# A Cozier and Cheaper Home: *Home Energy*'s Guide to Insulation

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by Cyril Penn

***Once you've decided to insulate, it's time to consider where, how much, and what type of insulation to install.***

Between 50 and 70% of the energy consumed in the average American home goes for heating and cooling, and this accounts for a large chunk of the total energy bill—particularly in electrically heated homes. Insulation can help minimize those costs. If properly installed, insulation is maintenance-free and continues to save energy for 20 years or longer. Even though insulating a home brings other, unmeasurable benefits like added comfort, reduced noise, conserved resources, and reduced pollution, the money it saves should be motivation enough.

The budget-conscious consumer can look at insulation as a financial investment, since it will pay for itself through lower energy bills. When installed in an existing home (as a "retrofit"), the investment pays a rate of return comparable to or better than many personal investments.

Before diving in, consider how to insulate for the best return. It's helpful to calculate costs and payback time in order to compare the economic benefits of adding insulation to each part of the home. The best placement, proper installation methods, appropriate materials, and suitable amount of insulation are all important factors.

Economic factors vary by local climate, energy expenses, characteristics of the house, material costs, and labor costs.

Applegate Insulation

**Blown-in loose-fill insulation is installed quickly with special equipment.**

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A partially insulated house may not be worth adding insulation to. Perhaps only sealing major leaks in ductwork and attics and insulating the walls is worthwhile. Money spent insulating areas that fail to pay for themselves in a reasonable amount of time would be better spent on other, more economical conservation investments. An energy auditor can help set these priorities, or the mathematically inclined may want to do their own calculations using the boxes "Is it Worth it?" and "How to Estimate Savings."

## Getting Started

For help in determining how much insulation is in the home already, where any new insulation should be installed, and how much is worthwhile to install, inquire with the local utility. Many utilities offer home energy audits, in which professionals evaluate the energy efficiency of the home, identify the amount of insulation needed, and indicate where retrofits will be most economical. The energy auditor can also check that the furnace is venting properly, measure the natural ventilation rate of the home, and advise about how much air sealing is safe. This is usually performed free of charge. Many utilities have energy efficiency programs in which they offer rebates to customers that upgrade. In many states, regulatory reforms have put utilities into the conservation business. They're often eager to help.

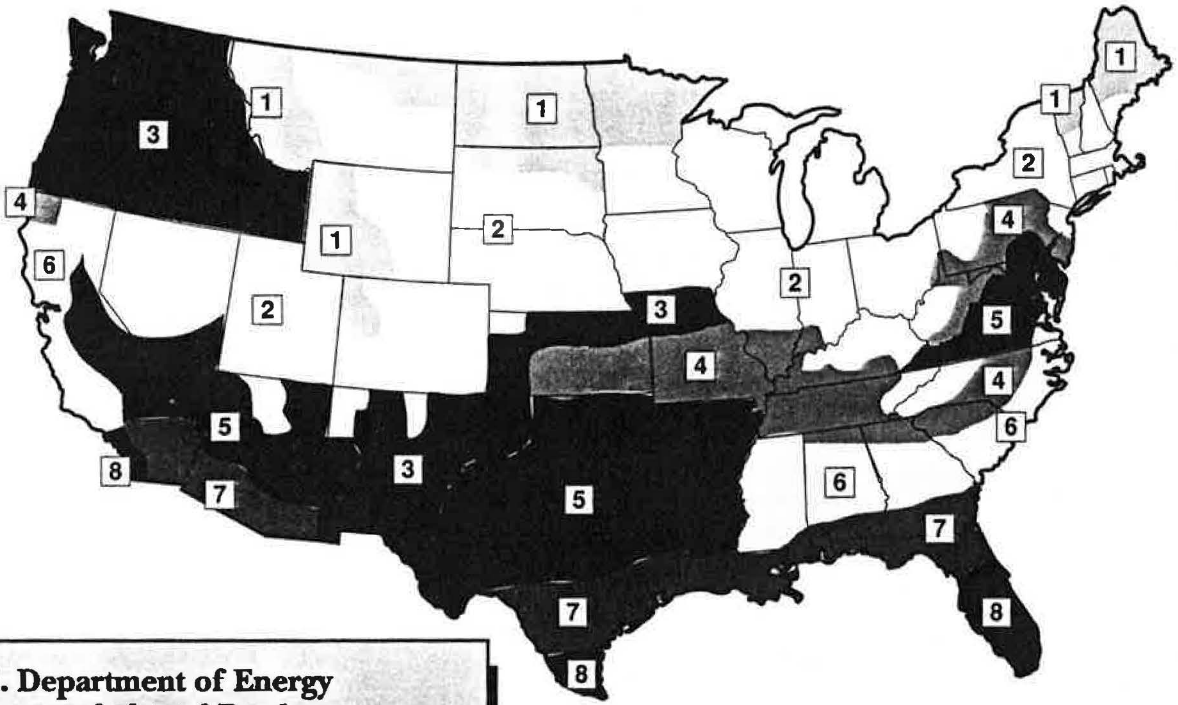
Another useful resource is the state energy office. Some states offer tax credits for money spent on home insulation. In addition to technical advice and information, some states offer financing for retrofits as well.

Insulating a home can be a do-it-yourself project or may be done by a qualified contractor. Homeowners handy with staple guns and comfortable wearing respirators may save money by investing their own labor. But more complex installations, like insulating existing walls, generally should be done by seasoned professionals. In either case, make sure the insulation is installed properly for maximum savings.

## A Good Time to Tighten Up

A complement to insulating is to control air leakage through holes and cracks. Professional "house doctors" or "air sealing specialists," who work for energy services companies or insulation contractors, can do the job effectively and safely. They use air leakage detection and measuring tools to make sure they seal the most egregious cracks first and leave enough natural ventilation. Auditors, too, often use such equipment, and may leave behind a list of the priority leakage areas to seal.

Per person, the indoor-outdoor air exchange rate should not fall below about one third of house air volume every hour or 15 cubic feet per minute, according to the American Society of Heating, Refrigerating, and Air-Conditioning




**U. S. Department of Energy recommended total R-values for existing houses in eight insulation zones.***

| Zone | Ceilings Below Ventilated Attics: Electric Resistance | Ceilings Below Ventilated Attics: Gas or Oil | Floors Over Unheated Crawlspaces, Basements (All Fuel Types) | Exterior Walls (Wood frame) (All Fuel Types) |
|---|---|---|---|---|
| 1 | 49 | 49 | 19 | 11-13 |
| 2 | 49 | 38 | 19 | 11-13 |
| 3 | 38 | 38 | 19 | 11-13 |
| 4 | 38 | 38 | 19 | 11-13 |
| 5 | 38 | 30 | 19 | 11-13 |
| 6 | 38 | 30 | 19 | 11-13 |
| 7 | 30 | 30 | 0 | 11-13 |
| 8 | 30 | 19 | 0 | 11-13 |

* These recommendations are based on the assumption that no structural modifications are needed to accomodate the added insulation.

The map was developed by Oak Ridge National Laboratory.

Engineers (ASHRAE). The lower the air exchange rate, the more energy-efficient the house, but too little air exchange can pose a safety hazard. Even at higher ventilation rates, indoor air can be poisonous if faulty heating equipment or unsafe flue conditions keep furnace or water heater exhaust from venting properly. Have these checked by an auditor or house doctor before weatherizing.

Believe it or not, the attic—not the front door—is the best place to start. After all, hot air flows upward. Look for gaps over the tops of walls (especially for the kitchen and the bathroom), wherever the attic level changes, and around the entire perimeter of the attic where the roof meets the ceiling. Similar gaps may be found at the connection of the basement ceiling and foundation wall. Seal all these holes before insulating, using sheetrock (or any permanent rigid barrier, like foam board, sheet metal, or cardboard). Cut the barrier to fit and seal it with caulk. This will increase the insulation's effectiveness and substantially reduce air leakage. Other areas to seal before insulating the attic are chimney or furnace flue penetrations. Most fire codes allow sheet metal to bridge the gap between the chimney and the attic floor, and the joint between the sheet metal and chimney can be sealed with furnace cement.

Traditionally, people have sealed houses completely before insulating, but new, more effective methods of insulating and concerns about air quality have changed the rules. Dense-pack cellulose helps reduce air leakage so much that it may make additional air sealing unnecessary. Check for safety and adequate ventilation before doing any more sealing.

The most important leaks and cracks are often not obvious even to the trained eye—another reason the house doctor's special equipment is so important. Still, only the resident knows all the little drafts and chills in a home, and if more sealing is warranted, these should be sealed next. Good candidates are windows near favorite chairs and kitchen tables. These should be weatherstripped and the spaces between the framing and rough opening should be filled with caulk or foam sealant.

## Ceiling, Walls, Floor, or Foundation?

Most energy auditors will say—and scientific study has confirmed—that home insulation should be considered in the following order:

- First, the ceiling or attic;
- Next, the walls; and
- Finally, the floors.

In mild climates, insulating the ceiling may be sufficient. In more severe climates, it may be economical to insulate the walls and foundation as well.

*Ceilings*

If previously uninsulated, ceiling insulation provides the largest and most cost-effective savings. Even in cases in mild climates where some attic insulation was already present, measured fuel savings in attic-insulated homes throughout the United States range from 13 to 21%, according to a recent compilation of fuel savings studies by the Lawrence Berkeley Laboratory.

Adding insulation to an unheated attic is usually a simple procedure. If there is no attic floor, either loose-fill insulation can be blown in or fiber-glass batts can be laid between the joists and stapled in place. If existing insulation comes up to the top of the joists, an additional layer of unfaced batts can be added across the joists. This helps to cover gaps in the first layer. In most of the country, a full foot of fiber-glass or cellulose insulation is cost-effective in the attic floor. Insulating a sloped cathedral ceiling can be much more difficult and may require professional assistance.

Makė sure the insulation is clear of vents to insure proper air circulation. For roof vents, 12 inches of clearance is usually recommended. For side vents, little clearance is necessary, as long as the vents are not blocked. Box around recessed light fixtures (or other fixtures that emit heat) to avoid fire hazards. Insulation should be distributed evenly and cover corners. If access to the attic is limited, blown-in insulation may be required. This can be difficult for the homeowner to do, because special blowing equipment is required. But truly handy people, like those who aren't intimidated by pouring cement, may want to rent insulation blowers from tool rental shops.

A radiant heat barrier can be added to attic insulation and may be effective in hot climates. Radiant barriers reflect infrared heat; in contrast, insulation retards conductive heat. However, a recent study by the Alberta Municipal Affairs Housing Division and performed by Dr. Tom Forest at the University of Alberta, Canada, confirms earlier research that warned against installing radiant barriers in colder climates. The study concluded that radiant barriers installed over attic insulation in cold climates may actually increase roof heat loss and cause moisture problems.

**Effective, inexpensive, and environmentally benign, blown-in cellulose is a popular insulation material, and reduces air leakage in walls.**

## Is it Worth it?

The economics of individual insulation improvements depend upon how much heat flows through the walls and the cost of energy. Cost-effectiveness means the benefits from the investment (utility bill savings) exceed installation costs, with a "payback time" some point down the road. That point will vary according to the savings and cost of each energy saving measure. Some measures offer a payback within a few months, while in other cases the payback can take from 20 to 30 years. The most common method for estimating this is called "simple payback." It factors in:

- the cost of the retrofit (initial investment),
- the annual energy savings from the retrofit, and
- the amount that energy would have cost if it hadn't been saved.

To find out the cost of the retrofit, get bids from insulation contractors or price out the amount of insulation needed for each area: attic, exterior walls, and bottom floor or foundation. Then estimate the heating and cooling energy savings using the method in the box "How to Estimate Savings." To calculate simple payback, divide the cost of the insulation by the utility bill savings and *voilà*: an estimate of payback time.

$$\text{Payback} = \frac{\text{cost of insulation}}{\text{annual utility bill savings}}$$

For example, a bid for \$350 to insulate an attic, with expected annual fuel bill savings of \$87, should produce the following equation:

$$\frac{\$350}{\$87/\text{yr}} = \text{about 4 years.}$$

Methods of calculating savings that account for changes in cash value and energy costs over time make more precise estimates than simple payback. These methods include the benefit-to-cost ratio and net present value. Benefit-to-cost analysis estimates the return for each dollar invested, while net present value shows how much more benefit may be received after the initial investment is recouped. Both methods utilize discounting, which allows the insulation payback to be compared to other investments, like earning interest at a bank. None of these methods can predict the economics of insulation exactly. The cost of energy fluctuates unpredictably as does human behavior. For instance, sloppy insulation work can lead to gaps in the insulation, which transfer heat in much greater proportion than their area. On the other hand, serendipitous changes can add to the savings. For example, the warmer surface temperature of an insulated wall or ceiling in winter will make residents feel warmer at a lower thermostat setting, while maintaining the same level of thermal comfort.

**(For more detail on these methods, see "Setting Priorities for Weatherization: Beyond Simple Payback," *Home Energy* magazine, July/Aug '90, p. 10.)**

Unless the attic already has existing insulation, add a vapor retarder when installing insulation. Most batts and blankets have a kraft-paper vapor retarder on one side. This prevents excessive moisture from condensing in the insulation, which could reduce its effectiveness. The vapor retarder must be installed on the warm side of the insulation (face down in cold climates, face up in hot climates) or it can do more harm than good. One other point: Do not store anything on top of ceiling insulation. When insulation is packed down, it tends to lose effectiveness.

*Wall Insulation*

Savings from exterior wall insulation retrofits depend primarily upon local climate conditions, the amount of existing insulation, and contractor prices. Data from recent U.S. studies suggest that wall insulation is particularly cost-effective in severe climates.

Even in milder climates, it still can be worthwhile, though the payback time is longer. In climates like Kansas City or Baltimore's (4,000 to 5,000 HDD), wall insulation is likely to be cost-effective.

However, local contractor prices (and competence) for this labor-intensive retrofit can vary widely. To blow insulation into each section of a wood-frame wall, parts of the siding usually have to be removed or the holes drilled have to be patched. If there already is some insulation in the walls, there usually isn't enough room in 2x4 construction to add enough extra insulation to pay for itself.

Most homes have no wall insulation, however. To check, unscrew a switchplate on an outside wall and peek inside. If no insulation is visible, turn off the circuit breaker and use a piece of wire to poke into the wall beside the electrical box.

It is often difficult to fully fill wall cavities from ceiling to floor, which is the main reason to hire a qualified contractor to do the job. (A high-quality contractor will use an infrared camera to make sure there aren't any air leaks or gaps, which reduce the insulation's effectiveness severely.)

The best time to add wall insulation is when remodeling, repairing a wall, or adding a room. Re-siding also presents a great opportunity to insulate walls. As a promotion, siding contractors often throw a couple of inches of foam board insulation between the old siding and the new.

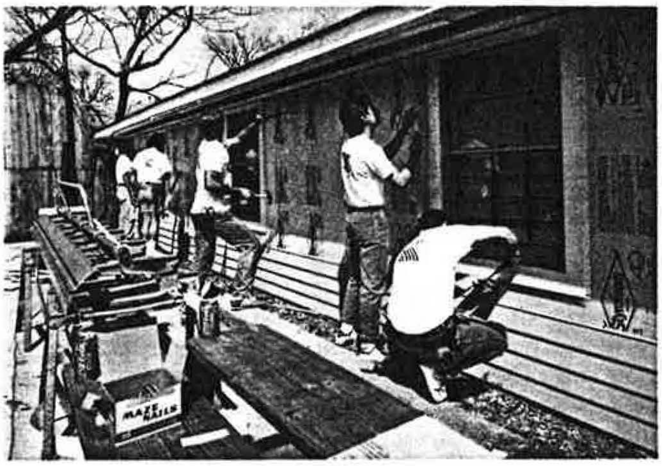
*Floors*

The last area to consider insulating is the floor or foundation. Heat loss through basement and foundation walls is common, even in new homes. In an otherwise well-insulated house, up to 20% of the total heat loss can occur through uninsulated foundation walls. Nonetheless, recent research on the cost-effectiveness of retrofit foundation insulation in unheated basements suggests that the payback period can be quite long—as much as 129 years in one Minnesota study! In mild climates, a pad and carpeting on the floor may provide ample protection. Where the underside of the floor is accessible, and the basement is neither heated nor cooled, floor insulation will be much more appropriate and less expensive. However, the payback period for foundation insulation improves greatly if the basement is used as living space. Added living space from a heated basement can also provide a benefit that makes the retrofit attractive. Other side benefits can be decreased condensation, which can help avoid mold and mildew, keeping pipes from freezing, and reduced energy losses from ducts running through the basement.

If the basement space is unheated and these benefits aren't desired, it may be best to insulate between floor joists instead of around the foundation. Unfaced fiber-glass batt insulation, supported from below with metal rods or wire mesh, can do the job.

The simplest method to convert an unheated basement into living space is to build 2x4 frames against the concrete foundation walls, insulate with fiber glass, and cover with drywall. Drainage problems may need to be addressed to insure that no exterior water leaks into the basement, and the concrete should be treated with water seal or vapor barrier paint.

If the basement is already finished, the foundation is easier to insulate from the outside. This requires digging out the foundation at least six inches. Attach rigid-board foam; add a protective covering, like fiber-glass panels, treated plywood, or cement coating; then fill in and compact the soil.



Dow Chemical Company

**Re-siding is an unparalleled opportunity to add wall insulation.**

## What to Buy

The effectiveness of insulation is measured by R-value, an indicator of thermal resistance to heat flow. The higher the R-value, the greater the insulating power. R-values vary according to the type of material, its thickness, weight, and density.

The appropriate R-value for a given installation varies according to the climate, the area of the house being insulated, the type of heating system in the house, and the amount of existing insulation, if any. Still, generalizations may be made, like those in the map at the top of page 27.

After locating the areas that should be insulated and determining what R-value to add, a decision must be made about what kind of insulation to buy. This is really a matter of personal choice. Insulation is generally made of: fiber glass, cellulose, mineral wool (rock wool) or rigid foam (polystyrene, polyurethane, etc.).

Always check the labels—the R-value is printed on the package. When buying insulation, check to see that it meets either federal or ASTM (American Society for Testing and Materials) standards. The label should state the product's fire-resistant qualities and precautions for installation. Because specific products have slightly different thickness and density, labels usually have charts that will help determine how much insulation is needed to achieve a given R-value.

*Loose-Fill*

Loose-fill insulation consists of loose fibers, or granules, and is made from rock wool fibers, cellulose, fiber glass, or other materials. Loose-fill insulation comes in a bag, and is easy to pour into open cavities. It can also be blown into cavities or attics with special equipment. Sometimes loose-fill fibers are sprayed with adhesive in order to cover irregularly shaped and hard-to-reach areas or to install in walls before sheathing. (One such technique is the "Blown-in Blanket" system.)

Cellulose is a popular and effective home insulation material. It's inexpensive and environmentally benign. (It's often made from recycled newspaper.) It can settle detrimentally over time if not installed properly, and each 1% loss in cellulose thickness results in about a 1% loss in R-value. An extensive study performed at Oak Ridge National Laboratory found that cellulose can settle from 13–22% within two to three years. Industry estimates are that cellulose settles by about 20% within three years. Thus, adding 20% more thickness may be desirable. Fiberglass loose fill also settles, but suffers from only about half as much R-value reduction.

However, the label should say how many bags of insulation will achieve the desired R-value even after settling. Don't overcompensate by packing the insulation too tightly. If it's too tight in walls, it may force drywall off the studs!

Loose-fill fiber glass, on the other hand, can allow air movement that reduces its effectiveness in attics. Tests at low temperatures conducted at Oak Ridge National Laboratory showed R-value of some brands of blown fiber glass decreased by 40% at 20°F attic air temperature and by 50% at –18°F.

### *Batts and Blankets*

Where one side of a partition is open, batts and blankets are easy to install. These flexible, bound insulations are made from glass or rock wool fibers. They come in rolls or strips in various but standard widths, usually to fit between framing on 16 or 24 inch centers; they are also manufactured in various thicknesses, to fit between 2x4 or 2x6 framing. Blankets are available in continuous rolls, whereas batts are pre-cut. Batts and blankets can be fitted in unfinished walls, floors, and ceilings. Hand cut blankets with a knife or razor, and there will be little waste. Batts are easier to handle than blankets. With either material, cut around electrical boxes for the best fit. Compressing the insulation to make it fit will increase air leakage and reduce the R-value.

### *Plastic Foam*

Plastic foam (or rigid foam or foam board) is a stiffer material and is the most expensive form of insulation. This material is used in special applications such as finished areas, exterior walls, foundations, and where space is limited or inaccessible. Since it provides a higher R-value per inch of thickness, it is useful where a lot of insulation is desired in cramped quarters, such as cathedral ceilings. Foam insulation should be covered with finishing material for fire safety. Look for foams that don't contain ozone-depleting chlorofluorocarbons (CFCs).

## How to Estimate Savings

The easiest way for a homeowner to find out what savings to expect, of course, is to ask an auditor. But the energy buff will want to know how it's done, so here's a simple explanation. (For anyone out there who truly enjoys making these calculations, you may want to consider a career change! Auditor positions go begging nationwide...)

The basis of most estimates of insulation energy savings is a "heat loss calculation" of the outer shell of the building. This number is like an overall R-value for the building—it measures how well the building insulates the inside from the elements outside. Even without any insulation, the building materials will provide some resistance to heat flow, and that amount is compared to the R-value with a certain amount of added insulation. Then the auditor estimates how much energy the heating system would use to deliver that much heat (or, in the case of air conditioning, to remove it).

*How Much Heat Flows through a Plaster Sandwich?*

To calculate heat loss, auditors use tables that tell the R-value for each type of building material in the ceilings, walls, and floors that connect directly to the outside (or to "unconditioned spaces" like unheated garages, attics, and basements). Then they measure the surface area of each portion of the shell and figure the average temperature difference across each, etc. For this they need to know average indoor and outdoor temperatures. For inside, they ask the resident about their typical thermostat settings, or better yet, take actual thermometer readings from various parts of the house, including the unconditioned spaces. Outdoor temperatures are estimated from local climate data, such as the average "heating degree days" (HDD), a measurement of how often and how far the temperature falls below 65°F in a given year. For instance, if the average temperature for a day is 64°F, this represents one heating degree day. The state energy office should know local degree days.

Expressed as a formula,

$$Q = \frac{A \times \Delta T \times t}{R}$$

where

$Q$ = Heat in loss in Btu
$A$ = Area in ft²
$\Delta T$ = Temperature difference in °F
$t$ = Time in hours
$R$ = R-value (from an industry table) in hours x ft² x °F / Btu.

Or, assuming a 70°F indoor temperature, use heating degree days:

$$Q = \frac{A \times DD \times 24hr}{R}$$

For example, suppose a house has 750 ft² of ceiling space. On the attic side, the temperature is 50°F, and the heated space is 72°F, a difference of 22°F. The R-value of the materials, plaster and drywall, is determined to be 2.0 according to an ASHRAE table. The heat loss over 24 hours will be

$$\frac{750 \times 22 \times 24}{2} = 198{,}000 \text{ Btu}$$

Calculate this separately for each surface that has a different R-value, with and without the added R-value of insulation and find the difference. This difference is the heat saved by the insulation. Divide the heat savings by an estimate of the heating system efficiency for an estimate of annual energy savings. Then multiply the energy savings times the cost of energy for the utility bill savings. (Reality check: the total amount *cannot* exceed the annual energy bill. It should be somewhere around 10 to 40%.) The same can be done for cooling.

— Karina Lutz

CertainTeed

**Batt materials are flexible, and can be easily fitted into unfinished walls, floors, and ceilings.**

### *Radiant Barriers*

Radiant barriers are made of aluminum foil with backing. They stop radiant heat from moving through an attic, but conduct heat easily, so should not be used alone. Radiant barriers are more effective in hotter climates, and are most effective in reducing downward heat flow. They are typically installed on the attic floor on top of the regular (conductive) insulation, or on the underside of the roof (the verdict is not in on which works better over the long haul). Radiant barriers are easy to cut and staple in place, but must be installed with the reflective side facing an air gap of some sort, such as the open attic.

## Beware of Hype!

Cellulose, the raw material, is combustible, and must be treated with fire retardant chemicals before it is used as insulation. There is some debate about whether treated cellulose retains its ability to retard the spread of flame over time, but no fires have been traced to cellulose flammability.

Fiber glass is the most popular insulation material, and is installed in millions of attics every year. Recently questions have arisen about whether the air-borne fibers cause lung cancer. Detractors have suggested that tiny glass fibers may be easily ingested into the lungs, and most recently, studies have found increased rates of lung cancer in workers in fiber-glass factories.

If these fears are borne out, blankets, which use a binder to keep the fibers together, are preferable to loose fill.


CertainTeed

**Batts and blankets should be cut to fit around existing outlets.**

The debate about these materials has its origin in competition within the industry. Manufacturers of fiber glass and cellulose have bickered about their respective sides of safety issues, often exaggerating their claims. It's important to keep in mind that none of the data here is conclusive. But the debate underscores the importance of proper precautions in installation. Even if just to avoid local irritation, always wear a high-quality respirator (not a flimsy disposable mask) when working with either type of insulation, and wear loose-fitting clothing and gloves when installing fiber glass.

When done correctly, insulation retrofit measures increase a home's energy efficiency and comfort, pay for themselves, and add value to the home. Insulation even acts as a sound buffer, keeping noise levels down. Upgrading the home's efficiency can bring added satisfaction, because saving energy is good for the environment in so many ways. ■