# Thermal insulation

From Wikipedia, the free encyclopedia

**Insulation** is any material used to reduce or “slow down” or “resist” the flow of energy. There are several different types of insulators:

- Thermal insulators reduce the flow of heat.
- Electrical insulators reduce the flow of electricity.
- Acoustical insulators reduce the flow of sound.

A material may insulate well in more than one way. Some materials, such as diamond, are superb insulators in one way (electrical), but extremely poor insulators in another way (thermal). A purified synthetic diamond conducts heat even better than copper, and has the highest thermal conductivity of any known solid at room temperature. Thus it is the worst thermal insulator known that's solid at room temperature.

Heat is the internal kinetic, vibrational energy that all materials contain (except at absolute zero). Heat spontaneously flows from a high temperature region to a low temperature region, and the greatest heat flow occurs through the path of least resistance.

The proximity of a high temperature region to a low temperature region constitutes a temperature gradient. Thermal insulation maintains a thermal gradient by reducing the flow of heat across the temperature gradient.

Insulation exists in most large appliances, for example, in ovens, refrigerators, freezers, and water heaters. In some cases, the insulation serves to prevent heat loss *to* the environment. In other cases, it serves to prevent heat gain *from* the environment.

## Contents

# Heat transfer

Materials transfer heat in three ways:

- Conduction.
- Convection (essentially = conduction + fluid flow).
- Radiation.

**Conduction**, the most common means of heat transfer in solids, is the transfer of heat through atoms and molecules that are in direct contact with one another, when there is a temperature gradient between them. Materials with high thermal conductivity, such as metals, transfer nearly all of the heat via electrons, whereas materials with low thermal conductivity – insulators – transfer nearly all of the heat via phonons.

**Convection**, the most common means of heat transfer in liquids and gases, is the transfer of heat via a combination of conduction and fluid flow. For example, when you heat water on a stove, the entire pot of water warms up uniformly. The reason is that hot water at the bottom of the pan doesn’t just heat surrounding water via conduction, but also becomes less dense, rises, and heats the water in the middle and at the top of the pan. Once the water cools, it becomes more dense, sinks, picks up heat from the bottom, and continues the process.

**Radiative** heat transfer is the transfer of heat via photons (electromagnetic radiation). Radiation is the only form of heat transfer that can occur in the absence of any form of medium – through a vacuum. Movements of atoms and molecules cause the emission of photons into the surroundings constantly, carrying away some of the heat. Atoms and molecules are also constantly absorbing photons from other atoms and molecules. Since hotter materials emit more radiation than cooler materials, a net transfer of heat occurs from the hotter materials to the cooler materials. For room temperature objects, the majority of photons emitted are in the infrared spectrum. Hotter objects transfer heat through emission of photons in the visible spectrum or beyond

Insulators reduce the flow of heat by reducing one or more of these heat transfer mechanisms. For example, a layer of thick foam can reduce convection and conduction. A reflective metallic film or coat of white paint can reduce thermal radiation. Some materials are good insulators using one heat-transfer mechanism, but poor insulators using another. For example, metals tend to be excellent radiative insulators, but poor thermal (conductive) insulators.

For the remainder of this article, the term “insulation” will mean thermal building insulation.

# Reasons for insulation

Americans spend large chunks of their money on heating and cooling. A house that is properly and sufficiently insulated:

- Is more energy-efficient, and therefore, saves the homeowner money.
- Does not need extra effort and expense to keep it comfortable – insulation is permanent and usually does not require maintenance.
- Is more comfortable. Floors are warmer, and temperatures are more uniform throughout the house. Thermal insulation of buildings is merely one means of achieving indoor comfort and energy-efficiency. Weatherization and thermal mass are others.
- Absorbs outside noise and is quieter.

Two indications that a house is poorly insulated and poorly ventilated:

- Dew and frost forms on cold surfaces in the attic, such as on the underside of the roof sheathing, during the winter.
- The attic is oppressively, almost unbearably hot in the summer.

The phrase “thermal envelope” refers to the conditioned or living space in a house. Normally, people treat the attic and basement as unconditioned space, but you can make either the basement, or the attic, or both, part of the conditioned space, if you choose.

# Materials used for thermal insulation

A wide variety of substances can serve as insulators. For example, an insulator can be organic, inorganic, fibrous, cellular, reflective, rigid, soft, or granular. Most organic insulators are made from petrochemicals and recycled plastic. Most inorganic insulators are made from recycled materials such as glass and furnace slag.

A new home might use half a dozen different insulating materials in different parts of the house. Each type of insulation is suited to specific tasks, and not suited to others.

Some types of insulation are difficult to find. Your local hardware store may only have fiberglass and polystyrene. Furthermore, some insulation is difficult to install yourself and you would be smart to hire a contractor.

While relatively poor insulators, adobe, earth, stone, and concrete can regulate indoor temperature by damping the daily swings in outdoor temperature. See thermal mass.

Commonly-used insulation materials in residential construction include batts and blankets, loose-fill, spray foam, rigid panels, and radiant barriers. Most residential insulation materials are primarily effective because they have low thermal conductivity; some are primarily effective at blocking convection or radiation. Some materials, for example, foil-faced rigid panels, reduce heat transfer effectively in more than one way.

Good thermal insulating materials can be styrofoam,aluminim foil/mylar,fiber glass batting,and fiber glass board.

# Methods of insulation

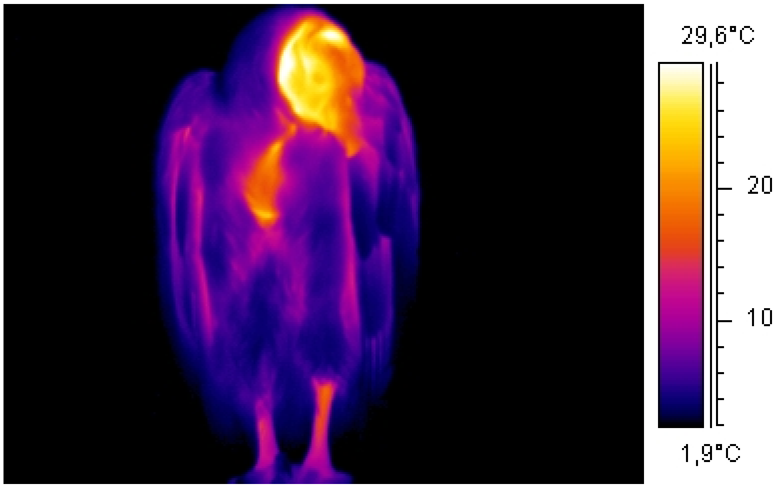
## Batts and blankets

These come in various thicknesses, depending on how much insulation capacity you need. Batts are precut, whereas blankets are available in continuous rolls. Blankets are ideal for covering joists and studs as well as the space between them. If you don't cover joists and studs with insulation, heat will tend to flow through them (known as "bridging" or "short-circuiting"), since they are the path of least resistance. Similarly, you can install batts in two layers across an unfinished attic floor, perpendicular to each other, for increased effectiveness.

Batts come in standard widths designed to fit snugly between framing (joists, rafters, studs) on 16-inch or 24-inch centers in ceilings, floors, and walls, and are generally easier to handle than blankets. However, batts can be challenging and unpleasant to install between joists under floors. You can run straps, or staple cloth or wire mesh across joists, to prevent insulation from sagging or falling down. Compressing batts reduces their effectiveness. Cut them to accommodate electrical boxes and other obstructions, and do not leave items resting on the batts.

Batts and blankets are susceptible to poor installation. Installers tend to leave bypasses (air gaps) that drastically reduce their effectiveness. Warm air and moisture always find their way to these bypasses. Even if you close all bypasses around batts and blankets, they remain poor barriers to air infiltration and are susceptible to convection loops, especially when there are large temperature differences on either side of the insulation (such as during cold weather). You can reduce air infiltration by adding a layer of cellulose loose-fill on top of the fiberglass. The only way to virtually eliminate air infiltration is with a near-perfect vapor barrier. An attic that only has fiberglass batts to keep out warm, moist air, but a poor or nonexistent vapor barrier, will probably *not* keep out the warm, moist air.

---




thermographic image of a vulture in the winter. He uses a layer of trapped air as insulation.

## Commonly-used batts and blankets

- Rock and slag wool. Usually made from rock (basalt, diabase) or iron ore blast furnace slag. Some rock wool contains recycled glass. Nonflammable. [1] (http://www.roxul.com/)
- Fiberglass. Made from molten glass, usually with 20% to 30% recycled industrial waste and post-consumer content. Nonflammable, except for the facing (if present). Sometimes, the manufacturer modifies the facing so that it is fire-resistant. Some fiberglass is unfaced, some is paper-faced with a thin layer of asphalt, and some is foil-faced. Paper-faced batts are vapor retarders, but are *not* good vapor barriers. Foil-faced batts are good vapor barriers. Be sure to face the vapor barrier in the proper direction.
- High-density fiberglass (only available to contractors).
- Plastic fiber. Usually made from plastic milk bottles. Does not cause irritation like fiberglass, but more difficult to cut than fiberglass. Not used in USA. Flammable, but treated with fire-retardant.

Natural fibre insulations (around 0.04 W/mK) all can be treated with low toxicity fire and insect retardents, available in Europe

- Cotton and polyester. Usually made from mill waste. Uncommon in USA. Flammable, but treated with fire-retardant.
- Hemp fibre and polyester.
- Flax fibre and polyester.
- Coco fibre and polyester.
- Wool fibre with and without polyester.

- Lightweight Wood Fibre and polyolefin batt.
- Cellulose and polyolefin batt
- and some which mix different natural fibres.

## Loose-fill

Loose-fill materials can be blown into attics, finished wall cavities, and hard-to-reach areas. They are ideal for these tasks because they conform to spaces and fill in the nooks and crannies. They can also be sprayed in place, usually with water-based adhesives. They frequently consist of recycled materials, and therefore, are relatively inexpensive.

General procedure for retrofits:

- Contractor drills holes in wall with hole saw, taking firestops, plumbing pipes, and other obstructions into account.
- He pumps loose fill into wall cavity, gradually pulling the hose up as the cavity fills.
- He caps the holes in the wall.

### Advantages of loose-fill

- Ecological
- R-Value 3.4 - 3.6
- Class I Fire Safety Rating
- No Formaldehyde-based Binders
- High Recycled Content
- Less Harmful to Installer

### Disadvantages of loose-fill

- Messy.
- Doesn't seal bypasses like closed-cell foams do.
- Need to pay attention to weight so ceilings do not sag.
- All loose-fill materials will settle over time, losing some of their effectiveness. If you install loose-fill, make sure you take into account the settled thickness (20% in the case of cellulose). Do not allow contractor to "fluff" insulation using fewer bags than the manufacturer specifies for your desired R-value.
- If you don't cover studs or joists with insulation, heat will tend to flow through them (known as "bridging" or "short-circuiting"), since they are the path of least resistance.

### Commonly used loose-fill

- Rock and slag wool, also known as mineral wool or mineral fiber. Made from rock (basalt, diabase), iron ore blast furnace slag, or recycled glass. Usually gray with black specs, or white, and more brittle, denser, and more resistant to airflow than fiberglass. Clumps and loses effectiveness when moist or wet, but does not absorb much moisture, and regains effectiveness once dried. Nonflammable. Older mineral wool can contain asbestos, but normally this is in trace amounts.
- Fiberglass. Usually pink, yellow, or white. Loses effectiveness when moist or wet, but does not absorb much water. Nonflammable (because the fibers are not in a plastic resin, unlike the fiberglass used in cars and boats). See Health effects of fiberglass.
- Cellulose. Usually gray and consists of recycled, shredded newspapers, boxes, waste paper, and wood pulp. Cellulose, like rock wool, is denser and more resistant to air flow than fiberglass, but cellulose settles (and therefore, loses effectiveness) much more than fiberglass and rock and slag wool. Persistent moisture can weaken the flame-retardants in cellulose. **Dense-pack cellulose** is highly resistant to air infiltration and is either installed into an open wall cavity using nets or temporary frames, or is retrofitted into finished walls. However, dense-pack cellulose blocks, but does not permanently seal, bypasses, as a closed-cell foam would. Furthermore, as with batts and blankets, warm, moist air will still pass through, unless there is a near-perfect vapor barrier. **Wet-spray cellulose** is cellulose mixed with water and adhesive to help the cellulose bind to the inside of open wall cavities, and to make the cellulose more resistant to settling. Wet-spray cellulose must be allowed to dry completely before sealing up the wall with a vapor barrier and drywall. **Moist-spray cellulose** uses less water to speed up drying time. Cellulose insulation is regulated as a recognized fire hazard by the Consumer Product Safety Commission (CPSC), which requires labeling of cellulose insulation to inform installers and consumers about the threat of fire. (See 16 C.F.R. 1209, 1404)

- Natural insulations such as granulated cork, hemp fibres, grains, all which can be treated with a low toxicity fire and insect retardants

### Less commonly used loose-fill

The following types of loose-fill are not often used but perfectly acceptable given the right thickness. You can expect to find one or more of these in an old house.

- Cotton and polyester. Difficult to find this type of loose-fill in the USA.
- Wool, hemp, and other naturally harvested materials.
- Vermiculite. Generally gray or brown.
- Perlite. Generally white or yellow.
- Granulated cork. No longer used in the US but used in Europe. Cork comes from the bark of a tree, and is a pretty good insulator, but it absorbs water like all wood. Exposure to water reduces its effectiveness (as for all types of open cell/open fibre insulations including synthetics) to much less an extent than that of other types of wood.
- Wood chips, sawdust, redwood bark, hemlock fiber, or balsa wood. No longer used. Wood absorbs water, which reduces its effectiveness as a thermal insulator. In the presence of moisture, wood is susceptible to mold, mildew, and rot.
- Corn cobs.
- Strawdust.

### U.S. regulatory standards for cellulose insulation

The following regulatory standards are applicable to cellulose insulation. Whether individual cellulose insulation products comply with these standards must be determined on a case-by-case basis:

- 16 CFR Part 1209 (Consumer Products Safety Commission, or CPSC) - covers settled density, corrosiveness, critical radiant flux, and smoldering combustion.
- ASTM Standard C-739 - loose-fill cellulose insulation - covers all factors of the CPSC regulation and five additional characteristics, R-value, starch content, moisture absorption, odor, and resistance to fungus growth.
- ASTM Standard C-1149 - Industry standard for self-supported spray-applied cellulose insulation for exposed or wall cavity application - covers density, R-value, surface burning, adhesive strength, smoldering combustion, fungi resistance, corrosion, moisture vapor absorption, odor, flame resistance permanency (no test exists for this characteristic), substrate deflection (for exposed application products), and air erosion (for exposed application products).
- 16 CFR Part 460 - (Federal Trade Commission regulation) commonly known as the "R-Value Rule," intended to eliminate misleading insulation marketing claims and ensure publication of accurate R-Value and coverage data.

## Spray foams (foam-in-place)

Normally, you would hire a contractor to install spray foam between wall studs. The contractor mixes the chemicals on site using special measuring and mixing equipment, and sprays or injects the expanding foam into the open wall cavity of an unfinished wall, against the interior side of the sheathing, or through holes drilled in the sheathing or drywall into the wall cavity of a finished wall.

### Advantages of spray foams

- You can fill wall cavities in finished walls without tearing the walls apart (like loose-fill).
- Work well in tight spaces (like loose-fill, but superior).
- Provide acoustical insulation(like loose-fill, but superior).
- Most of them expand while curing, filling bypasses, and providing excellent resistance to air infiltration (unlike batts, blankets, and most types of loose-fill, which can leave bypasses and air pockets).
- Increase structural stability (unlike loose-fill).
- Cementitious foam is fireproof.
- None uses CFC's anymore.
- You can use them in places where you can't use loose-fill, such as between joists and rafters. When used between rafters, the spray foam can cover up the nails protruding from the underside of the sheathing, protecting your skull.

- You can buy a can for small applications.

### Disadvantages of spray foams

- Some of them shrink while curing.
- Require protection from sunlight and solvents.
- All of them, except cementitious foam, are flammable, release toxic fumes when they burn, and require protection with fire-rated drywall on the interior of a house.
- Some still use HCFCs as blowing agents.
- Those that use non-air blowing agents eventually lose their trapped gases and suffer reduction in insulating effectiveness.

### Advantages of closed-cell foams over open-cell foams

- Closed-cell foams (such as polystyrene, polyisocyanurate, and "Great Stuff") *seal off* air flow, whereas open-cell foams (such as some, but not all, types of polyurethane) merely trap air and *slow down* airflow.
- Closed-cell foams are superior insulators (usually around R-6 as opposed to R-3 for open cell).
- Higher structural stability.
- Superior acoustical insulating.
- When you use a closed-cell foam, you may be able to do away with a vapor barrier. Most open-cell foams are resistant to water, but they do not block water vapor.

### Commonly-used spray foams

- Icynene spray formula. [2] (http://www.icynene.com/) Icynene "does not shrink, sag or settle. Icynene adheres to most construction materials and is the perfect insulation for walls, attics, ceilings and floors. As it expands, the material forces its way into every corner and crevice, completely filling the cavity. It creates its own virtually continuous air barrier by adhering to structural components. It always ensures a well filled, air sealed building envelope. It contains no gasses, so none escape." Icynene uses a mixture of carbon dioxide and water, and does not use harmful chemicals such as CFC's or HCFC's. Flammability is relatively low.
- Sealection 500 spray foam. [3] (http://www.sealection500.com/) So called "water-blown" as it uses water in a chemical reaction to create carbon dioxide and steam which expands the foam. Sealection 500 uses no CFC's, no HCFC's, contains no ozone depleting products and does not support mold growth. This product is commonly used in floor, wall and attic assemblies in Climate Zones 1 - 8 in North America with some special considerations when used in northern Canada and Alaska. Sealection 500 creates an air barrier which prevents infiltration and therefore prevents virtually all moisture migration through the skin of a building. Flame spread is 21 and smoke developed is 217 which makes it a Class I material (best fire rating).
- Cementitious foam, such as Air-Krete. [4] (http://www.airkrete.com/) Advantages: Environmentally friendly. Consists of magnesium oxide and air, made from magnesium silicate extracted from seawater. Blown with air. Nontoxic. Nonflammable (actually fireproof). Does not shrink. Relatively chemically inert. Insect resistant. Mold resistant. Disadvantages: Expensive. Susceptible to damage from water. Fragile at low densities.
- Polyisocyanurate. Less flammable than polyurethane.
- Phenolic. Uses air as blowing agent. Shrinks while curing.
- Closed-cell polyurethane. White or yellow. Uses harmless gases such as carbon dioxide as blowing agents. Resistant to water wicking and water vapor.
- Open-cell (low density) polyurethane. White or yellow. Expands to fill and seal cavity, but expands slowly, preventing damage to the wall. Resistant to water wicking, but permeable to water vapor. Fire resistant.
- Polystyrene.
- Great Stuff is a Dow Chemical product that comes in cans and consists of several complex chemicals mixed together (isocyanates, ether, polyol). Dow manufactures this for small applications, but there is nothing stopping you from buying dozens of cans for a large retrofit task, such as sealing the sill plate.

*Lingering question: If you install spray foam between rafters, and your attic is part of the conditioned space of your house (not kept cold in the winter), do you still need to leave an air baffle to allow air circulation against the underside of the sheathing?*

## Rigid panels

Rigid panel insulation is made from fibrous materials (fiberglass, rock and slag wool) or, more commonly, from plastic foam. They are sometimes sold in sections designed to fit tightly in standard wall cavities. When sold this way, they are called "batts", and they come in different thicknesses to match the depth of your wall cavity, for example, approx. 5½ inches to match a 2 x 6 wall cavity.

Where rigid panels are most-often used:

- Some, such as EPS "beadboard", are suitable for ground contact and are used against footings and exterior backfilled foundation walls.
- Against exterior exposed foundation walls (should be coated to protect from sunlight).
- Against exterior walls between foundation and roof, installed between sheathing and siding.
- Either under or on top of the roof sheathing.
- Inside unfinished interior walls, either as pre-cut batts, or as panels cut to fit inside walls and secured in place.
- Where space is limited and you need to pack great insulating capacity into a small space.

Important note #1: If you insulate the foundation with rigid panels, but you stop using rigid panels where the siding begins, then you should install flashing in between the bottom course of siding and the top edge of the rigid panels, to prevent water from seeping behind the panels.

Important note #2: When insulating the exterior foundation, you should install the rigid panels in two staggered layers, and fill the gaps at the seams with spray foam, to keep moisture from penetrating from the outside. However, when insulating between the sheathing and siding, you should leave slight gaps between the rigid panels to allow moisture to escape from the exterior side of the sheathing.

### Advantages of rigid panel insulation

- High R-value per inch - useful where space is tight or cramped, such as cathedral ceiling.
- Protect foundation and damp-proofing during backfilling (and, of course, insulate foundation).
- All are lightweight and strong - although EPS can be crumbly.
- Add to structural strength of walls.
- Provide acoustical insulation as well as thermal.
- Most are easily cut with utility knife.
- All are water resistant, some more so than others (but none should face prolonged exposure to water).
- Will not rot.
- All are highly resistant to air infiltration. They can be virtually airtight if they are installed without gaps between adjacent panels.
- Some types use some recycled content. (Most, however, are made from petrochemicals.)

### Disadvantages of rigid panel insulation

- All are susceptible to UV damage and solvents. You should coat them with plaster or stucco where they are above ground and exposed.
- All are flammable *(including fiberglass and rock wool panels, because of the plastic resin used to bind the fibers?)* and produce toxic fumes when they burn. All of them should be covered with fire-rated drywall (gypsum board) when installed in the interior of a house, *unless* they have a low flame-spread rating (below 25). Check with your local building inspector to be sure.
- More expensive than most other types of insulation.
- Some types may be susceptible to termites in certain areas. Termites use them for nesting purposes.
- Rigid panels that have R-values higher than that of still air usually contain some type of insulating gas that was blown into them during manufacturing. For many years, manufacturers used CFC's or urea formaldehyde as blowing agents. These blowing agents eventually leak out of the panels. CFC's deplete the ozone layer, and formaldehyde is toxic. Some manufacturers still use HCFC's, which are still harmful to the ozone layer, but not as harmful as CFC's.
- Eventually, as the blowing agent leaks, air replaces the insulating gas, and the R-value of the panel drops.
- Most rigid panels are made from crude oil byproducts, and some toxic pollution results during their manufacturing.

### Commonly-used rigid panels

- Fiberglass and rock wool. These are mainly used for acoustic applications. A company called Roxul in Ontario, Canada uses rock wool as the basis for all of their products, including panels for insulating the exterior foundation. All of their products are naturally fire-resistant. [5] (http://www.roxul.com/)
- Perlite - used in Europe
- Phenolic, also known as phenol-formaldehyde. Advantages: High strength. Less flammable than most other foams. Disadvantages: Material is mostly open-celled. This results in insulating capacity not as good as other foams, high water absorption, and high water vapor permeability. Degrades and releases some formaldehyde over time, but not nearly as much as urea formaldehyde.
- Polyurethane. White or yellow. Produced through mixing of isocyanate and polyether in presence of catalyst and blowing agent. Contains many tiny, closed cells. Relatively waterproof, and low water absorption, but must protect from prolonged exposure to water. Can use underground if conditions are relatively dry.
- Rigid cellular polystyrene (RCPS). This includes EPS, MEPS, XPS, XEPS, beadboard, blueboard, and Styrofoam.
- Polyisocyanurate *(also known as isocyanurate?)*. More stable at high temperatures and less flammable than polyurethane. Denser and more rigid than polystyrene panels, but more expensive. Must protect from prolonged exposure to water. Usually contains some recycled plastic, such as from PET beverage containers.
- Structural insulating panels (SIP's), also called stressed-skin walls.
- Vacuum insulation consisting of thin panels with extreme insulation capacities, as high as R-50 per inch!. However, like double-glazed windows, these eventually lose their air-tight seal.

Natural fibre insulations (around 0.04 W/mK) all can be treated with low toxicity fire and insect retardents, often used in Europe

- Lightweight Wood Fibre board.
- Cork

### Rigid cellular polystyrene panels

There are many types of rigid cellular polystyrene (RCPS). Styrofoam is simply Dow Chemical's brand name, and does not refer to any particular type of RCPS. Some polystyrene uses up to 50% recycled resin, including post-consumer plastic. Several states have banned polystyrene that uses CFC's as blowing agents.

- Molded expanded polystyrene, also known as MEPS, EPS, or beadboard, consists of many tiny foam beads molded and pressed together. EPS is manufactured in low-density and high-density versions. Low-density EPS is relatively inexpensive, resistant to the effects of moisture, and can be used underground. High-density EPS is even more moisture-resistant, and is manufactured for use on exterior foundation walls and burial against footings, if the soil is relatively dry.
- Extruded expanded polystyrene, also known as XEPS, XPS, or blueboard, has a smooth, cut-cell surface, is stronger than EPS, and is ideal for blocking air-infiltration. Dow Chemical colors their XPS blue and prints "Styrofoam" on the sides. Like EPS, XPS is also manufactured in low-density and high-density versions. High-density XPS is used for foundation slabs, concrete floors, roofs, and other applications that require higher bearing strength than EPS and low-density XPS.

## Structural insulating panels

Structural insulating panels (SIPs), also called stressed-skin walls, use the same concept as in foam-core external doors, but extend the concept to the entire house. They can be used for ceilings, floors, walls, and roofs. The panels usually consist of plywood, oriented strandboard, or drywall glued and sandwiched around a core consisting of expanded polystyrene, polyurethane, polyisocyanurate, compressed wheat straw, or epoxy. Epoxy is too expensive to use as an insulator on its own, but it has high R-value per inch (7 to 9), high strength, and good chemical and moisture resistance.

SIPs come in various thicknesses. When building a house, they are glued together and secured with lumber. They provide the structural support, rather than the studs used in traditional framing.

### Advantages of SIPs

- Strong. Able to bear loads, including external loads from precipitation and wind.
- Faster construction than stick-built house. Less lumber required.

- Insulate acoustically.
- Impermeable to moisture.
- Can truck prefabricated panels to construction site and assemble on site.
- Create shell of solid insulation around house, while reducing bypasses common with stick-frame construction. The result is an inherently energy-efficient house.
- Do not require much energy to manufacture.
- Do not use formaldehyde, CFC's, or HCFC's in manufacturing.

### Disadvantages of SIPs

- More expensive than other types of insulation.

## Urea-formaldehyde foam (UFFI) and panels - no longer used

Description: Brittle, whitish gray or yellow foam produced through mixing of urea and formaldehyde, developed in Europe in the 1950's. Most states have outlawed urea-formaldehyde insulation since the late 1970's or early 1980's because of its tendency to release formaldehyde gas, causing air pollution and problems of indoor air quality. The entire foam insulation industry suffered a setback during this time.

Reasons for residential ban: The chemical bond between the urea and formaldehyde is weak, resulting in degradation of the foam cells and emission of toxic formaldehyde gas into the home over time. Furthermore, some manufacturers used excess formaldehyde to ensure chemical bonding of all of the urea. Any leftover formaldehyde would escape after the mixing. Since emissions are highest when the urea-formaldehyde is new and decrease over time, houses that have had urea-formaldehyde within their walls for years or decades do not require remediation.

### Advantages

- Inexpensive.
- Good R-value per inch.
- Regains effectiveness when dried after having absorbed moisture.
- Open-cell material is good acoustic insulator.
- Contains no fire retardants, but resists spread of flames when burned.

### Other disadvantages (besides release of formaldehyde)

- Low mechanical strength. Material is weak and brittle.
- High water absorption.
- High water permeability.
- High water vapour permeability.
- Shrinks when curing.
- May take several weeks to cure completely.

Links: [6] (http://www.cmhc-schl.gc.ca/en/burema/gesein/abhose/abhose_ce06.cfm) [7] (http://www.epa.gov/iaq/formalde.html)

## Radiant barriers

*Main article: Radiant barrier*

These materials reduce radiated heat, rather than conducted heat. For this reason, trying to associate R-values with radiant barriers is difficult and inappropriate.

- Glass windows with low-emissivity (low-E) coating. Low-E glass has an invisible metal coating suspended between layers of glazing that reflects radiation that would normally escape, back into the house, and reflect radiation that would normally enter, back to the outside. Thus, they keep the house warmer in winter and cooler in summer. They work similar to the way that a Dewar flask works, in which the metal is in contact with a near-vacuum, greatly reducing the

conduction and convection that would normally occur, while taking advantage of the metal's superior radiative properties.
- Foil-faced polyurethane or foil-faced polyisocyanurate panels.
- Foil-faced polystyrene. this laminated, high density EPS is more flexible than rigid panels, works as a vapor barrier, works as an excellent thermal break. When using metalized plastic facing is a more effective reduces surface conductivity. Uses underside roof sheathing, ceilings , and on walls. for best results, this is not a cavity fill type insulation.
- Foil-backed bubble pack. This is thin, more flexible than rigid panels, works as a vapor barrier, and resembles plastic bubble wrap with aluminum foil on both sides. It is ideal for use on cold pipes, cold ducts, and the underside of the roof sheathing.
- Light-colored roof shingles and reflective paint. These help to keep attics cooler in the summer and in hot climates.

### Aerogels

Aerogels are high-performance, low-density materials used in special applications. They are mostly air, but they are not foam. They are still expensive and do not yet find much use in consumer applications.

- Silica aerogel has the lowest density and lowest thermal conductivity of any known substance, and has high resistance to convective currents.
- Carbon aerogel absorbs infrared radiation, and, like silica aerogel, has high resistance to convective currents.

The properties of silica aerogel complement those of carbon aerogel; the combination has the best insulating properties of any known material.

### Straw bales

The use of highly-compressed straw bales as insulation, though uncommon, is gaining popularity in experimental building projects for the high R-value and low cost of a thick wall made of straw. Densely-packed straw, on a *per-inch* basis, only has an R-value of around 1.45, but the *total* R-value of a straw-bale wall can approach R-20. When using straw bales for construction, the bales must be tightly-packed and allowed to dry out sufficiently. Any air gaps or moisture can drastically reduce the insulating effectiveness.

### Asbestos - no longer used

Asbestos once found common use as an insulation material in homes and buildings because it is fireproof, a good thermal and electrical insulator, and resistant to chemical attack and wear. We now know that asbestos can cause cancer when in friable form (that is, when likely to release fibers into the air - when broken, jagged, shredded, or scuffed). Only some people exposed to asbestos come down with cancer. The recommended course of action if you find asbestos in your house is to enclose (shield) and encapsulate (seal). Asbestos-cement shingles are harmless unless you saw into them.

When found in the home, asbestos often resembles grayish-white corrugated cardboard coated with cloth or canvas, usually held in place around pipes and ducts with metal straps. Things that typically might contain asbestos:

- Boiler and furnace insulation.
- Heating duct wrapping.
- Pipe insulation ("lagging").
- Ducting and transite pipes within slabs.
- Acoustic ceilings.
- Textured materials.
- Resilient flooring.
- Blown-in insulation.
- Roofing materials and felts.

## Health & safety issues

## Fiberglass

Fiberglass is the most common residential insulating material, and is usually applied as batts of insulation, pressed between studs.

Fiber glass is now the most thoroughly evaluated insulation material in the market. The fiber glass insulation industry is committed to ensuring that fiber glass products can be safely manufactured, installed and used. This industry has funded tens of millions of dollars of research at leading independent laboratories and universities in the United States and abroad. The weight of the scientific research shows no association between exposure to glass fibers and respiratory disease or cancer in humans.

In October 2001, an international expert review by the International Agency for Research on Cancer (IARC) re-evaluated the 1988 IARC assessment of glass fibers and removed glass wools from its list of possible carcinogens by downgrading the classification of these fibers from Group 2B (possible carcinogen) to Group 3 (not classifiable as to carcinogenicity in humans). All fiber glass wools that are commonly used for thermal and accoustical insulation are included in this classification. IARC noted specifically: "Epidemiologic studies published during the 15 years since the previous IARC Monographs review of these fibers in 1988 provide no evidence of increased risks of lung cancer or mesothelioma (cancer of the lining of the body cavities) from occupational exposures during manufacture of these materials, and inadequate evidence overall of any cancer risk."

The IARC downgrade is consistent with the conclusion reached by the U.S. National Academy of Sciences, which in 2000 found "no significant association between fiber exposure and lung cancer or nonmalignant respiratory disease in the MVF [man-made vitreous fiber] manufacturing environment."

The World Health Organization however, has declared fiber glass insulation as potentially carcinogenic. The product is still required to carry a cancer warning label in the USA.

Miraflex is a new type of fiberglass batt that has curly fibers that are less itchy and create less dust. You can also look for fiberglass products factory-wrapped in plastic or fabric.

## Loose-fill cellulose

Although cellulose is 100% natural, and usually made from recycled material, loose-fill cellulose is not as environmentally-friendly as some people would have you believe:

- Cellulose is treated with a flame retardants, usually boric acid and borax to resist insects and rodents. Some people think that the fire-retardant chemicals, insect repellants, dust, and newspaper ink in cellulose may be harmful to breathe and touch.
- One thing that has not contributed to mold problems is the growing popularity of cellulose insulation among knowledgeable home owners who are interested in sustainable building practices and energy conservation. Mycology experts (mycology is the study of mold) are often quoted as saying: “Mold grows on cellulose.” They are referring to cellulose the generic material that forms the cell walls of all plants, not to cellulose insulation.

- Unfortunately, all too often this statement is taken to mean that cellulose insulation is exceptionally susceptible to mold contamination. In fact, due to its favorable moisture control characteristics and other factors associated with the manufacturing process relatively few cases of significant mold growth on cellulose insulation have been reported. All the widely publicized incidents of serious mold contamination of insulation have involved fiber insulation materials other than cellulose.

### U.S. Health and Safety Partnership Program

In May 1999, the North American Insulation Manufacturers Association began implementing a comprehensive voluntary work practice partnership with the U.S. Occupational Safety and Health Administration (OSHA). The program, known as the Health and Safety Partnership Program, or HSPP, promotes the safe handling and use of insulation materials and incorporates education and training for the manufacture, fabrication, installation and removal of fiber glass, rock wool and slag wool insulation products. (See health effects of fiberglass). (For authoritative and definitive information on fiber glass and rock and slag wool insulation, as well as the HSPP, consult the North American Insulation Manufacturers Association (NAIMA) website (www.naima.org).)

# Effectiveness of insulation

## R-values

*Main article: R-value*

The R (Resistance) value of a material indicates its resistance to heat flow, and therefore its effectiveness as an insulator. R-values are measured at 75 °F (22 °C) and are calculated from the thermal conductivity, $k$, and the thickness, $d$, of materials: $R = d/k$.

The United States calculates R-values using different units than the rest of the world, namely, feet, degrees Fahrenheit, and British thermal units. Metric R-values are expressed as “RSI”, where the units for R are kelvins times square meters divided by watts ($K \cdot m^2/W$).

Some materials lose or gain R-value during changes in temperatures. This must be taken into account [8] (http://hem.dis.anl.gov/eehem/93/930104.html) when comparing R-values [9] (http://aboutsavingheat.com/cu-shoot-out.html) since some materials, especially blown fiberglass [10] (http://hem.dis.anl.gov/eehem/92/920510.html), suffer significant loss of insulating ability at lower temperatures. Other materials gain R-value at lower temperatures, such as polystyrene.

Old insulation usually loses its effectiveness to some degree. Furthermore, newer insulation sometimes uses different manufacturing techniques or materials than older versions of the same type of insulation, and can therefore have higher R-values.

Additionally, installation conditions [11] (http://www.greenbuildingsupply.com/utility/showArticle/?objectID=227) can significantly reduce R-value due to compression, wind washing [12] (http://www.foam-tech.com/case_studies/part2_ice_dam.htm) or temperature differences creating air convection bypassing the insulation through even very small air gaps. Sprayed in place foam and densely packed cellulose insulations [13] (http://www.cellulose.org/) avoid air gaps.

The thickness of the materials must be considered when comparing R-values. For instance, the R-value of a 14-inch adobe brick is about R-4, while that of an equal thickness of cellulose, at R-3 per inch, is about R-42.

How much insulation your house should have depends on your building design, climate, energy costs, budget, and personal preference. Each state has different recommendations as to what R-values each component of a house should have.

### U.S. regulation

The Federal Trade Commission (FTC) governs claims about R-values to protect consumers against deceptive and misleading advertising claims. "The Commission issued the R-Value Rule to prohibit, on an industry-wide basis, specific unfair or deceptive acts or practices." (70 Fed. Reg. at 31,259 (May 31, 2005).)

The primary purpose of the Rule, therefore, is to correct the failure of the home insulation marketplace to provide this essential pre-purchase information to the consumer. The information will give consumers an opportunity to compare relative insulating efficiencies, to select the product with the greatest efficiency and potential for energy savings, to make a cost-effective purchase and to consider the main variables limiting insulation effectiveness and realization of claimed energy savings.

The Rule mandates that specific R-value information for home insulation products be disclosed in certain ads and at the point of sale. The purpose of the R-value disclosure requirement for advertising is to prevent consumers from being misled by certain claims which have a bearing on insulating value. At the point of transaction, some consumers will be able to get the requisite R-value information from the label on the insulation package. However, since the evidence shows that packages are often unavailable for inspection prior to purchase, no labeled information would be available to consumers in many instances. As a result, the Rule requires that a fact sheet be available to consumers for inspection before they make their purchase.

## Typical R-values per inch of thickness

The FTC's R-value Rule generally prohibits calculating R-value per inch of thickness. (16 C.F.R. 460.20.) The FTC explained the reason for this prohibition: Since the record demonstrates that R-values are not linear, advertisements, labels, and other promotional materials that express a product's thermal resistance in terms of R-value per inch deceive customers. The FTC further explained that references to the R-value for a one-inch thickness of the material will encourage consumers to think that it is appropriate to multiply this figure by the desired number of inches, as though R-value per inch were constant. (44 Fed Reg. at 50,224 (27 August 1979).)

*All values are approximations, based on the average of the values listed on dozens of websites. If I saw wildly different values, then I took the lowest and highest values and expressed the R-value here as a range somewhere between them. For a more-official list, refer to one of these websites with duplicate R-value tables:* [14] (http://www.e-star.com/ecalcs/table_rvalues.html) [15] (http://coloradoenergy.org/procorner/stuff/r-values.htm) [16] (http://www.allwallsystem.com/design/RValueTable.html)

Furthermore, comparisons per inch of thickness are mostly relevant for conductive and convective heat transfer -- not radiant heat transfer -- but some of the materials listed below are designed to prevent radiant heat transfer.

- Air with no external wind = R-5 (still) to R-1 (with convective currents).
- Single pane glass window = R-1.
- Wood chips and other loose-fill wood products = R-1.
- Snow = R-1.
- Straw bales = R-1.45. [17] (http://www.buildinggreen.com/auth/article.cfm?fileName=070902b.xml)
- Double pane glass window = R-2.
- Double pane glass window with low emissitivity coating = R-3.
- Triple pane glass window = R-3.
- Wood panels, such as sheathing = R-2.5.
- Vermiculite loose-fill = R-2.13 to R-2.4.
- Perlite loose-fill = R-2.7.
- Rock and slag wool loose-fill = R-2.0 to R-3.3.
- Rock and slag wool batts = R-3 to R-3.85.
- Fiberglass loose-fill = R-2.2 to R-3.7.
- Fiberglass rigid panel = R-2.5.
- Fiberglass batts = R-2 to R-3.85.
- High-density fiberglass batts = R-3.6 to R-5.
- Cementitious foam = R-2 to R-3.9.
- Cellulose loose-fill = R-3 to R-3.8.
- Icynene spray = R-3.6.
- Icynene loose-fill = R-4.
- Urea-formaldehyde foam = R-4 to R-4.6.
- Urea-formaldehyde panels = R-5 to R-6.
- Phenolic spray foam = R-4.8 to R-7.
- Phenolic rigid panel = R-4 to R-5.
- Molded expanded polystyrene (EPS) = 3.7 for low-density, 4 for high-density.
- Foiled-faced expanded polystyrene (EPS) = R-10 to R-27.4.
- Extruded expanded polystyrene (XPS) = 3.6 to 4.7 for low-density, 5 to 5.4 for high-density.
- Polystyrene spray foam = R-5.
- Open-cell polyurethane spray foam = R-3.6.
- Closed-cell polyurethane spray foam = R-5.5 to R-6.5.
- Polyurethane rigid panel = 6 (expanded with air), 6.25 to 9 (expanded with CFC or HCFC).
- Dow "Great Stuff" = ?. [18] (http://greatstuff.dow.com/greatstuff/cons/faq.htm)
- Polyisocyanurate spray foam = R-4.3 to R-8.3.
- Foil-faced polyisocyanurate rigid panel = R-5.8 to R-7.4.
- Silica aerogel = R-10.
- Foil-backed bubble pack = R-6 to R-18? *NOTE: This value looks highly misleading, because this material is aimed at*

*preventint radiant heat transfer*.
- Vacuum insulated panel = as high as R-30?

Materials such as natural rock, dirt, sod, adobe, and concrete have poor thermal conductivity (R-value typically less than 1), but work well for thermal mass applications because of their high specific heat.

# How to insulate

## Where to insulate

Where to insulate depends on where your living or conditioned space (the space that you heat and air-condition) ends and where your unconditioned space begins. Treat unconditioned space as if it were outdoors, minus the rain and snow. Insulate the living space as if you were insulating from the outdoors. For example, if your crawlspace is unheated, and you want it to stay that way, then make sure it has adequate ventilation, and insulate the floor above. If your attic is unheated, and you want it to stay that way, also make sure it has adequate ventilation, and insulate between and over the floor joists.

If you occasionally want to heat only some sections of the living space, you should insulate the walls between the sections you want to heat and the sections you don't want to heat.

If the basement space is unheated, it may be best to insulate between floor joists (basement ceiling) instead of around the foundation (basement floor and walls). There is no harm done in insulating both the ceiling, and the floor and walls.

Generally, you should insulate:

- Attic, especially the attic door hatch.
- Doors and windows (see weatherization).
- Floors over unheated spaces.
- Ceilings with unconditioned spaces above.
- Knee walls and rafters of a finished or conditioned attic.
- All exterior walls.
- Walls between conditioned spaces (such as living room) and unconditioned spaces (such as unheated garage or storage area).
- Floors over unconditioned or outside spaces.
- Around the perimeter of a concrete floor.
- Around the slab (if present), close to grade level on the outside.
- Walls of finished, conditioned basement.
- Foundation walls above ground area.
- Foundation walls in heated basements
- At top of foundation, where foundation meets mudsill.
- Around perimeter of house at band joist.
- Between rafters, but leave an air space for ventilation between the insulation and the roof deck.
- Floors above cold spaces, such as vented crawl spaces and unheated garages.
- Any floor section that is cantilevered beyond the exterior wall below.
- Around slab floors built directly on the ground.
- Foundation walls of crawl spaces (people often insulate crawl spaces so poorly that the insulation is ineffective).

If you are curious what kind of insulation already exists, here are some ways to inspect your walls for insulation:

- Remove electrical cover plates and look through gap on side of electrical box.
- Remove piece of siding and sheathing.
- Drill hole in interior or exterior wall and extract sample.

## Location of structural insulation

Thermal insulation usually works best on the outside of the structure, by allowing the walls, floor and ceiling to stay at room temperature, which prevents condensation in the living area of the house. Generally, spray foam and rigid panel insulation provide the most bang for the buck. They have the highest R-values per inch, and provide the best protection against air intrustion (and therefore, convective heat loss).

A well-insulated house requires a vapor barrier because of the risk of condensation on cold parts of the structure with resulting damage, such as mold and rot. The vapour barrier is usually a sealed plastic film inside the wall and should go on the warm side of the insulation:

- In a heated house, the vapour barrier goes close to the warm inside of the wall.
- In very warm climates, on a well-insulated air conditioned house, the vapour barrier should go on the outside so that the insulation is between the vapour barrier and colder, air conditioned parts of the house.
- In some parts of the country, vapor barriers are controversial. Some people believe that in temperate, humid climates, you should leave out the vapor barrier entirely. See here.

## Insulating ducts and pipes

Insulate all ducts and water supply pipes where they pass through unconditioned spaces, such as through an attic or crawlspace that is not heated or air-conditioned. This includes heating, ventilation, air-conditioning, and return ducts, and both cold and hot water supply pipes.

Before insulating ducts and pipes:

- Cement duct joints.
- Check the ductwork for leaks, and repair any that you find. Do not use duct tape - it is not designed for permanent applications, and will dry out and fall off over time.

Why to insulate ducts and pipes:

- Preserve desired temperature of air or water, and save energy and money.
- Prevent condensation on ducts or pipes when cool duct or pipe runs through hot, non-conditioned space in the warmer months.

Insulating materials for ducts and pipes:

- Foil-faced fiberglass.
- Foil-backed bubble wrap.
- Rock and slag wool, fiberglass, or another non-flammable loose-fill (not cellulose!) around stove and furnace pipes where they pass through floors and walls. If the stovepipe reaches high temperatures, you should not pack any insulation around the pipe.
- Preformed closed-cell foam pipe sleeves for water pipes.

You may want to wrap your water heater in a nonflammable thermal blanket, especially if you have an older, inefficient water heater that does not have much internal insulation.

## Insulating around electrical fixtures

To prevent a house fire, keep insulation away from any electrical fixtures that generate great amounts of heat, such as ceiling fan motors, and older recessed lighting fixtures that are not IC-rated. Newer recessed lights contain a heat sensor to turn the lights off when they reach a threshold temperature. The newest recessed lights, known as IC-rated (Insulation Cover) fixtures, are designed so that they do not require any air clearance and will work safely buried deep in insulation. If you have non-IC-rated recessed lighting fixtures, you should install baffles around the fixtures to maintain at least 3 inches of clearance from insulation. This is a stop-gap measure to remedy the excessive heat. Ultimately, you should:

- Use low temperature compact fluorescent bulbs.
- Replace the old fixtures with new, IC-rated fixtures.

OR

- Replace the recessed fixtures with non-recessed fixtures.

## Insulating exterior of foundation

Ideally, a home should have poured concrete walls, waterproofing, and 2-inch rigid foam panels. Complete retrofit foundation insulation may be prohibitively expensive. Since most of the heat loss from a foundation occurs where the foundation is above grade and exposed, you can partially insulate the foundation wall and still have good results:

- Buy the thickest panels that you can find (2 inches is ideal).
- Dig around the foundation at least 6 inches down.
- Clean the foundation with water and let it dry out completely, then parge twice (that is, coat with two thin layers of Portland cement), for added protection and damp proofing.
- Attach rigid foam panels to the exposed part of the foundation. Make sure they are rated for use below grade, since part of them will be buried.
- Add a protective covering, such as cement plaster, fiberglass, plastic, or metal.
- Fill in and compact the soil.

The sheets of extruded polystyrene foam attached to exterior foundation walls before backfilling serve as insulation, but their main purpose is to protect the waterproof coatings or membranes applied to the foundation wall. You should protect them from backfilling, as well, since they will not function as effectively as possible if they are cracked or torn while backfilling.

Rigid foam panels applied to an external foundation wall:

- Protect both the foundation wall and its waterproof coating during backfilling.
- Insulate.
- Reduce dampness.
- Some types of rigid panels provide drainage or direct groundwater to the footing drains.

How to apply insulation to an exterior foundation wall when building a house:

- Waterproof the foundation wall (usually consists of an elastomeric rubber membrane).
- While the waterproofing is still tacky, spread the appropriate type of adhesive on the back of a rigid foam panel. Each type of panel has a type of adhesive that is designed to work with that type of panel.
- Stick the rigid foam panel to the foundation.
- Carefully backfill, preferably after you frame the first floor. A thermal weak spot is the spot where the foundation touches the mudsill. While building a house, make sure the builder puts a rigid closed-cell foam gasket between the top of the foundation and the mudsill, around the entire perimeter of the house. You should use sheathing grade 5/8-inch plywood and 2 x 6 timbers when framing the exterior walls of a house, not only for structural strength, but also for the increased space for insulation.

Rigid foam panels do not have to stop where the siding begins. You can extend them up, underneath the siding, all the way up to the roof. When you secure them to the sheathing, make sure that you use galvanized nails or coated screws, and make sure they penetrate sufficiently into the studs, without cracking the panels. Unlike with the panels installed against the exterior foundation, with these panels, you should leave slight gaps between them to allow moisture to escape.

## Self-insulating foundations

Exterior insulation and finish systems (EIFS) are a new type of home construction that uses “all-in-one” insulating and structural walls with a stucco-like finish. Face-sealed EIFS is susceptible to trapped moisture if it is not installed meticulously. Drainable EIFS allows moisture to escape. Some building experts think that EIFS should only be used in hot, dry climates because of its tendency to collect moisture. [19] (http://www.buildingscience.com/resources/walls/EIFS.pdf)

Some contractors pour insulation into concrete blocks while building the foundation. Turn this concept inside out, and you have an insulated concrete form. An insulated concrete form (**ICF**) is a rigid foam block, usually polystyrene, that homebuilders can stack so their centers are aligned, insert reinforcing bars into, and fill with concrete. These foundations are both structural and insulating – insulation is incorporated directly into the foundation walls, rather than added as an afterthought. The tricky part is making sure that concrete fills all of the voids in the foam blocks.

Here is an example of an ICF home: Habitat for Humanity ICF Build Apr 2004 (http://www.boblafferty.com/habitat-sfx-vis/photos/HabitatBuild_04-03-04/index.html)

### Roof insulation

In the construction industry it is felt roofers who apply felt to a roof, usually in several layers bonded together, to form a watertight covering and keep the interior of the building dry and insulated. It is a skilled job that requires specific training.

Future felt roofers will need a head for heights as the occupation involves working on the top of buildings. They will need to enjoy working outdoors and have good people skills and have a head for heights. A good head for figures is also important, as a felt roofer will be calculating plenty of areas and volumes. Safety is important too, as working at heights can be dangerous.

There are no specific academic requirements to train as a built-up felt roofer, although GCSE passes (D-G) / Standard Grades (4-7) in Math, English and Technology will be helpful for the calculations, measurements and theory. A passion for working outdoors is also important.

## Audits, help, and incentives

In a home energy audit, professionals evaluate the energy efficiency of the home, using blower doors, infrared cameras, and other air leakage measuring equipment. They identify the greatest leaks and recommend the best ways to improve the energy efficiency of your house. They tell you what you should do first for the best bang for the buck.

Who to call for a home energy audit:

- Public utility companies, or their energy conservation department.
- Independent, private-sector companies such as energy services company, insulation contractor, or air sealing specialist.
- State energy office.
- Websites for any of the above.

Utility companies are usually eager to provide this service, as well as loans and other incentives to insulate. They also often provide incentives to switch, for example, if you are an oil customer considering switching to natural gas.

Where to look for insulation recommendations:

- Local building inspector’s office.
- Local or state building codes.
- US Department of Energy.
- Websites for any of the above.

Remember, code tells you the bare minimum. You should always insulate beyond what code requires. There is no reason why you can't insulate far in excess of code.

Insulate as completely as you can while building a house. This is much easier than retrofitting. For example, if you don’t install a closed-cell foam gasket to the sill plate when your house is under construction, there is no way to install it afterwards. You can spray foam into the gap, but this is not nearly as effective as having the gasket installed from day one.

Even though it is much easier to insulate a home as it is being built, you can still add insulation afterwards. Some states provide loans to install insulation in a pre-existing house, or allow you to apply for a tax credit afterwards.

# External links

- Industrial Insulation Basics (http://www.cheresources.com/insulationzz.shtml)
- R-value Recommendations from DOE/CE (http://www.ornl.gov/sci/roofs+walls/insulation/ins_16.html)

- Natural Handyman, insulation article (http://www.naturalhandyman.com/iip/inf/inf/infxtra/infinsul.shtm)
- Austin Green Living insulation article (http://www.ci.austin.tx.us/greenbuilder/glfs_insulation.htm)
- New and alternative insulation materials (http://doityourself.com/insulate/newalternativeinsulatematerials.htm)
- Home Insulation (http://www.cus.net/insulation/insulation.html)
- Insulation and Weatherization Handbook (http://en.wikipedia.org/wiki/Image:Insulation_and_weatherization_handbook.pdf)
- Sheeps wool Home insulation (http://www.secondnatureuk.com/)
- The Differences Between Radiant Barrier & Reflective Foil Insulation (http://www.radiantguard.com/index.asp?PageAction=Custom&ID=21)

# References


- U.S. Environmental Protection Agency and the U.S. Department of Energy's Office of Building Technologies.
- Loose-Fill Insulations, DOE/GO-10095-060, FS 140, Energy Efficiency and Renewable Energy Clearinghouse (EREC), May 1995.
- Insulation Fact Sheet, U.S. Department of Energy, update to be published 1996. Also available from EREC.
- Lowe, Allen. "Insulation Update," The Southface Journal, 1995, No. 3. Southface Energy Institute, Atlanta, GA.
- ICAA Directory of Professional Insulation Contractors, 1996, and A Plan to Stop Fluffing and Cheating of Loose-Fill Insulation in Attics, Insulation Contractors Association of America, 1321 Duke St., #303, Alexandria, VA 22314, (703) 739-0356.
- US DOE Consumer Energy Information.
- Insulation Information for Nebraska Homeowners, NF 91-40.
- Article in Daily Freeman, Thursday, 8 September 2005, Kingston, NY.
- TM 5-852-6 AFR 88-19, Volume 6 (Army Corp of Engineers publication).
- CenterPoint Energy Customer Relations.
- US DOE publication, Residential Insulation (http://www.energycodes.gov/implement/pdfs/lib_ks_residential_insulation.pdf)
- US DOE publication, Energy Efficient Windows (http://www.energycodes.gov/implement/pdfs/lib_ks_energy-efficient_windows.pdf)
- US EPA publication on home sealing (http://www.energystar.gov/ia/home_improvement/home_sealing/DIY_COLOR_100_dpi.pdf)
- DOE/CE 2002 (http://www.ornl.gov/sci/roofs+walls/insulation/ins_02.html)
- University of North Carolina at Chapel Hill (http://www.unc.edu/)
- Alaska Science Forum, May 7, 1981, Rigid Insulation, Article #484, by T. Neil Davis, provided as a public service by the Geophysical Institute, University of Alaska Fairbanks, in cooperation with the UAF research community.
- Guide raisonné de la construction écologique (Guide to products /fabricants of green building materials mainly in France but also surrounding countries), Batir-Sain (http://www.batirsain.org/) 2004
- Thermal Insulation (http://www.pinkbatts.co.nz/)


# See also

- Building construction
- Dewar flask
- Superinsulation
- Weatherization
- Thermal mass



Categories: Articles containing how-to sections | All pages needing to be wikified | Wikify from July 2006 | HVAC | Insulators | Thermal protection | Building engineering