

# What Should I Do About My Windows?

*Window retrofit decisions will be made easier with a little help from an advisory tool.*

by **Bill Mattinson, Ross DePaola, and Dariush Arasteh**

**S**hould I get new windows, repair my existing ones, or buy retrofit products? Which strategy will save me more money on my monthly utility bills and make my house more comfortable? What is the best solution for my house and my budget?

As a building professional, you're asked these questions by friends, family members, and prospective clients. They may have turned to you because the only other source of window advice for most homeowners is a sales representative with just one solution: the product he or she is trying to sell. Whether it's storm windows or insulating blinds, replacement sashes or new windows, rarely does a salesperson offer alternatives. And the projected energy savings are all too often conjured from guesses and expectations, rather than from real data or calculations.

What makes valid energy savings projections particularly complicated is the lack of energy information for existing products. Although purchasers of new windows can find National Fenestration Rating Council (NFRC) ratings for U-factor and solar heat gain coefficient (SHGC) and Energy Star labels, these testing procedures haven't been applied to old windows or to many retrofit products, so consumers have few data to help make retrofit comparisons (see "A Window Glossary").

## *Developing a Retrofit Evaluation Process*

So how can you sort through the different retrofit solutions? We've been working on an advisory tool to help homeowners and energy professionals



ROSS DEPAOLA

make smarter window improvement decisions. The tool will invoke a Web-based decision tree that will present a series of questions and then, based on the answers, offer rational solutions for a variety of existing window scenarios in both hot and cold climates. At press time, this advisory tool was still a work in progress. We hope to complete it later this year. When it is publicly available, readers of *Home Energy* and visitors to the *Home Energy* Web site will be among the first to know. In the meantime, we are giving *Home Energy* readers a sneak preview of the lessons we've learned and the information we've generated from applying the prototype tool to a retrofit project in a cold climate.

Our decision tree will help users to answer basic performance and energy-

related questions, such as these:

- What is the existing system, and how well does it perform?
- How is the proposed system expected to perform?
- Will there be significant energy savings?
- Will comfort, condensation, fading, and noise problems be improved?

Answers to these questions, tempered by the budget and personal preferences of the homeowner, can help to take the guesswork out of decision making. As with any other home improvement project, nonenergy-related considerations—for example, how long the owner intends to keep the home and what effect the changes will have on the property value—will arise that are wildcards beyond the scope of our evaluation.

**Table 1. Tested Performance Values for Several Window Retrofit Scenarios**

Case	Product	U-factor	SHGC	Notes	Inside surface glass temp. at 0°F outside
1	Single-pane wood	0.98	0.64	Unimproved single-pane	16
2	Single-pane + exterior storm (existing DePaola)	0.49	0.56	Single-pane clear glass, storm added	44
3	Single-pane + low-e storm	0.38	0.48	Hard coat low-e on storm	51
4	Single-pane + interior film	0.50	0.57	Typical DIY interior storm	44
5	Single-pane + storm + film	0.32	0.51	Add exterior + interior storm glazing	53
6	Double-pane + cellular shade	0.24	0.24	Mfg. data (not tested by us), values are with shade closed	Not available
7	Double-pane wood/vinyl clear glass	0.50	0.58	Wood or vinyl double-pane, no low-e	45
8 high	Double-pane wood/vinyl low solar low-e argon	0.40	0.54	Wood or vinyl double-pane with high solar gain low-e glass + argon	55
8 low	Double-pane wood/vinyl low solar low-e argon	0.34	0.34	Wood or vinyl double-pane with low solar gain low-e glass + argon fill	57
9	Double-pane wood + exterior storm	0.32	0.47	Wood double-pane + clear single-pane exterior storm	54
10	Double-pane wood low-e + storm	0.29	0.41	Wood low-e + clear exterior storm	58

Note: Values for cases 7–10 are typical for similar products; ask suppliers if NFRC values are available.

Answering the first question, on the performance of the existing windows, is often difficult, because information on U-factor and SHGC values of older windows is scanty. To overcome this obstacle, we used WINDOW, an NFRC simulation tool available free from Lawrence Berkeley National Laboratory (LBNL), to calculate U-factor and SHGC values for some existing windows and various retrofit scenarios (see Table 1). The effects of infiltration were bounded using standard values for tight, average, and leaky installed windows. Homeowners, builders, or product vendors should be able to use these values and plug them into RESFEN—a software program that produces annual energy simulations for homes in most parts of the United States—to make reasonable energy performance calculations and develop dollar savings estimates for retrofit strategies that they are exploring. RESFEN is easy to use and is also available free from LBNL.

### *Replacing Windows in Wisconsin*

The process of working through the window decision tool will be very similar to sorting through an actual retrofit situation that is helping to shape the tool's development: the window improvement project taking place in the 50-year-old home in Madison, Wisconsin, occupied by the family of Ross DePaola, one of our team members. Much of the information presented here should be relevant to many other older residences in northern climates as well. We reviewed many options, both to help the DePaolas and to help fill in some of the branches in our future decision tree.

Located in south central Wisconsin, with 7,863 heating degree-days and a -11°F winter design temperature, the DePaola house offers this challenge: Find an affordable way to keep it warm and comfortable in winter. The single-story, ranch style home has 1,125 ft<sup>2</sup> of living area on the main level and a 650 ft<sup>2</sup> fin-

ished basement. Insulation has been added to the ceiling and most walls. The existing gas furnace and air conditioner are capable of meeting winter and summer loads. The 224 ft<sup>2</sup> of original wood single-pane, mostly double-hung windows are still in place; these are friction sliders with no sash weights or balances. Each has an aluminum exterior storm sash added. Like many old windows, including those improved with storm sash over the years, they present a variety of problems:

- The storm glass fogs or ices up when it's cold outside.
- In winter, air falling off the cold inside surface of the windows creates cool drafts, making it uncomfortable to sit near the windows.
- The double-hungs stick and are hard to open (or won't stay open).
- Some of the double-hungs won't lock—a security concern.

With mahogany sash, jambs, and stool, the natural interior finish on the existing double-hung, wood windows is one of

the most endearing features of the home, and the DePaolas are reluctant to give up that visual element. Exterior storm windows have been in place for many years, but they don't fully protect the exterior of the painted windows from degradation by sunlight over time. And while these exterior storm windows do improve energy efficiency and extend the life of the interior windows, they are also an inconvenience. Changing the lower storm panel from glass to screen and cleaning the outside of the upper window sash are awkward.

## Considering the Options

For cold climates, there are a variety of ways to improve window thermal performance beyond that provided by the single-pane window. Each of the following alternatives fills specific needs, and homeowners must weigh the advantages and disadvantages of each. Several of the following options incorporate low-emissivity glass (see "The Low-E Scoop").

**Repair or recondition the existing window system, including existing storms.** Whether one is adding storms or insulating shades, the existing window may still need weatherstripping, caulking, reglazing, and perhaps new friction channels. Excessive moisture may have caused the existing sills to rot, and any rot should be repaired, even when installing pocket replacement windows. And of course, old windows may have lead paint, which requires special handling as lead poses a serious health risk, particularly for children. (The use of lead in paint was banned in 1978.) Do not scrape,



This ranch-style home has 224 ft<sup>2</sup> of original wood, single-pane, mostly double hung windows.

sand, or heat windows or sills that may have lead paint. Information on how to safely remove and dispose of lead paint can be obtained from the federal Environmental Protection Agency (EPA).

The costs for window repair or rehab vary depending on the condition of the windows. But even a tight, functional, single-pane window will suffer from cold glass surface temperatures, so repairing existing windows is at best a partial solution.

**Install interior insulating window treatments, such as blinds, shades, or curtains.** Interior window quilts or cellular shades can add insulation value and reduce draft—but only when they are

drawn closed. Quilted shades offer higher R-values, but honeycomb shades are more readily available and are usually easier to install and operate. Quilts and honeycomb shades can admit diffused light, but they obscure the outside view when they are drawn. The cost of these shades is low to moderate, and is partially offset by the possible elimination of other window covering costs.

Vendors state that these shades are generally chosen to enhance interior décor, rather than to save energy. Yet, if these shades are well-designed and properly installed and operated, we think the energy savings could be significant. We haven't been able to assign an annual

## A Window Glossary

**U-factor:** A measure of the rate of heat loss through a material or assembly. For windows, the U-factor is typically stated for the entire window product. The lower the U-factor, the lower the heat loss.

**Solar heat gain coefficient (SHGC):** The fraction of solar radiation admitted through a window system. For example, an SHGC rating of 0.6 means that 60%

of the available heat can make it through the product.

**Sash:** The portion of the window that houses the glass (typically the movable members of a window).

**Frame:** The fixed, outer portion of a window that holds the sash.

**Storm window:** A separate exterior window typically designed for installation over a double-hung (vertical sliding) window. A triple-track storm incorporates an operable screen. A

variation is an interior storm.

**Sash replacement kit:** A kit that includes replacement sashes, jamb liners, and containing hardware.

**Insulating glass unit (IG):** A unit consisting of two or more layers of glass separated by a spacer.

**Window parts:** Head (top), Jamb (sides), Sill (bottom), Meeting Rail (center horizontal or vertical mullion), Stool (trim piece on exterior of jamb).



ROSS DEPAOLA

The window retrofit advisory tool we are developing should make sorting through the maze of retrofit options easier.

savings to this treatment because of the huge variety of insulating shades on the market, the significant technical unknowns in evaluating shade performance accurately (no NFRC procedures or guidelines exist on evaluating these products), and the uncertainty as to how they will be used.

While insulating shades can boost comfort and reduce heating costs, they can also worsen moisture problems. Since most such shades don't seal tightly enough to block room air from contacting the window, condensation may still occur on the window glass. In fact, condensation may actually be more likely to occur on windows with shades, because the glass surface is colder than it would be if it were directly exposed to the warm room air. In some homes, this temperature difference has even caused ice to form on the interior surface of the window.

**Install interior storm sash with low-e glass.** Interior storms make the most sense when the original window still provides an effective weather barrier. An inside-mounted storm minimizes moisture migration from the house to cold window surfaces and reduces condensation. When installed with an airtight compression or

that poses storage and convenience problems. Many interior storm products are sold in hardware stores or by mail and via the Internet as frame kits only; frame cost ranges from \$1.50 to \$3.50/ft<sup>2</sup> depending on size. The consumer then purchases the acrylic glazing panels cut to size at a local plastic supply source for about \$2/ft<sup>2</sup>. Operable manufactured interior storms with vinyl frames and low-e glass are available as double-hungs, sliders, and even patio doors, but these can be expensive at up to \$20/ft<sup>2</sup> plus installation.

**Install exterior storm sash, preferably with low-e glass.** Exterior storm windows can be a sensible choice when budget constraints rule out replacement sash or pocket insert windows. If new storm windows are under consideration, products with low-e glass are recommended, because they enhance performance significantly.

One option to consider is a triple-track storm window. These windows have one track for each of the two window sashes and one for the operating screen, so that the half screen and both lower sashes can be in the upper or lower half individually or together. These products allow ventilation without demount-

magnetic-seal attachment inside the existing opening, they lessen infiltration and will also reduce sound transmission. Typically, interior storms use clear film or acrylic glazing material or glass in vinyl or aluminum frames. Some offer an upgrade from uncoated to low-e glass for an additional \$2/ft<sup>2</sup>.

If the windows are not used for ventilation, fixed storms will typically stay in place year-round. Otherwise they must be removed and stored during the warmer months to allow ventilation through the primary windows—a process

ing or seasonal replacement of panels. Triple-track aluminum storms with low-e cost about \$10/ft<sup>2</sup>, plus installation.

Low-profile fixed external storms may be preferable when it is important to maintain the original architectural style of a building with classic single-pane windows. We've found little difference between the performance of aluminum and vinyl frame storms, since the highly conductive aluminum is not continuous from inside to out.

If functional exterior storms are already in place, upgrading to new low-e storm windows is unlikely to be cost-effective. But adding new low-e exterior storms to homes with failing storm windows or none at all could both improve comfort and yield significant energy savings. For example, if the DePaola windows were still single-pane, adding low-e storms might well reduce heating bills by up to \$300 per year, if the prime sash was reasonably tight.

**Install sash kit.** If the existing frame is in good shape and especially if it has other desirable characteristics, a replacement sash kit—consisting of a new sash with low-e glass, jamb liners, and hardware—should be considered. Although sash kits are only slightly less costly than complete replacement windows, they offer several advantages:

- The visible opening is only slightly reduced.
- The kit can be installed by do-it-yourselfers with basic carpentry skills. (This is also true of replacement insert windows.)
- Low-e glass units are readily available in standard and custom sizes.
- Tilt options allow access to external storms for cleaning.

Double-hung sash kits are available in wood or vinyl from many manufacturers. One interesting variation, available in New England and a few other locations, is the Bi-Glass system. In this system, the existing sashes are removed and routed to accept insulated glass and are then re-installed with new jamb liners, weatherstripping, and locks. Low-e glass is available, and the new sash can also tilt.

If the existing windows used sash weights, be sure to insulate and weatherseal the old sash weight cavities if possible. A new sash kit with low-e glass

# Windows

1A	Single-pane	0.3 CFM	\$356	Best-case, very tight-fitting, single-pane wood windows
1B	Single-pane	1.0 CFM	\$389	Tight single-pane wood windows
1C	Single-pane	2.0 CFM	\$437	Loose, leaky single-pane wood windows
2A	Single-pane +storm	0.3 CFM	\$176	Tight single-pane wood windows with storm windows
2B	Single-pane +storm (existing DePaola)	1 CFM	\$211	Loose fitting single-pane wood windows with storms
2C	Single-pane +storm	2 CFM	\$257	Single-pane wood with storm—large air leaks
3A	Single-pane + low-e storm	0.3 CFM	\$138	Existing single-pane + low-e storm; low air leakage
3B	Single-pane + low-e storm	1 CFM	\$170	Add low-e storm, moderately tight
4A	Single-pane + interior storm	0.3 CFM	\$180	Add interior DIY storm—very tight fitting
4B	Single-pane + interior storm	1 CFM	\$214	Add interior storm—moderately tight
5A	Single-pane + exterior storm + interior storm	0.3 CFM	\$104	Add both interior and exterior storm—low leakage
5B	Single-pane + exterior storm + interior storm	1 CFM	\$135	Add interior + exterior storm—moderate air leaks
6	Single-pane + cellular shade	NA	NA	Not available—Results depend on whether blind is open or closed
7	Double-pane clear	0.3 CFM	\$178	New double-pane wood or vinyl window
8A	Double-pane hard low-e	0.3 CFM	\$137	New double-pane wood or vinyl with high solar gain low-e
8B	Double-pane low solar low-e	0.3 CFM	\$137	New double-pane wood or vinyl with low solar gain low-e
9A	Double-pane, clear glass + exterior storm	0.3 CFM	\$109	New Double-pane wood + exterior storm (tight)
9B	Double-pane, clear glass + exterior storm	1 CFM	\$141	Existing Double-pane clear wood + exterior storm (moderate leak)
10	Double-pane low-e + exterior clear storm	0.3 CFM	\$100	High solar low-e (Note: Double-pane clear window/low-e storm performance is similar.)

Note: This table accounts for heat loss and gain through windows only.

improves U-factors and with proper installation—completely upgrading the whole window frame/sash interface—can reduce infiltration through the window compared to most existing windows with storm sash. If the old storm windows are in good condition, keeping them in place will protect and add further thermal value to the new sash. Retaining exterior storms with new vinyl sash or pocket replacements may not be advisable, since vinyl may warp inside the storm in hot weather; Check with the window manufacturer to be sure.

Sash kits are comparable in cost to pocket replacement or new construction windows with the same characteristics—frame material, low-e or plain glass, air or argon. These other options are discussed below.

**Install replacement insert or pocket low-e windows within existing frame.** With insert windows, the operating sash is removed, leaving only the existing frame. A new replacement window product containing all the necessary hardware and balancers is then installed onto the frame. These products do not require the installer to “undo” the frame/siding interface.

Heavily marketed by specialty replacement window contractors but also available from many manufacturers through their dealers, vinyl, wood, or composite replacement windows with

low-e glass provide a high performance upgrade with minimum alteration to the exterior wall. When they are carefully installed in a well-maintained existing opening, energy efficiency should be comparable to that provided by a new construction window, since the replacement is manufactured as a complete frame-sash-glass-hardware package. Homeowners should be aware of the probable reduction in window area, which can diminish visible light, ventilation, and available opening. This solution offers the convenience of tilt-turn operation for cleaning.

Replacement windows are available in custom and stock sizes, sliders, casements, and patio doors, with high or low solar gain low-e glass and argon gas fill options. Vinyl replacement inserts have gained a large share of the storm window market in recent years with energy performance very similar to that of wood and composite products. As with sash replacement kits, try to insulate and seal the old sash weight cavities whenever possible.

Homeowners with the necessary skills might want to consider purchasing and installing their own replacement windows. Others may find that employing an experienced general contractor with remodeling experience may be less costly than hiring a window replacement specialty firm that depends on high-volume sales and heavy

marketing directly to consumers. Pocket replacements can cost from several hundred dollars to a thousand or more per window, depending on product features, installation costs, and profit.

**Replace with a new low-e double or triple-glazed window and frame.**

A new construction window may be called for if the original window frame is in poor condition or the new window is to be a different size than the existing opening. For homes with wood siding and original windows installed with nailing flanges, it's relatively easy to cut back the siding, remove the original frame and sash and install a new window in the same opening. A new construction window may look less bulky from inside or out when compared with a replacement installed within the original frame. New windows are most often installed by contractors or window specialists and may cost a bit more than replacements; how much more depends on the existing conditions and on the construction of the replacement windows.

*Evaluating the Choices by the Numbers*

Any of the retrofits described above may be appropriate, depending on the condition of the existing windows, heating costs, aesthetic considerations, budget constraints, and product availability. While

## The Low-E Scoop

All low-e coatings reduce heat transfer by blocking long-wave radiant energy. For the DePaolas and anyone in a cold climate, low-e coatings help keep heat inside the house when it is cold outside. There are two general types of low-e coating. High solar transmittance coatings admit most solar radiation. Low solar transmittance coatings block almost all the near-infrared solar heat while admitting about 90% as much visible light as the high solar products, resulting in a decrease in solar heat gain of 40%.

These two classes of low-e coating are also distinguished by their application process. A high solar coating is generally applied pyrolytically—that is,

it is sprayed onto the surface of near-molten glass as it comes out of the furnace. Low solar coatings typically are sputtered near room temperature in a vacuum environment. Low solar low-e can greatly reduce solar heat gain and cooling loads in air conditioning climates. If cooling is not a problem, high solar low-e will admit more beneficial winter sun and may be preferable.

One more consideration when selecting low-e products: The lower the emissivity of the coating, the better it blocks radiant heat transfer. When selecting between new window products, look at the NFRC certified U-factors. These factors take into account the impacts of lower emissivities. When looking at retrofits involving storm windows, which

are not yet covered by NFRC, you will need to look at the coating emissivity. Pyrolytic high solar low-e have emissivities that range from as high as 0.3 to as low as 0.15.

Although low-e coatings can be installed on plastic films encased between layers of glass, the low-e coatings applied to storm windows and replacement or new construction windows are only available on glass, not on plastic film or sheet material. The low-e coating on interior and outside storm windows is always the pyrolytic high-gain type. Pyrolytic low solar gain coatings are just emerging on the market. Because sputtered coatings should not be exposed to moisture, they are only applied to an inner surface in a sealed insulating glass unit.

# Windows

Improving their home's efficiency and comfort was important to the DePaola family, but so was preserving the appealing, naturally finished mahogany frames of their existing windows.

many window retrofits will be made regardless of whether they save energy ("I just can't stand these old windows for another winter"), economic comparisons are important to any decision-making process and relatively easy to develop—if a window's performance values are known.

The U-factor and SHGC values that we calculated using WINDOW are necessary to predict heat flow through the window assembly, but they don't offer any direct indication of potential comfort. Since we believe most window retrofits are motivated by a desire for improved comfort as well as energy savings, we include in Table 1 the inside glass surface temperature calculated by the WINDOW software. The temperature shown is for the center of glass at the room side surface when the outdoor air is at 0°F and the indoor air is at 70°F.

Even when the inside room temperature is comfortable, our bodies experience discomfort in a room with cold window surfaces. ASHRAE Standard 55 predicts discomfort at an 18°F difference between air temperature and window surface. Recent research suggests that to maintain comfort, the difference should be even lower, particularly as window areas increase and if people are relatively close to the windows.

At the worst-case single-pane window scenario, glass-to-room air temperature differences of 50°F or more will magnify the radiant discomfort by convective air movement as room air is chilled by the cold glass and spills into the room. In such cases old single-pane windows will create a draft even when the wind isn't blowing.

Of course, lower U-factors are like higher R-values and yield less heat loss. Low SHGC values will admit less solar heat, reducing cooling loads but they also block solar heat gain in winter when it might be beneficial. The values shown above, like all NFRC ratings, are based on the whole product, not just center of glass. Ask the vendor for the specific NFRC values of replacement or new windows you are considering—they may vary from the numbers we used.



ROSS DEPAOLA

## Using RESFEN

Once homeowners have acquired realistic performance data on window retrofit products, they'll want to establish the potential savings for their own home. We used RESFEN, a computer tool for calculating the heating and cooling energy use in homes in many North American locations. RESFEN employs a simplified version of the DOE-2.1E energy analysis simulation program to calculate heating and cooling energy usage and costs as well as peak demands.

RESFEN takes just seconds to calculate each window option, making it possible to compare many different retrofit products in a very short time. The building features are limited to just a few categories—new or existing, several foundation types, and gas or electric heating. Though these may not exactly match the specifics for every home, the

user does enter actual house size and location, energy costs per kWh or therm, as well as area, U-factor, SHGC, and infiltration for windows on each of the four cardinal orientations.

RESFEN reports the annual heating and cooling cost for the whole house and for the windows alone. We looked at the window energy costs for our comparisons (see Table 2). The RESFEN default infiltration value is set at 0.3 CFM/ft<sup>2</sup> of window, realistic for new windows but probably optimistic for existing windows, although it may be reasonable for tight windows with storms installed. We estimated the DePaola windows at 1 CFM/ft<sup>2</sup>. For the single-pane and storm window examples, we repeated the RESFEN runs at 0.3, 1, and 2 CFM/ft<sup>2</sup> to determine the impact of infiltration on the results. The results for the DePaola existing case show \$211 annual heating and cooling cost attribut-

able to the windows, which RESFEN calculates by comparing the performance of the house as described to the performance of a similar house where the windows are replaced by a wall.

Interestingly, a window salesman visited the DePaola house recently and predicted at least \$200 per year savings with his new double-pane low-e vinyl pocket replacement windows, and he encouraged the DePaolas to remove their “useless” storm windows. We hope that *Home Energy* readers will be able to use the methods described here to arrive at more realistic predictions.

### *Making the Decision*

For the DePaola family, saving money is a prime consideration in deciding how to upgrade their windows; solving comfort, convenience, and maintenance problems are also key. From the RESFEN calculations, the DePaolas learned that they probably won't be saving as much money on their utility bills as some replacement window vendors had figured. Their annual window energy costs are currently about \$211, and the best-case retrofit saves them about \$100 a year at current rates. Obviously none of these improvements is going to pay for itself overnight in energy savings, but the potential to greatly increase comfort with warmer glass temperatures adds strong motivation to proceed with a retrofit.

Here's how the DePaolas rated each retrofit alternative for their home:

**Repair existing windows.** If they didn't do anything else, they would definitely tighten up the existing windows and improve their operation. But because this wouldn't reduce their cleaning and maintenance problems, they've decided to go beyond this choice.

**Install insulating shades.** These shades don't solve the DePaolas' convenience and maintenance problems, and the DePaolas don't find them visually appealing, so they rejected this option.

**Install interior storm sash.** They rejected this choice because the existing windows are not weathertight, so exterior storms are still needed. The combination of interior and exterior storms with the existing windows might reduce condensation, and it would be relatively inexpen-

sive, but it would make cleaning and maintenance more inconvenient and it would reduce ventilation options.

**Install exterior storms.** Replacing their existing storms with new triple-track low-e products and rehabilitating the existing windows would improve comfort, slightly reduce heating costs, and possibly diminish condensation. But the initial cost doesn't return enough convenience, savings, or added property value to appeal to the DePaolas, so they rejected this choice.

**Install sash kit.** This is the solution that is most appealing to the DePaola family. New wood tilt-turn sash with low-e glass satisfies all four of the criteria they've set for their window upgrades. Ross is hoping to install the sash himself and will most likely leave his existing exterior storms in place. They intend to stay in this home, and believe that the enhanced comfort and convenience provided by this upgrade is worth the investment. The DePaolas would like to install high solar gain low-e glazing on the south windows to maximize winter solar heat contribution. They prefer low solar gain low-e glass on the remaining windows.

**Install replacement insert windows.** This upgrade would be similar in cost and efficiency to installing the sash kit. But the reduction in total glass and ventilation area ruled out this choice.

**Install new windows.** The DePaolas rejected this choice because they wanted to preserve the original wood frame and trim, and because the condition of the existing frame does not warrant replacement.

### *What Would You Do?*

Finding the right window retrofit solution isn't easy, and while most people want to know how much energy and money the retrofit will save them, the decision won't always be based upon these factors. Comfort, convenience, appearance, and budget all play major roles. Our Wisconsin example describes a process that we hope you, the building professional or concerned homeowner, can build upon when considering a window project of your own.

Our next project is to look at window options in a hot cooling climate, probably

starting with another actual home that has real problems. We'll work through a number of retrofit strategies, weigh their pros and cons, and calculate the potential energy savings of each. Eventually we hope to combine what we've learned into a decision tool that helps you evaluate the options and make wiser choices in almost any U.S. climate. Meanwhile, we'd love to learn more from your experience. Please contact us to let us know about problems you've encountered and solutions you've found, as well as to point out anything we might have overlooked here.



*Bill Mattinson heads SOLDATA Energy Consulting, based in Santa Rosa, California. He designs and delivers energy-efficient window product trainings to the building industry. He can be reached by e-mail at [billm@soldata.com](mailto:billm@soldata.com).*

*Ross DePaola is an NFRC-accredited simulator for WESTLab in Madison, Wisconsin, and Wisconsin's Energy Star windows coordinator. He can be reached by e-mail at [rdwestlab@aol.com](mailto:rdwestlab@aol.com).*

*Dariush Arasteh is a staff scientist at the Windows and Daylighting Group at Lawrence Berkeley National Laboratory. He can be reached by e-mail at [d\\_arasteh@lbl.gov](mailto:d_arasteh@lbl.gov).*

### **For more information:**

To learn more about the window-related software available on LBNL's Web site, visit <http://windows.lbl.gov/software>. To use RESFEN, visit <http://windows.lbl.gov/software/resfen/>.

For a more extensive glossary of windows-related terms, visit [www.efficientwindows.org](http://www.efficientwindows.org).

The federal EPA publishes several lead safety brochures. They can be downloaded as PDF documents from the EPA Web site at [www.epa.gov/opptintr/lead/](http://www.epa.gov/opptintr/lead/).

### **Acknowledgements:**

The authors wish to thank Chris Yost, an experienced builder, for his invaluable contributions to this article.