Straight Answers About Efficient Windows

by JLC staff

Four independent experts weigh in on low-E coatings, orientation-specific glazing, window-selection tools, and more

The Participants

John Carmody — Director of the Center for Sustainable Building Research at the University of Minnesota in Minneapolis

Ross DePaola — National Fenestration Rating Council–accredited simulator at WESTLab in Madison, Wis.

Chris Mathis — Code expert and building performance consultant in Asheville, N.C.

Stephen Selkowitz — Program head of the Building Technologies Department at the Lawrence Berkeley National Laboratory in Berkeley, Calif.

Q

Which is most thermally efficient for window frames — wood, vinyl, or fiberglass?

A

DePaola It's really about how the window is built, not the material. Vinyl is a budget material that's not as strong as fiberglass, so the frame material is thicker and usually has more internal webs for strength. If you compare a hollow vinyl frame to hollow fiberglass, those webs might cut heat loss a little by reducing convection. But the webs in the vinyl frame make it harder to fill with foam. Wood is a good insulator, but it's going to vary with the species. If you want to compare thermal performance, look at the NFRC label — the frame material is more an aesthetic issue.

Carmody I don't take sides on that. There's not a huge energy distinction between those three until you get into the foam-filled fiberglass "super windows" or the wood-framed triple-glazed windows from Europe, both of which are very expensive. It's more a matter of what people feel — their perception of what looks right, the perceived durability, and other things that are hard to measure.

Q

Since blower-door tests have become common, builders have learned that air leakage through the building envelope can be a bigger driver of comfort problems and wasted energy than insulation levels. On a smaller scale, how big a problem is air leakage through window seals and weatherstripping?

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DePaola Some types of windows leak more air than others. Double-hungs and sliders are leakier than casements, and casements are leakier than fixed windows. But overall, windows aren't a big source of air leaks. Lots of new homes with vinyl double-hungs qualify under the Energy Star air-infiltration requirement. It's thermal bypasses, like attic openings and chimney chases, that are the real problem. Builders are getting better at installation, but air leaks around windows are likely to be bigger than leaks through the windows themselves.

Q

There's not enough space to include a comprehensive window installation guide here, but what about some general recommendations on preventing air and water leaks?

A

Mathis Once you leave the factory, you leave the world where things are controlled by the window industry and enter a world where things are controlled by lawyers. That gap between the window and the wall is something manufacturers have no control over, but it's the source of most of the callbacks and problems they get called in to fix.

There are literally thousands of little mom-and-pop window shops in the U.S. If you take the big guys together — the Andersens, the Pellas, and a few others — they've got maybe 30% of the market. A lot of the small manufacturers make excellent products. But the big players spend more money on testing, and they usually have really good installation advice, especially companies that have their own replacement crews. In the end, though, the builder has to understand the building science and figure out the installation for himself.

Carmody Installation is a messy area, and there's a disconnect between the guy in the field and the window manufacturer. But compared to 10 years ago, there are a lot of good information resources out there. For example, the Building Science Corporation [buildingscience.com/index_html] has some good directions based on their long involvement with the DOE's Building America program. The information is out there, but you have to go find it.

U-Factor and R-Value: What's the Difference?

A material's U-factor and R-value are both measurements of its insulation value, and put a number to how easily heat energy will pass through it by conduction. For windows, the accepted measurement is the U-factor (often — though incorrectly — called the U-value). Because a window's U-factor is a direct measure of conduction, the lower the number, the lower the rate of heat loss, and vice-versa. A single-glazed window with no storm typically has a U-factor of 1.1 or so, while a good-quality double-glazed low-E window will have a U-factor of 0.35 or less. The most efficient triple-glazed windows with insulated frames can have U-factors as low as 0.15.

R-value — the familiar measure of the insulating value of walls, floors, and ceilings — is essentially just a different method of expressing the U-factor of a material or assembly. The conversion is simple: Take the reciprocal of a U-factor, and you have its R-value. A U-factor of 0.33, for example, can be expressed fractionally as 33/100; the reciprocal value, 100/33, reduces to an R-value of 3. A super-efficient window with a U-factor of 0.15, or 15/100, has an R-value of 100/15, or about 6.7.

Why the two parallel methods of saying the same thing? Engineers and materials scientists use U-factors when calculating heat flows, as does the NFRC labeling system. (The U-factor listed on the window sticker averages out heat loss over the entire area of the window, including the frame. For an efficient modern window, the value measured through the center of the glazing — a number sometimes also mentioned by manufacturers — will typically be lower than that of the window as a whole.)

From a mass-market standpoint, though, there are two basic problems with using U-factors: First, the number goes down as the effectiveness of insulation increases, which can seem counterintuitive to consumers. Second, the units involved are small, so going from a U-factor of 0.10 to 0.02 may not seem very significant. Express the same thing in terms of R-value — as a change from R-10 to R-50 — and you get people's attention. Now we're talking!

As a result, it's becoming increasingly common for manufacturers of efficient windows to refer to them as "high-R" windows in their advertising. Provided that the numbers are accurate, that probably does make things easier for most consumers, so there's no reason to criticize the practice. "Everyone knows what R-values are," says Steve Selkowitz. "But mention 'U-factor' and all you get is a blank look."

Q Is there a useful distinction to be made between the low-E coatings used in the north, which are designed to prevent heat from radiating outward through the glazing, and those used in the south, which prevent solar radiation from overheating the interior?

A

Carmody The original low-E coatings that came along in the 1980s were designed to keep heat indoors. The only way to reduce solar heating at that time was with tinted glass, but no one really liked the resulting gray or green or blue windows. In the second wave, we figured out how to use low-E coatings to block radiant heat gain without losing too much visible light. In the '90s, people used to talk about what they called "northern low-E" and "southern low-E" glazing.

But it's not that simple anymore. In a place like Minnesota, where there are big heating loads, a northern-type window seems like an obvious choice. But it gets hot here in the summer, so if you also have air conditioning, as a lot of people do, switching to low-solar-gain glazing works to your advantage for part of the year. Depending on the situation, you might end up saving more in air conditioning costs than you give up in wintertime heat loss. If you don't have air conditioning, low-gain windows might make you more comfortable in the summer even if they don't save any money.

DePaola The original hard-coat low-E windows were coated on the inside surface of the glazing. Sputtered coatings came later and made it possible to put on enough metal to reject heat from outdoors. But sputtered coatings are softer, so the first low-gain windows had the coating on the outer surface of the inner layer of glass, where it would be protected by the outer glass [see illustration, next page]. In really hot areas, that caused some seal failures because the reflected heat built up between the inner and outer glass, like in a greenhouse. Now most low-gain windows are coated on surface 2 — the inside of the outer glass — so the heat is absorbed by the outer layer and reradiated. Glazing that's optimized for heating climates usually has the coating on surface 3.

Q

How does all that fit in with the "tuned glazing" approach promoted by some energy-conscious builders, where you might use high-gain windows to collect heat on a southern exposure, with low-gain windows on the east and west to control low-angle sun?

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Mathis You can design glazing based on orientation, but it's not for everyone. Production builders won't do it, because they're going to use the same plan on different lots with different orientations. With a custom home, it can make sense. You usually don't want to put a lot of glass facing west because the sun comes in low and you can't shade it with an overhang, but maybe that's where you have a great view of the mountains. Low-gain glazing can face that way without overheating.

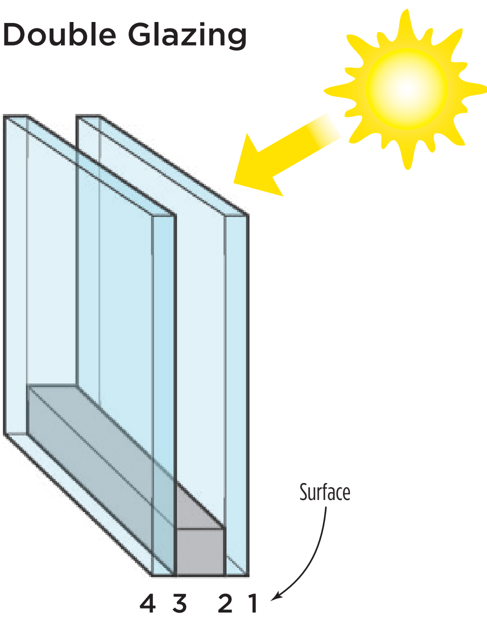
One thing to keep in mind is that different types of glazing admit different amounts of light. That could be a problem if you have two areas of different glass at a corner. If you can see both panes at the same time, you're going to see a noticeable difference.

But when it comes to putting high-gain glazing on the south to increase solar gain — which is what most people mean when they talk about tuned glazing — there's a real risk of overheating. Before you go with high-gain windows on the south, you want to be sure you've done your heat-load calculations and double-checked them. Make sure you've figured your overhangs correctly, sealed your ductwork, and fine-tuned everything else. For every one instance where someone benefits from high-gain glass, there are many, many more who will be less comfortable or have higher cooling costs.

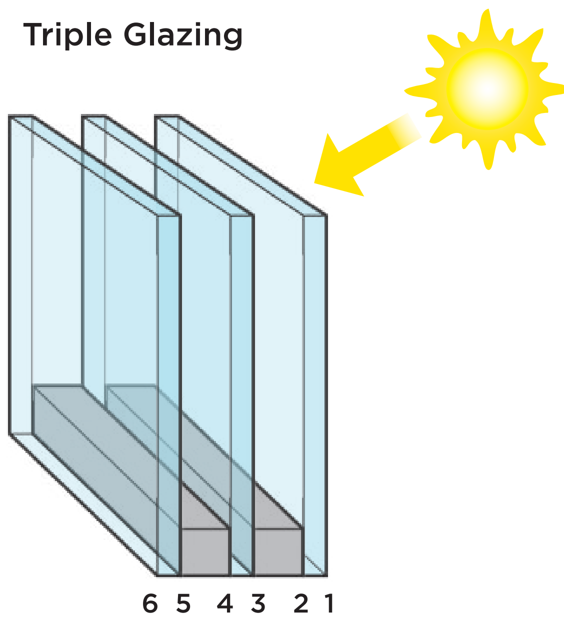
DePaola I'm often asked why it's so hard to find well-insulated high-solar-gain glass. The answer is that manufacturers worry about consumers complaining about overheating. They don't want to stock it, so they don't get many orders.

But I will say that the Canadian market has looked slightly larger in the eyes of manufacturers than it did during the building boom. The Canadian version of Energy Star rewards high-gain windows, so U.S. manufacturers may start looking at that also.

Double Glazing



Triple Glazing



The placement of low-E coatings on multi-glazed windows may vary with the climate zone. Glass surfaces are identified by number, beginning with outermost or "weather" surface. It is always designated as #1, the inner surface of the outer pane is surface #2, and so on. In glazing with suspended films rather than internal glass, the film surfaces are numbered the same way.

Q

Double-glazed windows are still driving the market in the U.S., but triple glazing has been gaining popularity with some energy-conscious northern builders. Is it eventually going to take over everywhere?

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Selkowitz Most of Northern Europe has already gone to triples — that's the norm. If you can get the window U-factors down to the 0.2-to-0.1 range, you're already at net zero as far as the windows go. You lose some heat on a cold winter night, but you'll make it up with solar gain during the day, even with a north-facing window that doesn't get any direct solar gain.

Under extreme conditions, triple glazing can also make sense in a cooling climate. Say you're in a place like Phoenix, where the temperature outside your window might reach 120°F. Depending on where you set your air conditioner, you could easily have a temperature difference of 50° between indoors and out. That's close to the difference you'd find on a cold winter night in a heating climate.

Mathis Triples are useful in most of Canada and parts of the northernmost U.S. In some ways, our thinking is still stuck in the energy crisis of the 1970s. The oil embargo was a huge problem in New England, where everyone heated with oil. That's why you see a lot of triple-glazed windows there now.

But in most of America, the issue is cooling. Seven of the 10 fastest growing states are in the south. People look to the Germans and the Canadians as a model for efficient windows, but that's not the situation faced in most of the U.S. Triple glazing makes the most sense where heating costs are much higher than air conditioning costs. Gas is cheap now and likely to get cheaper, but a lot of utilities are pretty much tapped out, especially in the south, so cooling costs are likely to increase a lot faster than heating costs in the coming years.

Carmody One point I'd make is that the U-factors of the best gas-filled double-glazed windows have come down to 0.28 or less, which is more or less where triple glazing used to be. That's a significant change — just a few years ago, a typical value for a good double-glazed window would have been 0.35 or so. The cost-effectiveness of going to triple isn't always there unless you're in a situation where you're trying to squeeze every last Btu out of the building envelope.

Q

What are the pros and cons of full triple glazing compared with double glazing with a suspended plastic film between the inner and outer panes of glass?

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DePaola You can put a low-E coating on both sides of a suspended film with clear glass on both sides, so you get low-E in both directions without overheating the space between the inner and outer glazing. The other big advantage to the suspended film is that it reduces weight and thickness. One reason triple-glazed windows are so expensive is that you need a thicker, stronger frame and heavier hardware. You might also need balancers to compensate for the weight, and that makes the window cost even more. If a manufacturer started cranking out suspended-film glazing units in volume, the market might eventually go to those.

Selkowitz Most European windows use full triple glazing, but there's no intrinsic reason why double glass with film can't be just as reliable. Look at laminated glass — that's a glass/polymer combination that has been around for a long time and is completely free of problems. Southwall Technologies [the only U.S. manufacturer of suspended films] used to sell the film to third parties and let them make their own glazing units, but they now have their own plant in the Chicago area.

Most films are not double-coated, but one of the advantages to film is that you can stockpile rolls of different materials and have them ready to go. That's a lot simpler than trying to inventory large amounts of glass.

Q

The NFRC rating system has obviously been very useful in providing basic information about window performance, but what other tools are out there for builders who want to go into more depth when selecting windows?

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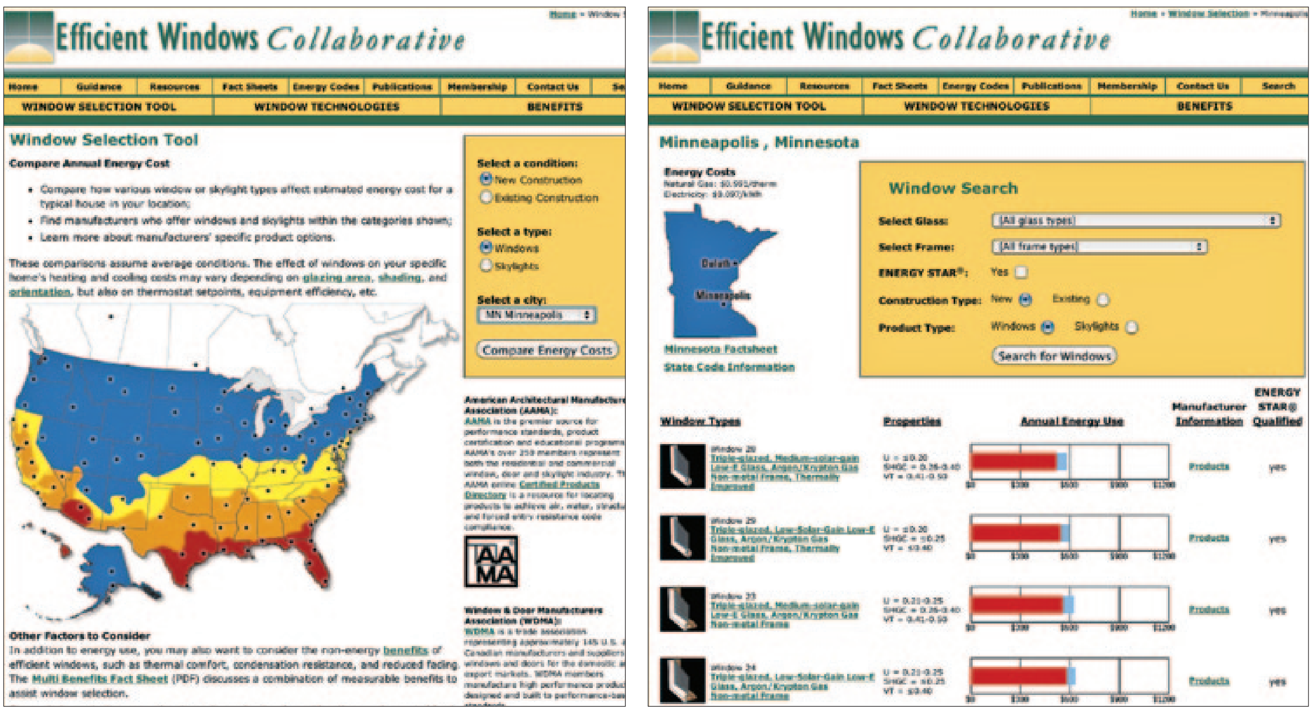
Carmody | Before the NFRC rating system was adopted 20 years ago, manufacturers could make any claims they wanted, but now windows have to be labeled and their performance is verified [see sample labels, facing page]. Assuming you know what your local code requires, the NFRC label lets you determine which windows meet it. It's a very effective system. The next layer up from that would be to select an Energy Star window.

Ideally, windows would have labels that spelled out their expected energy cost, like you see on a washing machine or a refrigerator. That's not practical because orientation, climate, and fuel costs vary so much. You can factor in all of those things with an energy modeling program like REM/Rate, but that's a lot of work, and it's more than most builders are going to want to do.

A more basic option that might take five or 10 minutes is to use the Efficient Windows Collaborative's window selection tool [see screen shots, below]. It lets you enter your location, information about the glazing you plan to use — double or triple, gas-filled or not, high, medium, or low solar gain — and select a window frame type. When you've done that, it will give you an estimated heating or cooling cost for a typical 2,250-square-foot house with a fixed number of windows. The number is going to be rough because it doesn't account for solar orientation or the actual house size, but we're just about to launch an improved version of the software that allows the user to enter more of those kinds of specifics. Once you have the energy cost estimate, you can continue to a list of manufacturers and specific products that match your window selection.

If you want to spent a little more time — maybe half an hour or so — you can use a program called RESFEN [windows.lbl.gov/software/resfen/resfen.html]. It was developed by the Lawrence Berkeley National Laboratory, and it lets you get much more specific in terms of size, orientation, shading, and the actual construction of the house. You also get more outputs, including peak heating and cooling demand. It's still not as powerful as REM/Rate, but you don't need any special training to use it.



The Efficient Windows Collaborative's window selection tool (efficientwindows.org/selection.cfm) is an easy-to-use guide for builders looking for information about the energy costs of available window options. On the landing page (left), the user specifies a city and chooses between new and existing construction. The site then provides projected annual energy costs at that location for a broad range of window types, from single-glazed clear glass in a metal frame to triple-glazed gas-filled units in thermally improved frames (right). Users can make additional selections to bring up lists of manufacturers that offer given types of windows, or to find specific products available from individual manufacturers.

U-Factor is a measure of heat transfer expressed in units of Btu/hr/ft^2/°F. The U-factor multiplied by the interior-exterior temperature difference and by fenestration product area yields the total heat transfer due to conduction and long-wave infrared radiation.

Visible Transmittance (VT) measures how much light comes through a window. VT falls between 0 and 1; a higher value means more light is transmitted.

Dynamic glazing products display two ratings that correspond to shades/blinds that are open or closed, or to electronic tinting that is on or off.

Solar Heat Gain Coefficient (SHGC) is the ratio of solar heat gain entering the space through the fenestration product to incident solar radiation. It's expressed as a value between 0 and 1.

Air Leakage (AL) indicates how much air passes through seams and gaps in a window or door assembly. A low AL (typically under 0.3 cfm/ft^2) indicates better performance.

Practically all residential windows sold in the U.S. are performance-tested under procedures established by the National Fenestration Rating Council, and carry individual labels documenting the test results. These labels provide mandatory values for U-factor, solar heat-gain coefficient (SHGC), and visible transmittance. Manufacturers can also report values for air leakage and condensation resistance, but since few of them do, many NFRC labels contain one or more blank cells. Windows that use dynamic glazing — which makes it possible to adjust light levels with integral blinds or electronic tinting — carry a modified label (above left) that lists the maximum and minimum U-factor, SHGC, and visible transmittance values.

Q What about the relationship between Energy Star, the codes, and the glass and window manufacturers? Can window performance keep getting ratcheted up indefinitely?

A **Selkowitz** That's been the great debate for the last year or two. Energy Star used to be 10% of the market, and now it's 70%. When the window and door criteria were revised in 2010, building codes in a good part of the country were already ahead of Energy Star. That put them in the absurd position of putting a premium label on windows that were worse than code.

The draft version for the 2014 version of Energy Star calls for U-factors of 0.27 in the north, down from 0.30. The numbers aren't final yet, but that's about as low as you can go without adding a suspended film or going to full triple glazing. The problem for Energy Star is that its products are required to be cost-effective. "Cost-effective" is in the eye of the beholder, but because the market isn't demanding triples, it would be hard for them to go there.

Q What kinds of new technologies can we expect to see in the next decade or so? Are there any real game-changers out there?

A **Selkowitz** There are three main areas of research right now. One is vacuum glazing, which works like a thermos bottle — you have two sealed layers of glass separated by a vacuum to reduce conductive heat transfer [see "Vacuum-Insulated Glass Takes On Triple Glazing," *JLC Report,* 10/10]. A Japanese company is already using that technology successfully outside the U.S.

A second approach has to do with ways to produce triple glazing that's thinner, lighter, and more cost-effective than what we have now. We're looking at ways to suspend a very thin, lightweight sheet of glass between conventional inner and outer panes without an extra set of spacers. We actually considered this years ago, but the thin glass was expensive and hard to find; now it's mass-produced for flat-screen TVs. We're also researching ways to bring down the cost of krypton, which is a more efficient gas fill than argon. Thin glass and krypton together could give you U-factors as low as 0.12 to 0.1 — that's R-8 to R-10 — with about the bulk and weight of double glazing today.

The third area is "dynamic glazing," using self-regulating electronic tinting or thermal blinds that open or close to keep heat in or out, depending on the conditions. We're working with a major window manufacturer on that now. The key to making that work is going to be giving the window enough onboard smarts and sensors to make the right adjustments on its own without a lot of user input.