Chapter 10

Tips & Traps For Replacing Windows

By Steve Easley

Fig. 10.1 Window replacement
When accomplished as part a measured home performance retrofit, modern gas-filled windows with Low-E coatings will help downsize the cooling and heating equipment. To be sure, the cost of window replacement is high. But in addition to equipment and energy cost savings, the comfort benefits are significant—all year long.

Fig. 10.2 Extensive frame damage - Consider replacement
Single-pane glass stays cold during winter weather, which can lead to condensation and damage, in addition to high heating bills.

Fig. 10.3 Double-pane seal failure - Consider replacement
These older douple-pane units have worn out, losing the seal that kept moisture out of the gap between the panes. Modern windows provide improved comfort, improved aesthetics and energy savings.

Tips & Traps for Replacing Windows & Sliders

By Steve Easley

Windows and sliding glass doors can be a significant source of heat gain and heat loss in a home as well as impact occupant comfort. While replacing windows and sliding glass doors won't reduce energy bills by enough money offset the cost of their reinstallation modern technologies do indeed save energy and increase comfort. Usually the homeowner is motivated by an intense desire to fix one or more of these annoying problems:

1. **Discomfort**. It's uncomfortable to sit or stay near the glass during sunny days or cold nights because the glass loses and gains so much heat.
2. **Leaks**. Rain or irrigation water leaks through or around the windows or sliding doors.
3. **Can't open**. Windows or sliding doors no longer open freely or close tightly. So the homeowner can't enjoy fresh air, and/or has to put up with hot air and cold air drafts near windows.
4. **Rot or rust**. Frames are rotted or corroded, leading to water leaks and drafts.
5. **Condensation**. The frames or the glass condenses and drips water, which in turn stains or warps the frames and sill, and stains the gypsum board under windows or stains the floor or carpet near the door. (Fig. 10.2)
6. **Window seal failure.** See fig. 10.3. The seal for the air gap between glass panes of an older-style double-pane window develops a leak. Moisture condenses in the gap between the panes, obscuring the view and ruining the unit's insulating value.

These aesthetic, durability and comfort problems are certainly worth fixing, and window replacement is an excellent way to solve them. When the windows need to be replaced anyway, the Performance Contractor can take advantage of modern glazing technology to reduce heating and cooling loads. When replaced as part of a comprehensive Measured Home Performance retrofit, modern glazing will improve comfort, allow further downsizing of cooling and heating equipment, and provide a moderate increase in the overall project's utility savings.

Here's the Deal With Windows

Windows leak a lot more heat than insulated walls. A old-style single-glazed window has a thermal resistance of about R-1. Compare that to a traditional wall at R-19 or a current code-compliant wall at R-24, and it's immediately obvious that old windows lose a lot of heat compared to the walls which surround them. Modern windows with high performance glass are a big improvement over old windows. In fact, they can be as much as 300% better than single pane aluminum windows at reducing heat loss.

But in most parts of sunny California, the window's R-value is not nearly as important as its ability to reduce the solar heat gain that gets through the glass. Old glazing allows a great deal of heat into the home, which increases the size of the AC unit needed to remove that heat. Windows are rated in this respect by their "Solar Heat Gain Coefficient" (SHGC). The SHGC is expressed as a decimal fraction of the total solar heat that they allow to pass. For example, the 0.85 SHGC of a single pane of conventional glass means that the glass is passing 85% of the sun's heat into the home.

You don't want that extra heat in the house. Your client would much prefer a modern, gas-filled double-glazed window with a low emissivity coating on the glass and insulated frames, because that window has an SHGC of 0.27 rather than 0.85. Modern windows will reduce cooling loads related to older windows by about 70%. Since solar heat gain accounts for about 45% of the design cooling load, the 70% reduction of that 45% means the home will be more comfortable, and its AC system will be much smaller and will use less energy.

The much lower SHGC of modern windows, together with their 300% improvement in R-value, explains why it's useful to install high performance windows when old glazing is replaced.

Keep it real - Window replacement usually involves more than just the windows

Homeowners considering window replacement become enthusiastic when they see the relatively modest cost of the windows at their local home improvement store. These may or may not be of the quality necessary for improved comfort and modern thermal performance. Also, owners often forget or grossly underestimate the cost of installation. And they are seldom even aware of the cost of fixing the occasional water leakage and air tightness problems ***around*** old window and door openings.

The Performance Contractor can only rarely pop out old windows and slide in new ones without disturbing the window casings, exterior siding and interior trim. New windows must be installed air-tight and flashed properly so they don't repeat or create water leakage problems. That means they must have structurally solid openings, durable siding and appropriate interior trim that can all be made air tight and water tight as the new windows are installed.

Usually, rough openings are sufficiently sturdy to support new windows. But sometimes, pulling out old windows exposes water leakage paths and rot around and under the rough opening, especially where the siding or stucco meets the window casing. In those cases, carpentry may be required to repair rotted structure, flash the window opening and the window itself, replace the exterior window casings, repair the siding where it connects to the new window assembly and replace interior trim to the owner's satisfaction.

The best time to discuss these facts of life with the homeowner is during the test-in visit, when the air leakage associated with windows is relatively easy to demonstrate to the owner with the blower door and thermal camera. If the costs of siding, new casings and structural repairs are not discussed early and tactfully, the homeowner will be in for major sticker shock, and consequently may suspect the contractor of highway robbery upon presentation of his proposal. Better to make a careful inspection and prepare the client for any high costs before the scope of the project becomes final in the customers mind.

Windows and Site Assessment

The test-in visit and evaluation will include an assessment of the existing windows' remaining useful life and their contribution to energy use. Without this information, the Performance Contractor would not be able to make a credible calculation of the home's heating and cooling loads. A useful assessment will include the:

a. General condition of the window: Does it operate smoothly and easily, and close tightly? Are the seals and weather stripping intact and resilient? Is the glass solidly set into the window frame so water won't leak in? Is there evidence of decay, water leakage or water stains on the windows inside, or around the window casings and siding on the outside?

b. Presence or absence of seal failure. If you see signs of condensation between the panes of glass of a multipane window, it's seal is broken. Condensation occurs when warm, moist air infiltrates through an air leak in the seal that attaches the glass panes to the spacer. When infiltrating humid air contacts the cold glass, moisture condenses on its surface (inside the gap between the panes). Over time, repeated cycles of condensation and evaporation leaves a residue that discolors the glass permanently. There is no practical way to get rid of this residue and repair the insulating glass seal on a permanent basis. The unit should be replaced.

c. Square footage of each window and sliding glass door.

d. Percentage of glazing area compared to the total surface area for each exterior wall. (Pay close attention to measuring the square footage of east and west facing glass, which has a greater effect on the cooling loads than does glass on the south or north sides of the home.)

e. Depth of any overhangs, porches or similar shading devices on the East, West and South sides of the home.

f. Amount of window shading from nearby trees, tall bushes and buildings (to estimate how much sun in fact strikes the windows).

g. Frame material. (Aluminum, wood or vinyl)

h. Number of layers of glass in each window (Single or double)

i. Presence of low-E coatings (By using a low-E coating detector)

j. Net solar heat gain coefficient of the combined glazing layers, coatings and tints (By using a solar power meter)

k. Climate. If the heating season extends for several months instead of weeks, it may affect the choice of glazing.

Finally and perhaps most important; ask the homeowner if there are any plans to replace the windows because of problems with operation, comfort issues or for aesthetic reasons. If a home owner is going to replace their windows anyway, the additional cost of upgrading beyond a new double pane window to a high performance low-E, gas filled product is less than $1 per square foot.

Window Retrofit Options

There are three retrofit options. The best choice depends on the condition of the existing windows siding, window trim, sills and flashing.

Full window replacement

The existing frame is removed and the new window placed into the same position that was occupied by the old window. This is an opportunity to fix issues such as water or air leakage that may have occurred around the old frame.

Inserting windows in existing frame

The old sash, side jambs and trim are removed, but the original frame is left in place. The new window is inserted into this opening. Accommodate slightly out-of-square conditions of the existing frame if possible. Significant out-of-square conditions should be fixed with complete window replacement.

Sash replacement

Many manufacturers offer replacement sash kits, which include jamb liners to ensure good operability and fit. This option allows for relatively easy installation, but the existing frame must be in good shape so that air and water tightness is ensured.

Energy Savings From Window Replacement

The California Energy Commission reports that California has nearly 8.5 million single family homes. The average age of a California home is 37.2 years. On average California homes have windows that make up 15% - 20% of the wall surface area. This means that 15%- 20% of the walls of a typical home are insulated to R-1 or less. In addition the percentage of heat from the sun that gets through single pane of glass is 85% which is a huge contributor to air conditioning loads.

High performance low-E windows did not become mainstream until the mid to late 1990's in California. There are millions of poorly performing single pane wood, aluminum and old-style double pane windows in the existing California housing stock. Most of the of windows installed in California from the early 1950's to the mid 1980's were single pane aluminum—the worst-performing window from a thermal perspective.

Many existing windows in California are well beyond their service life. A 2007 study by the National Association of Home Builders of life expectancy of building materials and components reports that aluminum windows have a service life of 15-20 years. Measurements suggests that there is a tremendous amount of energy to be saved by improving window glazing in existing California homes. Today California energy codes require high performance window products.

Newer technologies provide a 300% increase in thermal performance as well blocking over 70% of the sun's heat. The largest share of air conditioning loads is from solar gains through glass.

Lowering AC loads keeps more kilowatts in the cheap zone

Not every kilowatt-hour has the same cost, even in the same house. Power companies have sliding electrical rates, depending on how much energy is used by the homeowner. The higher the consumption, the more each additional kilowatt-hour will cost.

The "base load tier" is cheap. But above a certain consumption level, the cost of an extra kilowatt-hour goes up dramatically. It's important to discuss with the homeowner that usage above their base load tier can triple their cost per kWh. That's why it's so important for the performance contractor to take the time to disaggregate the bill.

Homeowners use most of their base-tier power for lights, laundry, cooking and electronics. So their cheap kWh's are gone by the time it's hot enough to turn on the AC. In California, almost all air conditioning energy ends up being charged at the higher-tier rates.

This real-world cost of air conditioning makes window retrofits more cost effective because modern windows reduce AC loads.

Incremental cost of excellent glazing is small

Based on a "first glance simple, payback analysis" retrofit windows are expensive. Given that fact, window retrofits make the most economic sense when the home owner is considering replacing their windows for reasons other than energy.

For example, modern windows improve comfort, reduce the potential for both window condensation and reduce UV fading of fabrics and furnishings. Modern windows also greatly reduce sound transmission—a significant benefit for those who have trouble sleeping.

When windows have to be replaced for reasons of durability or functionality, it does not take much more money to make them thermally excellent instead of just adequate. The incremental cost of upgrading the replacement from clear double glass to a gas-filled, low-E window is less than $1 per square foot of glass area.

Most studies show that the payback period for low-E glass rather than just conventional glass double-pane windows will be less than one year. This does not even take into account the cost savings of a downsized furnace and air-conditioner. Nor does it take into account the improved comfort of occupants, one of the greatest benefits of the revolution in glazing technology.

While the cost of replacing windows for energy reasons alone will be rather high, Home Performance Contractors would be remiss if they did not ask the homeowner if they have already have plans to replace their windows, before deciding on the full scope of their home performance project.

Energy Losses and Gains Through Windows

Windows loose energy in the winter by conduction and re-radiation to the colder outdoors. In summer the windows add heat to the home via conduction and solar radiation. Windows lose and gain heat through the frame, the glass and the spacers that separate the glass in double pane products.

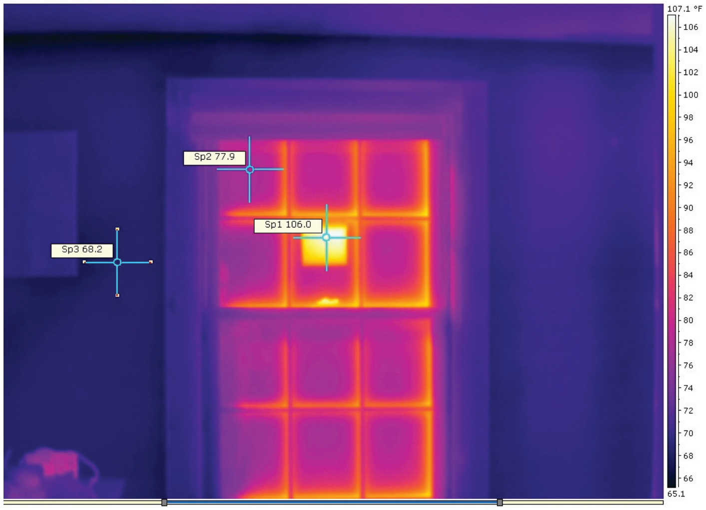
What's new about the new technologies

New window technologies for replacement windows have far better glass with low-emissivity coatings, gas filled spaces between two panes of that better glass, warm edge technology and thermally improved frames. Modern windows have net R-values of 3.3-3.8, (U .30-.26). This is a 300% improvement in R-value over single glazing. They also only let in 24% to 30% of the sun's heat. That's why upgrading windows reduces cooling loads dramatically.

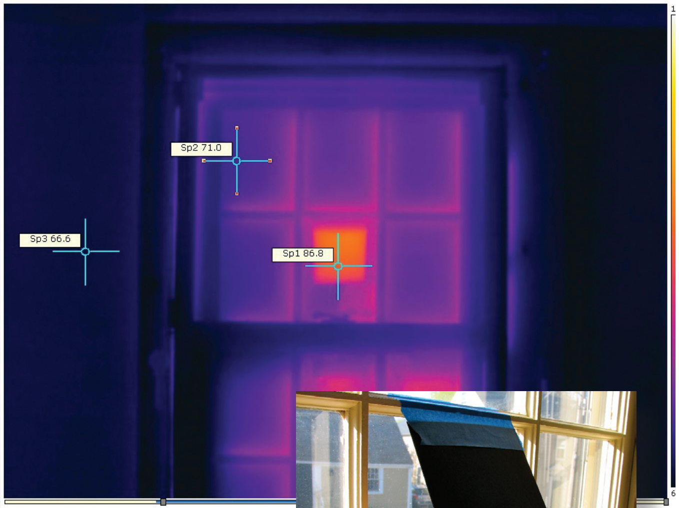
High U-values bad, Low U-values good

A single pane aluminum window has a net R-value of .9. The R-value is used as a figure of merit by the insulation industry, and it's range of values is familiar to contractors and homeowners. When you say that aluminum windows have an R-value of less than one... everybody more or less understands that aluminum windows transmit about 20 times more heat than an R-19 wall. The benefit of upgrading from an R-1 window to an R-4 window would be easily understood.

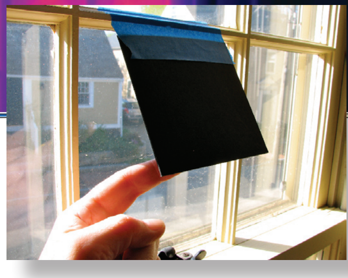
However, the window industry uses the U-value as a figure of merit instead of R-value. The U-value describes the *rate of transmission of heat*, rather than the degree of *resistance* to heat flow. The higher the U factor (transmission) the lower the R-value (resistance). So it gets confusing, because a high R-value is a good thing... but a high U-value is a bad thing. It's not good to have a high rate of heat transmission through walls or windows.



Old glass with storm window



High performance window



Cardboard squares taped inside each window help tell the story. At the old window, the cardboard surface temperature rises to 106°F! But at the high performance window, the cardboard stays below 87°F.

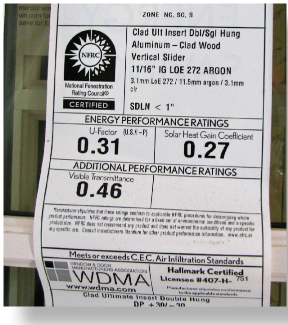


Fig. 10.4 High solar heat gain is not helpful
The old-style double-pane unit at left has a solar heat gain measured at 58.2. In other words, a little over 58% of the sun's heat comes though the window and into the house to increase cooling loads. In contrast, the modern high performance gas-filled, Low-E window at right shows a heat gain of 26.9, which neatly matches its manufacturer's label that shows the window's rated solar heat gain coefficient is 0.27.

But it's easy to convert between R and U-values. If you know the U-value, you can easily obtain the R-value of that assembly, because the R-value is the reciprocal of U-value, and vice-versa.

For example if a window has a U-value of 0.33, just divide 1 by that number to obtain it's R-value: 1÷0.33 = 3.0. And the procedure works in the other direction as well. Divide 1 by the R-value to obtain the equivalent U-value: 1 ÷ 3 = 0.33. The bottom line is that when shopping for modern energy-efficient replacement windows, don't bother with anything that has a U-value above 0.33 (don't bother with a window R-value of less than 3).

On balance, low solar heat gain is the best choice

In California, solar heat gain through windows can account for up to 45% of design cooling loads. The solar energy load on every square foot of vertical surface is approximately 250 Btu's per hour. So the cooling required to offset the solar gain of two 5 ft. X 5 ft. east or west facing windows is about 12,000 Btu/h. That means you'll need one ton of air conditioning to remove the heat from those windows alone, unless you use modern windows, with modern glazing.

One might reasonably assume that such high solar gain would help reduce winter heating bills. But usually, the assumed benefits do not occur in real life, for three reasons:

1. Winter days are shorter, so there's less potential solar gain available than one might expect.
2. There is more cloud cover during cold months, so the actual solar heat gain never matches the theoretical potential.
3. The lower angle of the sun during the winter means its energy is more effectively blocked by nearby houses and trees.

The net result is that for the majority of houses in California, the best choice is low solar heat gain glazing. These windows keep cooling loads so low that for much of the year, houses in milder climate zones may need no air conditioning at all. And when air conditioning becomes a necessity, low solar gain glazing keeps the cost of that cooling to a minimum.

Modern Window Technologies

For pragmatic, cost-effective decisions, it's helpful for both the contractor and homeowner to understand exactly *why and how* modern window technologies provide comfort and energy benefits. This section provides a brief summary of key recent innovations.

Low-E coatings

Low–E coatings are standard in the industry today. Low-E stands for (low-emittance). Emittance is a term used to describe how well a material gives off its heat energy. Low–E coatings are also highly reflective to infrared energy. About half the heat from the sun is in the infrared spectrum (which is not visible to the human eye). These coatings are also designed to reduce heating costs in winter as well as reducing cooling costs in summer.

Of the many window technologies developed in recent years, none has had as great an effect on window energy performance as the low-E coating. A low-E coating is a microscopically thin, transparent metal layer applied to one of the glass surfaces in the sealed space of the insulating glass unit (IGU) that is heat reflective. In an ordinary IGU (no coating) about two-thirds of the heat transfer across the gap is via thermal radiation. Low-E coatings will block most of this heat transfer. The net effect is that double pane glass with low-E insulates as well as uncoated triple- or quad-pane glass.

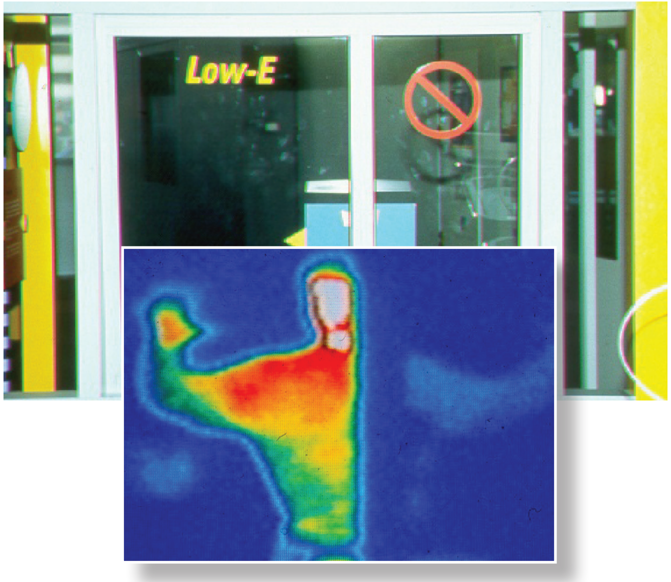


Fig. 10.5 Low-E coatings also keep heat in the house during winter
The thermal image shows how much more heat is reflected back into the house by the Low-E coating (the glass on the left) compared to the old-style uncoated glass on the right side of the same assembly.

Strategically-placed Low-E coatings also improve comfort in the winter. When the heat loss through the window is reduced, the room-side glass surface temperature is warmer during cold weather. The infrared photograph in Figure 10.5 shows two window units, one with low-e glass and the other without. The image on the left shows the heat from my body being reflected back to my camera from low-E glass. Compare that to the much lower amount of heat reflection from the window the unit on the right, which has ordinary double glass (no coating).

Low-E coatings increase comfort by making the inside surface of glass warmer, leading to less heat loss from the person to the window on a cold day. Also, people are more comfortable when a room's escaping heat is reflected back at them by low-E coatings. Another benefit is reduced condensation potential during he winter. A warmer surface on the inside of the glass means the outdoor temperature has to drop much lower than normal to chill the inside of the window low enough to produce condensation.

Spectrally selective Low-E coatings

Roughly half of the energy (heat) in sunlight is invisible to the human eye. Low-E coating manufacturers have learned how to design coatings that let most of the visible light pass through, with little tint or coloration, while blocking most of the solar heat. The different glass designs can be grouped into generic categories of high, medium, and low solar-heat gain.

Most homes in California have air conditioning. So a low solar gain product makes sense. Low solar gain low-E coatings also do a good job of preventing winter heat loss and reducing summer heat gain, while still allowing most of the visible light to enter the space.

Reduced fading with Low-E coatings

The spectral selectivity of low-E coatings also allows them to block significant amounts of ultraviolet (UV) light. Research into the fading of fabrics, artwork, finishes, and home furnishings, has shown that the radiant energy that affects fading includes portions of the visible light spectrum in addition to UV. The International Organization for Standardization (ISO) has proposed a damage-weighted scale called Tdw-ISO that accounts for the effects of both UV and visible light. The ratings for low-E glass suggest that low-solar-gain low-E glass would reduce the rate of fading by over 40% compared with clear glass.

Keep in mind, however, that for residential windows a claim that a glass type will "eliminate fading altogether" is highly suspect. Apart from spectrally selective, high-cost, low-visibility, museum-grade glass (not normally available in residential windows) there will always be a risk of some degree of fading. The rate of fading will vary with the type of material, the pigments used and the light exposure levels. Keeping sensitive fabrics, valuable documents and art work out of direct sunlight is always a good idea.

Warm edge insulating glass spacer systems

The aluminum spacer bars used to separate the two panes in old-style double glazing create a thermal bridge all around the edge of the glass. Consider the winter situation. Despite the warm center-of-glass temperatures achieved with low-E glass, the edges of the glass were cold because of thermal bridging. This can also lead to condensation (Figure 10.4) during cold periods.

The problem has been the spacer bars. Aluminum conducts heat 300 times faster than non-metallic materials. Today, more than 90% of the new or replacement residential windows use some form of "warm-edge" system. The designs vary from low-conductance metals (e.g., stainless steel) to foam or plastic replacements of the aluminum spacer. The thermal performance improvement from warm-edge technology is reflected in the improved (lower) window U-factors found on the National Fenestration Rating Council label (NFRC label - see figure 10.5). In addition to better thermal resistance, however, it's important to pay attention to window durability. Be sure to compare manufacturers' warranty provisions. Sometimes the best thermal performer will lack long-term warranty support due to concerns about the durability of new materials and technologies.

Gas fills

Adding an inert gas between the panes of glass to replace air improves the windows thermal performance. The gas, usually argon or krypton is heavier than air. Heavy is good. Heavier gas molecules slow down the destructive convection loops (thermosiphoning) between the panes which allow heat to move from one pane to the other.

Argon and krypton also enhance the performance gains from low-E coatings. When used in conjunction with a Low-E coating argon or krypton will typically improve (reduce) the window U-factor by about 10%. People often ask if the gas leaks out over time. It does.. but not much. Leakage will be less than 10% over the life of the window unless there is a seal failure. But of course leakage can vary by manufacturer. It's important to read the manufacturer's warranty to understand their provisions regarding gas retention.

Triple and quad pane glazing

Double-pane glass is optimized by adding a low-E coating and gas fill. To provide even better insulating values, some new window designs are incorporating triple and quad-pane systems with multiple low-E coatings (one coating in each air space). Concerns with weight and thickness have some manufacturers replacing the internal layer(s) with plastic or suspended films

Tinted glass

All energy from the sun is transmitted through the glass or reflected or absorbed by the glass. Tinted glass is sometimes used to reduce heat gain in hot climates. However, tinted glass gets hot in sunlight (from absorption) and eventually re-radiates that heat into living spaces.

Tinted glass also suffers more loss of light transmission than low-E coatings. There are some spectral tinted glasses available today that have a little high visible light transmittance buts it's usually light blue or green in color. Most residential windows usually avoid tints, given the market preference for clear glazing. Also, these tints don't reduce the heat transmission (U-factor), so they provide no benefit during the winter months.

Aftermarket applied films

Tint films are often retrofitted onto windows in rooms that overheat due to direct sunlight. While they can help address overheating, the films can be problematic because the low visible light transmission can excessively darken rooms. There can also be problems with film adhesion, and some window manufacturers will void their warranty if tint films have been applied. When buying new or replacement windows, look for products with a low SHGC, indicating that solar control is already built in to the window.

Courtesy of Cardinal Glass

INTERIOR GLASS SURFACE TEMPERATURE		
Double Pane Low-E coating	Summer day (89°F)	Winter night (0°F)
No coating	**91° F**	**44° F**
Low solar gain	**82° F**	**56° F**

Table 10.1 Benefit of Low Solar Gain Low-E coatings
In nearly all cases, the low solar gain coating is the best choice. It reflects heat back to your body during the winter, so you feel warmer. And during the summer, the coated glass emits much less heat than uncoated glass, so your skin surface stays cooler, even when the indoor air temperature is relatively warm.

Comfort and High Performance Windows

Windows have a huge impact on comfort. A study commissioned by Pacific Gas & Electric several years ago discovered that the number one reason customers make energy-efficiency improvements to their homes is to increase their 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 at an exponential rate, a room full of poorly insulating windows can make us feel uncomfortable (by radiant cooling of our bodies) 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.

Glass surface temperature strongly affects comfort

There's another subtle but very important comfort problem of poor glazing which increases cooling costs. Year round, and in all of California climates, windows can be the biggest source of thermal discomfort. (See table 10.1) During sunny days and clear nights, when you are sitting or sleeping close to windows, the inside surface temperature of the glass becomes just as important to your comfort as the indoor air temperature.

Consider the "open furnace" effect of poor glazing during hot sunny days. High solar heat gains, combined with the hot inside glass temperature make the occupant want to set the cooling thermostat about 4°F lower, to provide the same comfort as low solar-gain low-E glass. The lower the thermostat setting, the greater the cost of cooling.

We've already seen that the greater R-value of gas-filled double pane glass provides better insulation, which reduces the heating and cooling loads. But keep in mind that Low-E coatings add another energy benefit because occupants are not roasted by the glass surface temperature during summer or frozen during the winter. With less radiant heating and cooling from the glass, occupants are comfortable at more economical thermostat settings during both seasons.

Window Condensation, a Real Pain in the Glass

One common reason people replace their windows is because of inside surface condensation during cold weather. And if the home had window condensation *before* the Measured Home Performance Retrofit, the risk of condensation may go up afterwards, because the home will be so much more air-tight, keeping more humidity indoors (unless a ventilation system is part of the retrofit). But the good news is that adding window replacement with high performance glass to the project will significantly reduce the potential for condensation.

Home Performance and window replacement both reduce the risk of condensation

Many of the factors which led to past condensation will probably be eliminated by the Home Performance Retrofit.

Consider the ventilation improvement. When combustion safety and/or indoor air quality issues demand that the Home Performance Retrofit include a dedicated ventilation system, the risk of excessive humidity is reduced because humid air is exhausted and dry outdoor air is bought in to replace it.

Also, one reason for condensation is keeping curtains closed to avoid the body-chilling effect of large amounts of cold glass at night. The glass gets cooler, because the heat in the room does not get past the curtains. So even normal amounts of indoor humidity will condense on the windows, because they have become so cold. With better windows, there may be no need to close curtains for extended periods, because the glass surface won't pull so much heat out of the occupants.

Also, after a Home Performance Retrofit, there's little or no need to run a humidifier for comfort, because the indoor humidity is held in by the improved air tightness of the building. So there's less risk of over-saturating the air.

Predicting condensation

The chart in figure 10.4 shows the indoor relative humidity at which moisture will condense on the glass at given out door temperature, for different window configurations. The values come from the Building Scientists at the Department of Energy's Lawrence Berkeley Laboratory. As shown on the graphs, high performance windows with low U factors significantly reduce the potential for condensation.

The left side of the graph shows the indoor relative humidity (%) from 0-100%. The scale at the bottom of the graph represents out door temperature. So as an example, this chart shows us that if we have single pane windows and its 30 degrees outside we will experience condensation on the surface of this glass at an indoor relative humidity of about 32%. If we look at the same conditions for a double pane, low-E window with argon gas the window is likely not to experience condensation on the glass surface unless the relative humidity is above 72%! (An indoor humidity level that would also lead to mold growth on cool surfaces.)

The frames also matter

To avoid condensation, the type of frame is just as important as the glass and the low-E coatings. This means paying attention to the type of frame, glass configuration, spacers etc. Selecting or specifying the wrong window technology for a cold climate can be a costly mistake.

Window frames can be fabricated from metal, wood, vinyl, fiberglass, and composite materials. Its important to understand that metal conducts energy several hundreds times faster that wood or plastic materials. You can have excellent thermal properties for the glass but

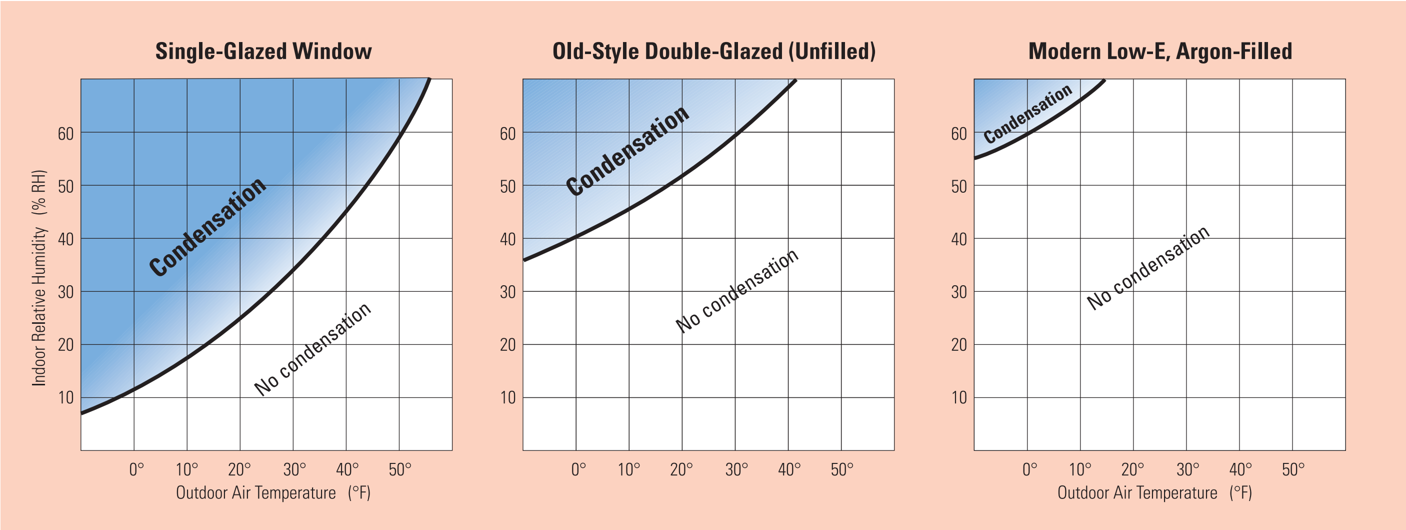


Fig. 10.4 Condensation risk of glazing alternatives
The risk of condensation is much less with moderrn glazing. That's because the inside surface of modern insulating glass is much warmer than conventional glass during the winter.

if you have a highly conductive metal frame you can easily experience condensation on the frame in cold weather.

In cold climates, condensation can still occur if indoor humidity is exceptionally high

Before you promise that new windows will solve all condensation problems, keep in mind that condensation can still happen in cold climates if the indoor humidity is exceptionally high. Windows neither generate nor eliminate the humidity that causes condensation—they only react to their environment. Indoor activities which sometimes lead to excessive indoor humidity include:

- Cooking or boiling water for hours rather than for minutes without operating an effective kitchen exhaust system.
- Deciding not to operate those annoying noisy bathroom exhaust fans as all sixteen members of the family (including the dogs) take baths and showers one after another.
- Implementing an interior decoration scheme based on the look of the Amazon rain forest, including dozens of plants which require daily watering.
- Drying clothes indoors during winter, or failing to connect the clothes dryer's vent hose to the outdoors.
- Operating a vaporizer for days rather than for a few hours.

If the home is in a cold climate zone and if any of those factors are at work and seem unlikely to change, the Performance Contractor will need to add a dedicated ventilation system to reduce indoor humidity, even if the replacement windows are superb.

The NFRC Label Is Your Friend

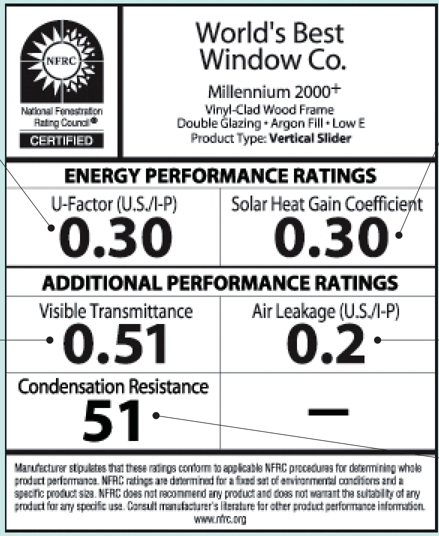
The National Fenestration Rating Council (NFRC) is a non-profit collaborative effort of manufacturers, the Dept. of Energy, utilities and other interested parties. The organization has been active in the public interest since the mid 1990's. It sets standards for rating energy

U-Factor

U-factor is a measure of how much heat escapes through the whole product. The lower the U-factor, the better the window is at reducing heat flow into or out of a home. U-factor is the inverse of R-value. 1/R= U and u=1/R. So a window with a U factor of .5 has an R-value of 2. The U factor is a helpful indicator of the window's winter performance. Look for U-Factors of 0.33 or less.

Visible Transmittance

This the percentage of visible light that comes through the entire window. The higher the number, the more visible light gets through the window. Basically this rating indicates how clear the glass is. Coatings or tints on glass increase energy performance — but also reduce the amount of light that gets through he window. You typically do not notice an appreciable reduction in light until the VLT gets below .5. It is important to remember that this is a total window rating so grids, larger frames etc. reduce the visible light transmission. For example two windows can have the same glass but if one has grids between the panes of glass it will have a lower VLT, even though the glass appears to be completely clear.



Solar Heat Gain Coefficient (SHGC)

Probably the most important number on the label for an air conditioned house. The SHGC is the percent of the sun's heat % of heat from the sun that gets through the window. In the cooling climates of California 45% of the air conditioning loads are solar gain through windows. Look for an SHGC of 0.30 or less.

Air Leakage

This number indicates how many cubic feet of air leak through a square foot of window area, at a test pressure of 50 Pascals (Rougly the pressure created by a 20 mph wind). Less leakage is better. Typical air leakage ratings of modern windows are 0.1 to 0.3 cfm/ft2 @ 50 Pa.

Condensation Resistance

This rating indicates a window's ability to resist moisture condensation on the interior surface of the window. The values will be between 1 and 100. The higher the rating, the better the window is at resisting condensation. Windows with low U factors have good thermal performance and thus have a higher (better) condensation resistance factor.

Fig. 10.5 - The National Fenestration Rating Council (NFRC) Label

performance of windows and doors. The NFRC rating consists of a series of measurements that rate the performance of the entire window, including its frame and any grids or muntins as well as its glass. The values which define the each unit's performance are included on the NFRC label, a certificate which is attached to every window rated according to NFRC standards. In recent years, local energy codes have required the use of the NFRC label on windows and glass doors, to provide certainty about their energy performance.

An example of the NFRC label is shown in figure 10.5 above, along with an explanation of each variable which appears on that label. In general terms, the values indicate the window's winter performance, it's summer performance, air leakage, the amount of light the window lets in and even it's resistance to condensation. Comparing values on the NFRC label allows you to fairly compare the costs and value provided by different windows.

Because of their need for summer cooling, (or their desire to avoid mechanical cooling altogether) most homes in most of California are usually best-served by a window which has:

a. Argon-filled, double glazing

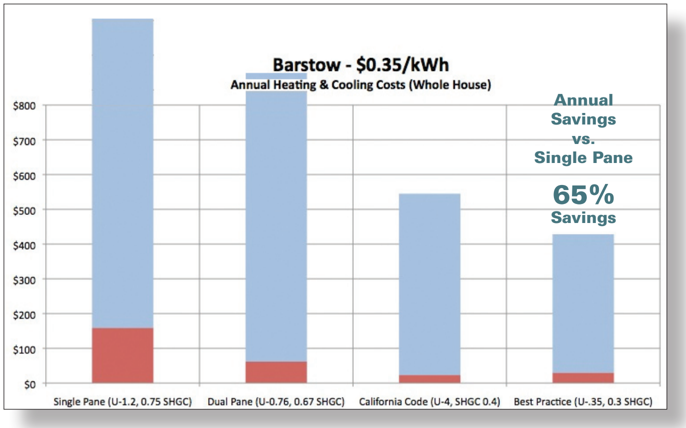
b. Low-solar-gain low-E glass

c. SHGC below 0.30

d. U-factor below 0.33

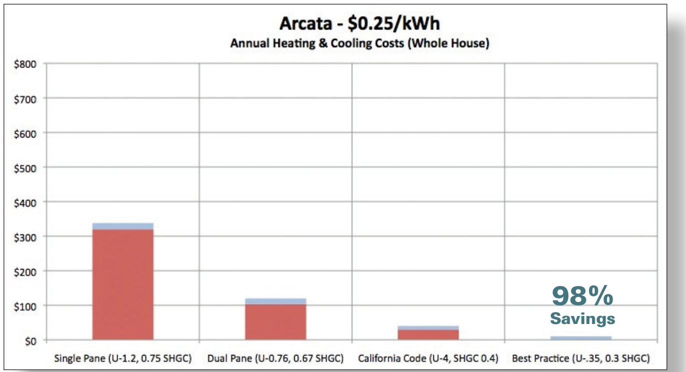
Energy Savings Comparisons

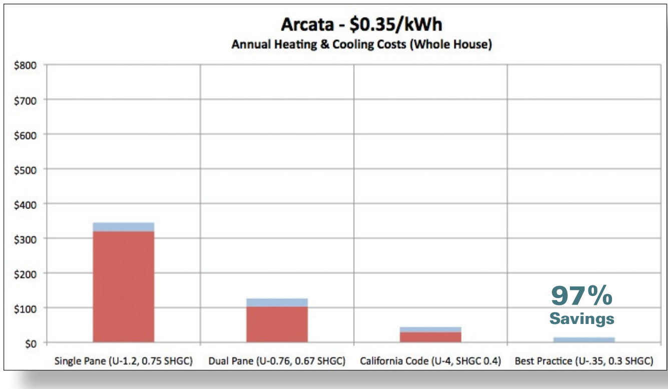
Energy savings from replacement windows are difficult to estimate accurately in a short (and economical) amount of time. In addition to energy costs, savings depend on the orientation, size and exact shading of each window, the design and operating characteristics of the HVAC system and of course the local climate in all it's variations year-to-

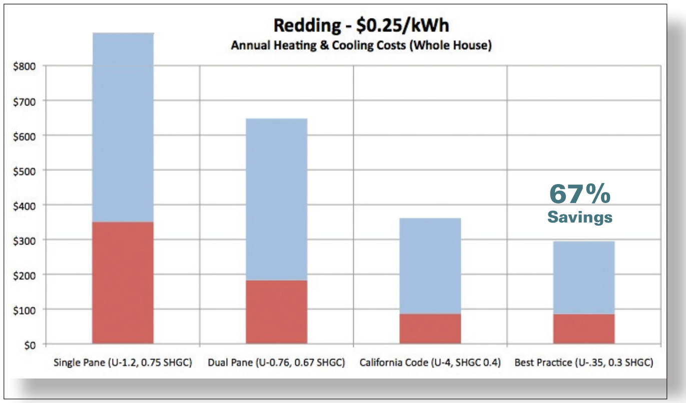


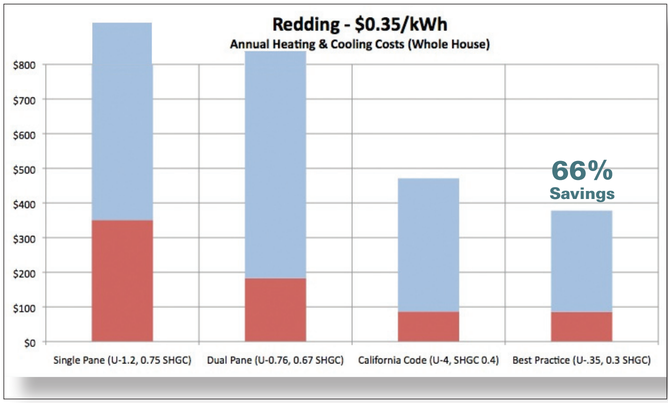
year. That said, it's possible to provide order-of-magnitude estimates which compare the effect of window choices on the whole house's annual heating & cooling costs in six California climates. These graphs show results for different costs of power—one which represents a current high-tier cost (24¢/kWh), and another (35¢ kwh) which may be common in the future. Other assumptions include:

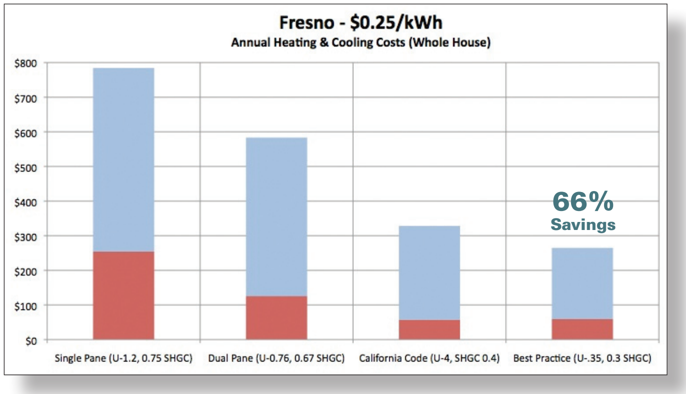
1. Floor area: 2,000 ft^2
2. Total glazing: 15% of wall surface (300 ft^2 total), evenly distributed on all sides of the home, with no exterior shading.
3. Heat: Natural gas at $1.50/therm, 92% AFUE furnace
4. Cooling: DX with a COP of 4.0, with power costs as noted.

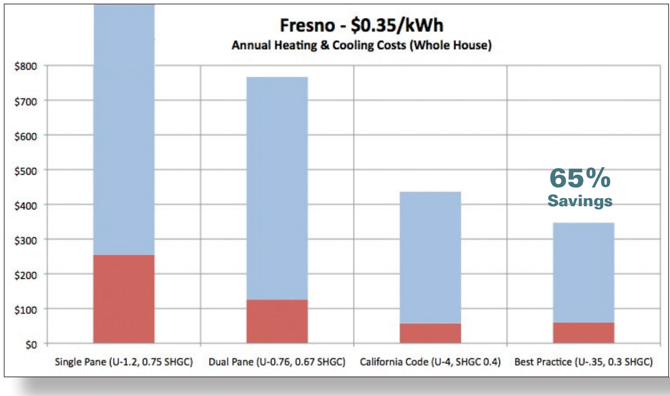









Fresno - $0.25/kWh
Annual Heating & Cooling Costs (Whole House)
$800
$700
$600
$500
$400
$300
$200
$100
$0
66%
Savings
Single Pane (U-1.2, 0.75 SHGC)
Dual Pane (U-0.76, 0.67 SHGC)
California Code (U-4, SHGC 0.4)
Best Practice (U-.35, 0.3 SHGC)


Fresno - $0.35/kWh
Annual Heating & Cooling Costs (Whole House)
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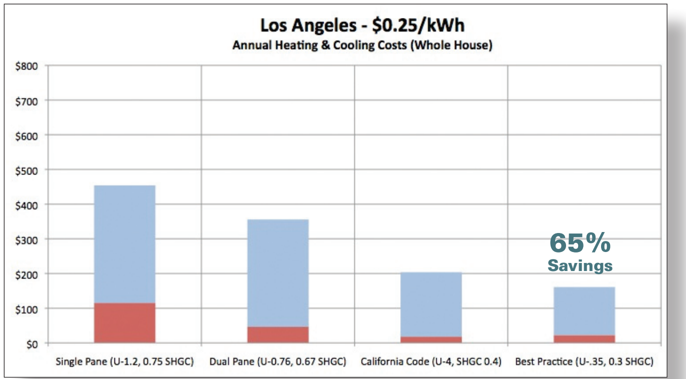
Los Angeles - $0.25/kWh
Annual Heating & Cooling Costs (Whole House)
$800
$700
$600
$500
$400
$300
$200
$100
$0
65%
Savings
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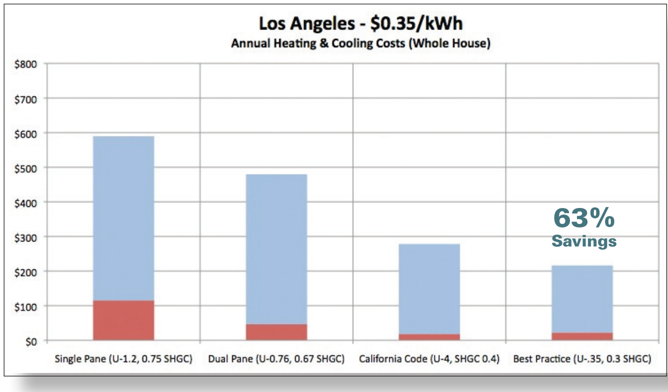
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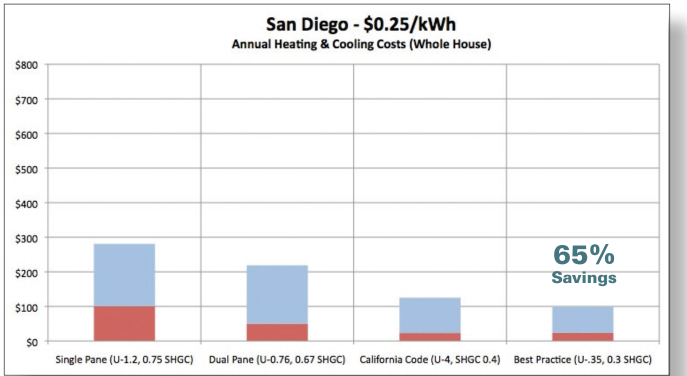
San Diego - $0.25/kWh
Annual Heating & Cooling Costs (Whole House)
$800
$700
$600
$500
$400
$300
$200
$100
$0
65%
Savings
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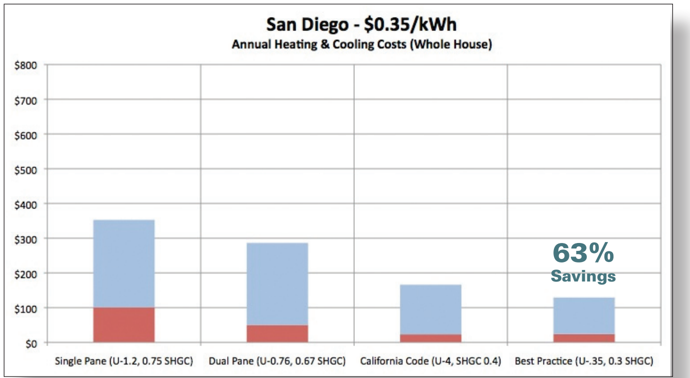
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