COURTESY PELLA

CHOOSING Energy-Efficient Windows

New high-performance glazings can cut heating and cooling costs, but you have to choose the right windows for your climate by Steve Easley

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 at breakneck speed. At the same time, "high performance" options have multiplied over the last few years. Choosing the right product can cut heating costs up to 25% and cooling costs by as much as 40%. 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. The terminology alone is enough to make your head spin.

To make matters even more challenging, consumers have grown to expect high performance from their windows, even when they don't understand the technologies involved. I once received a call from a homeowner who had bought tinted windows. A few sunny days after the installation, she wanted the windows removed because she didn't feel they were doing anything to reduce heat gain, as the salesperson had so zealously promised. After a few questions, I discovered that she had a 10-foot-wide covered porch wrapping all the way around her house. She was right: Her windows never received direct sunlight, so there was no way a tinted window was going to affect her energy costs. She had been sold the wrong product.

Comfort Is the Issue

So how do you choose the right window? The starting point is to figure out which window technologies work best for your climate (see Figure 1).

A study commissioned by Pacific Gas and Electric a few years ago 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 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. High-performance technologies can make windows feel warmer during cold weather by keeping the temperature of the interior glass surface higher.

Summer performance important. We tend to evaluate window products on what they do to reduce heating costs. Winter performance is important, but 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.

Better 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. Thanks to the efforts of the National Fenestration Rating Council (a collaborative effort between manufacturers, the Department of Energy, utility companies, and others), any window worth buying now comes with an NFRC label (Figure 2). This label gives you 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: the *U-factor*, the *solar heat gain coefficient* (SHGC), and the amount of *visible light transmittance* (VLT). These ratings are for the total window unit, not just the glass.

U–factor measures the amount of energy, in Btus, that transfers via conduction through a window. Essentially, 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 is.

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

Matching Windows to Climate

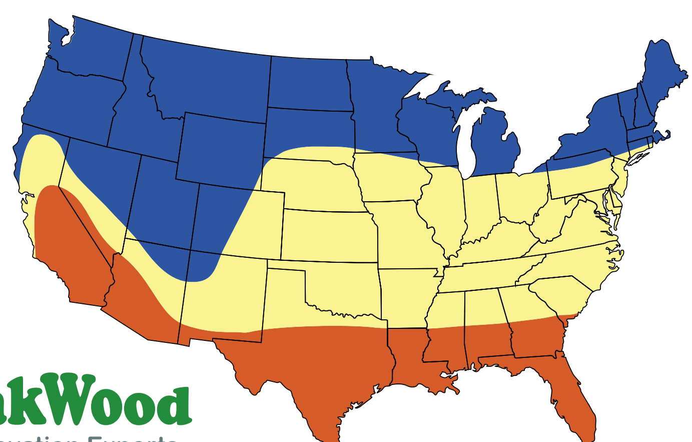

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Figure 1. Select windows to suit the climate in which they will be installed. In the northern regions of the country, windows must be good at keeping in wintertime heat; southern climate windows should primarily keep heat out in the summer. Windows installed in the middle of the country must balance summer and winter performance.

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 which 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. Since NFRC rates the entire window, including the frame, 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 would have a total product visible light transmission of .57. A double-pane aluminum window is .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.

Energy Star label. A companion to the NFRC label is the Energy Star label (Figure 3), 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)

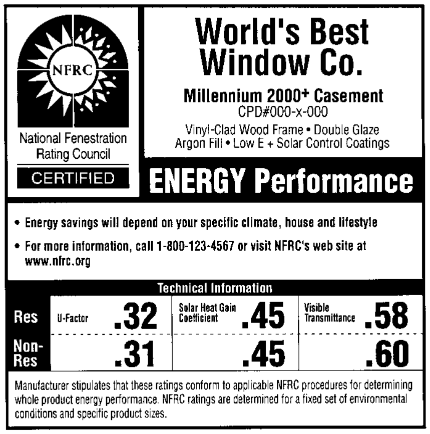
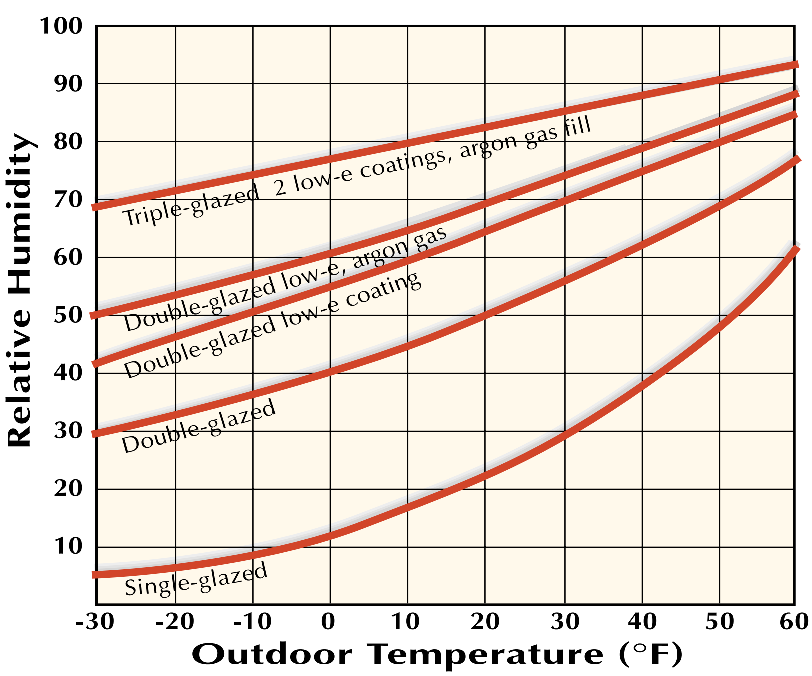


Figure 2. The NFRC label, found on most high-quality windows, makes it easy to assess a window's energy performance. Whether higher or lower U-factor and solar heat gain coefficient ratings are better depends on the climate where the window will be installed.

Dealing With Condensation

Condensation on windows, which often causes callbacks and disappointed customers, can be reduced with new glazing technologies. With a simple chart (below), it's easy to predict under what conditions condensation will form on a given window. Low-e windows can prevent the formation of condensation until relative humidity levels reach 65% at an outdoor temperature of 20˚. Relative humidity levels above 65% are excessive and will likely cause other problems besides dripping windows. I always recommend that contractors carry a digital hygrometer to measure and record indoor relative humidity while they are in customers' homes. *—S.E.*



Given an outdoor temperature of 20˚ F, project up vertically to the desired window product curve. A double-pane clear, for instance, corresponds to a relative humidity of 51%. Compare this with a double-glazed low-e argon product, which would allow almost a 70% relative humidity level before condensation would occur. This chart is for the glass only and not the frame.

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.

The Importance of Low-e

Of the many window technologies developed in recent years, none has as great an effect on energy performance as low-e coatings. A low-e ("low emissivity") coating is a microscopically thin, transparent metal coating applied between the panes of an IGU. These coatings have the ability to reflect heat, but they have a hard time giving off heat or emitting energy. In an infrared photo of a person standing in front of two windows, it's easy to tell which window glass has the low-e coating (Figure 4).

Low-e coatings make the inside surface temperature of glass warmer by reflecting heat back into the room. People are more comfortable when a room's escaping heat is reflected back at them. In addition, a warmer glass surface temperature means less of a temperature difference between a person and the window surface, leading to less heat transfer from the person to the window on a cold day. A warmer surface on the inside of the glass also means less potential for condensation.

Low-e coatings are not all the same. How manufacturers use low-e technology varies throughout the industry. Usually, one or two low-e coatings are applied directly to the inside glass surfaces of an IGU. Some manufacturers apply the low-e coating to a plastic film that is then installed between glazing layers (Figure 5).

Different low-e technologies have different applications. First-generation coatings from the 1980s do a good job of letting in light and reducing heat loss by reflecting heat back into a room. These standard low-e coatings are a good choice when there is little concern about summer air conditioning costs. But they do not do as much to keep out solar heat as do the "spectrally selective" low-e coatings.

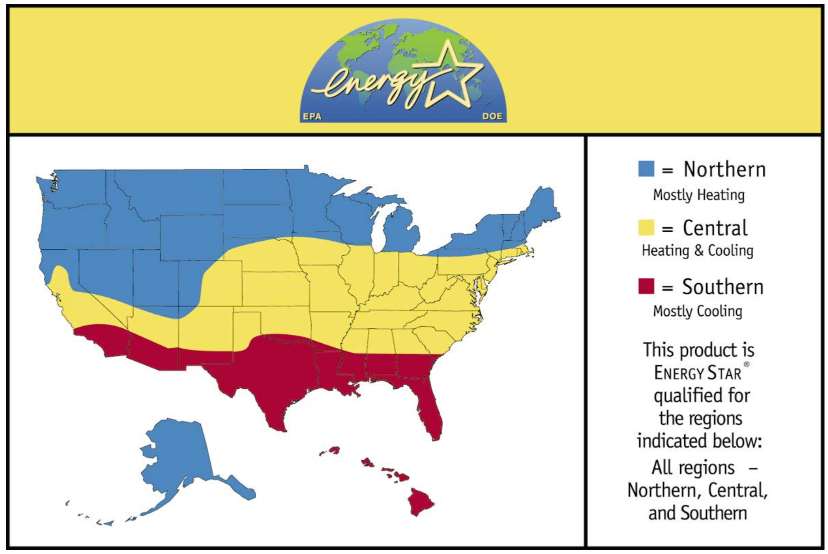


Figure 3. The Energy Star label uses color coding to match a window to the climate in which it should be used.

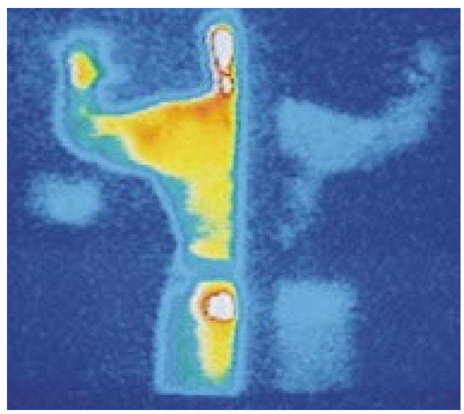


Figure 4. This infrared photo shows a person standing in front of a divided window. The left side has a low-e coating, the right side does not. The brighter image on the left indicates that much of the person's heat is being reflected back into the room rather than passing through the glass.

Figure 5. Southwall's Heat Mirror film is a low-e coated plastic that is suspended between the glass panes in an IGU. The product shown here has two layers of Heat Mirror.

How Spectrally Selective Low-e Works

Insulating Glass Product	Visible Light Transmittance	Center of Glass Winter U-Value	Solar Heat Gain Coefficient
Clear	82	.49	.78
Standard Low-e	75	.30	.72
Spectrally Selective Low-e	72	.24	.41

Figure 6. Spectrally selective low-e coatings do a good job of reducing summer heat gain and preventing winter heat loss while still allowing most of the visible light to enter the space. The chart compares the performance of standard low-e and spectrally selective low-e to that of clear glass.

Reducing Fading With Low-e

Insulating Glass Product	UV Transmittance	Tdw
Clear	58%	61%
Standard Low-e	47%	52%
Spectrally Selective Low-e	16%	33%

Figure 7. Although blocking UV light is important for preventing fading, some damage is also caused by light on the edge of the visible light spectrum. To determine the actual fading potential of light passing through any particular glazing system, use the *total damage weighted (Tdw)* values. The lower the Tdw, the less fading will be caused.

A spectrally selective coating lets through most visible light but blocks the shorter wavelength infrared solar heat waves (Figure 6), thus greatly improving summer performance. Spectrally selective coatings reduce solar heat gain by as much as 40% over a double-pane clear window. These coatings also improve winter performance by about 20% compared with standard low-e coatings, making them a good choice in most parts of the country. The exception would be a passive solar design, which relies on heat gain from the sun to offset winter heating costs. In this case, standard low-e is the best choice.

Occasionally, a sophisticated building designer may use different glass coatings on different sides of a house to optimize energy performance — for example, standard low-e on the south side to allow for solar heat gain in the winter and spectrally selective on an exposed west side to block summer heat gain. While this strategy can work, it's important to warn customers that different coatings might have slightly different color tints. I've heard of jobs where homeowners demanded window replacement because the glass on different house walls didn't look the same.

Reasonable cost. The cost of low-e products is very low compared to their value. The additional cost averages between $1 to $1.75 per square foot. Many manufacturers are now offering spectrally selective low-e products at the same cost as standard low-e. If you're already planning to buy higher-end windows, low-e products may be available at the same price by simply speccing them.

Other Low-E Advantages

Another advantage of low-e coatings is that the improved energy performance does not sacrifice the quality of visible light passing from outside to inside. The visible light transmission rates of these products are only slightly less than a generic clear IGU. In essence, windows with both standard low-e and spectrally selective low-e glass look clear. In the case of spectrally selective coatings, this is remarkable because these coatings cut solar heat gain by as much as some of the dark commercial tints while allowing plenty of daylight to pass through.

Low-e coatings can reduce fading. The fading of fabric and wood surfaces is caused by a combination of ultraviolet (UV) and visible light that passes through windows. Window manufacturers often claim to protect against fading by citing the amount of UV light blocked by the glass coatings on their products. This accounts for only part of the problem, however, because some fading still occurs in the visible spectrum. To determine just how much various glass coatings protect against fading, "total damage weighted" (Tdw) values describe how much fade-causing natural light (both UV and visible) actually passes through a window. Tdw values are not often publicized but manufacturers will provide the information when asked.

Spectrally selective low-e coatings can reduce UV transmission to 16%. A corresponding Tdw value of 33% means that a spectrally selective coating blocks 67% of the rays that cause fading (Figure 7). It is important to look for the lowest transmission percentages to minimize fading problems. I recently visited a 6-month-old home for a builder that had a callback due to ultraviolet light damage. The family room had hardwood floors. The owner had placed an area rug on the floor near an 8-foot-tall sliding glass door that faced west. The floor had darkened except where the rug was located. Needless to say, most homebuyers would not be happy and would expect to have the floors refinished. If the builder had spent another $60 for low-e, he probably never would have had the callback.

Tinted Glass

Spectrally tinted glazings are used in the lightly tinted blue or green glass products (two common trade names are Azurlite and Evergreen). These new products are far better than the older darker tints at reducing heat gain because they allow more visible light to pass through. But these new spectral tints are not heat reflective like low-e coatings and will not enhance the U-factor or winter performance of the window. They serve only to reduce heat gain and visible light glare.

Figure 8. Conductive heat loss around the perimeter of insulated glass units (dark areas in thermographic image, left), caused by metal edge spacers, has led to recent innovations in "warm-edge" non-metal spacers, such as the PPG Intercept (right).

Tint films are often retrofitted onto windows in rooms that overheat due to direct sunlight. Tint films can be problematic because they have low visible light transmission and can excessively darken rooms. Also, some window manufacturers will void a window warranty if tint films have been applied to their products.

Gas Fills

Many manufacturers are putting argon or krypton gas between glazing layers because these gases are less thermally conductive than air. Gas will not make a huge difference in a window's U-factor — window performance improves only about 5% to 10%. The real benefit of argon or krypton gas is in the colder climates where any possible improvement helps to reduce condensation. All in all, gas fillers are usually available as an extra feature at little extra cost.

Warm Edge Technologies

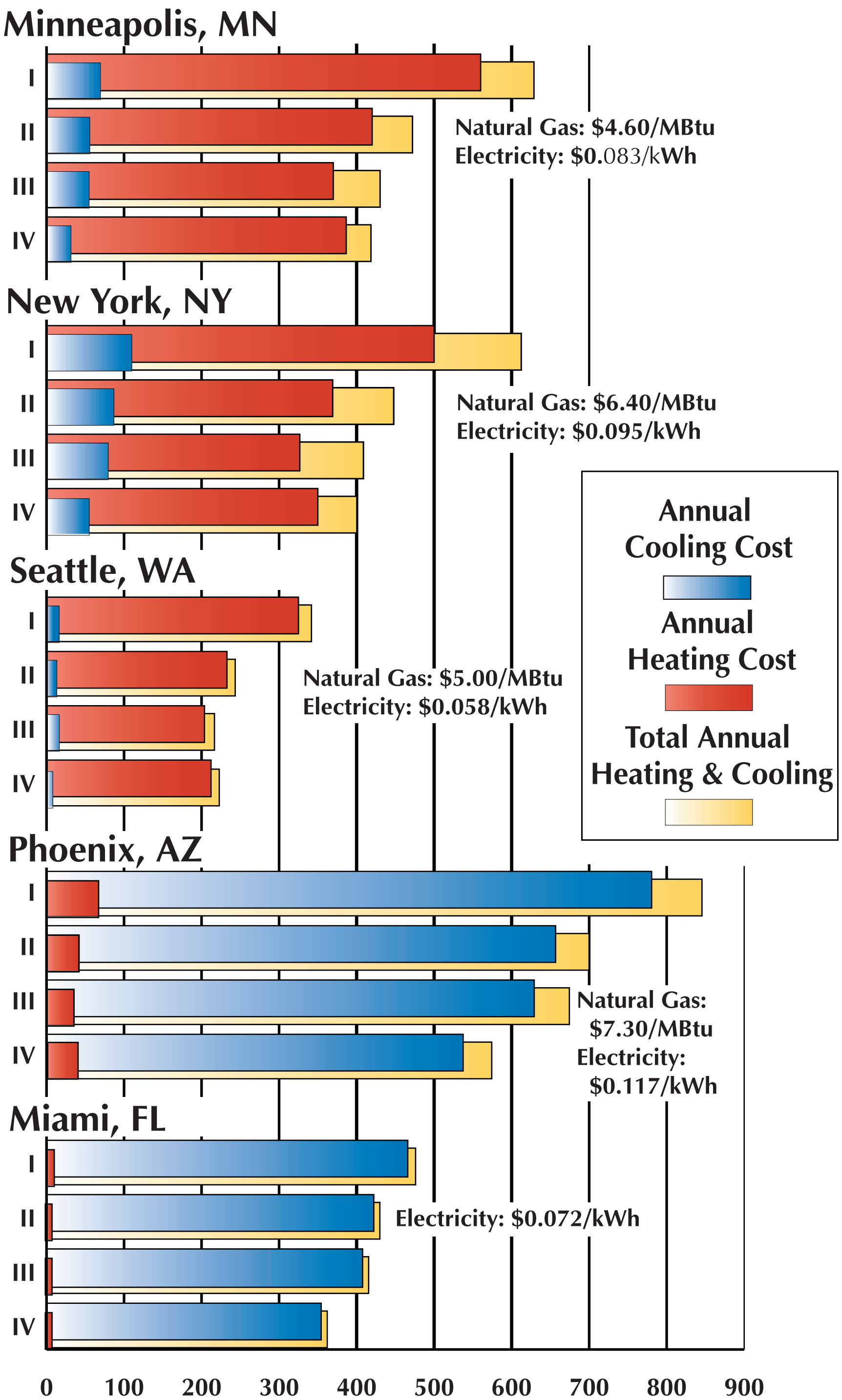
IGU manufacturers use edge spacers to separate the multiple panes of glass. Traditional double-pane windows use aluminum tube spacers. Although these are structurally reliable, they are also heat conductive and therefore cause heat loss. A thermographic image of a window (Figure 8) shows the heat loss associated with the edge spacer. The darkest areas of the image are the coldest. You can see that the spacer around the inside perimeter of the window is conducting heat very well.

In recent years some manufacturers have begun to use materials and spacer designs that are less conductive such as Intercept, SwiggleSeal, and SuperSpacer. These newer "warm edge" spacers reduce condensation and ice buildup at the edge of the window. The jury is still out on the long-term durability of these products, but overall I believe these new spacers are reliable.

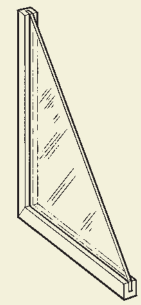
Some sort of warm-edge technology is used in about 40% of the windows manufactured today. When buying new windows, it's always wise to pick a manufacturer with a good warranty and a good reputation for customer service in case any of the new technologies cause problems down the road.

Window frames affect both energy bills and condensation potential. Wood, vinyl, fiberglass, and composites all perform about the same thermally. Aluminum frames, however, are far more conductive and therefore much more susceptible to condensation; they should be restricted to southern climates. When using aluminum-framed windows, choose products built with thermal breaks, which lower the U-factor and help reduce condensation.

Energy Costs vs. Type of Window

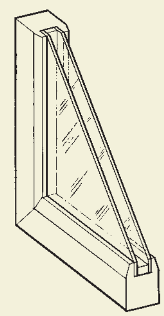


Window Guide



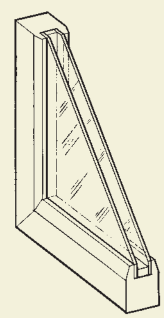
I

single glazing
clear glass
aluminum frame
U = 1.30
SHGC = 0.74
VLT = 0.70



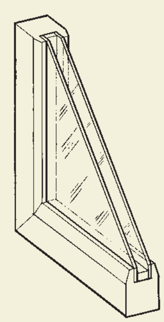
II

double glazing
clear glass
vinyl/wood frame
U = 0.49
SHGC = 0.57
VLT = 0.57



III

double glazing
low-e coating
argon gas fill
vinyl/wood frame
U = 0.33
SHGC = 0.52
VLT = 0.52



IV

double glazing
spectrally selective
low-e coating
argon gas fill
vinyl/wood frame
U = 0.29
SHGC = 0.30
VLT = 0.51

Note: The annual energy performance figures shown here were generated using the DOE2.1E program for a typical 2,000 sq. ft. house with 300 sq. ft. of window area (15% of floor area). The windows are equally distributed on all four sides of the house and are shaded with overhangs, trees, and other buildings. The heating system is a gas furnace with electric air conditioning for cooling. U-factor, SHGC, and VLT are for the total window, including frame.

Courtesy: Efficient Windows Collaborative
U = U value
SHGC = Solar Heat Gain Coefficient
VLT = Visible Light Transmittance

Figure 9. These graphs illustrate the energy costs associated with four common window choices. In New York, for example, if you had aluminum-frame single pane windows, you could save about $225 annually by installing double-pane argon-filled windows with a spectrally selective low-e coating. With the same scenario in Phoenix, the savings would be almost $300.

Airtightness

Windows vary in airtightness and water resistance — important characteristics in areas prone to strong wind and rain or in areas with stiff winter winds, which cut down energy efficiency. Getting information on window tightness is difficult because it is not usually included on product labels. Areas with heavy wind and rain exposure require windows with better air and water resistance. Search for products that have design pressure ratings suited to their applications. The American Architectural Manufacturers Association (AAMA) and the Window and Door Manufacturers Association (WDMA) define the minimum design air pressure for residential doors and windows as 15 pounds of air pressure per square foot and 2.86 pounds of water pressure per square foot. A residential window that meets these performance criteria is designated a Grade R-15 window (R stands for "residential"). In hurricane-prone areas, builders might use a higher-rated window — a Grade 40 or even a Grade 60. Unfortunately, many manufacturers do not submit their products to AAMA or WDMA for official testing.

Cost of Upgrading

Energy experts often downplay the value of energy-efficient windows by arguing that it will take homeowners six times longer to recover the costs than they will ever live in their home. The reality is that most people replace their windows for aesthetic reasons or because the old windows are worn out. If the decision has already been made to replace the windows, the cost to add high performance features ranges from almost nothing to about $40 per window. If the client is upgrading from aluminum-framed with single-pane glass, annual energy savings can top $300 (Figure 9). Depending on local energy costs, the energy savings features can sometimes pay for themselves in less than two years.

Steve Easley *is a construction consultant in Danville, Calif., and a cofounder of the California Window Initiative, a group that educates and promotes the use of energy-efficient window technologies.*

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www.aamanet.org

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Low-E^2
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