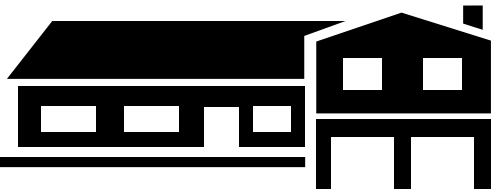
Residential Insulation



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Introduction

All of us pay to heat and cool our homes and wish we could pay much less than we do. In a typical home, space conditioning and comfort bills can account for up to one-half of a home's energy bills with the remaining portion due primarily to water heating, lighting, and appliances.

Installation of the cost-effective level of insulation is extremely important. Homeowners can affect their energy usage, save money, and help the environment all at the same time. Investing in energy-efficient options, such as insulation, will provide a continued payback to the homeowner, not only in dollars and cents, but also in a more enjoyable and comfortable living environment for many years, as well as a reduction in emission of greenhouse gases.

Purpose of this fact sheet

The following are the purposes of this fact sheet:

1. Explain how insulation works,
2. Assist homeowners and new home buyers in determining the correct level of insulation for their homes,
3. Present different types and uses of commercially available insulation, and
4. Explain where insulation should be applied in the home.

How does insulation work?

Heat naturally flows from a warmer area to a cooler one due to a difference in temperature. The greatest heat flow is through the path of least resistance. In the wintertime, any heated space of your home will lose heat to unheated areas such as the garage, attic, crawlspaces, or the outside. In the summertime, heat is transferred to the interior of your home due to a high outside temperature and admission of solar radiation (sunlight). In both cases, your home's heating and cooling system must replace or remove heat lost or gained. Proper insulation of the attic, walls, floors, and basement of your home will significantly help reduce heat transfer, reducing your monthly energy bills.

All forms of insulation are rated by an R-factor which is defined as its resistance to heat flow. The higher the R-factor, the greater the resistance to heat flow. The R-factor of thermal insulation depends upon the type of material used and its thickness and density. Adding additional insulation to your home increases the R-value and hence the resistance to heat flow, because the R-values of individual layers are added together. Two layers of insulation, one with an R-value of 19 and another with an R-value of 11, sum to a total R-value of 30 (19+11).

However, a greater level of insulation does not automatically insure cost-effectiveness. Energy savings associated with installing an additional layer of insulation may not be enough to pay for adding it. The amount of energy conserved, and hence money saved due to a greater level of insulation, will depend upon local climate conditions and the size, shape, con-

struction, and orientation of your home. In addition, the type and efficiency of your heating and cooling system and fuel costs play an important role. Other energy efficiency measures such as installation of energy-efficient windows and periodic maintenance of the furnace and air-conditioning system also affect overall savings. Each situation must be evaluated separately to determine cost-effectiveness of installing additional insulation.

Insulation effectiveness

Installation is highly critical with insulation. Installing the proper level of insulation in your home does not insure the insulation will stop heat loss if it is installed incorrectly. The following are some of the most common insulation installation problems:

1. Compression of batts--insulation that is compressed will provide less thermal resistance than its rated value and can provide a channel for convective air and heat movement.
2. Batts or vapor barrier stapled to the inside of studs--this can allow for unwanted air movement between the studs and the insulation. Always staple on the top of the stud; this will allow the batt to completely fill any cavity into which it is placed.
3. Not completely filling irregular areas--even small voids in irregular framing or at the end of the batt of 1-2% of the insulation area can result in a 25-40% loss of R-value.
4. Not installing loose-fill cellulose to its proper density (fluffing).

In addition, the total R-value of a wall, ceiling, floor, etc. will be different than the R-value printed on the insulation because heat can be conducted through studs and joists of the home (referred to as bridging or short-circuiting the insulation). With careful design and proper installation, short-circuiting can be dramatically reduced.

Where should insulation be applied in the home?

Primary spaces in which to insulate your home are shown in Figure 1 and include the attic, walls, floors, and around the crawlspaces/basement. In order of

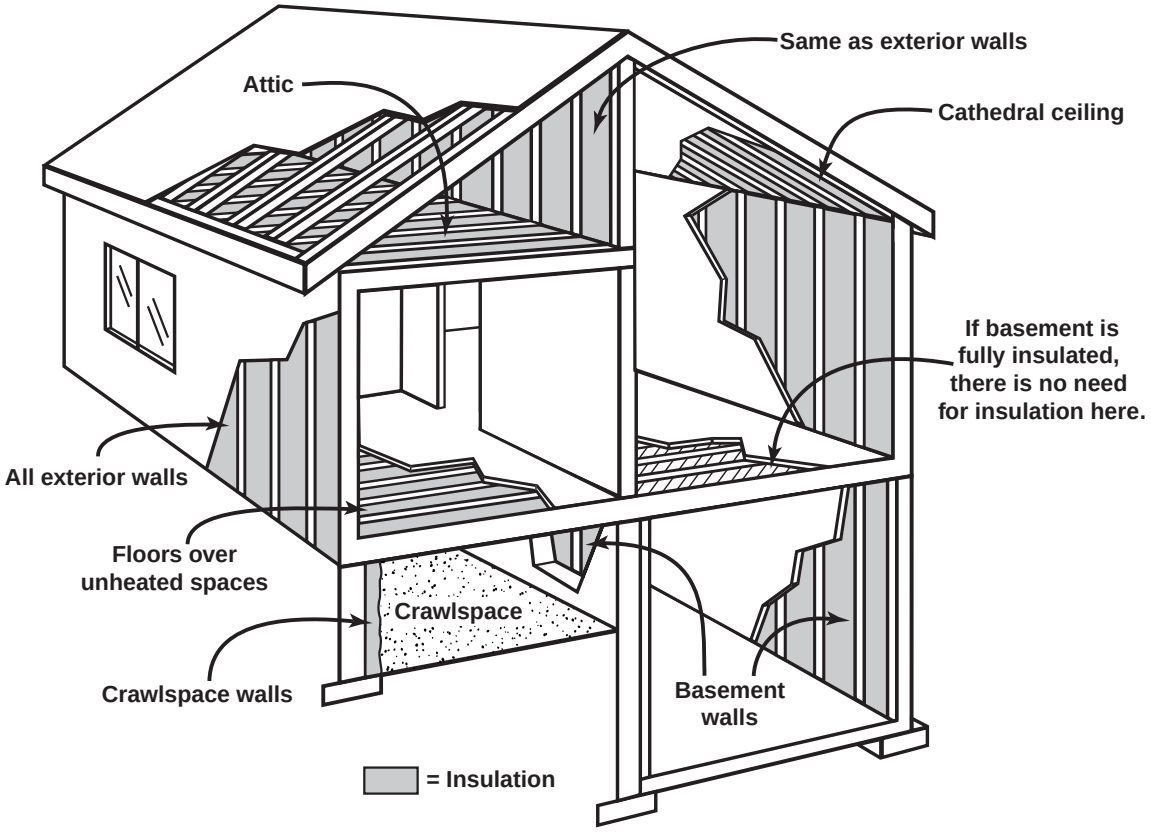

Figure 1. Places in the home where insulation should be applied

priority, the attic, including the attic door or cover hatch, should be insulated first followed by beneath floors above unheated spaces, around walls in a heated basement or unventilated crawlspace, and around the edges of slabs-on-grade, taking necessary precautions to treat for termites.

In unfinished attic spaces, insulate between and over the ceiling joists. In finished attic spaces, insulate between the studs of "knee" walls, between the studs and rafters of all exterior walls and the attic roof, and on top of ceilings with any cold space above. Insulate all exterior walls including walls between living spaces and unheated garages, and the foundation wall. For further information on foundation insulation, refer to Foundation Insulation Fact Sheet at *www.oznet.ksu.edu/dp_nrgy/ees*. Floors above cold spaces such as crawlspaces, any portion of a room that is cantilevered beyond the exterior wall below (i.e., bay windows), and slab floors built directly on the ground should definitely be insulated. Also, extend insulation into the band joists to prevent airflow.

What is the correct amount of insulation required for your home?

The correct amount of insulation required for a home in Kansas is dependent upon location of the home within the state (climate), how the home was constructed, type and efficiency of the home's heating and cooling system, and type of fuel used to heat the home. Guidelines have been established, and are presented in Table 1, to assist homeowners in determining the minimum level of insulation (R-factor) required for all areas of a home for three different climate zones in Kansas (shown in Figure 2). These levels depend upon the type of heating system, fuel used, and price of fuel/electricity. If the fuel/electricity price exceeds $6.50 per MCF of natural gas, $0.60 per gallon of propane, or 5.5 cents per kilowatt-hour for electricity, use the "Better" level.

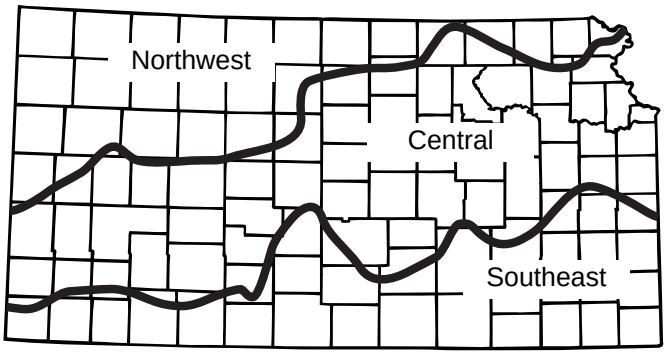

Figure 2. Climate zone map

For example, a home in Topeka (central climate zone) that has a natural gas furnace, basement walls, and pays $6.00 per MCF could use the "Minimum" insulation level which would be R-32 for the attic, R-20 for floors over unconditioned spaces, and R-9 for basement walls. For additional information on insulation in new home construction, consult the Tips for Purchasing an Energy-Efficient Home brochure at *www.oznet.ksu.edu/dp_nrgy/ees*.

Table 1. Recommended minimum and better levels of insulation (R-factor) in Kansas

	Northwest		Central		Southeast	
	Minimum	Better	Minimum	Better	Minimum	Better
Attic	36	40	32	38	30	36
Floor over unheated spaces	20	24	20	24	20	24
Walls	19	24	20	24	13	19
Foundation insulation						
basement wall	10	15	9	15	9	13
crawlspace walls	16	16	16	16	10	10
slab-on-grade	5	10	5	10	5	10

Checking for the correct amount of insulation in an existing home

Many older homes contain less insulation than is recommended by today's standards. Unless your home was recently built (1990 to the present), it would be a good idea to check the amount of insulation in the attic and walls. You can do this yourself simply by measuring the thickness and identifying the type of insulation used in each location. If your home was recently constructed, the builder should be able to tell you the level of insulation in each area of the home. Otherwise, check the attic, walls, and floors adjacent to the outside or unheated spaces like the garage, and verify that the basement, crawlspaces, and walls are insulated.

Where structural frame elements such as ceiling joists and wall studs are exposed, it is simple to check insulation. When walls are finished, it may be easier to remove an electrical outlet on the wall (making sure to turn off the power first) and shine a flashlight into the cavity around the outlet box. When you have determined the current level of insulation in your home, compare it with recommended levels presented in the section above. If insulation is absent or if levels are significantly below recommended levels, contact an insulation contractor about adding additional insulation. Remember to insulate the attic first, followed by the floors over unheated spaces, and then walls.

What needs to be done before insulation is installed?

Before insulation is installed in your home, either during construction or as a retrofit, the home needs to be checked for proper air sealing and moisture control. Air infiltration into the living spaces of your home, both in the summer and winter, can significantly increase your monthly energy bills. In general, insulation will not stop these leaks; therefore, taking time to seal points of air leakage before installing or adding extra insulation can result in big energy savings as well as a more comfortable living space. For more detailed information concerning air leakage and sealing in your home, consult the Air Sealing Your Home Fact Sheet available at *www.oznet.ksu.edu/dp_nrgy/ees*.

Control of moisture is also a major concern when installing insulation because warm air inside the home contains water vapor. If this vapor is allowed to pass into or through the insulation and condense, the insulation will lose its rated value, mold and mildew may form causing indoor air quality problems, wooden structural members may rot, and exterior paint will peel. Moisture moves throughout a home with air and by diffusion, but air movement is far and away the most important mechanism of moisture transport within a home. Therefore, good air sealing is extremely critical to controlling moisture problems.

To restrict moisture diffusion insulation, use a vapor-retarder paint (low permeability paint) or vapor barrier that is installed on the warm side–the lived-in side–of the space to be insulated.

Insulation forms and materials

Insulation usually comes in four forms–blankets and batts, loose-fill blown-in or sprayed-in-place, foamed-in-place, and rigid. Each type is made to fit in a different part of your house. Table 2 presents common types of insulation and important aspects associated with their use.

■ BLANKETS, in the form of batts or rolls, are flexible products typically made from fiberglass. Batts are lightweight, fit standard floor joist and wall stud spaces, are simple enough to install by yourself, and, if installed carefully, will not slump or settle.

Continuous rolls can be hand-cut and trimmed to fit and 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.

Blankets do not, however, readily fit into irregular spaces and can leave "insulation voids." If fiberglass insulation is installed with voids, its performance degrades substantially due to air convected around and through the batts. Even small gaps in the insulation will produce significant thermal degradation. Therefore, it is extremely critical that fiberglass of any form completely fill any cavity in which it is

Table 2. Types of insulation – Basic forms and applications

Form	Method of Installation	Where Applicable	Advantages
Blankets and Batts (Rolls) Fiberglass Rock wool	■ Fitted between studs, joists, and beams	■ All exposed walls, floors, and ceilings	■ Do-it-yourself ■ Vapor barrier ■ Suited for standard stud and joist spacing, which is relatively free from obstructions
Loose-fill (blown-in) or Sprayed-in-place Rock wool Fiberglass Cellulose	■ 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) ■ Spray-applied cellulose and foam provide an air barrier ■ Good for irregularly shaped areas and around obstructions
Foamed-in-place Polyurethane foam Isocyanurate foam	■ Applied by professional applicator using special equipment	■ Exterior stud wall cavities, irregular-shaped shapes, perimeter joist spaces	■ High R-values and will act as an air barrier
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 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.) ■ Unvented low-slope roofs	■ High insulating value for relatively little thickness ■ Can block thermal short circuits when installed continuously over frames or joists

installed and should not be covered with heavier insulation or other materials which may compress it. Figure 3 presents the correct installation of batt insulation in the attic; Figure 4 illustrates the proper way in which to install batt insulation with a vapor barrier attached.

R-values range from 3.2 to 4 per inch for batts and most loose-fill insulation. Recent research indicates performance of fiberglass degrades in cold weather due to convective air movement. Adding a "cap" layer of blown cellulose in the attic reduces this phenomena. Fiberglass is an irritant to skin and eyes; therefore, wear protective clothing when handling it.

Figure 3. Correct installation of batt insulation

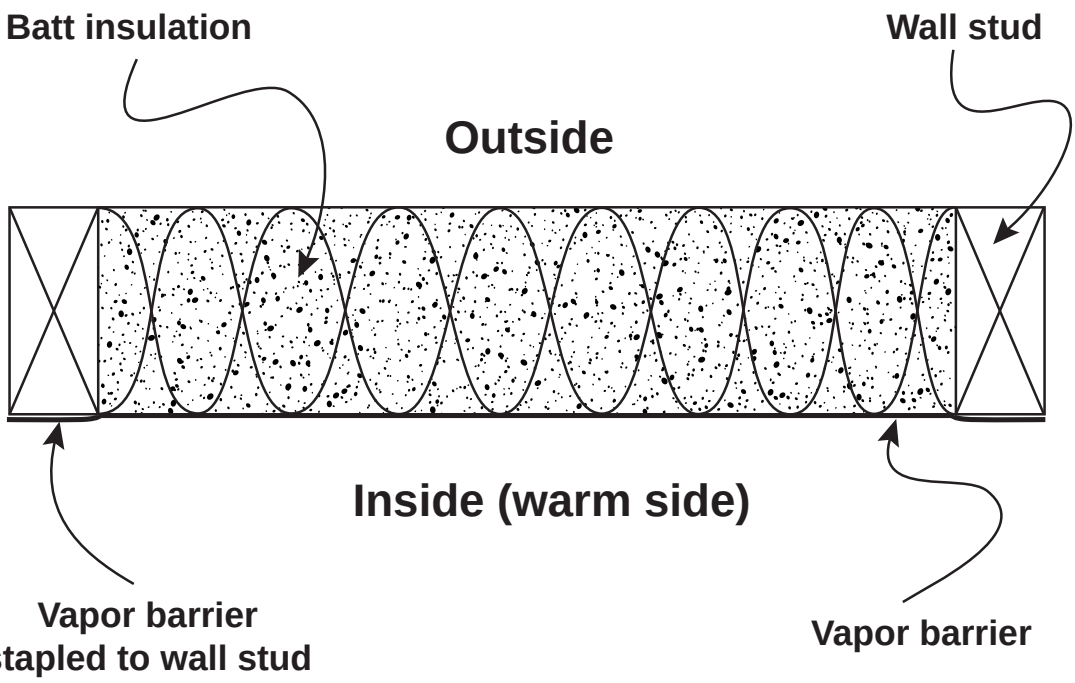

Figure 4. Proper batt insulation installation with vapor barrier

■ LOOSE-FILL, blown-in insulation is comprised of cellulose or loose fibers blown into building cavities or attics using special pneumatic equipment. Blown-in cellulose can provide additional resistance to air infiltration if the insulation is sufficiently dense. This technique, refered to as "dense pack," is often used to insulate and air seal existing walls. Figure 5 shows loose-fill insulation being blown into the attic.

Cellulose insulation is made from finely shredded newsprint which is chemically treated to resist fire, and fungal and insect growth. Properly installed blown-in cellulose has an average R-value of 3.6 per inch which is dependent on the chemical mix, paper type, and its blown density. If the insulation is not blown to manufacturer's recommended density, settling will occur, gaps will form, and the intended R-value will not be obtained. Cellulose must be installed at a density of 3.5 to 4.4 pounds per square foot to ensure it will not settle and that gaps do not form. **When having cellulose installed, always get a written guarantee of settled depth from the installer.** When using cellulose in an attic, it should not be covered with heavier insulation or other materials which may compress it. Cellulose will fill irregular spaces and will help minimize air movement.

■ SPRAYED-IN-PLACE insulations are loose-fill products such as cellulose, fiberglass, and mineral wool that are mixed with an adhesive (usually water-based) and blown into wall cavities. When properly installed, wet-spray insulations will resist settling and shifting, and allow the cavity to be completely filled. Wet-spray cellulose reduces air movement, while fiberglass and mineral wool don't.

Spray cellulose has an R-value of 3.5 per inch; blown fiberglass 2.9 per inch, when blown to the proper density; and mineral wool about 3 per inch. Installation generally requires a trained contractor.

■ FOAMED-IN-PLACE polyurethane and isocyanurate foam insulations can be applied by a professional applicator using special equipment to meter, mix, and spray into place. These foams also help to reduce air leaks. Polyurethane foams can be used for a variety of spray applications and are ideal for use with irregular-shaped surfaces and narrow openings, e.g., shim spaces around doors and windows. The foam will act as an air barrier but not a vapor barrier, and should be protected from prolonged exposure to sunlight. When the foam is used in the interior of a house, it must be covered with a fire-resistant material such as drywall. Polyurethane foam has an R-value of 6.0 per inch.

Isocyanurate foam is a semi-flexible, spray-applied, plastic foam insulation best suited for use in exterior stud wall cavities, perimeter joist spaces, and in small and irregular shapes and areas such as shim spaces around doors and windows. The material can be used as an air barrier, but when installed on the interior of the house, it should be covered with a fire-resistant material such as drywall. Installation requires specially trained contractors. Isocyanurate plastic foam has an R-value of 4.3 per inch.

Polyurethane and polyisocyanurate insulations are usually double-faced with foil, or sometimes come bonded with an interior or exterior finishing material. The boards must be protected from prolonged exposure to water and sunlight and, if used on the interior, must be covered with a fire-resistant material such as drywall. Due to the relatively high cost of these insulations, use is generally limited to areas which require a high R-value, but where space is very limited. Faced boards have a typical R-value of 5.8 per inch to 7.2 per inch.

Figure 5. Loose-fill insulation installation

■ 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 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. Rigid foam boards are made of polyisocyanurate, extruded polystyrene (XPS or blueboard), expanded polystyrene (EPS or beadboard), or other materials. These boards are lightweight, provide structural support, and generally have an R-value of 4 to 7 per inch. Rigid board insulation is made to be used in confined spaces such as exterior walls, basements, foundation and stem walls, concrete slabs, and cathedral ceilings.

Extruded polystyrene (XPS) is a lightweight foam plastic board manufactured in low and high densities suitable for both above- and below-grade applications. However, the high-density board should be used where the material will be exposed to relatively high pressures, such as below a concrete slab or in built-up roofing. When properly installed, it can act as an air barrier. Low-density extruded polystyrene has an R-value of 4.7 per inch while high-density XPS has an R-value of 5.0 per inch.

Expanded polystyrene (EPS) or "beadboard," as it is often called, also comes in low- and high-density boards. This high-density board is more moisture resistant and can be used on the exterior of a foundation, providing the surrounding soil is dry, sandy, and properly drained. Low-density expanded polystyrene has an R-value of 3.7 per inch while the high-density type has an R-value of 4.0 per inch. In general, expanded polystyrene is less expensive than extruded polystyrene or other rigid insulations.

Polystyrene will "break down" if left exposed to sunlight for prolonged periods and must also be protected from solvents. If the insulation is to be used in the interior of a house, it needs to be covered with a fire-resistant material such as drywall.

Other places to insulate in your home

Ducts of your heating and cooling system and water lines of your home also need to be insulated. Insulate those locations where ducts run through unheated or uncooled spaces, such as an attic or crawlspace. Heating and cooling ducts should be insulated to R-6, but first check for air leakage in the ductwork. Repair any leaks with water-soluble mastic and embedded fiberglass mesh or metal-backed tape (do not use duct tape as it will not stay in place), then insulate the ducts with duct wrap insulation. Piping can be insulated with conventional, round, fiberglass insulation. Remember: simple duct tape will not seal joints over an extended period.

Further information

The following Web sites offer additional facts and information on residential insulation:

- *www.ornl.gov/roofs+walls*
- *www.epa.gov/energystar.html*
- *www.eren.doe.gov/consumerinfo*

For questions regarding this fact sheet or further information on residential insulation, please contact Engineering Extension at 785-532-6026. This fact sheet is posted on the Kansas State University Engineering Extension Web page at *www.oznet.ksu.edu/dp_nrgy/ees*. Other KSU Engineering Extension Fact Sheets posted at this site include the following:

- Tips for Purchasing an Energy-Efficient Home
- Foundation Insulation
- Selecting a Home Heating System
- Selecting a Home Cooling System
- Energy-Efficient Mortgages
- Energy-Efficient Windows
- Air Sealing Your Home

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