Rocky Mountain Institute's **Home Energy Briefs**

#1 BUILDING ENVELOPE

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The term *building envelope* refers to your home's walls, roof, windows, and foundation, which shield your living space from the elements. The typical family can spend as much as $680 per year to heat and cool its home.[1] This expense is *not* necessary even in extreme climates and can be reduced by up to 50 percent through investment in building envelope improvements such as sealing air leaks, adding adequate insulation, and upgrading window features.[2] These measures will save you energy by keeping your home warmer in winter and cooler in summer. Once your home is sufficiently sealed, you can downsize your existing heating or cooling system or switch to low-energy alternatives to save even more money (see *Home Energy Brief No. 3: Space Cooling* and *No. 4: Space Heating*). An effective building envelope provides additional services, such as blocking outside noise, protecting your home's structure from weather, and increasing indoor air quality.

Other titles in Rocky Mountain Institute's **Home Energy Briefs** include:

No. 1	Building Envelope
No. 2	Lighting
No. 3	Space Cooling
No. 4	Space Heating
No. 5	Water Heating
No. 6	Cleaning Appliances
No. 7	Electronics
No. 8	Kitchen Appliances
No. 9	Whole System Design

This Brief guides you through building envelope improvements by covering the following topics:

- Understanding **how your home loses and gains heat** in hot and cold weather;
- **Insulation** of your attic, walls, and foundation;
- **Sealing air leakages** and weatherproofing your home; and
- **Window improvements**, such as adding storm windows or replacing panes and frames.

HEAT LOSS AND HEAT GAIN

Heat naturally flows from warmer objects to cooler objects via the processes of *radiation*, *convection*, and *conduction*. ***Radiation*** of heat from objects takes the form of electromagnetic waves that travel through space. You may be familiar with radiant energy from the sun, and its effect on your building envelope. A dark roof on a hot sunny day will absorb 70–90 percent of the sun's energy and re-radiate this into your home. Without adequate attic ventilation or insulation this heat gain can add 40 percent to the cooling load on your air conditioner.[3] In cold weather, if you are standing in a poorly insulated room or near a window, heat radiates from your body to the colder space, making you feel cold and prompting you to turn up the thermostat.

The movement of a fluid such as air is called ***convection***. Convection is the driving cause of air leakage through seams, cracks, and other openings in your building envelope. Typically warmer air flows upward through your attic or chimney, pulling cooler air in from the basement and in through gaps around windows and doors. Sealing air leakages also helps prevent moisture infiltration, inadequate ventilation, and makes living spaces draft-free. ***Conduction*** is the transfer of heat through a solid object, from its warmer side to its cooler side. Glass objects (such as windows) and metal are good conductors of heat and bad insulators, whereas foam and fiberglass make poor conductors and thus good insulators. ***R-value*** is a measure of a material's resistance to heat transfer by conduction—the higher the R-value, the better its insulating properties.

INSULATION

Proper insulation of your building envelope will stem the flow of heat from your home to the outside. Determining if your insulation is adequate depends on a number of factors: where it is installed,

For additional information, as well as a downloadable version of this document, please see our website: www.rmi.org

This document was last updated: 12/3/04

how it is installed, and what and how much material is used. This section will show you how.

What kind of insulation do I have?

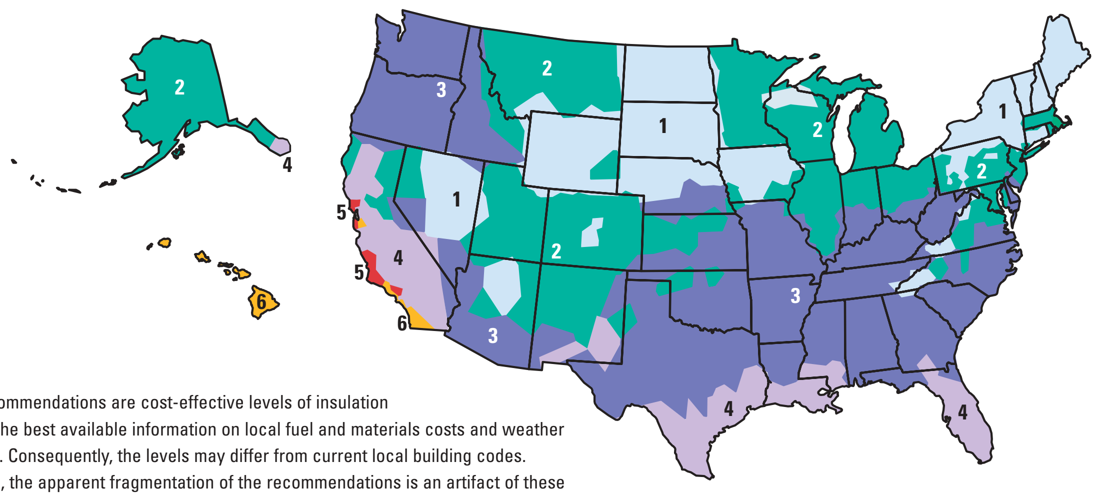
Look in the attic, exterior walls, and basement, and document the type and thickness of insulation you have by using the "Properties of common insulation materials" in Table 2 (see p. 4). It can be difficult to see insulation in finished walls and areas; two simple ways to access it are to remove a power outlet cover or to drill a hole in a closet or hidden area. Then calculate the R-value using the table and simply adding R-values for each additional inch of material. Alternatively you can contact a local building professional who might use infrared technology to give you an accurate reading of your insulation's effective value. The U.S. Department of Energy (DOE) Insulation Fact Sheet provides further guidance (see www.ornl.gov/sci/roofs+walls/insulation).

How do I evaluate the benefit of adding more insulation?

The decision on whether to further insulate your home depends on your climate, your budget, and the savings you'll realize in energy bills. The DOE has a tool online

Table 1: Recommended R-values for homes

U.S. Department of Energy recommended* total R-values for new construction houses in six insulation zones



* These recommendations are cost-effective levels of insulation based on the best available information on local fuel and materials costs and weather conditions. Consequently, the levels may differ from current local building codes. In addition, the apparent fragmentation of the recommendations is an artifact of these data and should not be considered absolute minimum requirements.

					Ceiling						Basement	
ZONE	Gas	Heat pump	Fuel oil	Electric furnace	Attic	Cathedral	Wall (A)	Floor	Crawl space (B)	Slab edge	Interior	Exterior
1	✔	✔	✔		R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
1				✔	R-49	R-60	R-28	R-25	R-19	R-8	R-19	R-15
2	✔	✔	✔		R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
2				✔	R-49	R-38	R-22	R-25	R-19	R-8	R-19	R-15
3	✔	✔	✔	✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
4	✔	✔	✔		R-38	R-38	R-13	R-13	R-19	R-4	R-11	R-4
4				✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
5	✔				R-38	R-30	R-13	R-11	R-13	R-4	R-11	R-4
5		✔	✔		R-38	R-38	R-13	R-13	R-19	R-4	R-11	R-4
5				✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
6	✔				R-22	R-22	R-11	R-11	R-11	(C)	R-11	R-4
6		✔	✔		R-38	R-30	R-13	R-11	R-13	R-4	R-11	R-4
6				✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10

(A) R-18, R-22, and R-28 exterior wall systems can be achieved by either cavity insulation or cavity insulation with insulating sheathing. For 2" x 4" walls, use either 3.5" thick or 3.5" thick R-13 fiber glass insulation with insulating sheathing. For 2" x 6" walls, use either 5.5" thick R-21 or 6.25" thick R-19 fiber glass insulation.

(B) Insulate crawl space walls only if the crawl space is dry all year, the floor above is not insulated, and all ventilation to the crawl space is blocked. A vapor retarder (e.g., 4- or 6-mil polyethylene film) should be installed on the ground to reduce moisture migration into the crawl space.

(C) No slab edge insulation is recommended.

Source: Department of Energy, www.eere.energy.gov/consumerinfo/energy_savers/r-value_map.html that can help you decide (see Table 1). If the DOE recommended R-value is substantially greater than what you have in your home, you can be sure that insulating is a worthwhile investment. Where your insulation is already adequate, adding more insulation may not be the best investment.

There is no simple formula to determine what you will save by adding insulation (check out the DOE energy savers calculator at www.eere.energy.gov/consumerinfo/factsheets/ea3.html). However, if you have high heating and cooling bills, then improving your insulation will pay for itself over time. If you heat with gas or oil, or use air conditioning, the payback period will be about five years; if you heat with an electric furnace or baseboard heating, the payback period will be shorter.

What insulation materials should I use?

Your selection of insulation will depend on cost, where you add the insulation, environmental considerations, and the insulation's R-value. Table 2 (see next page) describes the key properties of common insulation material.

Is it safe?

The environmental and health impacts of insulation materials vary, and those need to be weighed against insulation benefits. Green insulation, such as cotton batting, sheep wool batting, and insulation made from recyclables, such as cellulose and slag wool, are readily available. Note that production of most foam and polystyrene materials emits chlorofluorocarbons (CFCs) that deplete the ozone layer, and materials in fiberglass and mineral wool can be carcinogenic. For further guidance on green insulation choices, contact the North American Insulation Manufacturer's Association (www.naima.org).

What does it cost?

In general, adding insulation to your home is a cost-effective measure, especially considering the additional benefits of indoor air quality, reduced noise, and protecting your building structure from the weather. Insulation can cost anywhere between $0.40 and $2.00 per square foot. You may also have to factor in installation costs.

Where should I insulate?[4]

The attic is generally a top priority because it is easy to insulate and insulating it provides immediate benefits. If there is no floor in the attic, simply add more insulation. If existing insulation comes to the top of the joists, add an additional layer of unfaced batts across the joists. If an attic floor is in place, you may need to remove the floor before adding insulation (be careful not to step through the ceiling below!). A full twelve inches of cotton, wool, fiberglass or cellulose insulation is cost-effective in most parts of the United States.

If the attic is finished with a sloped cathedral ceiling, adding insulation is more difficult and you might need to hire a contractor. This is because adding insulation above a sloped cathedral ceiling involves installing rigid material to the top of the roof and then re-roofing. However, the investment is expensive and you may prefer to focus your efforts elsewhere.

Insulating walls can be expensive. However, walls constitute the largest surface area of a building envelope, and their insulating characteristics have a significant impact on heat loss and gain. Your best option is to hire an insulation contractor to blow cellulose or fiberglass into the walls. Most people don't realize that up to 20 percent of home heat is lost through uninsulated foundations, which can cause heating bills to be very high, especially in northern climates. If the basement or crawl space is unheated and will remain that way, you can insulate between the floor joists with unfaced batts supported by wire or metal rods if necessary. Cover the underside of the joists with a moisture-permeable air barrier. If using faced batts, staple them into place and allow the facing to provide the air barrier. In crawl spaces, cover the ground with 6-millimeter thick polyethylene to keep ground moisture from getting into the crawl space. If the basement is heated and used, insulate the basement walls instead. The simplest method is to build two-by-four-inch or two-by-two-inch wooden frames against the concrete foundation walls, pack them with rigid insulation, and cover them with drywall. You can learn how to do this effectively by consulting a good do-it-yourself manual, or you can hire a contractor.

Did you know?

In southern parts of the United States, attics can reach 120º Fahrenheit. A radiant barrier typically stapled on the underside of rafters or top of ceiling joists can magnify the benefits of insulation and reduce heat gain by 7 to 21 percent.

Table 2: Properties of common insulation materials

Type	Materials	R-value/inch	Installation method	Where applicable	Characteristics
loose-fill	cellulose fiberglass mineral wool	3.1–3.7 2.5–4.0 2.4–4.0*	Blown into place by machine	Finished walls. Unfinished attic floors and hard to reach places. Enclosed cavities	Generally installed by contractor. Skilled do-it-yourselfer can rent a machine to blow in loose cellulose. Easy to use for irregularly shaped areas and around obstructions
blankets or batts	fiberglass mineral wood	3.1–3.4 3.1–3.4 4.0**	Fitted between studs, joists, and beams. Some may be formed in place	All unfinished walls, floors and ceilings	Suited for do-it-yourself. Suited for standard stud and joist spacing that is relatively free from obstruction. Comes with or without vapor retarder facing. If used with facing, vapor retarder must be on the side toward the inside of the house
rigid board	expanded polystyrene (beadboard) extruded polystyrene (colored styrene) polyisocyannurate (foil faced) rigid fiberglass	3.5–5 5 5.4–7.5 4.2	Rigid board insulations are typically cut to fit and glued, caulked, or mechanically fastened into place. Polystyrene must be covered with 1/2-inch sheet-rock for fire protection	All used on exterior sheathing or basement interior walls. May be used below grade (the exterior or interior of foundation walls). Also used on flat roof and cathedral ceiling	
spray-in insulation and high-density blown-in products	cellulose fiberglass mineral wool polyurethane	3.2–3.7 3.2–4.1 3.4 5.4–7	Spray applied to surfaces. Spray applied behind a net facing. Also can be blown into cavities	Walls Ceilings Other enclosed cavities such as flat roofs	40° or above for 72 hours after application. Specifically formulated polyurethane may be applied at temps below 40°F
reflective	aluminum foil (single sheet and multiple sheet)	Varies depending on heat flow direction.	Staple to studs or joists	Floors and walls	Works best when heat flow is downward (i.e., in floors). Air space between foil and adjacent surface is essential for performance
others	perlite vermiculite polystyrene beads urea formaldehyde air entrained cement other foam plastics	Approximately 4 or more, depending on product	Pour into place Contractor installed	Pour-in products are not as readily available as other insulation systems. They also allow for considerable air movement, thus reducing their performance. Urea formaldehyde is not recommended for residential applications	Suited for do-it-yourself. Perlite, vermiculite, and polystyrene beads are expensive and have lower R-value than other types of insulation. Vermiculite contains asbestos

* Note: at extreme winter temperatures, R-values of fiber glass and mineral wool loose-fill insulation may be reduced.
** For high density fiberglass and mineral wool.

Source: Minnesota Department of Commerce Home Insulation fact sheet, p. 8, www.state.mn.us/mn/externalDocs/Commerce/Home_Insulation_110802040945_HomeInsulation6-04.pdf

Insulation installation tips:

- Keep in mind that for insulation to work effectively, it must be a continuous layer of material with no gaps, cracks, or air bypasses. Consult a good do-it-yourself manual or hire a reputable contractor to ensure the job is done properly.
- Note that if insulation is installed incorrectly it will lose its effectiveness, regardless of the R-value. Do not squeeze batts to fit into a space and make sure that blown-in insulation is the right depth.
- Do not leave gaps around openings for pipes, wires, and other utilities, and remember that you should not cover electrical equipment.
- Make sure you take proper health and safety precautions!

SEALING AIR LEAKS

The U.S. Department of Energy estimates that air leakage can add 10 percent to your annual energy bill.[5] This equates to about $70 per year for the average home. Your first priorities should be the attic and basement, as this is where air pressure is strongest and leakage is the most prevalent. This section shows you what to do.

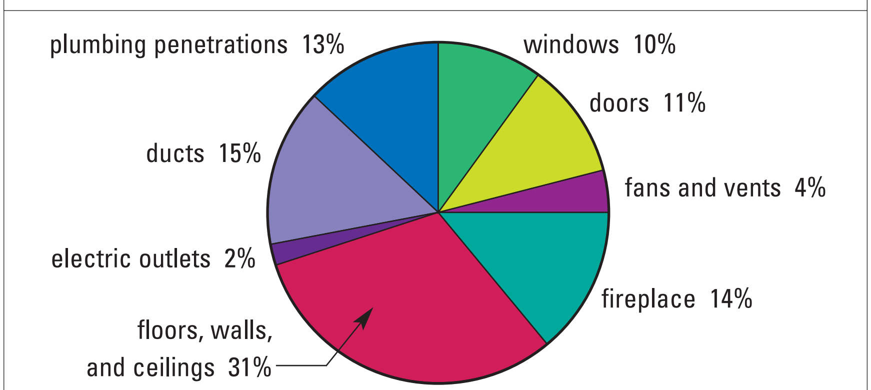
Do I have an air leakage problem?

You can find air leakage points by holding a lit incense stick or piece of string near doors, windows, vents, and other seams or openings. Drafts will become apparent as the incense or string moves with the air current. You should mark these points with chalk and determine if *caulking* (the sealing of spaces in non-moving surfaces, such as gaps in walls around ducts and electrical outlets) or *weatherstripping* (the sealing of the edges of moving surfaces like windows and doors) is required. For best results choose a cool, windy day and turn on exhaust fans, the furnace, and the clothes dryer. This will draw air out of the house and prompt outside air to come in at leakage points and replace it. Your local utility or building contractor might also offer a blower door test. This typically costs $50–200 and uses infrared technology to pinpoint air leakage locations while pressurizing your home with a blower door.

How do I fix air leakage problems?

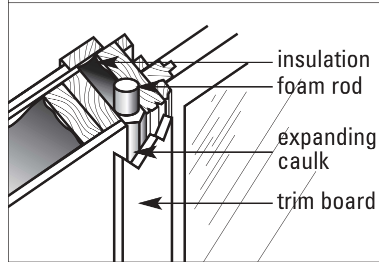
The cost of air sealing measures in new and existing homes ranges from $100 to $600 per house.

Figure 1: Sources of air leaks in homes
How does the air escape? Air infiltrates through every hole, nook, and cranny. About one-third of this air infiltrates through openings in your ceilings, walls, and floors.



Source: DOE *Energy Savers* booklet, p. 9. www.eere.energy.gov/energy_savers

Figure 2: Caulking windows and doors



Source: Adapted from Minnesota Department of Commerce Caulking and Weatherstripping fact sheet, p. 7, www.state.mn.us/mn/externalDocs/Caulking__Weatherstripping_110802035458_Caulk&Weather05-03.pdf

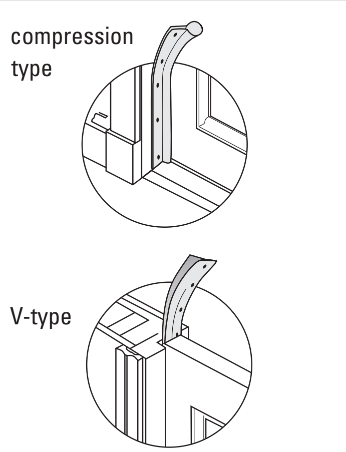
The low end of this range includes do-it-yourself options, while the upper end includes blower door testing and the labor of experienced professionals. Caulking and weatherstripping materials are available at hardware stores. Here are some guidelines for the more complicated do-it-yourself sealing options:

Caulk is best for cracks and gaps less than about one-quarter-inch wide. Expanding foam sealant is good for sealing larger cracks and holes that are protected from sunlight and moisture, and backer rod or cracker filler, which is another foam material, is sold in one-quarter to one-inch-wide coils for sealing large cracks and providing backing in very deep cracks that are then sealed with caulk.

The first task is to seal seams and gaps in the basement. You can prevent drafts along the floor by caulking along the sill and rim joist. Where there are large openings, such as plumbing chases and attic hatch covers, you can use wool, cotton, or cellulose insulation wrapped in plastic instead. The second task is to seal around windows and doors. The space left around these fixtures after installation can be a major source of air leakage. Often insulation is simply stuffed into cracks. While this might insulate a home, it often does not stop airflow. Figure 2 shows you what to do. If windowpanes are loose in their wood frames you can caulk using putty compounds. Glass panes in metal and vinyl frames are best sealed with vinyl strips. You can also seal window edges and cracks easily with rope caulk. Don't forget to also caulk around the chimney and electrical and duct outlets.

Weatherstripping is an effective way to cut air leakage through windows and doors. It does not affect opening and closing mobility and it is unseen. As shown in Figure 3, the type of weatherstripping you use depends on the window. Compression type weatherstripping and V-strip weatherstripping are widely available in building supply stores. There are two ways to weatherstrip the bottom of doors: one, by replacing a threshold, and two, by attaching a door bottom or sweep. Thresholds are generally installed to replace existing worn out ones, for example, where the vinyl or rubber weatherstripping is defective. Door bottoms or sweeps are usually installed in doors with no existing sill to provide a positive seal against air movement.

Figure 3: Weatherstripping



Source: Adapted from American Council for an Energy-Efficient Economy, *Consumer Guide to Home Energy Savings*, 7th edition, p. 9

What about proper ventilation? Sealing air leaks helps prevent winter moisture problems and structural damage. When warm air hits a cold surface, condensation can occur causing water or frost damage and the growth of mold and mildew. This is most notable in air pockets, cracks, and gaps in uninsulated or poorly insulated walls and windows, and in spaces between walls and ceilings. However, if you seal your home too tightly you may not have enough airflow to supply certain devices (like furnaces, boilers, and clothes dryers) with adequate air or enough airflow to exhaust airborne pollutants to the outside. Here are some rules of thumb for proper ventilation (for more information see the resources list or contact a local professional):

- Install exhaust vents near humidity sources in kitchens and bathrooms;
- Ensure all fuel-burning appliances have an adequate air supply and vent to the outside; and
- Ventilate your attic with gables and soffit vents.

WINDOWS

Windows make up 10 to 30 percent of the exterior wall area of a typical home and, along with doors, can contribute up to 30 percent of heat loss and gain. Heat is lost through windows by direct conduction through the glass and frame, by air leakage through and around the window assembly, and by radiation of heat by room-temperature objects, such as people and furniture (in hot weather the process works in reverse). There are many options for improving the efficiency of your existing windows, ranging from caulking and weatherstripping to replacing parts of the window. This section shows you how.

What type of windows do I have?

Nearly half of the windows in the United States are uncoated single pane windows and almost all the remaining windows are uncoated double pane (or double glazed) windows.[6] Uncoated single pane windows do little more than keep wind from blowing through the structure; uncoated double pane windows are regarded as a minimum requirement for residential construction in hot climates. The most common window frames are aluminum, vinyl, and wood.

Should I invest?

If your windows are in good shape, it will be cost effective to boost their efficiency by weatherstripping and caulking (see Sealing Air Leaks above), fitting them with insulating

A window glossary

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

Pane
A framed sheet of glass within a window.

Sash
The portion of the window that houses the glass (typically the movable parts of a window).

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

Window parts
Head (top), jamb (sides), sill (bottom), meeting rail (center horizontal or vertical mullion), stool (trim piece on exterior of jamb).

> **Did you know?**
> A study on window-heating in Madison, Wisconsin found that single pane windows had a heating cost of $356, double pane windows cost $178, and double pane windows with low-e and exterior storm panels cost $100. The most energy efficient option provided a 200 percent decrease in window-heating bills![7]

storm panels, and installing insulating curtains and blinds. If your windows have rotted or damaged wood, cracked glass, locks that don't work, or poorly fitting sashes, then you can replace various parts with energy-efficient ones.

New window?

Due to high product and installation costs ($465 per window or $5,000–$20,000 for a typical home), replacing whole window units is, generally, only recommended for new construction or major remodeling projects. However, if you are purchasing a new heating or cooling system, or have a high number of heating or cooling days, then it may be a cost-effective option. For more information, look at Table 4 (see p. 9) for features of energy efficient windows, refer to the resources list, and also check out *Home Energy Brief No. 9: Whole System Design*.

Where existing windows are in good condition

Insulating blinds, **shades**, or **curtains**.[7] 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 view when they are drawn. The cost of these shades is low to moderate, and can be partially offset by the elimination of other window coverings such as storm windows or awnings. The rule of thumb is to keep curtains and blinds closed during the night in winter and on hot sunny days in summer. Also look for ones that fit into tracks to keep air from passing around the edges, which is a primary cause of condensation.

The simplest type of **storm window** is plastic film taped to the inside of the window frame.[8] Such "storm windows" typically cost $3–8 per window, last one to three years, and are available from your local hardware store. These films are especially suitable for apartments where exterior improvements may not be possible. Removable or operable storm windows with glass or rigid acrylic panes are also available for interiors and exteriors, and are more suitable if you plan to stay in your home for a few years. Make sure you purchase one with air leakage rates lower than 0.3 cubic feet per minute per foot (cfm/ft) and with low-e coatings on the glass (or plastic) pane to improve the energy performance (see window glossary, on p. 6, for a description of terms). These types of storm windows typically cost $50–120 depending on size, quality, and the labor required for installation, and come in wood or aluminum frames. Table 3 (see next page) outlines the benefits of several different window and frame scenarios.

Where windows are not in good condition

When improving the efficiency of your existing windows, you need to know how windows are rated and the features of energy efficient replacement parts (sash, frame, glass, etc.). Table 4 provides a summary of components that will need to be considered. When you are purchasing new window products also look out for industry certified National Fenestration Rating Council (NFRC) labels and the U.S. Environmental Protection Agency certified Energy Star® labels.

There are several options when replacing parts of your window, and these are set out (below) in order of cost. Note that the third option involves replacing the whole window unit:[9]

1. Install new sash kit. If the window frame is in good shape and has other desirable characteristics, such as quality material or aesthetics, consider a replacement sash kit. Sash replacements are ideal for double hung windows with worn out sashes that do not operate smoothly, will not shut tight, have been nailed or painted shut, or simply look old and worn. As long as the frame is solid and in good condition, the sash can be replaced without disturbing the frame or the original trim.

Also, low-e glass units are readily available, the kit can be installed by anyone with basic carpentry skills, and tilt options are available to allow access to external storm windows when cleaning. The cost range is $250–400 per window.

2. Install replacement insert low-e windows within existing frame. With insert windows, the operating sash is removed, leaving only the existing frame. A new replacement window containing all the necessary hardware and balancers is then installed into the frame. These products do not require the installer to "undo" the frame/siding interface. Sashes and frames are available in vinyl, wood, or a composite of materials; and panes are available in low-e glass and filled with argon. When they are carefully installed in a well-maintained existing opening, their insulating characteristics should be comparable to that of a new window. Note there may be a reduction in window area, which can reduce light and ventilation. Such pocket replacements (inserting, or pocketing, an energy efficient, maintenance-free *window* into your existing *window frame*) can cost from several hundred dollars to a thousand or more per window, depending on product features and installation costs.

3. Replace with a new low-e, double- or triple-glazed window and frame. A new window may be called for if the original 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 with nailing flanges, it's relatively easy to cut back the siding, remove the original frame and sash, and install a new window. A new window may look less bulky compared to 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 requirements of the project. Expect to pay $400–600 per window, not including installation.

Table 3: Tested performance values for several window retrofit scenarios

Case	Product	U-factor	SHGC	Notes	Inside surface glass temp. at 0ºF 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

Source: *Home Energy Magazine* July/August 2002, Feature article. www.homeenergy.org/19-4.htm

Table 4: Energy efficient windows features[10]	
Whole-window	
Feature	**Description**
U factor	Indicates how well a product prevents heat from escaping. Ratings are usually between .20 and 1.20. The lower the U-value, the better its insulating characteristics. Refer to the Energy Star website to determine the best rating for your climate (www.energystar.gov/index.cfm?c=windows_doors.pr_tips_windows)
solar heat gain coefficient	Describes how well a product blocks heat created by sunlight. Coefficient "ratings" are between 0 and 1. The lower the number, the less solar heat a product transmits. Refer to the Energy Star website to determine the best rating for your climate (www.energystar.gov/index.cfm?c=windows_doors.pr_tips_windows)
visible transmittance	The amount of light that comes through a product. Ratings are between 0 and 1. The higher the number the more light is transmitted
air leakage	The number of cubic feet of air passing through a square foot of window area per unit of time. The lower the number, the less air will pass through cracks in the assembly. Better windows have leakage rates in the 0.01–0.06 cfm/ft range
Window glass [a 3 x 5 ft casement window can cost $200–350]	
Feature	**Description**
Multiple glazing (panes)	Generally, the more panes the better the insulating characteristics of the window. Look for double or triple panes
gas filling	When filled with various types of gases, the space between glazings can add to the window's insulating characteristics. The efficiency increases when certain types of gases (such as argon or krypton) are used
low-e coating	Adding a metallic coating to one or more panes of glass (usually on inside layers) reduces the window's heat transferring characteristics, thereby saving energy
insulating spacer	Traditional aluminum spacers are excellent heat conductors, and consequently make terrible insulators. The primary benefit of using an insulating material for spacing is reducing the potential for condensation
Sashes and frames	
Feature	**Description**
solid steel and aluminum	Least effective, because although durable, they are poor insulators and tend to expand and contract more than any other material. Avoid windows made of these materials. These can cost $10–15 per square foot
wood	Traditionally used because it is a good insulator. Wood frames also expand and contract less than most other materials, but require more maintenance and are susceptible to moisture damage. Wood components treated with a preservative or clad with metal or vinyl offer the benefits of low maintenance and high insulating values. These can cost $20–30 per square foot
vinyl	Nearly maintenance free and similar to wood in insulating characteristics. However, make sure you have a guarantee against sun damage, peeling, warping, and discoloration. Like metal, vinyl expands and contracts with temperature changes. Is also available with a fiberglass core. These can cost $15–20 per square foot
fiberglass	Offers good insulation characteristics as well as low susceptibility to expansion. These can cost $20–30 per square foot
Source: Minnesota Department of Commerce Windows and Doors fact sheet, pp. 2–4, www.state.mn.us/mn/externalDocs/Windows__Doors_110802042904_Window&Doors05-03.pdf	

SUMMARY

One of the key features of an energy efficient home is a tight and properly insulated building envelope. Improvements such as adding insulation, sealing air leaks, and improving window features provide simple and affordable measures that often do not require a professional contractor. A typical homeowner may invest $1,000 on his home's building envelope, but he can save up to $300 on energy bills each year and enjoy year round indoor comfort.[11]

ADDITIONAL RESOURCES

For a complete and frequently updated free list of resources, download "Green Building Sources" (RMI publication #D03-17) at www.rmi.org in the Library's Buildings & Land section.

U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE) — Comprehensive and useful selection of fact sheets on all aspects of space cooling, including a complete Home Energy Booklet that can be downloaded for free (www.eere.energy.gov/consumerinfo/factsheets.html).

Minnesota Department of Commerce, Energy Information Center — Easy to read fact sheets and pamphlets containing cost-effective Home Cooling and Home Heating ideas (www.commerce.state.mn.us).

American Center for Energy-Efficient Economy: *Consumer Guide to Home Energy Savings, 8th ed*, Alex Wilson et al., Washington, DC: ACEEE, 2003. Comprehensive resource on all aspects of home energy saving ideas, including a list of most efficient appliances and heating and cooling systems (www.aceee.org).

North American Insulation Manufacturers Association — Good source of information on green insulation products and options (www.naima.org).

National Fenestration Rating Council — Independent industry and community organization that provides information on all aspects of energy efficient windows (www.nfrc.org).

NOTES

1. EIA (Energy Information Administration), *Residential Energy Consumption Survey: Total Energy Consumption Tables*, (Washington, DC: EIA, 2001), www.eia.doe.gov/emeu/recs/recs2001/detailcetbls.html#total.

2. EERE (U.S. Department of Energy, Energy Efficiency and Renewable Energy), "Elements of an Energy-Efficient House," (Washington, DC: EERE, July 2000), p. 4, www.eere.energy.gov/consumerinfo/factsheets/eehouse.html; Estimate is only for air sealing, so whole of building envelope improvements can be even more significant.

3. Lawrence Berkeley National Laboratory, "Cool Roofs," (Berkeley, CA: LBNL, 27 April 2000), http://eetd.lbl.gov/HeatIsland/CoolRoofs.

4. A. Wilson, J. Thorne & J. Morrill, *Consumer Guide to Home Energy, 8th ed.* (Washington, DC: ACEEE, 2003), pp. 21–25.

5. EERE. Energy Savers: *Tips on Saving Energy and Money at Home.* (Washington, DC: EERE, Undated), p. 7. www.eere.energy.gov/energy_savers.

6. E SOURCE, *Technology Atlas, Space Heating*, (Boulder, CO: E SOURCE, 2001), p. 110, www.esource.com/public/products/prosp_atlas.asp.

7. B. Mattinson, et al., "What Should I Do About My Windows?" *Home Energy* (July/Aug 2002), www.homeenergy.org/19-4.html.

8. A. Wilson, J. Thorne & J. Morrill, *Consumer Guide to Home Energy, 8th ed.* (Washington, DC: ACEEE, 2003), pp. pp 19–20.

9. B. Mattinson, et al., "What Should I Do About My Windows?" *Home Energy* (July/Aug 2002), www.homeenergy.org/19-4.html.

10. Minnesota Department of Commerce, Energy Information Center, "Windows and Doors Home Energy Guide" (St. Paul, MN: MN DOC, May 2003), pp. 2–4, www.commerce.state.mn.us.

11. RMI calculation based on lower cost Building Envelope improvements (air sealing, insulation and storm windows), DOE estimate of 50 percent reduction in utility bill for air sealing alone (see endnote 2) and energy bills of a typical home (see note 1).

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