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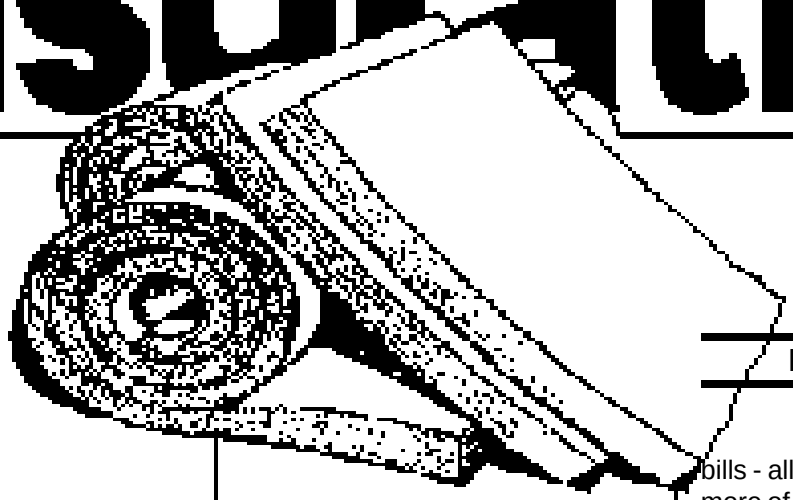
Department of Energy
Assistant Secretary
Energy Efficiency and Renewable Energy

Insulation – Fact Sheet



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INTRODUCTION

Electricity bills, oil bills, gas bills - all homeowners pay for one or more of these utilities, and wish they paid less. Often many of us do not really know how to control or reduce our utility bills. We resign ourselves to high bills because we think that is the price we have to pay for a comfortable home. We encourage our children to turn off the lights and appliances, but may not recognize the benefits of insulating the attic.

Why Should You Insulate?

Heating and cooling (space conditioning) account for 50 to 70% of the energy used in the average American home. About 20% goes for heating water. On the other hand, lighting and appliances and everything else account for only 10 to 30% of the energy used in most residences. It makes good sense to turn lights and appliances off when they are not needed, and you'll save even more on your energy costs if you reduce the amount of energy needed for heating and cooling.

Unless your home was constructed with special attention to energy efficiency, adding insulation will probably reduce your utility bills. Much of the existing housing stock in the United States is not insulated to the best level. Older homes are likely to use more energy than newer homes, leading to very high heating and air-conditioning bills. Even if you own a new home, adding insulation may save enough money in reduced utility bills to pay for itself within a few years, continue to save you money for as long as you own the home, and increase the resale value of your house.

The Crucial Role of Thermal Insulation

Inadequate insulation and air leakage are leading causes of energy waste in most homes. Insulation saves money and our nation's limited energy resources. It can also make your house more comfortable by helping to maintain a uniform temperature throughout the house. Walls, ceilings, and floors will be warmer in the winter and cooler in the summer. Insulation can also act as a sound absorber or barrier, keeping noise levels down.

It is possible to add insulation to almost any house. You may be able to do the job yourself if the structural framing is accessible – for instance, in unfinished attics or under the floor over an unheated space. Or, you may prefer to hire an insulation contractor. In either case, it is important to choose and install the insulation correctly.

The amount of energy you conserve will depend on several factors: your local climate; the size, shape, and construction of your house; the living habits of your family; the type and efficiency of the heating and cooling systems; and the fuel you use. Once the energy savings have paid for the installation cost, energy conserved is money saved – and the annual savings will increase if utility rates go up.

Insulation Priorities

It is most important to:

- *Insulate your attic* to the recommended level, including the attic door, or hatch cover.
- Provide the recommended level of insulation *under floors above unheated spaces, around walls in a heated basement or unventilated crawl space, and on the edges of slabs-on-grade.*
- Use the recommended levels of insulation for *exterior walls* for new house construction. When remodeling or re-siding your house, consider using the levels recommended for new construction in your existing walls.

HOW DOES INSULATION WORK FOR YOU?

Heat flows naturally from a warmer to a cooler space. In the winter, this heat flow moves directly from all heated living spaces to adjacent unheated attics, garages, and basements, or to the outdoors; or indirectly through interior ceilings, walls, and floors – wherever there is a difference in temperature. During the cooling season, heat flows from outdoors to the house interior. To maintain comfort, the heat lost in winter must be replaced by your heating system and the heat gained in summer must be removed by your air conditioner. Insulating ceilings, walls, and floors decreases this heat flow by providing an effective resistance to the flow of heat.

Insulation is rated in terms of thermal resistance, called R-value, which indicates the resistance to heat flow. *The higher the R-value, the greater the insulating effectiveness.* The R-value of thermal insulation depends on the type of material, its thickness, and density. In calculating the R-value of a multi-layered installation, the R-values of the individual layers are added. Installing more insulation in your home increases R-value and the resistance to heat flow.

The effectiveness of an insulated wall or ceiling also depends on how and where the insulation is installed. For example, insulation which is compressed will not give you its full rated R-value. Also, the overall R-value of a wall or ceiling will be somewhat different from the R-value of the insulation itself because some heat flows around the insulation through the studs and joists. That is, the overall R-value of a wall with insulation between wood studs is less than the R-value of the insulation itself because the wood provides a thermal short-circuit around the insulation. The short-circuiting through metal framing is much greater than that through wood-framed walls; sometimes the metal wall's overall R-value can be as low as half the insulation's R-value. With careful design, this short-circuiting can be reduced. More information about whole-wall R-values can be found on the Web page referenced on page 18.

DOES YOUR HOME NEED MORE INSULATION?

To begin to answer this question, you must first find out how much insulation you already have and then determine how much more would be cost-effective. Many older homes have less insulation than homes built today. A qualified home energy auditor will include an insulation check as a routine part of an energy audit. For information about home energy audits, call your local utility company. State energy offices are another valuable resource for information. An energy audit of your house will identify the amount of insulation you have and need, and will likely recommend other improvements as well.

If you don't have someone else inspect your home, you'll need to look

Figure 1. **Examples of Where to Insulate**

1. In unfinished attic spaces, insulate between and over the floor joists to seal off living spaces below.*
   1A attic access door

2. In finished attic rooms with or without dormer, insulate...
   2A between the studs of “knee” walls;
   2B between the studs and rafters of exterior walls and roof;
   2C ceilings with cold spaces above;
   2D extend insulation into joist space to reduce air flows.

3. All exterior walls, including...
   3A walls between living spaces and unheated garages, shed roofs, or storage areas;
   3B foundation walls above ground level;
   3C foundation walls in heated basements, full wall either interior or exterior.
   (See *Builder's Foundation Handbook* on page 19.)

4. Floors above cold spaces, such as vented crawl spaces and unheated garages. Also insulate...
   4A any portion of the floor in a room that is cantilevered beyond the exterior wall below;
   4B slab floors built directly on the ground;**
   4C as an alternative to floor insulation, foundation walls of unvented crawl spaces;
   4D extend insulation into joist space to reduce air flows.

5. Band joists.

6. Replacement or storm windows and caulk and seal around all windows and doors.

* Well-insulated attics, crawl spaces, storage areas, and other enclosed cavities should be ventilated to prevent excessive moisture build-up.

** For new construction, slab on grade insulation should be installed to the extent required by building codes, or greater.

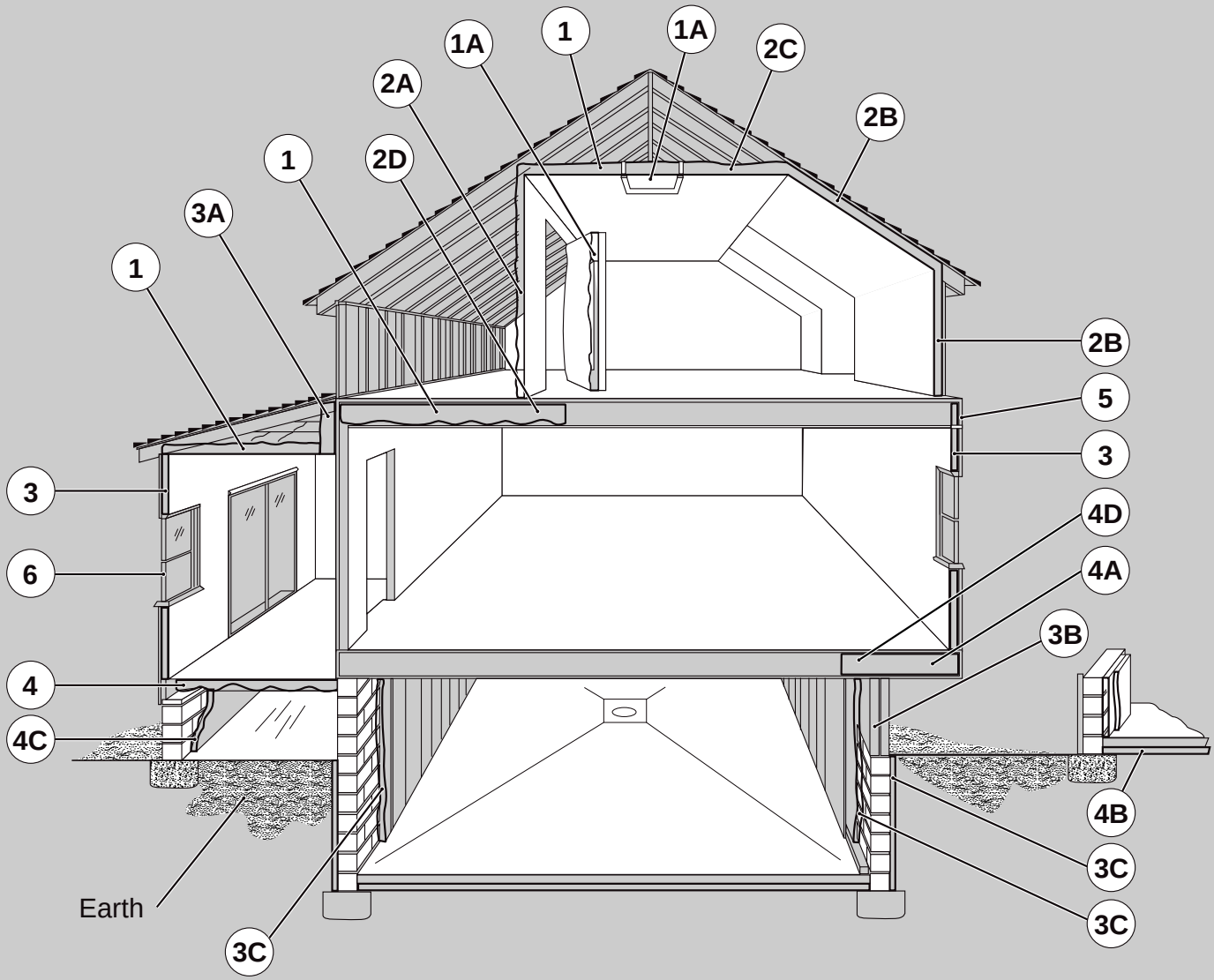

Table 1. Types of Insulation—Basic Forms

Form	Method of Installation	Where Applicable	Advantages
Blankets: Batts or Rolls Fiber glass Rock wool	Fitted between studs, joists and beams	All unfinished walls, floors and ceilings	Do-it-yourself Suited for standard stud and joist spacing, which is relatively free from obstructions
Loose-Fill (poured in) Vermiculite or Perlite*			
Loose-Fill (blown-in) or Spray-applied Rock wool Fiber glass Cellulose Polyurethane foam	Blown into place or spray applied by special equipment	Enclosed existing wall cavities or open new wall cavities Unfinished attic floors and hard to reach places	Commonly used insulation for retrofits (adding insulation to existing finished areas) Good for irregularly shaped areas and around obstructions
Rigid Insulation Extruded polystyrene foam (XPS) Expanded polystyrene foam (EPS or beadboard) Polyurethane foam Polyisocyanurate foam	Interior applications: Must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety Exterior applications: Must be covered with weather-proof facing	Basement walls Exterior walls under finishing (Some foam boards include a foil facing which will act as a vapor retarder. Please read the discussion about where to place, or not to place, a vapor retarder) Unvented low slope roofs	High insulating value for relatively little thickness Can block thermal short circuits when installed continuously over frames or joists.
Reflective Systems Foil-faced paper Foil-faced polyethylene bubbles Foil-faced plastic film Foil-faced cardboard	Foils, films, or papers: Fitted between wood-frame studs joists, and beams	Unfinished ceilings, walls, and floors	Do-it-yourself All suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present Effectiveness depends on spacing and heat flow direction

*not currently used for home insulation, but may be found in older homes

for insulation in several places. Figure 1 shows the places in a typical house where insulation should be installed. These are the areas you should check. In each location, you'll need to measure the thickness of the insulation and identify which type of insulation was used (see "Types of Insulation – Basic Forms" in Table 1).

Your home may have one or more of several different insulation materials. Mineral fiber insulation, including fiber glass and rock wool, is produced from either molten glass, slag, or rock. Fiber glass insulation is usually very light-weight, and yellow, pink, or white in color. Fiber glass can be found in loose-fill and blanket, either batt or roll, forms. Rock wool loose-fill is usually more dense than fiber glass, and is most commonly gray with black specks. Some rock wool products, however, are near-white. Loose-fill cellulose insulation is commonly manufactured from recycled newsprint, cardboard, or other forms of waste paper. Most cellulose is in the form of small flat pieces rather than fibers. However, some cellulose products are so finely divided they look fibrous as well. Vermiculite- and perlite-loose-fill products are no longer commonly used as home insulation, but you may find them in an older home. They are produced by expanding naturally occurring minerals in a furnace. The resulting granules are non-combustible and are commonly poured-in-place.

First, check the attic; then check walls and floors adjacent to an unheated space like a garage or basement. In these places, the structural frame elements (the ceiling joists or wall framing boards) are often exposed, making it easy to examine the insulation (if any) and to measure the depth or thickness of the insulation. It is more difficult to inspect finished

exterior walls. One method is to use an electrical outlet on the wall, but first be sure to turn off the power to the outlet. Then remove the cover plate and shine a flashlight into the crack around the outlet box. You should be able to see whether or not insulation is in the wall. You may need to pull a small amount out to determine which type of material was used. Also, you should check separate outlets on the first and second floor, and in old and new parts of the house, because wall insulation in one wall doesn't necessarily mean that it's everywhere in the house. An alternative to checking through electrical outlets is to remove and then replace a small section of the exterior siding.

Next, inspect and measure the thickness of any insulation in unfinished basement ceilings and walls, or above crawl spaces. If the crawl space is not ventilated, it may have insulation on the perimeter wall. If your house is relatively new, it may have been built with insulation outside the basement or foundation wall. However, this insulation would not be visible because it would be covered by a protective layer of stucco, plastic, fiber glass, metal flashing, or a rigid protection board. The builder or the original homeowner may be able to tell you if such exterior insulation was used.

Compare your findings with recommended levels of insulation by following the steps described next.

DETERMINING THE R-VALUE YOU NEED FOR AN EXISTING HOUSE

The amount of insulation you need depends on the climate, type of heating (gas, oil, electricity) you use, and the section of the house that you plan to insulate. The attic is the first area to consider because it is accessible and therefore less expensive to insulate.

A computer program is available to help you calculate the amount of insulation appropriate for your house. This program will run on a personal computer and the reference sources on page 18 tell you how to find it on the Internet. The program is called the ZIP-Code because it includes weather and cost information for local regions defined by the first three digits of each postal service zip code. The program also allows you to define your own local costs and certain facts about your house to improve the accuracy of the recommendations. If you don't want to use this computer program (or other computer programs that exist), or just want to make a quick estimate, you can follow the steps outlined here.

Tables 1 and 2 will help you to identify the type of insulation and its R-value as presently installed. Determine the kind of insulation you have from Table 1, and circle it on Table 2. Then, multiply the thickness of your insulation by the "R-value per inch". This will give you the total R-value of your existing insulation.

The next step is to compare the R-value of your insulation with the recommended total R-value for your house and your type of space heating. These recommended R-values can be found by using Tables 3, 4, and 5. (More precise recommendations than can be shown in this fact sheet can be found for your zip-code on the Internet site shown on page 18).

Find the first three numbers of your zip code in Table 3 to determine the Insulation Zone for your location (or look at Fig. 2). Next go to Table 4 to find out which Insulation Group is appropriate for your Insulation Zone and heating system type; be sure to use the columns labled "Existing Houses". Then, on Table 5, locate your Insulation Group in the left column. Reading across this line, find the recommended R-values for the various parts of your house. Having determined these recommended R-values, use the formula on the bottom of Table 2 to subtract the R-value of the insulation already in your home. The result will be the R-value you should add.

You can use the information on Table 2 to estimate the thickness required from different materials to achieve this added R-value. This approximate thickness may help you choose your insulation material, especially if you are working within a confined space. However, when purchasing or installing new insulation, always consult the product label for accurate thickness information. Many special products have been developed to give higher R-values in a smaller thickness. On the other hand, some materials require a greater initial thickness to offset eventual settling or to assure that you get the rated R-value under a range of temperature conditions.

When you stack new insulation on top of existing attic insulation, the existing insulation is compressed a small amount. This will slightly decrease the R-value of the existing insulation. This effect is most important if the new insulation is more dense than the old insulation. You can compensate for this stacking effect and achieve the desired total R-value by adding about one extra inch of insulation if the old insulation is fiber glass, or about 1/2 inch if the old insulation is rock wool or cellulose.

As an example of the use of the tables, consider an existing house in St. Paul, Minnesota (zip code 55103) with a gas furnace. Table 3 shows that the region with zip codes starting with 551 are in Insulation Zone 8. Now look at Table 4 and locate Insulation Zone 8 in the left-hand column. Next look for the gas heat column under "Existing Houses", which shows that the Insulation Group for this house is E5. Looking at Table 5, the recommended R-value for attic floor insulation for Insulation Group E5 is R-38. If the existing attic floor insulation has an R-11 insulation value, then an additional R-27 would be needed to bring the attic floor

insulation up to the level recommended for that house. The homeowner could then check Table 1 to find several choices. Remember to buy the new insulation based on this R-value, and to check the product label to determine the proper thickness of the new insulation. Choosing a slightly higher level of insulation, such as R-30, would serve to offset the stacking effect discussed above.

MAKING YOUR DECISION

The amount of money you are willing to invest in insulation will of course depend on your personal finances. But remember that the initial investment will pay for itself in reduced energy consumption, particularly where the amount already installed is substantially less than recommended. If fuel and electrical power costs rise, it will make even more sense to invest in insulation. If you are financing a new home, or a major home improvement, you may wish to check to see if banks in your area allow larger loan amounts for energy efficient housing.

The insulation levels recommended here were chosen based on a life-cycle cost analysis. This analysis includes many assumptions about system efficiencies, and what rate of return you would like to earn on your investment. If you want to find out more about how the recommended insulation levels were chosen, please see the *Supporting Documentation* in the list of US DOE publications on page 19. Also, remember that the ZIP-Code computer program on the Internet (see page 18) will let you calculate insulation levels for your own set of assumptions about costs, efficiencies, and desired return on investment.

Table 2. Evaluating the R-value of Insulation Previously Installed in Existing Homes (Includes Effects of Aging and Settling).

Insulation type	R-value per inch of thickness
Fiber glass blanket or batt	2.9 to 3.8 (use 3.2)
High performance fiber glass blanket or batt	3.7 to 4.3 (use 3.8)
Loose-fill fiber glass	2.3 to 2.7 (use 2.5)
Loose-fill rock wool	2.7 to 3.0 (use 2.8)
Loose-fill cellulose	3.4 to 3.7 (use 3.5)
Perlite or vermiculite	2.4 to 3.7 (use 2.7)
Expanded polystyrene board	3.6 to 4 (use 3.8)
Extruded polystyrene board	4.5 to 5 (use 4.8)
Polyisocyanurate board, unfaced	5.6 to 6.3 (use 5.8)
Polyisocyanurate board, foil-faced	7
Spray polyurethane foam	5.6 to 6.3 (use 5.9)

Use this formula to determine the R-value of your **existing** insulation:

	x		=	
Thickness (inches)	*x*	*R-value per inch*	=	*Total R-value*

Use this fornula to determine how much insulation you need to **add:**

	-		=	
Total recommended R-value	-	*Existing insulation R-value*	=	*R-value needed*

Do you want to know if you have the space available to add the insulation you need? Then use this formula to determine the *approximate* thickness you need to add:

	÷		=	
R-value needed	÷	*R-value per inch*	=	*Approximate thickness needed*

However, remember to use the product information on the insulation packaging to determine the actual thickness for any *new* insulation.

Table 3. **Zip Codes and Corresponding Insulation Zones** For Use With Recommendations in Table 4

If Your Zip code Begins With These Three Numbers	Your Insulation Zone Is:
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011	6
012	8
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***For Hawaii, Puerto Rico, and Virgin Islands, your Insulation Zone is 1.**

Table 4: **Insulation Groups for Each Insulation Zone for Six Heating System Types,** Use with Tables 5 and 6 to Determine Recommended Insulation Levels (a)

Insulation Zone	Existing Houses						New Houses					
	Gas heat	Electric furnace	Electric baseboard(b)	Heat Pump	LPG	Fuel Oil	Gas heat	Electric furnace	Electric baseboard(b)	Heat Pump	LPG	Fuel Oil
1	E1	E4	E3	E3	E2	E2	N1	N5	N4	N2	N2	N2
2	E2	E4	E4	E3	E2	E3	N2	N5	N5	N3	N4	N3
3	E3	E4	E3	E3	E2	E3	N3	N5	N5	N3	N5	N3
4	E3	E6	E4	E3	E4	E3	N5	N5	N5	N5	N5	N5
5	E4	E6	E5	E4	E6	E5	N5	N5	N5	N5	N5	N5
6	E4	E6	E6	E6	E6	E5	N5	N6	N5	N5	N5	N5
7	E5	E6	E6	E5	E6	E5	N5	N5	N5	N5	N5	N5
8	E5	E6	E6	E6	E6	E5	N5	N6	N5	N5	N5	N5
9	E6	E6	E6	E6	E6	E6	N5	N7	N6	N5	N5	N5

(a)Electric air conditioning is assumed for all heating system types.

(b)Use for any electric resistance heating system without ducts, and for a central electric furnace if the ducts are totally within the conditioned part of the house.

BEFORE YOU INSULATE

You Must Control Air Leakage

Most homeowners are aware that air leaks into their houses through what seem to be small openings around doors and window frames and through fireplaces and chimneys. Air also enters the living space from other unheated parts of the house, such as attics, basements, or crawl spaces. The air travels through any openings in your walls, floors, or ceilings, such as cracks where two walls meet, where the wall meets the ceiling, or near interior door frames. Other openings may also be found, such as gaps around electrical outlets and switch boxes, recessed fixtures, recessed cabinets, pull-down stairs, furred or false ceilings such as kitchen or bathroom soffits, behind bath tubs and shower stall units, floor cavities of finished attics adjacent to unconditioned attic spaces, and plumbing connections. These leaks between the living space and other parts of the house are often much greater than the obvious leaks around windows and doors. Since many of these leakage paths are driven by the tendency for warm air to rise and cool air to fall, the attic is often the best place to stop them. *It's important to stop these leaks before adding attic insulation because the insulation may hide them and make them less accessible.* Usually, the attic insulation itself will not stop these leaks and you won't save as much as you expect because of the air flowing through the insulation. Sometimes these leak locations are visible because the existing insulation has been stained by dust carried by the air flow. Some of the openings to look for include:

- Top openings of interior partition wall cavities: staple a plastic sheet over the opening and seal it around the edges with a high quality caulking material.
- Around the chimney: pack gaps around an insulated chimney with UNFACED rock wool or UNFACED fiber glass insulation. Do not insulate bare, hot flue pipes. DO NOT USE ANY COMBUSTIBLE PRODUCTS, SUCH AS CELLULOSE INSULATION OR PLASTIC FOAMS, HERE.
- Around the attic trap door or entry door: weatherstrip the edges.
- Areas above staircase ceilings and dropped ceilings: staple a plastic sheet over the opening and seal it around the edges with a high quality caulking material.
- Around pipes (look under your sinks and behind your toilets) and ducts penetrating a wall or attic floor: pack insulation tightly into the gap. You can also fill the area around them with spray polyurethane foam.

Sometimes joints between walls and floors allow open passage of air between the heated part of the house and the attic area or outdoors. Look for such joints in your attic or in the

space over a porch ceiling. This air leakage path is commonly found in Cape Cod-type houses, or if attic space has been converted to living space (see 2D in Fig. 1). A similar arrangement occurs when the second floor of a two-story house is larger than the ground floor and has an overhang over the outdoors (see 4D in Fig. 1). Another major source of air leakage can be the joint between a porch roof and a side wall. If you can reach these areas, you can stop the leaks by carefully covering the openings with plywood. If the areas are more difficult to reach, you can greatly reduce the air leakage by blowing high-density insulation or injecting plastic foam insulation into these joints, thus reducing these energy-gobbling air paths.

You Must Prevent Moisture Accumulation

Much more is now known about moisture problems than was understood when this fact sheet was written in 1997. A 2002 Addendum that tells much more about this important issue is found at the back of this publication.

Table 5: Recommended Total R-values for Existing Houses(a)

Insulation Group	Attic	Floor over unconditioned space	Wall cavity	Crawl space wall(b)	Basement wall	Add insulated sheathing to an uninsulated wall(c)	Add insulated sheathing to an insulated wall(c)
E1	19	11	0	11	11	5	0
E2	30	11	11	11	11	5	0
E3	38	11	11	19	11	5	0
E4	38	19	11	19	11	5	0
E5	38	25	11	19	11	5	5
E6	49	25	11	25	11-13	5	5

(a) R-values have units of °F•ft^2•h/Btu. This table, when used with Tables 3 and 4, provides recommended total R-values for existing houses and was produced using the ZIP-Code computer program. The recommendations are based on an analysis of cost-effectiveness, using average local energy prices, regional average insulation costs, equipment efficiencies, climate factors, and energy savings for both the heating and cooling seasons.

(b) Use only if floor is uninsulated and the crawlspace is unventilated - see the discussion about unventilated crawlspaces.

(c) Recommendation assumes that the exterior siding was removed for other purposes, i.e., does not include any consideration of the cost of removing and replacing the exterior siding. The R-values shown here represent 1 inch of foam sheathing. Foam sheathing with R-values up to R-7 could be used.

BUILDING A NEW HOUSE? SOME THINGS YOU SHOULD KNOW

If you are buying or building a new house, make sure that recommended energy-saving features are included. The Federal Trade Commission (FTC) home insulation rule requires the seller of a new home to provide information on the type, thickness, and R-value of the insulation that will be installed in each part of the house in every sales contract. Insulation contractors are required to give their customers similar information. Many state or local building codes include minimum requirements for home insulation. Be sure that your new home or home addition meets these building codes. Also, some government home financing programs require that the home be built to meet the *Model Energy Code*. You may wish to install insulation beyond the minimum specified in such codes, especially if those minimum levels are below those recommended in this fact sheet.

To keep initial selling prices competitive, many home builders offer standard (not optimal) levels of insulation, although additional insulation would be a good investment for the buyer. The *Model Energy Code* and other guidelines for new home construction are published by several organizations listed on page 19. Following these guidelines will provide you with a more energy efficient home. These guidelines also describe methods you can use during house design to compensate for energy lost through metal studs in the walls or a large amount of windows. You should find out if your builder constructs homes in accordance with these guidelines. It is almost always more economical to install the recommended levels of thermal insulation during initial construction rather than adding insulation later.

How Much and Where?

Figure 1 shows which building spaces should be insulated. Discuss the house plans with your builder, and make sure each of these spaces is insulated to the R-values recommended for your situation. Tables 3, 4, and 6 give the information required to determine recommended R-values. For example, consider a house under construction in St. Paul, Minnesota (zip code 55103) with a gas furnace. Table 3 shows that the region with zip codes starting with 551 are in Insulation Zone 8 (or see Fig. 2.) Now look at Table 4 and locate Insulation Zone 8 in the left-hand column. Next look for the gas heat column under "New Houses", which shows that the Insulation Group for this house is N5. Looking at Table 6, the recommended R-value for attic floor insulation for insulation group N5 is R-49. The homeowner could then check Table 1 to find several choices. Remember to buy the insulation based on this R-value, and to check the product label to determine the insulation's proper thickness. Specialty insulation products are available to provide higher insulation values in confined spaces in new homes, such as in wall cavities and cathedral ceilings.

In Table 6, both insulative sheathing and cavity insulation are specified for walls because it is important to use them together as a system. Any combination of sheathing and cavity insulation shown in this table will give you a similar life-cycle savings. If you support energy conservation or believe that energy costs will be escalating, you should choose the higher levels shown. If your only concern is first costs, you can get about the same life-cycle savings with the lower levels. Also, these recommendations assume that the insulative sheathing will be placed outside a wood sheathing product. If you choose to replace the wood sheathing with a combination of insulative sheathing and necessary bracing, you should choose sheathing with an R-value near the high end of the R-value range.

The band joists, or outside edges of frame floors, should be insulated while the house is under construction. Foundation insulation options for new construction are broader than for existing homes. The builder may, for example, choose to insulate the exterior of a basement or crawlspace wall. You should discuss termite inspection and control options with your builder when choosing your foundation insulation method. Special sill plate (the joint between the top of the foundation and the bottom of the house frame) mineral fiber sealing products are designed to reduce air leaks if installed during the initial house construction. Spray polyurethane foam insulation can be applied to a home under construction and will not only insulate, but will also reduce air leakage in the building envelope. This foam insulation, along with other flammable insulations or insulation facings must be covered or otherwise protected to meet fire codes.

Design Options

Some new homes are built using metal frames instead of wood. When you insulate a metal-framed building, it is important to recognize that much more heat flows through metal studs and joists than through pieces of wood. Because of this difference, placing insulation between the wall studs, or between attic or floor joists, doesn't work as well for metal-framed houses as it does for wood-framed houses. If your walls have metal frames, you will probably need to place continuous insulative sheathing over the outside of the wall frame, between the metal framing pieces and your exterior siding. (Note that this insulative sheathing cannot take the place of plywood or other seismic bracing.) If your attic has metal joists, you may want to place rigid foam insulation between the joists and the ceiling drywall. Table 6 has recommended insulation levels for metal frame

BUILDING A NEW HOUSE? SOME THINGS YOU SHOULD KNOW (continued)

buildings. *It's important to recognize that even if you install the recommended level of insulation in a metal frame building, you will not necessarily get thermal performance as good as you would get from a wood structure with its recommended level.* That's because the insulation R-values given in this fact sheet were chosen based on an economic evaluation of life-cycle costs to the consumer, not to meet an arbitrary energy conservation target.

Insulating concrete forms can be used to construct walls for new homes. These special concrete walls come in a variety of configurations and can provide additional thermal mass to your home to help reduce the effect of outdoor temperature swings. The Insulating Concrete Form Association is listed on page 18 and they can give you more information about insulating concrete walls.

Structural insulated panels can also be used to construct a house. These panels sandwich plastic foam insulation between two layers of a wood product, thus eliminating the need for structural wood framing members. This system can reduce air leaks into and out of the structure and therefore may offer improved thermal performance compared to stick-built walls. The Structural Insulated Panel Association is listed on page 18, and they can give you more information about structural insulated panels.

Some homes are built with an External Insulation Finish System (EIFS) that gives a stucco-like appearance. There is some controversy right now about whether or not these homes are likely to experience moisture problems. You should discuss this possibility with your builder and your insurance agent if you are considering this type of building.

Figure 2. **Insulation Zones** for use with Recommendations in Table 4. (For Hawaii, Puerto Rico, and Virgin Islands, your Insulation Zone is 1.)

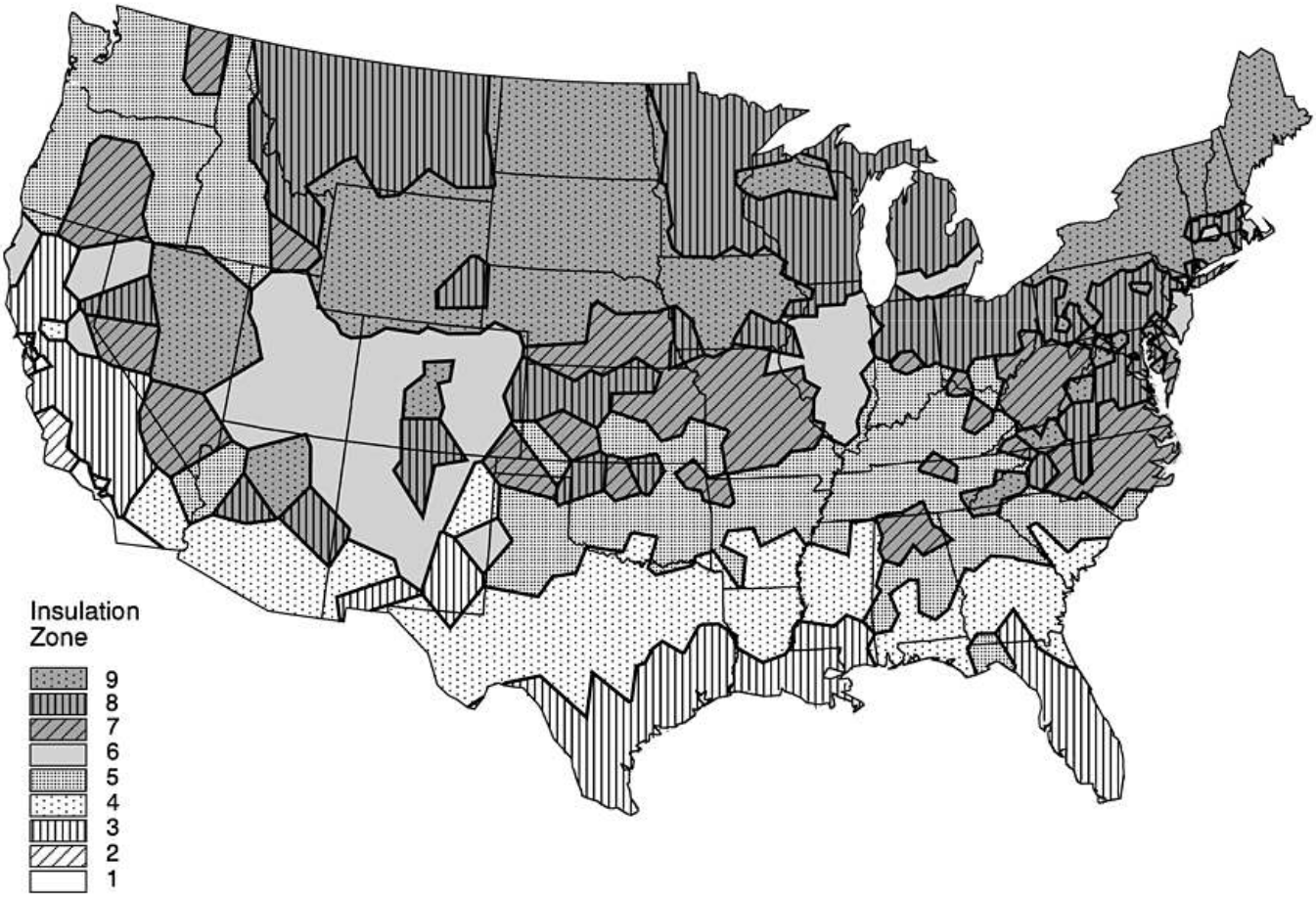


Table 6. **Recommended R-values for Residential New Construction(a)**

Attics and Floors

Insulation Group	Attic(b)	Floors	Cathedral ceilings(c)		Metal-framed building(**d**)	
					Attic(b)	Floors
N1	22	11	22		30	11
N2	38	11	30		30	25
N3	38	13	38		49	25
N4	38	25	38		49	25
N5	49	25	38		49	25
N6	49	25	38		49	25
N7	49	25	60		49	25

Walls

Insulation Group	Wood frame wall assembly (c,e)		Optimum-Value Engineered (OVE) wall cavities(f)	Above-grade masonry wall interior (g)	Band joist	Metal frame wall assembly(c,**d**,e)	
	Insulative Sheathing	Cavity				Insulative Sheathing	Cavity
N1	0	11 to 13	19	5.7	19	2.5 to 5	11 to 13
N2	0	11 to 13	19	9.5	19	2.5 to 5	11 to 13
N3	0	11 to 15	19	11.4	30	2.5 to 5	11 to 13
N4	0 to 5	11 to 15	19	11.4	30	2.5 to 7	11 to 15
N5	0 to 7	11 to 15	19	11.4	30	5 to 7	11 to 15
N6	2.5 to 7	13 to 21	21	15	30	5 to 7	11 to 21
N7	5 to 7	19 to 21	21	15	30	5 to 7	13 to 21

Basements and Foundations

Insulation Group	Crawl space walls(h)	Slab edge	Basement wall exterior (below grade)	Basement wall interior (below grade) (g)
N1	11	0	4	11
N2	13	4	4	11
N3	19	4	4	11
N4	19	4	5	11
N5	19	8	10	11
N6	19	8	15	19
N7	19	8	15	19

(a) R-values have units of °F•ft^2•h/Btu. This table, when used with Tables 3 and 4 provides recommended R-values for new houses and was produced using the ZIP-Code computer program. The recommendations are based on an analysis of cost-effectiveness, using average local energy prices, regional average insulation costs, equipment efficiencies, climate factors, and energy savings for both the heating and cooling seasons.

(b) Does not include the cost of raised heel framing necessary to install the higher levels of insulation in the portions of the attic near the eaves.

(c) Includes the cost of thicker framing where necessary.

(d) *The recommended insulation levels for metal frames will not necessarily give you performance as good as the recommended levels for a wood-framed building. Please see the discussion about heat loss paths associated with metal frames.*

(e) For new construction, it is important to use both the insulative sheathing and cavity insulation recommended, especially for metal walls. Assumes insulative sheathing placed outside of wood sheathing product. For a full discussion of the ranges shown here, see page 10.

(f) These recommendations assume that a 2x6 wall can be built for the same cost as a 2x4 wall, using a careful design procedure called Optimum Value Engineering. Discuss this option with your builder.

(g) Evaluation included cost of necessary framing but did not include cost of finishing drywall and paint.

(h) Crawl space walls are only insulated if the crawl space is unventilated. Please see the *Builders Foundation Handbook* listed on page 19.

Ventilation

Adequate ventilation in your house is important for two reasons:

- Moisture Control - Ventilation will prevent elevated moisture levels within the conditioned space during the heating season. These elevated levels can lead to condensation on window surfaces and give rise to surface mold and mildew, as well as concealed condensation within walls and roof spaces.
- Avoiding Indoor Air Pollution - When natural ventilation has been sharply reduced, as in super-energy-efficient houses, it may be necessary to provide fresh air ventilation to avoid build-up of stale air and indoor air pollutants. Special air exchange units with heat-saving features are available for this purpose. The Home Ventilating Institute, listed on page 18, can give you more information about such heat-recovery ventilators.

A well-insulated attic should be adequately ventilated to prevent moisture accumulation. Attics may be ventilated with a combination of soffit vents at eaves and continuous ridge vents. Attic vents may also be installed in gable faces. Many codes and standards require one square foot of unobstructed ventilation opening for each 300 square feet of attic floor area if a vapor retarder is included in the top floor ceiling. Twice as much ventilation is recommended if there is no vapor retarder. The net free area of a vent is smaller than its overall dimension because part of the vent opening is blocked by meshes or louvers. The openings should be equally distributed between the soffit and ridge vents or between each gable face. Never cover or block vents with insulation. Take care to prevent loose-fill insulation from clogging vents by using baffles.

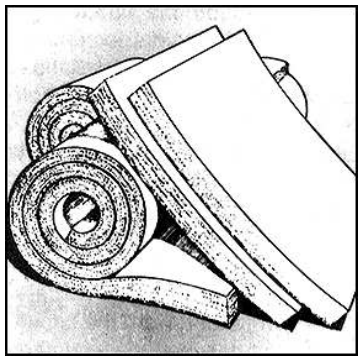
Whether or not to ventilate a crawl space has been a controversial issue. Most building codes presently require installation of vents to provide ventilation with outside air, but a recent symposium on crawl space design organized by the American Society of Heating, Refrigerating and Air Conditioning Engineers concluded that there is no compelling technical basis for crawl space ventilation requirements. However, if the crawl space is not ventilated, it is crucial that all of the crawl space ground area be covered with a durable vapor retarder, such as heavy-weight polyethylene film. Other concerns that must be considered before eliminating ventilation to your crawl space are discussed in the *Builders Foundation Handbook*, listed on page 19.

WHAT KIND OF INSULATION SHOULD YOU BUY?

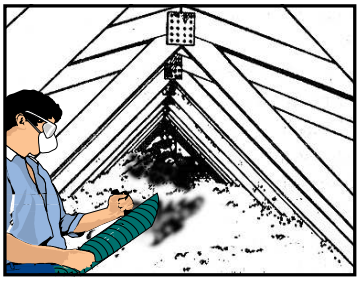
Once you have located the areas in your house requiring insulation, and have determined what R-value is needed, you will need to decide what type to buy. Some types of insulation require professional installation, and others you can install. You should consider the several forms of insulation available, their R-values, and the thickness needed. Remember, for a given type and weight of insulation, the thicker it is, the higher its R-value. The basic forms of thermal insulation are summarized in Table 1. Here is some additional information.

Basic Forms of Thermal Insulation

BLANKETS, in the form of batts or rolls, are flexible products made from mineral fibers. They are available in widths suited to standard spacings of wall studs and attic or floor joists. Continuous rolls can be hand-cut and trimmed to fit. They are available with or without vapor retarder facings. Batts with a special flame-resistant facing are available in various widths for basement walls where the insulation will be left exposed.

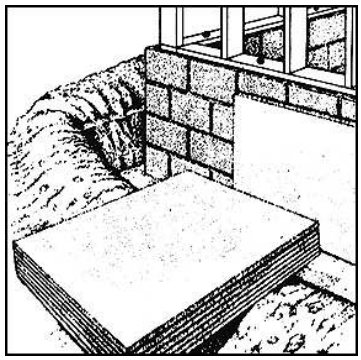


BLOWN-IN loose-fill insulation includes loose fibers or fiber pellets that are blown into building cavities or attics using special pneumatic equipment. Another form includes fibers that are co-sprayed with an adhesive to make them resistant to settling. The blown-in material can provide additional resistance to air infiltration if the insulation is sufficiently dense.



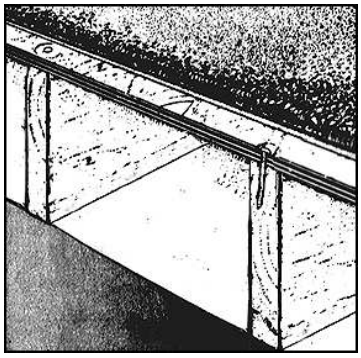
FOAMED-IN-PLACE polyurethane foam insulation can be applied by a professional applicator using special equipment to meter, mix, and spray into place. Polyurethane foam can also help to reduce air leaks.

RIGID INSULATION is made from fibrous materials or plastic foams and



is pressed or extruded into board-like forms and molded pipe-coverings. These provide thermal and acoustical insulation, strength with low weight, and coverage with few heat loss paths. Such boards may be faced with a reflective foil that reduces heat flow when next to an air space.

REFLECTIVE INSULATION SYSTEMS are fabricated from aluminum foils with a variety of backings such as kraft paper, plastic film, polyethylene bubbles, or cardboard. The resistance to heat flow depends on the heat flow direction, and this type of insulation is most effective in reducing downward heat flow. Reflective systems are typically located between roof rafters, floor joists, or wall studs. If a single reflective surface is used alone and faces an open space, such as an attic, it is called a RADIANT BARRIER. Radiant barriers are installed in buildings to reduce summer heat gain and winter heat loss. They are more effective in hot climates than in cool climates. All radiant barriers must have a low emittance (0.1 or less) and high reflectance (0.9 or more).



MAKE YOUR SELECTION

The type of insulation you use will be determined by the nature of the spaces in the house that you plan to insulate. For example, since you cannot conveniently "pour" insulation into an overhead space, blankets, spray or board products, or reflective systems are used between the joists of an unfinished basement ceiling. The most economical way to fill closed cavities in finished walls is with blown-in insulation applied with pneumatic equipment or with foamed-in-place polyurethane foam. Table 1 provides a concise summary of the appropriate applications for the various types of thermal insulation.

It is important to know that the different forms of insulation can be used together. For example, you can add batt or roll insulation over loose-fill insulation, or vice-versa. Usually, material of higher density (weight per unit volume) should not be placed on top of lower density insulation that is easily compressed. Doing so will reduce the thickness of the material underneath and thereby lower its R-value.

In cold climates, some low-density loose-fill insulation allows air to circulate between the top of your ceiling and the attic. This air circulation can decrease the effective thermal resistance of the insulation and may be significant for regions with more than 5000 heating degree days, or north of a line running from New York to Pittsburgh to St. Louis to Topeka to Santa Fe to Reno and up to Portland, Oregon. You can eliminate this air circulation by covering the loose-fill insulation with a blanket insulation product or with a higher density loose-fill insulation.

CHECK THE LABEL BEFORE YOU BUY

No matter what kind of insulation you buy, check the information on the product label to make sure that the product is suitable for the intended application. A good insulation label should have a clearly stated R-value, and information about health and safety issues. An informative label should state:

- The type of insulation material;
- The R-value (measured at 75°F);
- The types of spaces that can be insulated;
- Safety precautions in application and use, including any fire-hazard related restrictions;
- The quantity in the package;
- The name and address of the manufacturer or distributor.

CAN YOU DO IT YOURSELF?

Whether or not you install the insulation yourself depends on the structural design of your house and the type of materials used in its construction.

Placing insulation in the attic floor is usually easy, requiring only laying the material between the parallel joists of the frame. Be careful about where you step in the attic. Walk only on the joists so that you won't fall through the drywall ceiling. You may need to place walking boards across the tops of the joists to make the job easier. Remember that it is important to seal up air leaks between your living space and the attic before adding insulation in your attic. Also, bear in mind that insulation placed between joists, rafters, and studs does not retard heat flow through the exposed frame. This heat flow is called thermal bridging and is especially important in houses with metal frames or joists. In attics,

thermal bridging can be reduced by adding sufficient loose-fill insulation thickness, or cross-installed batts, to cover the wood or metal frame as much as possible. In some houses with low-pitch roofs, it is difficult to gain access to all of the attic floor, so blowing equipment may be needed to place insulation in relatively inaccessible areas. In most attics, it is easier to get complete coverage with blown-in insulation. It is best to hire an insulation contractor for this job.

In existing buildings, installing insulation in the cavity of exterior walls is difficult. It usually requires the services of a contractor who has special equipment for blowing loose-fill insulation into the cavity through small holes cut through the sidewall, which later are closed. It is sometimes feasible to install rigid insulation on the outdoor side of masonry sidewalls such as concrete block or poured concrete. When new siding is to be installed, always consider adding thermal insulation under it. Generally the services of a qualified contractor are needed to make such installations.

The homeowner can often insulate basement or crawlspace walls, or floors over unheated areas, using rigid insulation or batt insulation. Sprayed-on insulation products are also available for these locations, but would require a qualified contractor. If you insulate a floor above a crawl space, all ducts and water lines running below the insulation should be insulated as well. Insulate crawl space walls *only* if the crawl space is dry all year, the floor above is not insulated, all ventilation to the crawl space is blocked, and a vapor retarder (e.g., heavy-weight polyethylene film) is installed on the ground to reduce moisture migration into the crawl space. The *Builders Foundation Handbook* is a complete guide to foundation insulation, including basement, crawl space, and slab insulation and is listed on page 19 so that you can get more information.

Adding thermal insulation to the ceiling or walls of a mobile home is complex and usually requires installation by specialists. However, it is often possible to add floor insulation to such a home, just as you would for any other type of house.

IF YOU DO IT YOURSELF

These do-it-yourself instructions cover installation of batts and blankets, loose-fill materials, rigid boards, and reflective insulations. *Before beginning the work, read and observe the following precautions:*

- *Wear clothing adequate to protect against skin contact and irritation.* A long-sleeved shirt with collar and cuffs buttoned, gloves, hat, glasses, and disposable dust respirator are advisable in all do-it-yourself insulation projects. Also, read the label and follow all the manufacturer's directions.
- *Do not cover or hand-pack insulation around bare stove pipes, electrical fixtures, motors, or any heat-producing equipment such as recessed lighting fixtures.* Electrical fire-safety codes prohibit the installation of thermal insulation within three inches of a recessed fixture enclosure, wiring compartment, or ballast, or above the fixture so that it will trap heat and prevent free circulation of air, unless the fixture is identified by label as suitable for insulation to be in direct contact with the fixture. THIS IS FOR FIRE SAFETY.

Also, if your home is very old, you may want to have an electrician check to see if the electrical insulation on your wiring is degraded or if the wires are overloaded. In either of these two situations, it may be hazardous to add thermal insulation within a closed cavity around the wires because that could cause the wires to overheat. If your home was wired using a now obsolete method called knob and tube wiring, the National Electric Code forbids the installation of loose, rolled, or foam-in-place insulation if the insulation would surround the wires and prevent heat dissipation from the electrical conductors to a free air space. THIS IS FOR FIRE SAFETY.

- *Do not cover attic vents with insulation.* Proper ventilation, especially in attics, must be maintained to avoid overheating in summer and moisture build-up all year long.

Blanket Insulation: Batts and Rolls

Installing batts and rolls in attics is fairly easy, but doing it right is very important. On unfinished attic floors, work from the perimeter toward the attic door. In new construction, the vapor retarder facing should be installed with the facing placed down toward the ceiling gypsum board, except in hot humid climates where unfaced batts should be used. If reinsulating over existing insulation, it is recommended that unfaced batts be used. If there is not any insulation in your attic, fit the insulation between the joists. If the existing insulation is near or above the top of the joists, it is a good idea to place the new batts perpendicular to the old ones because that will help to cover the tops of the joists themselves and reduce heat loss or gain through the frame. Also, be sure to insulate the trap or access door. Although the area of the door is small, an uninsulated attic door will reduce energy savings substantially.

On walls, begin at the top and work down. Place the vapor retarder towards the lived-in side, except in hot humid climates. Fit the insulation between the wood frame studs, cut off the excess length where necessary, and secure the insulation by stapling the flanges of the vapor retarder according to the manufacturer's instructions. Cut the batt carefully to fit around obstructions with no gaps. Don't compress the insulation to fit behind pipes or wires. Instead cut to

the middle of the batt's thickness so you have a flap under the wire and one over the wire.

Owens-Corning

The kraft paper or standard foil vapor retarder facings on many blanket insulation products must be covered with gypsum or interior paneling because of fire considerations. Some blanket products are available without these facings or with a special flame resistant facing (labeled FS25 - or flame spread index 25) for places where the facing would not be covered. Sometimes, the flame resistant cover can be purchased separately from the insulation. Also, there are special fiber glass blanket products available for basement walls that can be left exposed. These blankets have a flame-resistant facing and are labeled to show that they comply with ASTM C 665, Type II, Class A.

When a fiber glass blanket is used to insulate the inside of basement walls, it is necessary to attach wood furring strips to the walls by nailing or bonding; or to build an interior stud-wall assembly on which the interior finish can be attached after the insulation is installed. The cavity created by the added framing should be thick enough for the desired insulation R-value.

When a fiber glass blanket is used to insulate the walls of an unventilated crawlspace, it is sometimes necessary to attach wood furring strips to the walls by nailing or bonding. The insulation can then be stapled or tacked into place. Alternatively, the insulation can be fastened to the sill plate and draped down the wall. Because the insulation will be exposed, be sure to use either an unfaced product or one with the appropriate flame spread rating. If you live in a very cold region, you should continue the insulation over the soil for about two feet (on top of the necesssary ground vapor retarder discussed previously).

Batts and rolls must be cut and fit around such obstructions as cross-bracing between floor joists, and window frames in walls. Strips of insulation may be cut off and stuffed into tight spaces by hand. Do not hand-pack insulation around hot spots such as recessed light fixtures. THIS COULD CAUSE HEAT BUILD-UP AND MAY BECOME A FIRE HAZARD.

When batts or rolls are used overhead, such as above an unheated crawl space or basement, fit the insulation between the beams or joists and push it up against the floor overhead as securely as possible without excessive compaction of the insulation. The insulation can be held in place, either by tacking chicken wire (poultry netting) to the edges of the joist, or with snap-in wire holders. Don't forget to place insulation against the perimeter that rests on the sill plate (see Figure 1). If you insulate above an unheated crawl space or basement, you will also need to insulate any ducts or pipes running through this space. Otherwise, pipes could freeze and burst during cold weather.

Rigid Board Insulation

When rigid foam insulation boards are used to insulate the interior of masonry walls, they do not require added vapor retarder treatment. If foil-faced board is used, the foil side is placed toward the room. To install boards, wood furring strips should be fastened to the wall first. These strips provide a nailing base for attaching interior finishes over the insulation. Fire safety codes require that a gypsum board finish, at least 1/2 inch thick, be placed over plastic foam insulation. The gypsum board must be attached to the wood furring strips or underlying masonry using nails or screws.

When rigid foam insulation boards are used to insulate the walls of an unventilated crawlspace, they can be bonded to the wall using recommended adhesives. Because the insulation will be exposed, be sure to check the local fire codes and the flame-spread rating of the insulation product. If you live in a very cold region, you should continue the insulation over the floor of the crawl space for about two feet (on top of the required ground vapor retarder discussed previously). If you live in an area prone to termite damage, check with a pest control professional to see if you need to provide for termite inspections.

Loose-Fill Insulation

This insulation is most efficiently installed by blowing it into place with pneumatic equipment. This method effectively breaks up any lumps and incorporates air so that the insulation has the desired density and thickness. When using loose-fill insulation in new construction, install a vapor retarder on the living side (see earlier section on moisture control). When loose-fill is used as additional insulation, either placed over existing loose-fill or over batts or blankets, do not install an additional vapor retarder.

Loose-fill insulation must be prevented from shifting into vents or from contacting heat-producing equipment (such as recessed lighting fixtures). Block off those areas with baffles or retainers to hold the loose-fill insulation in place.

Reflective Systems

Installing reflective insulation is similar to placing batts and blankets. Proper installation is very important if the insulation is to be effective. Study and follow the manufacturer's instructions. Often, reflective insulation materials have flanges that are to be stapled to joists in attics or floors, or to wall studs. Since reflective foil will conduct electricity, one must avoid making contact with any bare electrical wiring.

Radiant barriers may be installed in attics in several configurations. The radiant barrier is most often attached near the roof, to the bottom surface of the attic truss chords or rafter framing. A separate DOE fact sheet is available for radiant barriers in the attic to show which parts of the country are most likely to benefit from this type of system (see the citation on page 19).

IF YOU HAVE IT DONE PROFESSIONALLY

You should obtain cost estimates from several contractors for a stated R-value. Make sure you describe the job in writing in the same terms to each one. You may want to ask each contractor about their air-sealing services as well. Remember that you want good quality materials and labor, as well as price. **Do not be surprised to find the quoted prices for a given R-value installation to vary by more than a factor of two.** When you talk to a contractor, talk of R-values. Don't forget that R-values are determined by material type, thickness, and installed weight per square foot, not by thickness alone.

Each bag of insulating material used by the contractor should be marked with an R-value for the area to be covered. Although these figures may differ among manufacturers, the area figure will tell you the right number of bags to be used for loose-fill. Similarly, packages of other types of insulation should be identified by their R-value. It is important that you check that the proper amount is installed in your residence. Ask the contractor to attach vertical rulers to the joists prior to a loose-fill installation in your attic to help you see that the proper depth was installed. Also, the installer must provide a signed and dated statement describing the insulation installed, stating thickness, coverage area, R-value, and number of bags installed. In some areas, infrared thermography services are offered to help discover any gaps in the insulation.

Consumers may want to have their attic R-value evaluated to ensure that they are getting what they paid for. You can evaluate batt insulation installation by measuring the batt thickness and by checking for gaps between batts. "Cookie-cutting" is the insulation industry recognized procedure of evaluating installed loose-fill insulation. Many independent (third-party) firms offer "cookie-cutting" services to homeowners throughout the country. Contact the Insulation Contractors Association of America for a list of firms that offer these services; they can also provide you with brochures and fact sheets about inspecting your insulation job.

OTHER PLACES IN YOUR HOME FOR ADDED INSULATION

Don't overlook another area in your home where energy can be saved – the ductwork of the heating and air-conditioning system.

If water lines and the ducts of your heating or air-conditioning system run through unheated or uncooled spaces in your home, such as attic or crawl spaces, then the water lines and the ducts should be insulated. First check the ductwork for air leaks. Repair leaking joints first with mechanical fasteners, then seal any remaining leaks with water-soluble mastic and embedded fiber glass mesh. Never use gray cloth duct tape because it degrades, cracks, and loses its bond with age. If a joint has to be accessible for future maintenance, use pressure- or heat-sensitive aluminum foil tape. Then wrap the ducts with duct wrap insulation of R-6 with a vapor retarder facing on the outer side. (If you live in the deep South or southern California, you can use R-4 insulation.) All joints where sections of insulation meet should have overlapped facings and be tightly sealed with fiber glass tape; but avoid compressing the insulation, thus reducing its thickness and R-value. In many parts of the country, this type of insulation will pay for itself in energy saved.

Return air ducts are more likely to be located inside the heated portion of the house where they don't need to be insulated, but they should still be sealed off from air passageways that connect to unheated areas. Drywall-to-ductwork connections should be inspected because they are often poor (or nonexistent) and lead to unwanted air flows through wall cavities.

WANT TO KNOW MORE?

Additional and more detailed information about thermal insulation materials and installation and about energy conservation in buildings is available from the agencies and organizations listed below. Your public utility company may also provide information and assistance on home energy conservation practices and materials.

Internet Sites

Electronic version of this fact sheet, including specific recommendations for each 3-level zip code,
http://www.ornl.gov/roofs+walls
or http://www.eren.doe.gov

Building Envelope Research topics, see
http://www.ornl.gov/roofs+walls

Environmental Protection Agency Energy Star Programs,
http://www.epa.gov/energystar.html

Home Energy Saver Web project, produced by Lawrence Berkeley National Laboratory's Center for Building Science,
http://eande.lbl.gov/CBS/VH/vh.html

Computer Program

ZIP-Code Computer Program:
Operable version found on the internet at:
http://www.ornl.gov/roofs+walls
CD-ROM version available from:
the Buildings Technolgy Transfer Program Manager, Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6070

Manufacturer's Associations

Cellulose Insulation Manufacturers Association (CIMA)
136 South Keowee Street
Dayton, OH 45402
Phone 888-881-2462
Fax 937-222-5794
http://www.cellulose.org

Expanded Polystyrene (EPS) Molder's Association
1926 Waukegan Road, Suite 1
Glenview, IL 60025-1770
Phone 800-607-3772
Fax 847-657-6819
http://www.epsmolders.org

Home Ventilating Institute
30 West University Drive
Arlington Heights, IL 60004
Phone 847-394-0150
Fax 847-253-0088
e-mail amca@amca.org

Insulating Concrete Form Association
960 Harlem Avenue Suite 1128
Glenview, IL 60025
Phone 847-657-9730
Fax 847-657-9728

North American Insulation Manufacturers Association (NAIMA)
44 Canal Center Plaza, Suite 310
Alexandria, VA 22314
Phone 703-684-0084
Fax 703-684-0427
http://www.naima.org

Polyisocyanurate Insulation Manufacturers Association (PIMA)
1001 Pennsylvania Avenue, N.W., 5th Floor
Washington, DC 20004
Phone 202-624-2709
Fax 202-628-3856
http://www.pima.org

Reflective Insulation Manufacturers Association
P.O. Box 90955
Washington, DC 20090
Phone 800-279-4123

Structural Insulated Panel Association (SIPA)
1511 K Street NW, Suite 600
Washington, DC 20005
Phone 202-347-7800
Fax 202-393-5043

Manufacturer's Associations (cont)

Society of the Plastics Industry, Inc.
1801 K Street NW, Suite 600K
Washington, DC 20006-1301
Phone 202-974-5200
Fax 202-296-7005
http://www.socplas.org
Polyurethane Division
Phone 212-351-5425
e-mail polyu@socplas.org
http://www.polyurethane.org
Spray Polyurethane Division
Phone 800-523-5154
Foamed Polystyrene Alliance
Phone 202-974-2486
e-mail fpa@socplas.org

Reference Sources

U.S. Department of Energy
Energy Efficiency and Renewable Energy Clearing House (EREC)
PO Box 3048
Merrifield, VA 22116
Phone 800-363-3732
Fax 703-893-0400
electronic bulletin board
800-273-2955
http://erecbbs.nciinc.com
e-mail doe.erec@nciinc.com
Energy Efficiency and Renewable Energy Program Office Home Page
http://www.eren.doe.gov

Insulation Contractors Association of America (ICAA)
1321 Duke Street, Suite 303
Alexandria, VA 22314
Phone 703-739-0356
Fax 703-739-0412

National Association of Home Builders (NAHB)
1201 15th Street NW
Washington, DC 20005
Phone 202-822-0200
NAHB Research Center, Inc.
400 Prince Georges Boulevard
Upper Marlboro, MD 20772-8731
Phone 301-249-4000 ext. 702
Fax 301-249-0305
http://www.nahbrc.com
HomeBase Hotline 800-898-2842

National Institute of Building Sciences
1201 L Street NW, Suite 400
Washington, DC 20005
Phone 202-289-7800
Fax 202-289-1092

Other Publications

U.S. Department of Energy
Office of Scientific and Technical Information(OSTI)
P.O. Box 62
Oak Ridge, TN 37831
Phone 423-576-2268 or 576-8401

Attic Radiant Barrier Fact Sheet, DOE/CE-0335P
Builders Foundation Handbook, ORNL/CON-295
Moisture Control Handbook, ORNL/SUB--89--SD350/1
Supporting Documentation for the 1997 Revision to the DOE Insulation Fact Sheet, ORNL-6907

U.S. Department of Housing and Urban Development

Washington, DC 20410-6000
HUD Rehabilitation Energy Guidelines for One-to-Four Family Dwellings (HUD-7480)
HUD Rehabilitation Energy Guidelines for Multi-Family Dwellings (HUD-7481)

U.S. Environmental Protection Agency
Atmospheric Pollution Prevention Division
APPD
401 M St., Mail Code 6202J SW
Washington, DC 20460
Phone 888-STAR-YES

Energy Star fact sheets
Builder guides

Insulation Contractors Association of America (address above)

A Plan to Stop Fluffing and Cheating of Loose-Fill Insulation in Attics
Evaluating Installed Loose Fill Attic Insulation, Technical Bulletin No. 17
Verification of Contracted R-value in Improved Existing Attics Using Cookie Cutting, Technical Bulletin No. 25

National Association of Home Builders (address above)

12 Fact sheets available on home remodeling

Guidelines for New Home Construction

Model Energy Code
Council of American Building Officials
5203 Leesburg Pike
Falls Church, VA 22041
Phone 703-931-4533
also found at
http://huduser.org:73/1/2/c/mec

ASHRAE STANDARD 90.2-1993 Energy-Efficient Design of New Low-Rise Residential Buildings
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329

National Association of Home Builders (address above)

Many fact sheets, including information about metal-framed buildings

Thermal Design Guide for Exterior Walls
American Iron and Steel Institute
1101 17th St., N.W., Suite 1300
Washington, DC 20036-4700
Price: $10
hot line at 1-800-79STEEL

U.S. Department of Energy
Office of Scientific and Technical Information(OSTI)
P.O. Box 62
Oak Ridge, TN 37831
Phone 423-576-2268 or 576-8401

Builders Foundation Handbook, ORNL/CON-295
Moisture Control Handbook, ORNL/SUB--89--SD350/1

Building Standards and Guidelines Program (BSGP)

http://www.energycodes.org
BSGP Hotline: Phone 800-270-CODE.

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Department of Energy
Assistant Secretary
Energy Efficiency and Renewable Energy

Insulation Fact Sheet Addendum: Moisture

MOISTURE IN YOUR HOME

There is always some moisture in the air around us. An indoor relative humidity of about 50% is usually considered a healthy level because it is comfortable for humans and because many molds and mites are unlikely to thrive in that environment.

When Is Moisture a Problem?

Even though you need some moisture in the air you breathe, too much moisture in your home can cause problems. When moist air touches a cold surface, some of the moisture may leave the air and become liquid, or condense. If this happens on a cold pane of window glass, you will see the water run down and collect on the window sill, where it may ruin the paint or rot the wood trim. The water may even freeze, producing frost on the inside surface of the window. If moisture condenses inside a wall, or in your attic, you will not be able to see the water, but it can cause a number of problems. For example, mold and mildew grow in moist areas, causing allergic reactions and damaging buildings. Structural wood may rot and drywall can swell (see Figure 1). If moisture gets into your insulation, the insulation will not work as well as it should, and your heating and cooling bills will increase.

How Does Moisture Come into Your Home, and How Does it Move Around Inside the Building?

The most obvious way that moisture enters your home is through *rain*, either falling on a leaky roof, wind-driven against a poorly-sealed wall, or collecting against (and eventually leaking through) the walls of your basement or crawlspace. Roof leaks are usually noticeable and must be repaired immediately. Rain coming through a wall may be less apparent, especially if it is a relatively small leak and the water remains inside the wall cavity. These kinds of leaks may occur around window or door frames, so it is important to replace any missing or cracked caulking. Rain seeping through the ground into your basement or crawl space may appear as damp, moldy walls or may be handled by a sump pump. In any event, you want to be sure that all rain coming from the roof, gutters, or across the landscape is directed well away from your house.

You also *generate moisture* when you cook, shower, water your indoor plants, use unvented space heaters, do laundry, even when you breathe. More than 99% of the water used to water plants enters the air. If you use an unvented natural gas, propane, or kerosene space heater, all the products of combustion, including water vapor, are exhausted directly into your living space. This water vapor can add up to 5 to 15 gallons of water per day to the air inside your home. If your clothes dryer is not vented to the outside, or if the outdoor vent is closed off or clogged, all that moisture will enter your living space. Just by breathing and perspiring, a typical family adds about 3 gallons of water per day to their indoor air.

Because air always contains some moisture, *any air movement carries moisture with it.* Did you know that your house breathes? We inhale and exhale through our noses, but your house inhales through one air pathway and exhales through another. Usually houses inhale around their bottom half and exhale around their top half. These air pathways include all available openings, both small and large. Back when homes had central fireplaces or open furnaces, the chimneys took care of most of the exhaling. Now, however, much of that job is handled by small leaks through your walls, floors, or ceilings. Remember that if any air is leaking through electrical outlets or around plumbing connections into your wall cavities, moisture is carried along the same path. The same holds true for air moving through any leaks between your home and the attic, crawl space, or

Figure 1 Damage due to moisture inside a wall.

garage. Even very small leaks in duct work can carry large amounts of moisture, because the airflow in your ducts is much greater than other airflows in your home. This is especially a problem if your ducts travel through a crawlspace or attic, so be sure to seal these ducts properly (and to keep them sealed!). Return ducts are even more likely to be leaky, because they often involve joints between drywall and ductwork that may be poorly sealed, or even not sealed at all.

Moisture also moves through a process called *diffusion*. Diffusion occurs if some part of your home has a higher moisture level than another part, such as the movement of moisture from the bathroom to the bedroom after a hot shower has filled the bathroom with steam. Another example of diffusion is the movement of moisture through a floor above a damp crawl space and into the house above. Diffusion happens even if there is no air movement at all. Just as heat travels from a hot space to a cold space, even if it has to go through a wall, water vapor will travel from a space with a high moisture concentration to a space with a lower moisture concentration, again, even if it has to go through a wall. Cold air almost always contains less water than hot air, so diffusion usually carries moisture from a warm place to a cold place.

Liquid Movement can also happen within your walls, such as when water runs down an internal wall surface, or seeps through your insulation. Capillarity is another kind of liquid movement, and it can carry moisture from the ground up into your walls. This is the same process used by trees to carry water from their roots to their leaves. (Did you ever put a stalk of celery into a glass of colored water and watch the color climb to the leaves?). This process can carry water through concrete slab floors into your home. It can also carry water from the foundation into your walls, so your builder should include a vapor retarder between the foundation and the walls.

Moisture can also enter your home during the *construction process*. The building materials can get wet during construction due to rain, dew, or by lying on the damp ground. Concrete walls and foundations release water steadily as they continue to cure during the first year after a home is built. During the house's first winter, this construction moisture may be released into the building at a rate of more than two gallons per day, and during the second winter at a slower rate of about one gallon per day.

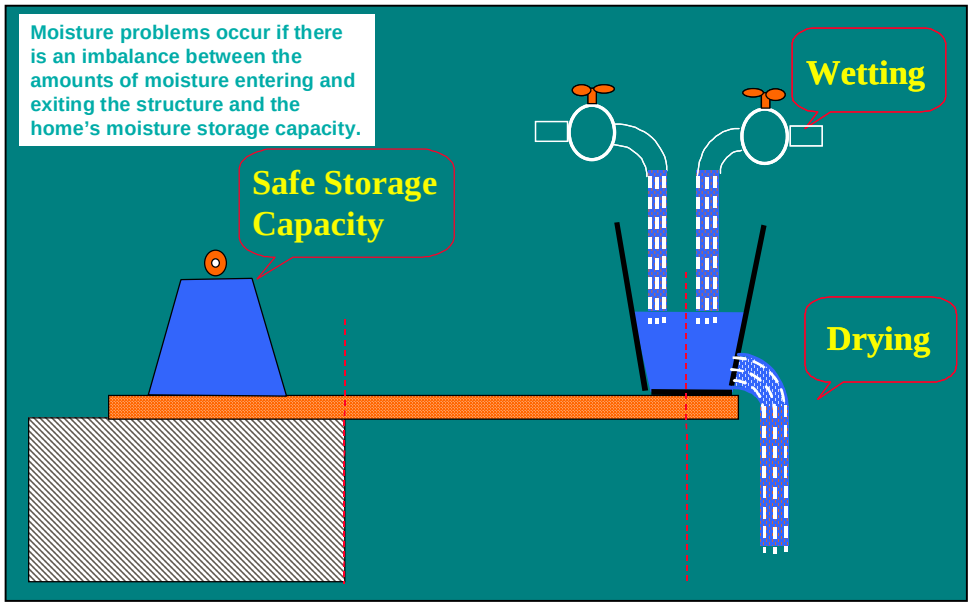

Figure 2 The moisture balance within your home

We have talked about moisture moving through your house, but your house is also able to *store moisture*. All building materials, including the wood studs within your walls and the gypsum wallboard, can hold a certain amount of moisture and still do their job properly. So if your weather alternates wet times with dry times, the building materials may be able to hold the moisture until drier air carries it away, as illustrated in Figure 2. But if the drying times are not long enough, or often enough, the extra moisture will cause problems.

What Does Insulation Have to Do with Moisture Problems?

Adding insulation can either cause or cure a moisture problem. When you insulate a wall, you change the temperature inside the wall. That can mean that a surface inside the wall, such as the sheathing underneath your siding, will be much colder in the winter than it was before you insulated. This cold surface could become a place where water vapor traveling through the wall condenses and leads to trouble. The same thing can happen within your attic or under your house. On the other hand, the new temperature profile could prevent condensation and help keep your walls or attic drier than they would have been.

So how do you know what to do? Your home's moisture performance will depend on the type and position of the insulation, whether you install a vapor retarder (these retarders are described later in this fact sheet), and where the vapor retarder is located. We used to think that the best insulation approach only depended on your weather. But now we know that it is more complicated than that. Moisture problems and their solutions depend not only on your climate, but on the type of house construction, the amount of moisture you produce inside the house, the way you ventilate your house, and the temperature conditions you maintain inside the house.

Why does the climate change the way you should use insulation? Remember that diffusion usually carries moisture from a warmer space to a colder space, and that moisture will condense to a liquid, or even solid, form if it contacts a cold surface. The location of the cold surface, and the location of the higher moisture concentration both vary with climate and season. If the outside air is colder than the inside of a home, then moisture from inside the warm house will try to diffuse through the walls and ceiling toward the cold, dry outside air. If the outside air is hot and humid, then moisture from outside will try to diffuse

through the walls toward the dry, air-conditioned inside air. In both of these cases, what's important is the difference between the inside and outside climates. So next-door neighbors could install the same insulation and vapor retarder but get very different results, depending on what temperatures they maintain inside their homes and how much moisture their lifestyles generate.

How does house construction impact moisture problems? Different materials will hold and transport moisture differently. For example, a brick surface will allow more moisture to pass than does aluminum siding, but the brick is also capable of storing moisture. And the house design will make a difference too. For example, attics, basements, and crawlspaces can be vented, or can be sealed and act as a part of your conditioned space. Insulation can be placed inside a wall, or on the inner or outer surface of the wall. These configurations obviously require different approaches if you want to avoid moisture problems.

So How Can You Avoid Moisture Problems?

Here are six things you should consider:

1. You need to stop all rain-water paths into your home by making sure your roof is in good condition and by caulking around all your windows and doors. If you are planning a new house, choose wider overhangs to keep the rain away from your walls and windows. You can also keep rainwater away from your basement walls or crawlspace by making sure that all water coming off your roof is directed away from your house and by sloping the soil around your house so that water flows away from your house. Be sure that dripping condensate from your air conditioner is properly drained away from your house. You can place thick plastic sheets on the floor of your crawlspace to keep any moisture in the ground from getting into the crawlspace air, and then into your house. These actions can also help reduce capillary water flows from the ground into your walls. You should also be careful that watering systems for your lawn or flower beds do not spray water on the side of your house or saturate the ground near the house.

2. You need to ventilate your home to remove the moisture that results from human activities within your home, such as breathing, bathing, cooking, etc. You especially need to vent your kitchen and bathrooms. You may be able to see mold (see a close-up view in Figure 3) that grows around your bathtub, but you will not be able to see mold growing inside the walls or in the attic. So, be sure that these vents go directly outside, and not to your attic, where the moisture can cause problems. Remember that a vent does not work unless you turn it on; so if you have a vent you are not using because it is too noisy, replace it with a quieter model. Some of the better vents are available with timers or moisture sensors so that you can be sure that the vents run long enough to remove all the excess moisture from that room. (While you are in the bathroom, it is also a good idea to check the caulking around your tub or shower to make sure that water is not leaking into your walls or floors when you bathe.)

3. When you think about venting to remove moisture, you should also think about where the replacement air will come from, and how it will get into your house. Many older homes have relied on leaky construction, drawing in their fresh air around window and door frames, building corners, wall-foundation joints, wall-roof joints, chimneys, etc. Air coming into your home through these pathways often travels through places you can not see, such as wall cavities, the space between floors, the crawlspace, or attic. If this outside air contains moisture, you will effectively be pumping moisture into these unseen places. As we seal up our homes to save energy, we need to replace these uncontrolled air pathways with energy-efficient pathways. Air-to-air heat exchangers can keep the indoor air at a healthy moisture level without increasing your energy costs. In humid regions, attic ventilation may also be a moisture source because you may be pulling air into your attic that has more moisture in it than the air in your home.

4. It is very important to seal up all air-leakage paths between your living spaces and other parts of your building structure. Measurements have shown that air leaking into walls and attics carries significant amounts of moisture. The Insulation Fact Sheet tells you how to do this.

5. Plan a moisture escape path. Some moisture will always be present in your home. You can help this moisture escape with well-planned ventilation or by careful selection of your building materials. Typical attic ventilation arrangements are one example of a planned escape path for moisture that has traveled from your home's interior into the attic space. You can also use a dehumidifier to reduce moisture levels in your home, but it will increase your energy use and you must be sure to keep it clean to avoid mold growth. If you use a humidifier for comfort during the winter months, be sure that there are no closed-off rooms where the

Figure 3 A magnified view of mold spores

humidity level is too high.

6. You can use vapor retarders to reduce moisture diffusion through your walls, floors, and ceilings. This is relatively easy to do when building a new house, but there are a few things that you can do for existing houses as well. The kind of vapor retarder you should use, and where you put it, depends on whether moisture is more likely to be moving into or out of your house. If moisture moves both ways for significant parts of the year, you may want to avoid the use of a vapor retarder completely.

What Is a Vapor Retarder?

Vapor retarders are special materials including treated papers, paints, plastic sheets, and metallic foils that reduce the passage of water vapor. Tests are made to measure how much water vapor can travel through each material, and the results are called permeance, or perms. The lower the perm, the better the vapor retarder. Table 1 lets you compare the permeance of some of the vapor retarders used in buildings.

Where Can I Learn More?

If you want to learn more about controlling moisture in your home, there are several useful books available:

Moisture Control in Buildings, Heinz R. Trechsel, Ed., American Society for Testing and Materials, Philadelphia, PA, 1994, ISBN 0-8031-2051-6 , www.astm.org

ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 2001, www.ashrae.org

Moisture Control Handbook, by Joseph W. Lstiburek and John Carmody, Van Nostrand Reinhold, New York, NY, 1993, ISBN 0-442-01432-5, (earlier edition available as ORNL/Sub/89-SD350/1 from the National Technical Information Service, Springfield, VA, 1991, www.ntis.gov)

Environmental Protection Agency web site about molds and moisture: http://www.epa.gov/iaq/molds/moldguide.html

Table 1. Permeance of building materials, in perms (source - ASHRAE Fundamentals)

Paints	Primer-sealer	6.3
	Exterior acrylic paint	5.5
	Vapor retarder paint	0.45
Papers	Kraft-doubled	31
	Vapor retarder paper	0.2
	Foil/asphalt sheet	0.002
Insulation	Polystyrene, expanded (1 in.)	2
	Polystyrene, extruded (1 in.)	1.2
Foils and Films	Cellulose acetate (0.01 in.)	4.6
	Polyvinyl chloride (0.004 in.)	0.8
	Polyester (0.0032 in.)	0.23
	Polyethylene (0.002 in.)	0.16
	Polyethylene (0.006 in.)	0.06
	Aluminum foil	0
Structural Materials	Brick (4 in. thick)	4.7
	Concrete block (8 in. thick)	2.4
	Gypsum wall board	50
	Plywood (0.25 in.)	0.7 to 1.9