Get Energy Smart
Insulation Options

Claire Anderson

Johns Manville's line of formaldehyde-free fiberglass insulation is available in pre-cut batts to fit standard wall cavities.

Courtesy Johns Manville

Do you know where your energy dollars are going? Chances are, if your energy bills are going through the roof, your home's heat might be going there, too—as well as through your walls, ceilings, and floors.

If you want to cut your costs, reduce your overall energy use, and make your home more comfortable, insulation is one of the best energy investments you can make. If you're living in an old home, it's almost assured that you can make improvements in insulation, and save energy and money. And even new homes built within the past few years may benefit from additional insulation.

The good news is that according to the U.S. Department of Energy (DOE), investing just a few hundred dollars in good insulation and home weatherization strategies can reduce your heating and cooling needs by up to 30 percent. Paired with good passive solar design, having a well-insulated home could even eliminate the need for mechanical heating and cooling in some climates.

Why It Works

Heat naturally migrates from warmer objects to cooler ones. Insulation helps slow this heat transfer considerably. Most insulation works by trapping tiny air pockets within the material. These pockets effectively reduce the material's conductivity, and help it resist heat transfer. This thermal resistance (or "R-value") is usually measured per inch of material. The more material you add, the greater its effectiveness

(see R-value table on page 46). Insulation's performance also hinges on how and where the insulation is installed. (See the sidebar "Adding It Up.")

Taking Shape

Insulation takes many forms: loose-fill, blankets (batts or rolls), rigid board, and liquid foam (which expands to fill a cavity as it dries). Insulation is also being integrated into building materials like structural insulated panels (SIPs) and insulated concrete forms (ICFs). If you're building a new home or an addition, you may want to investigate these "all-in-one" options. Some types of insulation require professional installation, while others are fairly easy to install yourself.

Loose-fill and liquid foam insulation are usually best suited to places where they can be blown in, such as attics and wall cavities. Special pneumatic equipment is usually necessary. Batts and rolls are sold in standard widths to fit between wall studs or ceiling or floor joists, and can be hand-cut to fit nonstandard spaces. Faced batts, covered on one side with a kraft paper or a reflective-foil vapor barrier, can be used where required by code. Rigid foam board can be used to insulate exterior walls, basements, concrete slabs, and foundation and stem walls.

Besides choosing an insulation material based on how well it works within a particular building system, also consider its long-term performance, its embodied energy (the energy used to make and transport the material), and any potential health impacts it might have, while it's being installed or after it's in place.

Measuring Up

The DOE provides minimum R-value recommendations for homes based on climate, heating source, and the space needing insulation, such as attics, basements, or walls (see the R-value map on page 48). Consider exceeding these levels (also known as "superinsulating" a home) for maximum energy efficiency. You'll need to compare the life-cycle savings to your initial budget for insulation to figure out the best return for your investment.

Start at the Top

If you have a limited budget for insulation, experts recommend insulating your attic or ceiling first. Compared to floors and walls, attics are a major contributor to a home's heat gain and loss, and bundling up an attic can shave up to 30 percent from your energy bills. Besides having a large surface area for heat transfer, attics can also have other conduits for air infiltration, such as recessed lights, plumbing and electrical chases, chimneys, exhaust fans, and ductwork. Together, these can account for more heat transfer than the *entire* flat surface of your attic.

Shawn Schreiner

Cotton batt insulation, made from post-industrial denim and other fibers, offers itch-free, easy installation and similar R-values to cellulose insulation.

Next, insulate walls and floors. In new homes, adequately insulating walls is a no-brainer. In older homes, however, it may be an expensive and difficult task. Get an estimate first, and then do the math to see how long it will take you to recoup your investment at a 16 to 20 percent savings on your heating and cooling costs. Insulating crawl spaces and underneath floors can save 5 to 15 percent on heating costs, and is usually an easier job.

These days, a wide variety of insulation materials are available. Here are some of the more common types you might choose, and brief descriptions of their properties.

Fiberglass. You might be most familiar with the "fluffy pink stuff"—fiberglass insulation. This insulation uses molten silica sand spun into fibers, along with different additives, such as boron, or a phenol formaldehyde or acrylic binder. Fiberglass is widely available in loose-fill and blanket products, and is relatively inexpensive.

Most fiberglass insulation manufacturers use recycled bottle glass—either pre-consumer glass scraps (known as cullet) or post-consumer glass from bottle-recycling

Adding It Up

An insulation's R-value indicates how well it resists heat flow. Generally, the higher the R-value, the better the insulation is at doing its job. But how and where insulation is installed also affects its performance. Insulation that is compressed too tightly into a space will not give its fully rated R-value. And a ceiling or wall's total R-value will usually be lower than the R-value of the insulation, mainly due to thermal bridging (increased conduction) that occurs through studs or joists because of their lower thermal resistance.

programs, incorporating 20 to 30 percent post-industrial and/or post-consumer material into their products. The production of the glass fibers can be energy intensive, but the low-density product means that the embodied energy is comparable to other insulation types.

Airborne fibers may be inhaled and absorbed into the lungs, particularly during installation. But phenol formaldehyde products used as binders have overshadowed this risk. This chemical off-gasses, and can contribute to poor indoor air quality. Acute effects of formaldehyde exposure include watery eyes, throat irritation, and nausea. Long-term effects have been harder to study, but the International Agency for Research on Cancer (IARC) classifies formaldehyde as a "probable human carcinogen." In response to this concern, some insulation manufacturers, like Johns Manville, have replaced formaldehyde binders with an acrylic binder. This formaldehyde-free insulation is off-white—the natural color of the fiberglass.

Cellulose. Old newspapers enjoy a new life in cellulose insulation, which is applied as loose fill or damp-sprayed into cavities. Cellulose insulation manufacturers purchase newsprint, cardboard, and paperboard that have been collected at recycling centers and shred it into fine pieces. After shredding, fire-retardants and mold inhibitors, such as boric acid, sodium borate (borax), and ammonium sulfate, are added. The finished product is about 80 percent recycled material by weight.

In terms of energy performance, cellulose insulation rivals high-density fiberglass batts, at roughly R-3.7 per inch. But because it generally packs more tightly than fiberglass batts, especially in damp-spray applications, cellulose is more effective at controlling air leakage. Settling can be a problem in loose-fill applications and can affect thermal performance.

Cellulose insulation is considered one of the greenest conventional insulation materials—from its raw materials to its manufacture. Because its production relies on a low-tech process, manufacturing plants can be small and localized, so transportation energy is usually low.

Questions have been raised about possible health risks of the chemicals and heavy metal residues (from newspaper ink) in cellulose insulation. But most researchers conclude that cellulose insulation does not pose a health risk to a home's occupants. As with other insulation materials, installers should minimize their risk of inhaling dust and fibers by using proper respiratory protection.

Cotton. Cotton insulation offers similar insulation value to cellulose. It's made primarily of blue-jean manufacturing trim waste (85 percent), with the remaining 15 percent consisting of microscopic plastic fibers to give it loft, and borates to resist pests and combustion. This product offers the installer itch-

Insulation Comparison

	R-Value Per Inch*	R-Value Per Thickness*
Loose Fill		
Fiberglass	2.2–2.9	–
Rock wool	2.2–2.9	–
Cellulose	3.1–3.7	–
Batts		
Fiberglass	2.9–3.8	–
Wool	3.5	–
Cotton	3–3.7	–
Rigid Board		
EPS	3.9–4.2	–
XPS	5.0	–
Polyisocyanurate	5.6–7	–
Liquid Foam		
Air Krete	3.9	–
Polyurethane	5.6–6.2	–
Other		
Straw bale	1.5	–
Straw-clay	1.6	–
Rastra (8 in. thick block)	–	11.0
SIPs (3.5–9.38 in. thick)	–	14.0–37.0
ICFs	–	18.0–35.0

*All values are estimates; total R-value will vary depending on material and installation techniques.

Courtesy Thermafiber

Slag wool, made from by-products of the steel mill industry, can also be sprayed into wall cavities.

free, fairly easy installation. Its installation and use poses few, if any, health risks to installers or a home's occupants.

Mineral (or Rock) Wool. Although "mineral wool" can be used to refer to fiberglass insulation or natural stone (usually basalt), most often it refers to a brittle material made from steel-mill slag—calcium, magnesium, and aluminum silicate minerals that are by-products of the steel manufacturing process. The slag is melted and then spun into fibers, an energy-intensive process, but one that doesn't require mining raw materials.

Moisture-resistant mineral wool retains its insulation abilities even when wet. It has excellent acoustic dampening qualities, and is more fire resistant than either fiberglass or cellulose. The company Thermafiber manufactures a spray-on mineral wool product with an R-value similar to sprayed cellulose insulation or high-density fiberglass batts.

The IARC puts mineral wool (rock and slag wool) in its Group 2B class: "possibly carcinogenic to humans." Although in some study groups, an elevated risk of death from respiratory system cancer and nonmalignant respiratory disease was observed, no consistent evidence of an association between those elevated risks and respirable mineral wool fibers was found. Mineral wool poses no off-gassing risks, and few health risks to a home's occupants.

Rigid Foam. Also called foam board, rigid foam insulation is most commonly used to insulate foundations and slabs, as well as exterior roofs and walls. With up to twice the R-value per inch of fiberglass or cellulose, it packs an insulation punch. Three types of rigid foam insulation are available.

Rigid foam polyisocyanurate insulation can be used to completely cover a building's exterior walls, reducing heating and cooling losses significantly.

Don't Forget Ducts

After ceilings, floors, and walls, ductwork can account for up to 15 percent of a home's winter heat loss, according to the DOE. This network of tubes in a home's walls, floors, and ceilings carries conditioned air to the rooms in your home. Most systems, unless they're relatively new, are uninsulated or not insulated properly. And uninsulated and leaky ducts translate into energy dollars down the drain.

Insulating and sealing ducts is especially important if they are located in unconditioned, unheated spaces. In the wintertime, ducts can leak heat, and in the summertime, they can actually draw in hot air, decreasing your central air conditioner's efficiency.

Minor duct repairs are easy to do yourself, but you may want to consult a pro to insulate and seal ducts in unconditioned spaces. First look for sections that should be joined, but have separated, and then look for obvious holes. Seal your ducts with Underwriters Laboratories (UL) certified tape to ensure a long-lasting bond. Insulating ducts in a basement will make the basement colder, so if both the ducts and the basement walls are uninsulated, consider insulating both. To help prevent condensation on cooling ducts, make sure that a well-sealed vapor barrier exists on the outside of the insulation. In most areas, use duct wrap insulation of R-4 or R-6.

Going Green

Because insulation reduces energy consumption—and the pollution associated with this energy use—any type of insulation can be considered "green," says Alex Wilson of BuildingGreen.com. Over a home's lifetime, the environmental benefits of that alone can outweigh any negative consequences that result from an insulation's manufacture.

From an embodied energy standpoint, some materials measure up quite differently—from what kind of materials they were made of and their manufacturing process—and this may be a consideration when you're making insulation decisions. You may also want to consider the health implications of using certain materials, whether you're doing it yourself or hiring an installer. Some insulation may off-gas (slowly release) volatile chemicals, such as formaldehyde, or shed small fibers, which can be inhaled, during installation.

Expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate (polyiso) are made from polymers—petrochemical-based foam plastics—that are expanded with a blowing agent.

XPS has a higher R-value and compressive strength than EPS, and is more moisture-resistant. Inch for inch, polyiso boasts the best insulation value of the three rigid foam boards. Aluminum-foil and plastic-faced polyiso offer even greater resistance to heat flow. Most of the rigid foam insulations undergo a gradual deterioration in their insulation value over time. This "thermal drift" eventually stabilizes, but can represent a significant shift from the product's original, rated R-value.

Blowing agents that are used to manufacture foam boards have been the target of environmental concerns because of their damaging effects on atmospheric ozone, a molecule that screens out harmful high energy ultraviolet rays. EPS, or beadboard, is made from polystyrene beads that are expanded with liquid pentane. As the agent disperses from the foam board, tiny, trapped bubbles in the material fill with air, giving the foam its insulative value. EPS has the least environmental impact because it is not manufactured using ozone-depleting chemicals. The pentane used as an expansion agent in EPS does, however, contribute to the formation of ground-level smog.

Most XPS or blueboard is made from polystyrene and HCFC-142b—a hydrochlorofluorocarbon expansion agent. While HCFCs are only 5 percent to 11 percent as damaging to atmospheric ozone than their CFC precursors, a single molecule can still damage *thousands* of ozone molecules. In the United States, HCFC-142b must be phased out by 2010.

Until 2003, most polyisocyanurate foam board was manufactured using HCFC-141b as the blowing agent. Today, most polyiso companies have switched to using a hydrocarbon mix, which causes no damage to atmospheric ozone.

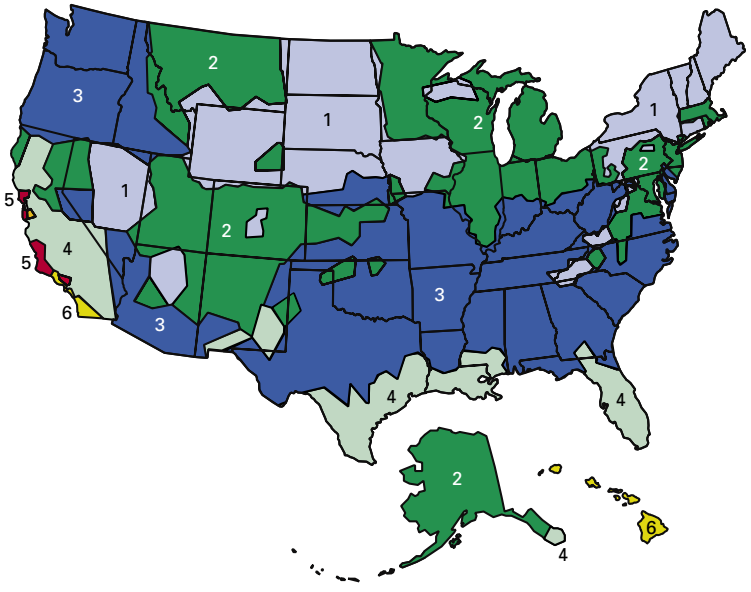
Besides relying on petrochemicals, foam board is energy intensive to manufacture, making it one of the insulation materials with the highest embodied energy. The use of

Recommended R-Values

Zone	Attic	Wall	Floor
1	R-49	R-18/R-28*	R-25
2	R-49	R-18/R-22	R-25
3	R-49	R-18	R-25
4	R-38/R-49	R-13/R-18	R-13/R-25
5	R-38/R-49	R-13/R-18	R-11/R-25
6	R-22/R-49	R-11/R-18	R-11/R-25

*First value is for homes heated with natural gas; second is for electric furnaces

Source: U.S. DOE, www.eere.energy.gov/consumer/tips/insulation.html



rigid foam board insulation poses few health risks, although there have been some concerns about the potential off-gassing from flame retardants and the plastic polymers.

Liquid Foam. Foamed-in-place insulation has the advantage of filling wall and ceiling cavities completely, providing high R-values (3.6 to 6.5 per inch) and blocking air leakage very effectively. Installation requires special equipment, however, and must be done by licensed contractors. Generally, liquid foam is sprayed into open wall cavities, where it rapidly expands—sometimes up to 100 times its original volume—to fill the space. Once it has dried, excess insulation is easy to trim off. Some foams can be used in closed wall cavities. These products expand more slowly, to reduce the risk of structural damage.

Courtesy Agriboard

All-in-one insulation and wall systems, such as Agriboard's SIP, made with strawboard and compressed straw, can reduce thermal bridging and air infiltration.

Most liquid or spray-foam insulation products are high-density, closed-cell polyurethanes, made from petroleum—and some of these still use the ozone-depleting HCFC-141b blowing agent. Open-cell, low-density polyurethane foams have been produced with water or carbon dioxide as the blowing agent for some time.

Compared with closed-cell polyurethane, open-cell products also use significantly less material, making them attractive from a resource standpoint. These spray-foams provide an airtight, water vapor resistant seal, and eliminate the need for vapor barriers in stick-framed homes. And most resist shrinking, settling, and sagging.

Polyurethane foams rank close to rigid foam insulations in terms of their embodied energy. To improve this energy-to-efficiency balance, some manufacturers are reducing their reliance on petroleum, replacing up to three-quarters of the petrochemical-based foam with a soy-based product.

Air Krete is one of the few nonpetroleum-based foams. Made with magnesium chloride, ceramic talc, and a proprietary foaming agent, it is sprayed into wall cavities with pressurized air. One drawback is that since it does not adhere to surfaces, material shrinkage or movement in a building may eventually cause gaps in the insulation, compromising the whole wall R-value. Air Krete offers superior fire-resistance.

Installers need to take safety precautions when working with these materials; others should not be present while polyurethane insulations are being installed. However, most indoor air quality professionals consider this product to be inert once it has cured.

Other Options: Wool & Straw. Sheep's wool has been commonly used in Australia and New Zealand for decades, but is now just starting to make its way into U.S. homes. With an insulation value higher than standard fiberglass, it also retains its value when wet and is naturally flame-resistant, although some wool insulation manufacturers add boric acid as an additional flame retardant.

Straw bales have been used as a cheap and effective building and insulation material since the nineteenth century. Oak Ridge National Laboratory determined the R-value to be R-27.5 (or R-1.45 per inch), or R-33 for three-string (23-inch-wide) bale wall systems. The California Energy Commission reports that a plastered straw bale wall has an average R-value of 30. Straw-clay, a mixture of short, chopped strands of straw and clay slip, can be packed into wall forms or ceilings to create thick, fire-resistant, and fairly mold- and mildew-resistant walls, with an estimated R-value of about R-1.6 per inch, according to research results reported by the Canadian Mortgage and Housing Corporation.

Because these materials undergo little or no processing, and can be sourced locally, their embodied energy and resulting environmental impacts are generally low. They pose no or very little health risk to installers or a home's occupants.

Integrated Insulation. Some homebuilders today opt for all-in-one construction, combining insulation within their wall and ceiling structures. Several different products are available to meet this need. Structural insulated panels (SIPs) sandwich a polystyrene, isocyanurate, or even a

compressed straw core between plywood, oriented strand board, or strawboard panels. Using these large panels reduces thermal bridging and air gaps more common in conventionally insulated stick-frame homes.

Insulating concrete forms (ICFs) integrate poured concrete into interlocking foam board or hollow-core polystyrene blocks to make a complete wall or foundation system. Because of its flammability, though, ICFs exposed to occupied spaces must be covered with a fire-resistant material.

Rastra "blocks" incorporate recycled polystyrene, Portland cement, and additives into a framework, which is glued or clamped together until the concrete is poured. This lightweight, strong material can be easily worked with all woodworking tools, and carved to achieve curves. By volume, Rastra contains 85 percent recycled content. No energy is used to cure the elements, and only about 1 KWH is required to produce one Rastra element—a 10-inch-thick, 15 by 10-foot panel. This product provides high insulation values with no off-gassing, and is pest- and fire-resistant.

Access

Claire Anderson, PO Box 520, Ashland, OR 97520 • claire.anderson@homepower.com

Thanks to Mark Piepkorn, Associate Editor at *Environmental Building News* (www.buildinggreen.com), and Andre Desjarlais, Program Manager of the Building Envelopes Program at Oak Ridge National Laboratory's Buildings Technology Center, for their expert review of this article.

Select Insulation Manufacturers/Distributors:

Agriboard Industries, 8301 E. 21st N., Ste. 320, Wichita, KS 67206 • 866-495-3595 or 316-630-9223 • Fax: 316-636-9255 • info@agriboard.com • www.agriboard.com • SIPs made with a compressed wheat-straw core

Bonded Logic Inc., 411 E. Ray Rd., Chandler, AZ 85225 • 480-812-9114 • Fax: 480-812-9633 • www.bondedlogic.com • Cotton insulation

Good Shepherd Wool Insulation, RR 3, Rocky Mountain House, AB, Canada T4T 2A3 • 403-845-6705 • Fax: 403-845-6705 • www.goodshepherdwool.com • Sheep's wool insulation

InnoTherm, PO Box 226, Newton, NC 28658 • 877-466-0612 or 828-466-1147 • Fax: 828-466-1498 • rcfrazier@hickorysprings.com • www.innotherm.com • Cotton insulation

Insulating Concrete Forms • www.icfweb.com • General ICF information

Johns Manville, PO Box 5108, Denver, CO 80217 • 800-654-3103 or 303-978-2000 • www.jm.com • Formaldehyde-free fiberglass insulation

Nu-Wool Inc., 2472 Port Sheldon Rd., Jenison, MI 49428 • 800-748-0128 • Fax: 616-669-2370 • info@nuwool.com • www.nuwool.com • Cellulose insulation

Rastra Corp., North American Corp. Office, 7621 E. Gray Rd., Ste. A1, Scottsdale, AZ 85260 • 877-935-3545 or 480-443-9211 • Fax: 480-443-9228 • info@rastra.com • www.rastra.com • Rastra insulated blocks

Structural Insulated Panel Association, PO Box 1699, Gig Harbor, WA 98335 • 253-858-7472 • Fax: 253-858-0272 • staff@sips.org • www.sips.org • General SIP information

Thermafiber, 3711 W. Mill St., Wabash, IN 46992 • 800-294-7076 or 260-563-2111 • Fax: 260-563-8979 • info@thermafiber.com • www.thermafiber.com • Rock wool insulation

Urethane Soy Systems Co. Inc., PO Box 500, Volga, SD 57071 • 888-514-9096 or 605-627-6393• Fax: 605-627-5869 • tom.kosakowski@soyol.com • www.soyol.com • SoyTherm 50, soy-based polyurethane insulation

U.S. GreenFiber LLC, 809 W. Hill St., Ste. A, Charlotte, NC 28208 • 800-228-0024 • Fax: 704-379-0685 • greenfiber.info@us-gf.com • www.us-gf.com • Cellulose insulation

Online Insulation Assessment: ZIP-Code Insulation Program • www.ornl.gov/~roofs/Zip/ZipHome.html