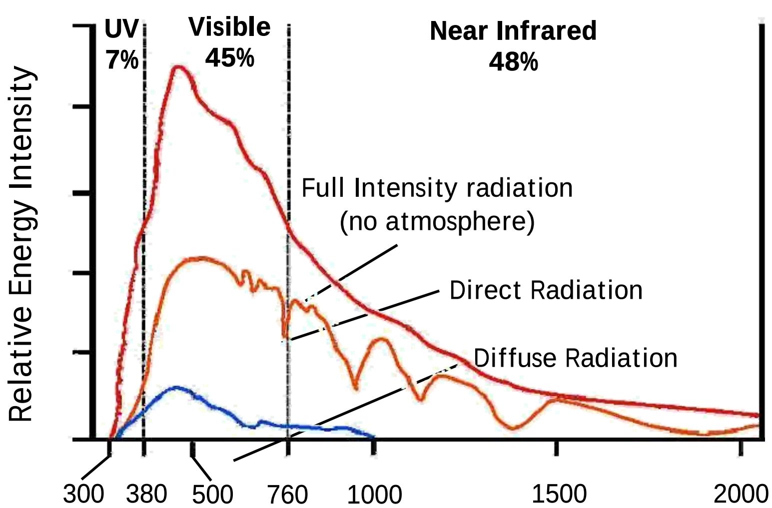
- *NFRC Label* - NFRC adopted a new energy performance label in 2005. It lists the manufacturer, describes the product, provides a source for additional information, and includes ratings for one or more energy performance characteristics.

R-value and U-value – These are ratings given for the insulating values of components. R-values refer to the resistance to heat flow; therefore, the higher the R-value, the better the insulation. U-values measure the ability of the component to conduct heat and are the inverse of R-values, meaning that a low U-value corresponds to a high R-value. Standard wood, double-glazed windows have U-values of 0.5 (1/2), thus having R-values of about 2. A typical new window having a low-emissivity coating and an inert gas fill might have a U-value of about 0.30 and R-value of 3.3.

Solar Heat Gain Coefficient – Commonly referred to as SHGC on NFRC labels, it is the percentage of solar energy that actually penetrates a window compared to what would enter through the total window area. A window with a SHGC of 80% allows 4 times as much solar radiation to enter a home as a window with a SHGC of 20%. To reduce summer cooling bills, windows with low SHGC values should be used. Tinted and reflective windows, or units with solar films, generally have low SHGCs compared to clear glass, but not low enough to comply with 2006 IRC.

To better understand solar heat gain, it is important to recognize that sunlight consists of more than just visible light. Figure 6-3 shows the relative energy intensity of the full spectrum of sunlight. The spectrum is broken into ultraviolet (UV), visible, and near infrared. The percentage of energy coming from each range of the spectrum is determined using the areas under the curve.

Figure 6-4
Relative Intensity of the Solar Spectrum



Shading Coefficient – This is an older method of measuring solar heat transfer. This method of indicating the relative solar transmission through windows assigns single-glazed, clear windows a shading coefficient of 1.0. Double-glazed, clear windows have a shading coefficient of 0.87. If you know the shading coefficient of a window, you can find the SHGC by multiplying the shading coefficient by 0.88.

Visible Light Transmittance - Commonly denoted as VT, this is a measure of the percentage of available light normally visible to humans that penetrates a window. Higher visible transmittances are typically desirable. Allowing more visible light to enter the home will reduce the amount of power required for the lighting system.

Infiltration – The rated air leakage of a window is usually measured in cubic feet per minute (cfm) per linear foot of the seam around the window unit. Double-hung units are typically the leakiest, while fixed units are the tightest.

Window Types – There are several different window types available on the market today. All types are generally available with wood, pre-primed wood, aluminum clad, or vinyl frames.

- *Double-hung and single-hung windows* – most traditional, leakiest, can only open halfway when ventilating.

- *Fixed windows* – very low air leakage, provide no ventilation, have the least interrupted view, less expensive.

- *Casement, Awning, and Hopper windows* – low air leakage, open fully for ventilation but sash may receive direct rainfall, more expensive.

High Efficiency Windows

The window industry has unveiled an exciting array of higher efficiency products. The most notable developments include:

- Low-emissivity coatings which reduce radiant heat flow
- Tighter weather stripping systems to lower air leakage rates
- Inert gas fills, such as argon and krypton that help reduce convection in the air space between layers of glazing, thus increasing the insulating values of the windows
- Thermal breaks to reduce heat losses through highly conductive glazing systems and metal frames
- Windows with low transmission rates of infrared and ultraviolet light

Table 6-2
Cost Comparison of Window Alternatives
($/square foot of rough opening)

Type of Window	Builder's Quality	Premium Quality
Single Glazed:		
Double-hung wood	5	11 - 18
Double-glazed:		
Double-hung - wood	8	11 - 18
Double-hung - vinyl or aluminum clad	10	12 - 25
Casement or awning - wood	14 - 18	20 - 27
Casement or awning - vinyl or aluminum clad	19 - 23	25 - 31
Sliding glass door - metal	5 - 8	7 - 10
Sliding glass door - wood	9 - 14	10 - 15
Fixed/hinged operable door combination	n/a	11 - 18

*Sealed, double-glazed glass units cost about $2.50 per square foot. Labor and trim may cost about $7 per square foot of rough opening.

Table 6-3
Sample Window Performance Characteristics

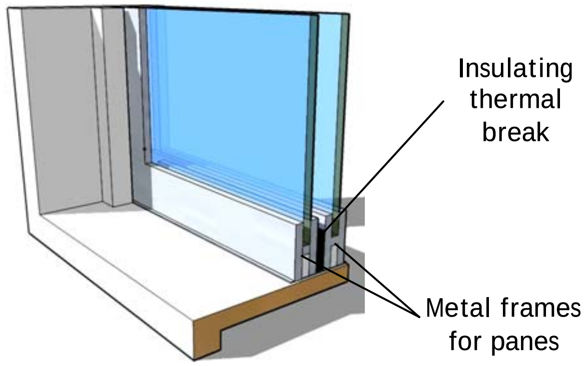
Type	U-value	Solar Heat Gain Coefficient	Visible Light Transmittance	Infiltration (cfm/linear ft of crack)
DH, 1G, wood*	1.10	0.79	0.90	0.20 - 0.35
DH, 1G, metal	1.30	0.79	0.90	0.50 - 0.98
DH, 2G, wood, bronze tint	0.49	0.55	0.61	0.15 - 0.30
DH, 2G, wood or vinyl, Low-E	0.39	0.31	0.53	0.15 - 0.30
CS, 2G, low-e, wood	0.38	0.50	0.74	0.07 - 0.15
CS, 2G, low-e, inert gas fill, wood	0.30	0.50	0.74	0.07 - 0.15
CS, 2G, low-e, inert gas fill, wood, tinted	0.29	0.31	0.72	0.07 - 0.15
DH, 3G, low-e inert gas fill, wood	0.24	0.37	0.68	0.15 - 0.30
DH, 4G, low-e, inert gas fill, wood	0.17	0.30	0.62	0.15 - 0.30

*Ratings shown are for the entire window unit, not just the center of glass. Double and triple glass systems have 0.5" air spaces between the layers of glass.
**DH = Double Hung, CS = Casement (awning and hopper would have similar air leakage values, fixed would have lower air leakage). 1G = Single glazed, 2G = double glazed, etc.

Thermal Breaks and Window Spacers

Thermal breaks in metal window frames are of particular importance. Metal is a very poor insulator, thus it conducts heat well. A thermal break improves insulating values by separating inside and outside pieces of the metal window frame with an insulating material. Always specify windows with thermal breaks, listed as "T.I.M." (thermally insulated metal) when purchasing metal windows. When shopping for windows, you can find the total U-value on the NFRC label.

Figure 6-5
Metal Window with Thermal Break



Low-Emissivity Coatings

Low-emissivity (Low-e) coatings are designed to reduce radiant heat flow through multi-glazed windows. Some surfaces, such as flat black metal used on wood stoves, have high emissivities and radiate heat easily. Other surfaces, such as shiny aluminum, have low emissivities and radiate little heat, even at low temperatures. Most low-e coatings are composed of a layer of silver applied between two protective layers.

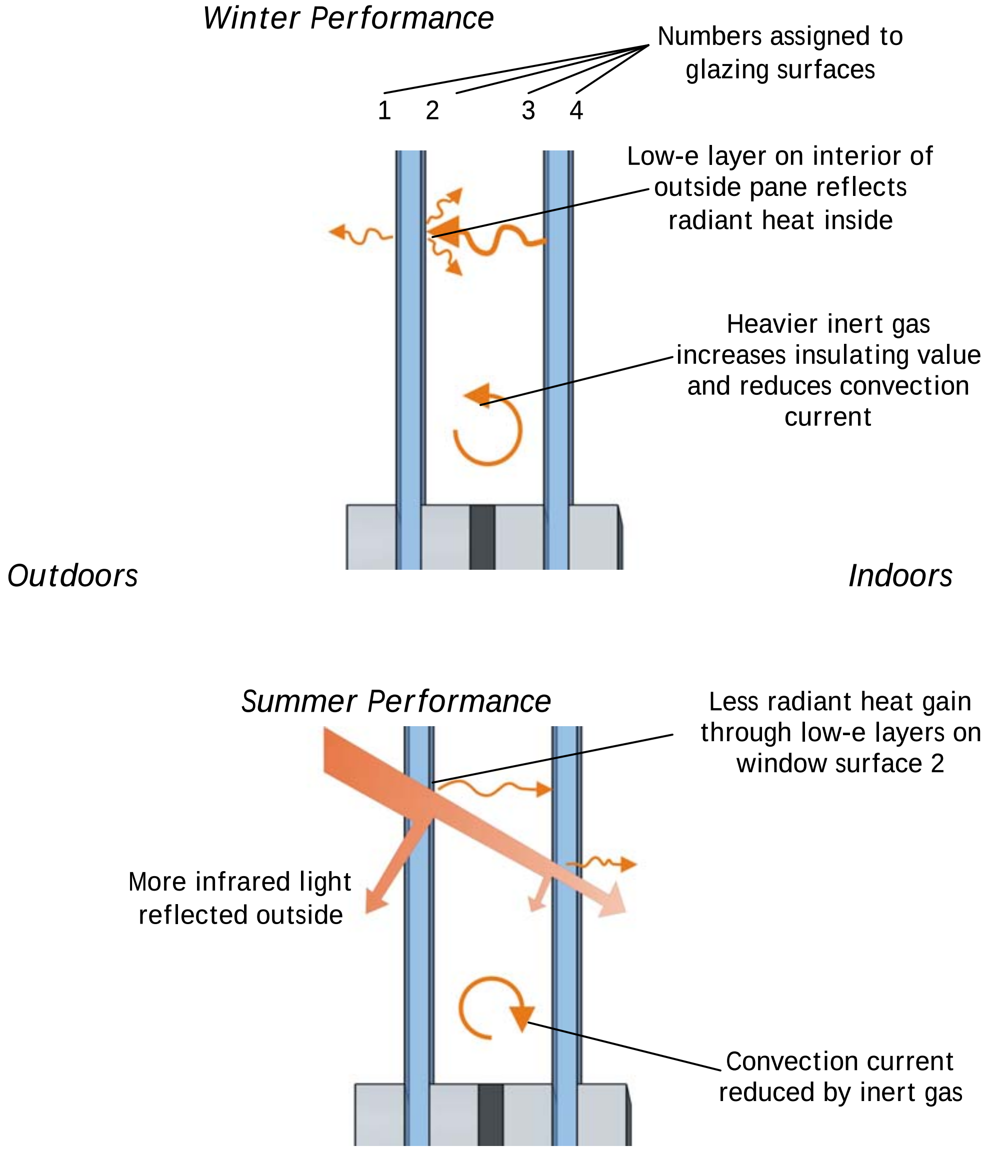
There are many benefits of low-e windows in addition to reducing the summer heat gain and winter heat loss. They screen ultraviolet radiation, which can, in turn, reduce fading of interior surface finishes. In winter, the interior surface of the glass is warmer, which increases comfort and helps prevent condensation from forming.

Spectrally Selective Low-E Coatings

These are the most advanced form of Low-E coatings, usually multiple coatings, which provide the lowest SHGCs while providing good visible transmission. They stop nearly 100 percent of the ultraviolet and infrared from passing through.

Figure 6-6 shows window surfaces numbered 1 to 4 from the exterior surface, 1, to the interior surface, 4. In Louisiana and other areas where the cooling is more prevalent than heating, the low-e coating should be on surface 2.

Figure 6-6
Low-e, Gas-filled Windows



Caution about Window Insulating Values

New energy codes require manufacturers to report window R-values consistently and accurately. The National Fenestration Rating Council, NFRC, offers a testing program for window and door products. The NFRC reports an average whole window U-value. If windows used in your home are listed by the NFRC, they will include a label showing test data for your windows.

Window insulating values are reported in U-values, the inverse of R-values. Single-glazed windows generally have average R-values of 1.0 and thus have U-values of 1.0. Double-glazed products may have R-values higher than 4.0, or U-values of lower than 0.25 (1/R = 1/4 = 0.25).

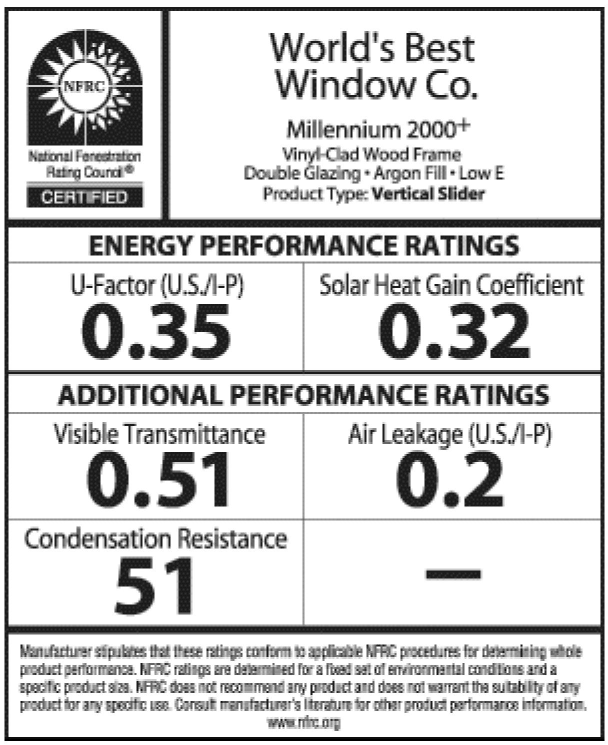
Sometimes insulating values are reported through the glass surface alone. However, these values do not apply to the entire window assembly.

Windows have a frame or sash; spacer strips that hold apart the sections of glass in a double-glazed window; and a jamb. These components each affect the insulating value of the window. Window frames and sashes reduce the transparent glass area, thus reducing the solar heat gain coefficient of the window. Spacer strips separating the glass layers add areas of direct conduction through the edge of the glazing unit. Thermal breaks reduce the conduction, improving the performance of the window. The claimed U-value should reflect the overall insulating value of all of the components.

NFRC labels show the following key window performance features:

- Air leakage rates
- Solar heat gain coefficient
- Visible light transmittance
- Condensation Resistance

Figure 6-7
NFRC Label



Proper Window Installation

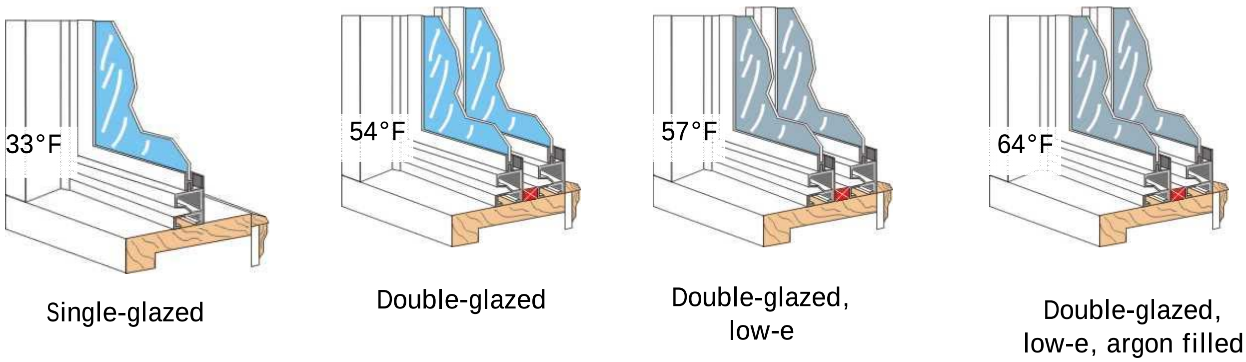
Step 1: Make sure window fits in rough opening and that the sill is level

Step 2: Install window level and plumb according to the manufacturer's instructions

Step 3: Use a dry, pliable foam gasket or non-expanding foam sealant to seal between the jamb and the rough opening, or stuff the gap with backer rod or insulation and cover the insulation with caulk (remember, most insulation does not stop air leaks – it just serves as a filter)

Step 4: If using an interior air barrier (such as drywall) or an exterior air barrier (such as housewrap), seal the barrier to the window jamb with long-life caulk or other appropriate, durable sealant.

Figure 6-8
Inside Window Temperatures in Cold Weather
(when 75°F inside and 20°F outside)



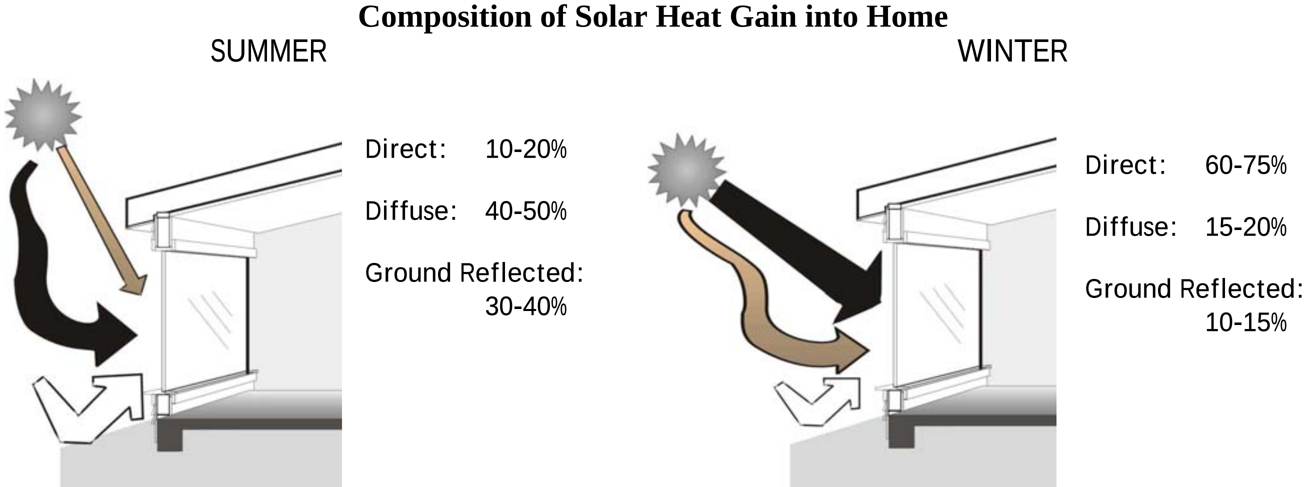
Window Shading Options

Well-designed homes carefully consider window location and size. In summer, unshaded windows can double the cost of cooling the home. Year round, poorly designed windows can cause glare, fading of fabrics, and reduced comfort.

The effectiveness of different window shading options depends on the composition of the incoming sunlight. Sunlight reaches the home in three forms: direct, diffuse, and ground reflected. On a clear day, most sunlight is direct, traveling as a beam from the sun to a home's windows without obstruction. Figure 6-8 shows that most of the direct sunlight striking windows in winter is transmitted into the home. However, in summer, sunlight hits south-facing windows at a steeper angle, and much of the direct sunlight is reflected.

The majority of the sunlight entering south-facing windows in the summer is either diffuse – bounced between particles in the sky until it arrives as a bright haze – or is reflected off of the ground. In developing a strategy for effectively shading windows, consider both direct and indirect sources of sunlight. Overhangs, long thought to be totally effective for shading south-facing windows, are best at blocking direct sunlight and are therefore only a partial solution. Other shading options include landscaping and trees, awnings, exterior and interior shades, window films, and solar window screens.

Figure 6-9
Composition of Solar Heat Gain into Home

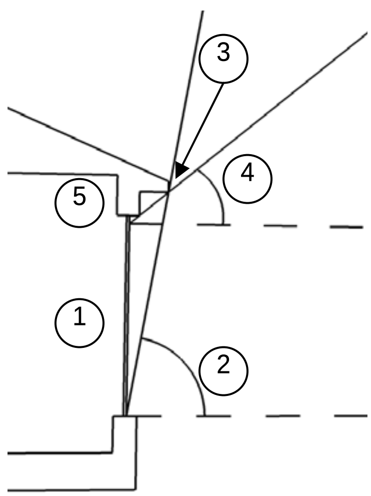


Overhangs

Overhangs shade direct sunlight on windows facing within about 30 degrees of south. Overhangs on east and west windows are less effective because of the low angle of the sun around sunrise and sunset. Overhangs above south-facing windows should provide maximum shade for the glazing in midsummer – around July 21- yet still allow access to winter sunlight. For a standard 8-foot wall with windows, the overhang should be 2 to 2 ½ feet in length. Figure 6-10 shows how to size overhangs for south-facing windows.

Retractable awnings allow full winter sunlight, yet provide effective summer shading. They should have open sides or vents to prevent accumulation of hot air underneath. Awnings may be more expensive than other shading options, but they also serve as an attractive design feature.

Figure 6-10
Guidelines for Overhangs



Size south overhangs using the adjacent diagram and these steps:

1. Draw to scale the window and wall to be shaded.
2. Draw the summer sun angle upward from the bottom of the glazing.
3. Extend the overhang until it intersects the summer sun angle line.
4. Draw the line at the winter sun angle from the bottom edge of the overhang to the wall.
5. Use a solid wall above the line where the winter sun hits. The portion of the wall below that line should be glazed.

Table 6-4
Summer and Winter Sun Angles
(Degrees from Horizon at Mid-day)

	July 21	January 21
Alexandria	78.5	38.5
Baton Rouge	79.5	39.5
New Orleans	80.0	40.0
Shreveport	77.5	37.5

Interior Shading Options

Shutters and shade located inside the house include curtains, roll-down shades, and Venetian blinds. More sophisticated devices such as shades that slide over the windows on a track and interior movable insulation are also available.

Interior shutters and shades are generally the least effective shading measures because they block sunlight that has already entered the room. However, if windows do not have exterior shading, use interior measures. The most effective interior treatments are solid shades with a reflective surface facing outside. In fact, simple white roller blinds keep the house cooler than more expensive louvered blinds, which do not provide a solid surface and allow trapped heat to migrate between the blinds and the house.

Reflective film, which adheres to glass and is found often in commercial buildings, can block up to 85% of incoming sunlight. It is best suited for use on west-facing windows. These films are not recommended for windows that experience partial shading because they absorb sunlight and heat the glass unevenly. This uneven heating may break the glass or ruin the seal between double-glazed units.

The installed cost of reflective films is higher than $4 per square foot. Price should not be the sole criterion when selecting an installer – quality is a vital consideration affecting the appearance of the house and the beauty of the view to the outside.

Most window manufacturers offer tinted windows, which reduce Solar Heat Gain Coefficients. The window tints add color, such as green, amber, gray, or a reflective finish to the window. These tints are often inexpensive, costing only $3 to $10 extra per window for many units. However, the tint is permanent, so incoming sunlight will be blocked in both summer and winter.

Exterior Shading Options

Exterior window shading treatments are effective cooling measures because they block both direct and indirect sunlight outside of the home. Hinged decorative exterior shutters which close over the windows are excellent shading options. However, they obscure the view, block daylight completely, may be expensive, are subject to wear and tear, and may be difficult for many households to operate on a daily basis. They work best in hot, sunny climates, like that of Louisiana, where they can be closed for weeks at a time.

If they are hurricane protection shutters as well they may be worth the price to some. They can be closed on those windows that need shading and open on all the rest letting in daylight. When storms approach they can be fastened closed to protect the windows from wind blown debris.

Solar shade screens are an excellent exterior shading product with a thick weave that blocks 70 percent or more of all incoming sunlight. The screens absorb sunlight, so they should be used on the exterior of the windows only. From outside, they look slightly darker than regular screening, but from the inside many people do not detect a difference. Most products also serve as insect screening and come in several colors. They may be removed in winter to allow full sunlight through the windows. More expensive alternatives to the fiberglass shade screen are thin, louvered metal screens that block sunlight, but still allow a view from inside to outside.

According to the U.S. Department of Energy Report, “Landscaping for Energy Efficiency” (DOE/GO-10095-046), careful landscaping can save up to 25% of a household’s energy consumption for heating and cooling. Trees and vines are very effective means of shading in the summer month, as well as providing protection from winter winds. Also, shrubs or groundcover outside of windows can reduce the amount of ground reflected light entering the home.

Select Shading Options Wisely
It is important to understand that not all shading is created equally. Exterior shading is inherently more effective than interior shading. This is because exterior shading stops the heat before it enters the home, whereas interior shading tries to stop the heat after it has already entered the home. Each type of shading also has its own benefits and drawbacks. Selecting shading options depends on several variables to determine effectiveness. Not only are there different types of products for shading windows, but variations of effectiveness of products. For instance, vinyl blinds do not reject as much heat as aluminum blinds. It is important to consider all factors including window orientation, aesthetic value, and cost when selecting shading options.

Special Considerations for Hurricane Prone Regions
A large part of Louisiana is required to have added protection from the effects of hurricanes. Portions of Louisiana falling south of the 100 MPH wind load line, as per the 2003 version of the IRC, must either have impact-resistant glass installed or be protected from windborne debris by storm shutters or other covering. These windows must also be able to resist the cyclical loading of high pressure differences between the inside and outside of the home. One drawback of impact-resistant glass is that it poses a safety hazard in the event of a fire. When a window must be entered to rescue an occupant, the impact-resistant glass seriously impedes the firemen, as it will not shatter and allow entry. Storm shutters, when used properly, provide protection from windborne debris while allowing safety personnel to enter through the window in the event of an emergency.

Future Window Options

Electronic Windows
A new type of windows is composed of special materials that can darken the glazing by running electricity through the unit. Some manufacturers already have prototypes of these technologically advanced windows in operation. At night and on sunny days, an electric switch can be turned on to render the windows virtually opaque.

"Solid" Windows
Another new window technology uses an aerogel up to one inch thick between layers of glazing. Aerogels are produced by replacing the liquid in a gel with a gas. The result is a very low-density material that feels similar to expanded polystyrene. Aerogels are effective at reducing all three forms of heat transfer. However, the effectiveness against each form of heat transfer depends on the type of aerogel used. These windows offer increased insulating values, but are not completely transparent and are not economical in Louisiana.

Doors
Exterior wooden doors have low insulating values, typically R-1.8 to 2.2. Storm doors increase the R-value only to about R-3.0 and are not good energy investments. The best energy-conserving alternative is a metal or fiberglass insulated door. Metal doors have a foam insulation core which can increase the insulating value to R-7 or greater. They usually cost no more than conventional exterior doors and come in decorative styles, complete with raised panels and insulated window panes.

Insulated metal or fiberglass doors usually have excellent weatherstripping and long lifetimes. They resist warping and offer increased security; however, they are difficult to trim, so careful installation is required. Table 6-1 includes the costs and savings of energy conserving doors.

As with windows, it is important to seal the rough openings. Thresholds should seal tightly against the bottom of the door and must be sealed underneath. After the door is installed, check it carefully when closed to see if there are any air leaks.

Glass in Doors

Special consideration must be given to doors that include glass areas. Whereas solid doors must only deal with conduction through the unit, doors with glass areas must also contend with solar heat gain. Doors with half height glass must meet the SHGC requirements of the IRC.

Accessible Design

Almost one out of ten people will suffer from physical disabilities during their lifetime. Designing homes to provide accessibility for the physically impaired adds little to the cost of a home. One important feature is to design both exterior and interior door openings and hallways 3’ wide to allow passage of a wheelchair or walker.

Overall Window and Door Recommendations

- Use double-glazed windows with low-e coatings as required by IRC.
- South-facing windows should be shaded with about a 2-foot horizontal overhang for single-story windows.
- East and west facing windows should have low Solar Heat Gain Coefficients (under 0.40) through the use of tinting, reflective or selective coatings, or window films. West window areas, in particular, should be limited to avoid afternoon solar gain.
- North-facing windows are excellent for indirect lighting and ventilation.
- Insulated doors should be used.