Insulation Materials: Environmental Comparisons

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Contents:

Decisions about insulation are among the most important you will make relative to the environmental impact of buildings. Because insulation reduces the energy consumption, it provides ongoing environmental benefits throughout a building's life. However, not all insulation materials are equal environmentally.

In assessing the environmental characteristics of insulation materials, we need to consider a broad range of issues relating to the resources going into their production, manufacturing processes, pollutants given off during their lifecycle, durability, recyclability, and impact on indoor air quality. This article addresses the primary lifecycle concerns of various insulation materials and provides comparisons between both existing and new materials.

Raw Material Acquisition

The raw materials used to produce insulation vary widely, ranging from the sand used in fiberglass to the petrochemicals in foam plastic insulation and the old newspaper in cellulose insulation. Environmental concerns with raw material acquisition include, on the negative side, depletion of limited resources and pollution resulting from mining. On the positive side is the recycled content of many common insulation materials.

Limited resources

The most obvious resource limitation among materials used to produce insulation is the availability of fossil fuels used in foam plastic insulation. Polystyrene is produced from ethylene, a natural gas component, and benzene, which is derived from petroleum. Polyisocyanurate and polyurethane are made from polymeric methylene diioscyanate (PMDI) and polyol, both of which are derived from petroleum. While fossil fuels are not going to run out any time soon, the reserves are finite, and as they dwindle in the next century, costs are likely to rise.

While other insulation materials are not made from petrochemical feedstocks, most require fossil fuel energy for mining, manufacture, and transport, so they lead indirectly to fossil fuel depletion (see discussion of embodied energy below).

Another raw material that is potentially in short supply is the boron used in fiberglass insulation and as a fire retardant in some cellulose insulation. Fiberglass insulation is the number one end-use of boron, most of which comes from two primary deposits: the largest in the southwestern U.S. and Turkey. Boron improves the flexibility of fiberglass and the energy efficiency of manufacture. Fiberglass insulation is approximately 6-8% boron oxide (B_2O_3) by weight, according to Dr. Kelvin Shen of U.S. Borax. At today's level of extraction and with current economics, U.S. Bureau of Mines data shows a 54-year reserve of boron in the U.S., and total known U.S. reserves of about 200 years.

Pollution from resource extraction

Environmental impacts from raw material acquisition include air pollution, water pollution, and erosion from mining of minerals (for example, sand and limestone used in fiberglass, diabase rock used in rock wool, and bauxite for the aluminum used in foil facings and radiant barriers). Often these environmental impacts are multi-tiered. For example, mining usually produces tailings waste, which results in runoff with high levels of suspended solids, which increases turbidity in surface waters, which can cause deoxygenation of those waters, which in turn can kill fish. Pollution from oil spills and well-head leaks occurs when extracting and transporting the fossil fuels used to make plastic foam. The same fuels provide the energy for mining and other resource extraction.

Recycled content

Recycled content is the most recognized environmental feature of building products. Materials with recycled content have three advantages: 1) they require less natural resource; 2) they divert materials from the solid waste stream; and 3) they use less energy during manufacturing.

The insulation industry is full of good examples of recycled material use. Considerable use of recycled materials in producing insulation has been driven to some extent by the U.S. Environmental Protection Agency's recycled-content procurement guidelines, and similar state-level mandates, most notably in California. EPA procurement guidelines specify minimum recycled content for construction projects receiving over $10,000 in federal funding (see Table 1). A number of examples of insulation materials with recycled content are covered below.

Table 1. EPA Recycled-Content Procurement Guidelines

Material Type	Minimum Recycled Content Percent by Weight
Cellulose (loose-fill and spray-on)	75% post-consumer recovered paper
Fiberglass	20-25% cullet (post-industrial or post-consumer glass)
Mineral wool	75% recovered materials
Polyisocyanurate rigid foam	9% recovered material (polyol resin component)
Polyurethane spray foam	5% recovered material (polyol resin content)

(If your browser will not accept tables, please click here for a GIF image of the table.)

Cellulose. Cellulose is perhaps the best example of recycled material use in insulation. Most cellulose insulation is approximately 80% post-consumer recycled newspaper by weight; the rest is comprised of fire retardant chemicals and--in some products--acrylic binders. The cellulose industry used approximately 840 million pounds (381 million kg) of recycled newspaper in 1994, according to Dan Lea of the Cellulose Insulation Manufacturers Association (CIMA).

New cellulose insulation technologies are helping that recycled newspaper go further. There is increasing use of lower-density cellulose produced by "fiberizing" the newspaper (breaking it down into individual fibers that are fluffier). The industry is switching to this process from the older hammermill process because it results in a better product--cleaner, less dust, slightly higher R-value--and, most important, because it stretches the resource base (see "Cellulose Expands Despite High Material Costs" on page 4). More manufacturers are offering *stabilized* cellulose to prevent settling of loose-fill attic insulation. (For detailed information on cellulose insulation, see EBN Volume 2, No. 5 -- September/October 1993.)

Mineral Wool. While mineral wool was at one time the most common type of insulation, its market share was largely lost to fiberglass in the 1960s and 1970s. In the past few years, however, the product appears to have begun a comeback. There are currently several manufacturers of mineral wool in the U.S. and about eight plants that produce it.

"Mineral wool" actually refers to two different materials: slag wool and rock wool. Slag wool is produced primarily from iron ore blast furnace slag, an industrial waste product. Rock wool is produced from natural rocks, such as basalt and diabase. Slag wool accounts for roughly 80% of the mineral wool industry, compared with 20% for rock wool. Given the relative use of these two materials, mineral wool has, on average, 75% post-industrial recycled content. According to the North American Insulation Manufacturers Association, over 938 million pounds (425 million kg) of blast furnace slag were used in 1992 to produce slag wool.

Fiberglass. The big-three fiberglass insulation manufacturers--Owens Corning, Schuller International (previously Manville), and CertainTeed--all use at least 20% recycled glass cullet in their insulation products to comply with the EPA recycled-content procurement guidelines. Schuller's fiberglass is certified by Scientific Certification Systems (SCS) to contain 25% recycled glass (18% post-consumer bottles and 7% post-industrial cullet), according to Reed Larson of the company, and they have most actively promoted that environmental benefit. Unlike the others, Schuller's manufacturing equipment readily handles colored glass, making it easier for the company to use post-consumer recycled cullet. CertainTeed and Owens Corning rely primarily on *post-industrial* cullet from flat glass manufacturers.

Recycled glass content in excess of 90% is feasible, according to Mike Rapp of Owens Corning. Tom Newton of CertainTeed notes that obtaining a consistent supply of quality, clear glass cullet has been a problem. Each percent of glass cullet (over 10%) substituted for raw sand reduces energy use by about 1% according to Newton; the company has one plant using 40% recycled glass, but they claim a 20% average among all their plants. Owens Corning, the largest producer of fiberglass insulation, is now averaging 30% recycled glass, according to Jim Worden of the company, though Rapp said that one of their foreign plants is using in excess of 90%.

Polystyrene. Recycled plastic resin is used in some extruded and expanded polystyrene. Amoco Foam Products uses 50% recycled resin in its Amofoamreg.-RCY extruded polystyrene (XPS), half of which is is post-consumer, according to the company. Currently, Amoco Chemical offers Amofoam-RCY exclusively in 1", 1.5" and 2" (25 mm, 38 mm and 50 mm) 2x8 and 4x8 (600x2400 mm and 1200x2400 mm) boards, and regular (non-recycled Amofoam) in all other sizes. Amofoam products are marketed primarily in the East and Midwest. None of the other three XPS manufacturers currently produce any recycled-content insulation, though Dow experimented with recycled material in certain Styrofoamreg. products for a short while.

Expanded polystyrene (EPS) can also be made out of recycled polystyrene. The simplest recycling involves crumbling the old EPS into small pieces and re-molding them into usable shapes. Any polystyrene can be recycled into building insulation, but because of fire retardants, old building insulation cannot usually be recycled into non-building applications.

Polyisocyanurate. The polyisocyanurate foam insulation industry also uses recycled material in its products. The Polyisocyanurate Insulation Manufacturers Association (PIMA) says that almost all products today meet the EPA procurement guidelines for federally funded buildings, which call for a minimum 9% recycled content. Rather than using recycled foam, however, manufacturers buy polyol chemical components with recycled content. The industry used some 20 to 30 million pounds of recycled post-consumer chemicals in 1993, according to Jared Blum of PIMA. In fact, according to the AIA *Environmental Resource Guide*, the industry is one of the largest markets for mixed-color recycled PET beverage containers, which have traditionally been difficult to recycle. In addition to the raw chemicals having recycled content, the foil facings used on polyiso are typically 70-80% recycled aluminum.

Radiant Barriers. Like foil facings on polyisocyanurate insulation, the aluminum used in radiant barriers is also mostly recycled. At least one radiant barrier insulation material, Low-E Insulation(TM), made by Environmentally Safe Products, Inc. of New Oxford, Pennsylvania, also uses recycled plastic in the foam core. The $^{1}/4$" (6 mm) polyethylene foam insulation in the product is 100% recycled high-density polyethylene (at least 15% post-consumer). The product's recycled content is certified by SCS.

Cotton Insulation. Greenwood Cotton insulation is the new kid on the block in the fiber insulation industry--or at least it is about to be. After numerous start-up delays, the company expects to begin shipping insulation from its new Roswell, Georgia factory in February or March of this year. Cotton insulation was originally developed as "Insulcot(TM)" by a small West Texas company using virgin cotton. Promoted initially as a non-irritating alternative to fiberglass, early market research revealed an interest in use of recycled fiber, and the company switched to mill scraps from denim and T-shirt mills. The developer eventually licensed production of the insulation to Greenwood Mills, a large textile manufacturer. The present product, Greenwood Cotton insulation, is approximately 95% post-industrial recycled fiber, 25% of which is polyester fiber. The polyester improves tear strength and recoil characteristics.

The biggest concern with cotton insulation has been fire safety. A Habitat for Humanity environmental home insulated with Insulcot in Austin, Texas, burned in March 1994 when a plumber's torch ignited some exposed insulation. Kirk Villar, Vice President of Greenwood Cotton, told EBN that fire retardants for cellulose insulation were used in Insulcot, and different chemicals are used today, but he would not be more specific about the chemicals that are used.

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Insulation made from mill-waste cotton and polyester should be widely available in the Southeast this spring

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Pollution from Manufacture and Use

Nearly all manufacturing processes generate pollution. So, too, with insulation. Much of the pollution generated by insulation production is a result of energy use (generally fossil fuel combustion), so a simple way to compare manufacturing impacts of different insulation materials is to compare the manufacturing energy required, or *embodied energy* (see page 14).

Chemical Precursors

With some insulation materials, there are industrial processes that result in non-energy-related pollution. To manufacture isocyanate, a precursor of polyisocyanurate and polyurethane insulation, two chlorine-based chemical intermediates are used: phosgene and propylene chlorohydrin. Citing pollution problems, a number of environmental groups, including Greenpeace, are calling for the phase-out of certain industrial uses of chlorine (see EBN Vol. 3, No. 1).

The styrene used in polystyrene insulation is identified by EPA as a possible carcinogen, mutagen, chronic toxin, and environmental toxin. Further, it is produced from benzene, another chemical with both environmental and health concerns.

Most fiberglass insulation is produced using a phenol formaldehyde (PF) binder to hold the fibers together. Though exact quantities of binder used in manufacture of fiberglass are not disclosed by industry, Mike Rapp of Owens Corning says they comprise 5-7% of typical residential fiberglass insulation products, and Tom Newton of CertainTeed says they may account for 10-15% of the total material cost. During manufacturing, most of the binder apparently dissipates and is captured with pollution control equipment, according to several industry sources.

A new type of fiberglass--Miraflex(TM)--that does not require a binder is being introduced in the first quarter of this year by Owens Corning (see product review on page 8). Because there are no binders or other chemicals (such as colorants) in this product, pollution-control equipment is not required, and pollution emissions during manufacturing will be much less of a concern.

CFCs and HCFCs

The most significant pollutants found in insulation materials are chlorine-based chemicals that destroy the earth's protective ozone layer. Chlorofluorocarbons, or CFCs, which are also greenhouse gases, were used until recently as blowing agents in extruded polystyrene, polyurethane, polyisocyanurate, and phenolic foam (see Table 2). As revelations about the role CFCs play in ozone depletion came to light and regulations to restrict their use were enacted, however, these industries have turned to other, less damaging, foaming agents.

Table 2: Blowing Agents in Rigid Boardstock and Spray Polyurethane Insulation

Product	Examples	Original blowing agent	Current blowing agent	Date of CFC phase-out	Date of HCFC phase-out	Comments
Extruded polystyrene (XPS)	Styrofoam Amofoam FoamulaR Diversifoam	CFC-12	HCFC-142b	Varies: Jan. 90 to Dec. 93	Prod. cap by 2010 Phase-out by 2020	
Polyiso-	Thermax, R-		HCFC-			Rapid phase-out of HCFC-141b because

cyanurate	max, ENRGy, Tuff-R	CFC-11	141b	1993	Dec. 2002	of high ozone-depletion potential
Spray polyurethane	Not generally sold by name	CFC-11	HCFC-141b (or water, HCFC-22, HFC-134a)	1993	Dec. 2002	Using HCFC-22 or HFC-134a requires shipping chemicals under pressure; lower R-value with water-blown
Phenolic foam boardstock	Manville (discont'd) Domtar; Fiberglas Canada	CFC-11	HCFC-141b and/or recycled CFCs	1992	Dec. 2002 (HCFC-141b)	No longer produced in U.S.; two Canadian manufacturers
Expanded polystyrene (EPS)	AFM affiliates, many small Manufacturers	Pentane	Pentane	N.A.	N.A.	Several manufacturers now reclaim pentane and burn it.
Rigid fiberglass	Fiberglas Canada-GlasClad	None	None	N.A.	N.A.	In the U.S. only commercial products are available.

(If your browser will not accept tables, please click here for a GIF image of the table.)

Among building insulation materials, extruded polystyrene (XPS) led the shift to less damaging hydrochloro-fluorocarbons (HCFCs). Dow and Amoco Chemical began shifting from CFC-12 to HCFC-142b in 1989 and completed the transition in 1990. UC Industries (FoamulaR) eliminated the use of CFCs by December 1992 (FoamulaR has since been acquired by Owens Corning), and Diversifoam in January 1993. XPS manufacturers were able to switch quickly because HCFC-142b had already passed toxicity testing and companies were able to produce it without additional testing.

Other CFC users were not so fortunate. Polyisocyanurate, polyurethane, and phenolic foam were all foamed with CFC-11, and the best replacement found, HCFC-141b, had not been tested for toxicity so was not on the market. Thus, those industries could not shift away from CFCs as quickly. In mid-1993, PIMA announced that the polyiso industry had completed the shift from CFC-11 to HCFC-141b. Spray polyurethane and the two Canadian phenolic foam products are now also foamed with HCFC-141b.

Unfortunately for these industries, the HCFCs that replaced the CFCs cannot be used for long either. HCFC-141b is slated for phase-out by December 31, 2002, and HCFC-142b by 2020. While HCFCs are only 5% to 11% as damaging to ozone as CFCs (because they do not last as long in the atmosphere), they are almost as damaging for the period of time when they are there, and all are significant greenhouse gases (believed to cause global warming). Foam insulation manufacturers and chemical producers are working hard to find zero-ozone-depletion alternatives.

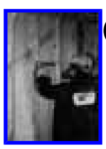
CFC-Free Foam Insulation

Among foam insulation materials, there are several alternatives to those made with ozone-depleting chemicals:

EPS. Expanded polystyrene (EPS) is the only common rigid foam boardstock insulation made with neither CFCs nor HCFCs. During manufacture, polystyrene beads are expanded with pentane, a hydrocarbon that contributes to smog but is not implicated in ozone depletion or global warming; the pentane quickly leaks out of the insulation and is replaced by air. To meet strict air pollution standards in California, several EPS manufacturers have redesigned their plants to recover up to 95% of the pentane used in production. And one of the largest polystyrene bead producers, BASF, has shifted to a low-pentane formulation.

SuperGreen Polyurethane. While the polyurethane industry as a whole has gone the route of replacing the CFC-11 with HCFCs, one foam producer and an insulation contractor have bucked the trend and gone to a non-ozone-depleting hydrofluorocarbon (HFC). Foam-Tech, Inc. uses HFC-134a, as the foaming agent in its SuperGreen(TM) polyurethane foam (see EBN, Volume 2, No. 4 -- July/August 1993). The higher cost of this foaming agent results in an upcharge of about 10% over conventional polyurethane. Preferred Foam Products of North Branford, Connecticut produces the HFC-based foam components for Foam-Tech, the sole customer. While HFCs are ozone-safe, they are significant greenhouse gases.

Icynene. Icynene(TM) is a Canadian product developed in 1987 and introduced to parts of the U.S. about four years ago. There are currently about 30 licensed installers in the U.S., primarily in the Northeast and Northwest, but also scattered as far south as North Carolina, Texas, and Oklahoma. The foaming agent is a mixture of carbon dioxide and water. This eliminates polyurethane's HCFC-related environmental problems but also means a lower R-value. Like polyurethane, Icynene is foamed into wall cavities, but the resultant open-cell foam is soft, not rigid. In fact, it is marketed as much for its air sealing characteristics as its insulation properties. A recent development with Icynene is a second formulation that can be foamed into closed cavities.

(filesize 38k)

Icynene is sprayed into open cavities and the excess trimmed off after curing

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Water-Blown Polyurethane. Another manufacturer, Resin Technology Company, has developed several polyurethane insulation products that do not require HCFCs, but these materials have not yet been released to the building industry. They have both a closed-cell water-blown polyurethane (RT-2050) with an installed density of about 2 lbs/ft^3 (32 kg/m^3), and an open-cell water-blown polyurethane with an installed density of .5-.8 lb/ft^3 (8-12.8 kg/m^3). The latter is probably quite similar to Icynene. Company president James Doose did not say when these products might be introduced.

Tri-Polymer Foam. Produced by C. P. Chemical Company of White Plains, NY, Tri-Polymer Foam is a a non-CFC, non-HCFC cavity-fill insulation used primarily in masonry block walls. It is essentially a phenolic foam and was developed as an alternative to urea formaldehyde foam insulation around 1980. It has very good fire resistance properties but does exhibit some shrinkage over time, which degrades its thermal performance.

Air Krete. Air Krete(TM) has gained a following both for environmental and health reasons. It is an inorganic foam produced from magnesium oxide (derived from sea water). It is foamed under pressure with a microscopic cell generator and compressed air; no CFCs or HCFCs are used. Because of its inorganic composition, Air Krete has very low VOC emissions, is totally inert, and non-combustible. It is foamed in place in closed wall or masonry block cavities, or behind mesh in open cavities to form a lightweight and rigid, but very friable, foam.

Embodied Energy

It surprises a lot of people to learn that a state-of-the-art, energy-efficient, passive-solar house built today may consume less heating and cooling energy over 30 or even 50 years of operation than was required to build it. This means that if our society wants to continue the impressive gains that have been made over the past 20 years in reducing energy use, we will need to focus attention on *embodied* energy as well as operating energy. Embodied energy is the energy required to produce and transport materials. If two insulation materials insulate equally well and other manufacturing impacts are comparable, the one with lower embodied energy is environmentally preferable.

While the embodied energy of insulation materials is usually quite low compared with the energy a given amount of insulation will save over its lifetime, it is nonetheless important. Embodied energy values for common insulation materials are compared in Table 3. Because these values were obtained from different sources and may have been obtained using different assumptions, they should not be considered highly accurate. They do provide useful order-of-magnitude comparisons, though.

Just how embodied energy values relate to environmental performance of a product is complicated by the fact that different fuels have different environmental impacts. For this broad comparison, it is reasonable to assume that a Btu of energy used by one industry is roughly comparable in terms of resource use and resultant pollution to a Btu used by another industry.

Table 3: Estimated Embodied Energy of Several Insulation Materials

Material	**Embodied Energy in Btu/lb. (MJ/kg)**	**Weight per insulating unit[1] in lbs. (kg)**	**Embodied Energy per insulating unit in Btu (MJ)**
Cellulose[2]	750 (1.75)	0.812 (0.37)	600 (0.6)
Fiberglass[3]	12,000 (27.9)	0.379 (0.17)	4,550 (4.8)
Mineral Wool[2]	6,500 (15.1)	0.458 (0.21)	2,980 (3.1)
EPS[3]	48,000 (111.6)	0.375 (0.17)	18,000 (19.0)
Polyiso[3]	30,000 (69.8)	0.476 (0.22)	14,300 (15.1)

1. "Insulating unit" refers to the mass of insulation required to provide R-20 (RSI-3.52) over one ft^2 (0.093m) at standard density.

2. Figures from personal communication with manufacturers.

3. Figures from the final report: "Comparative Energy Evaluation of Plastic Products and Their Alternatives for the Building and Construction and Transportation Industries," 1991, Franklin Associates, Ltd., prepared for The Society of the Plastics Industry.

(If your browser will not accept tables, please click here for a GIF image of the table.)

Durability

Durability of building materials, including insulation, is a very important environmental consideration. Clearly, more durable materials are environmentally superior to less durable ones. Most insulation materials will perform very well over lifetimes measured in decades or even centuries. There are exceptions, however, and various factors that affect performance over time.

The biggest long-term performance concern with cellulose insulation is possible loss of fire-retardant chemicals. Because borates are water soluble, they can leach out if the insulation gets wet. Some people claim that those chemicals gradually disappear even if the material does not get wet, though these claims have not been substantiated. According to Dan Lea of CIMA, there is a shift within the industry toward ammonium sulfate fire retardants, which actually *improve* in fire retardancy performance over time. A concern with ammonium sulfate, however, is corrosion of metals in contact with the insulation, particularly with wet-spray applications.

Other concerns with loose-fill fiber insulation are settling, displacement as a result of wind, and infestations of rodents. It is also possible that, over many decades, dust and dirt accumulation could reduce the R-value--either by compressing the insulation or by filling air pockets.

Insulation materials that rely on reflectivity for their thermal performance are prone to reduced performance as accumulating dust reduces the reflectivity. Oak Ridge National Laboratory has published a number of studies on impact of dust on radiant barrier performance.

Rigid foam insulation materials that were produced using low-conductivity blowing agents (CFCs and HCFCs) are prone to *R-value drift* as the blowing agents leak out of the cell structure and air leaks in. Polyisocyanurate foam comes from the factory with an insulating value over R-8 per inch (RSI/m-55), but that may drop as low as R-5.6 (RSI- 39), according to some estimates. Depending on the material (especially the facing), the application, and installation practices, a reduction to R-5.6 per inch might take from several years to a century or more.

In some parts of the country, foam insulation materials are also prone to infestation of wood-boring insects, such as carpenter ants. Tunnels and nesting cavities will reduce thermal performance and, with foam-core panels, may affect structural performance as well. To address this concern, EPS manufacturers affiliated with AFM Corporation now incorporate a borate additive (Tim-Bor(TM)) into EPS foam-core panels.

Reusability and Recyclability

Most insulation material reaches the end of its life not because it has worn out or has ceased to function properly, but because the building it was installed in is altered or taken down. The most obvious exception to this is commercial roofing. Many built-up roofing systems incorporate both rigid insulation and asphaltic roof surfacing. When re-roofing becomes necessary, the whole roof surface is often removed--insulation and all.

The reusability of insulation materials is dependent on how those materials were installed. To facilitate re-roofing without replacing the insulation, Mike Tobin of AFM Corporation recommends installing a layer of sheathing between the insulation and the roofing membrane. If rigid boardstock insulation can be removed without breaking it up, it can often be reused. Performance of reused polyisocyanurate insulation will not be as good as that of new material, both because some of the low-conductivity gases will have escaped and because of nail holes. XPS, EPS, and all fiber insulation materials should not appreciably change in their insulating performance, though dust in fiber insulation materials will make working with the stuff at best disagreeable and at worst hazardous.

A new product introduced in 1993, the "Big Green Machine," is designed to chop up batt insulation to produce a loose-fill product for insulating attics (see EBN Volume 3, No. 2 -- March/April 1994). While primarily used by insulation contractors to reuse scraps left over from batt insulation jobs, the machine should also work for reprocessing batts recovered from old buildings during remodeling or demolition. The Big Green Machine can also be used to process waste Icynene insulation; large quantities of which are typically generated during installation.

Because of dust and dirt, it is unlikely that any fiber insulation materials could be easily recycled into products other than insulation. Of the foam insulation materials, polystyrene (EPS, XPS) is easier to recycle than polyisocyanurate or polyurethane. Polystyrene is a *thermoplastic*, meaning that it can be melted and reformed into other products with minimal chemical modification. Polyisocyanurate and polyurethane are *thermoset* plastics that do not melt; most of the research being done on recycling of these materials is focusing on grinding the insulation and using the resultant powder as an additive in various unrelated materials.

Another issue of concern relating to disposal of insulation is the CFC blowing agents that are "banked" in our existing buildings. A large portion of the CFC blowing agents that have been used in building insulation over the past 20 years have not yet been released into the atmosphere; they are still in the insulation. If studies show that even phasing out new production of CFCs and HCFCs is not enough to stem the ozone depletion that is occurring, there might be pressure to capture and thermally destroy CFCs in foam insulation that is being disposed of. This is already happening to a limited extent with refrigerators that are being recycled by utility companies through demand-side management programs.

Indoor Air Quality

Though indoor air quality issues are different from environmental issues, they are related and should be considered at the same time. Concern about health effects of insulation materials dates back to the 1970s, when improperly installed urea formaldehyde foam insulation (UFFI) caused high levels of formaldehyde emissions in tens of thousands of homes. No insulation materials in use today exhibit indoor air quality problems approaching those of UFFI, but the rapidly growing interest in healthy homes is spurring a close examination of health impacts.

Some argue that the fibers released from fiberglass insulation may be carcinogenic, like asbestos. A spate of recent technical articles about the carcinogenicity of glass fibers has been damaging to the image of the fiberglass industry, as has the requirement for cancer warning labels. To address health concerns, both Owens Corning and Schuller International now offer fiberglass batts wrapped in perforated polyethylene. While touted as a convenience feature for do-it-yourselfers, most industry observers consider it a reaction to growing health concerns about glass fiber. CertainTeed has increased the use of binder in its loose-fill fiberglass insulation to reduce the amount of loose fibers escaping into the air, but higher levels of phenol formaldehyde binder raise concern among some about formaldehyde off-gassing.

The most significant new fiberglass product to address the health concern about glass fibers is Owens Corning's Miraflex fiber (see page 8). Because the fibers are stronger and less brittle, the product may not have to carry the cancer warning label (a decision is still pending). Also, this type of fiberglass contains no chemical binders or dyes, so there should be no offgassing.

There are also claims that the fire retardant chemicals or respirable particles in cellulose insulation may be hazardous. Much of the concern about fiberglass and cellulose has been generated by competing manufacturers or trade associations, and it has become difficult to pick out areas of real concern from all the hype and exaggeration bandied about. Properly installed, neither fiberglass nor cellulose should pose any health risks (see recommendations).

Some individuals have acute chemical sensitivity to the small quantities of chemicals that offgas from nearly all common insulation materials. The binders used in conventional batt insulation, inks from the recycled newspaper in cellulose, and VOCs released from foam insulation are examples of such offgassing. This has led to increasing interest in such products as Air Krete(TM), discussed above.

An interesting new development is the use of Icynene as the preferred insulation material in a subdivision of homes in Sharon, Ontario that are designed and built for "maximum indoor air quality." Bruce Small, president of Green Eclipse, Inc., which has developed the Envirodesic(TM) certification system for healthier indoor environments, claims that preliminary air quality studies of their first home insulated with Icynene look very promising and that this may become the insulation material of choice for their "certified" homes.

Table 4: Summary of Environmental and Health Impacts

Type of insulation	Installation method(s)	R-value per inch (RSI/m)	Raw materials	Pollution from manufacture	IAQ impacts	Comments
Fiber insulation						
Cellulose	loose fill, wet-spray, dense pack, stabilized	3.0 - 3.7 (21-26)	newspaper, borates, ammonium sulfate	Negligible	Fibers & chemicals can be irritants, should be isolated from interior space	High recycled content, very low embodied energy
Fiberglass	batts, loose fill, stabilized, rigid board	2.2 - 4.0 (15-28)	silica, sand, limestone, boron, PF resin, cullet	Air pollution from energy use	Fibers & chemicals can be irritants, should be isolated from interior space	New Miraflex fiber has no binder
Mineral wool	loose fill, batts	2.8-3.7 (19-26)	steel slag, PF natural rock	Air pollution from energy use	See fiberglass	
	batts, loose	3.0-3.7	cotton &		Considered	Fire retardant

Cotton	fill	(21-26)	polyest. mill scraps	Negligible	very safe	unknown
Perlite	loose fill	2.5-3.3 (17-23)	volcanic rock	Negligible	Some nuisance dust	
Foam Insulation						
Expanded polystyrene	rigid boards	3.6-4.4 (25-31)	fossil fuels, pentane	Pentane emissions contribute to smog	Concern only for those with chemical sensitivities	The only non-HCFC foam board
Extruded polystyrene	rigid boards	5.0 (35)	fossil fuels, HCFC-142b	Ozone depletion, global warming, energy use	Concern only for those with chemical sensitivities	Only Amofoam-RCY has recycled-content
Polyiso-cyanurate	foil-faced rigid boards	5.6-7.7 (39-53)	fossil fuels, HCFC-141b	Ozone depletion, global warming, energy use	Concern only for those with chemical sensitivities	
Phenolic	foil-faced rigid boards	8.0 (55)	fossil fuels, HCFC-141b	Ozone depletion, global warming, energy use	Concern only for those with chemical sensitivities	Not currently manufactured in U.S.
Polyurethane	sprayed-in	5.8-6.8 (40-47)	fossil fuels, HCFC-141b	Ozone depletion, global warming, energy use	Concern only for those with chemical sensitivities	
Icynene	sprayed-in	4.3 (30)	fossil fuels	Negligible	Unknown, appears to be very safe	Doesn't harden, good air sealing
Air-Krete	sprayed-in	3.9 (27)	magnesium oxide from sea water		Considered very safe	
Radiant barriers						
Bubble pack	stapled to framing	depends on installation	aluminum, fossil fuels			Recycled PE foam in one product
Foil-faced paperboard	stapled, requires air space	depends on installation	aluminum, wood fiber			Often high recycled content
Foil-faced	stapled, requires air	depends on	aluminum,			High recycled

polyethylene	space	installation	fossil fuels			content	

Sources: Manufacturers data, ASHRAE Handbook of Fundamentals, 1993, *Environmental Building News*

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Making Decisions -
EBN's Recommendations

The environmental characteristics of insulation are complex and often not well understood. For this reason, deciding on one material over another can be difficult. Even when choices seem obvious today, factors may change, so those decisions should be reevaluated periodically. We offer the following recommendations relating to insulation selection and use:

- Provide adequate insulation levels. Reducing the energy use of a building is usually the single most important thing you can do to reduce the building's overall environmental impact. Don't substitute a "green" insulation material for a non-green material if the change will hurt energy performance.

- With lower R-value materials, increase insulation thickness. If substituting a green insulation material for a higher-R-value but more environmentally damaging insulation material, design the building to permit greater insulation thickness so that there is no sacrifice in energy performance.

- Try to avoid HCFC-foamed insulation materials. HCFCs are far less destructive to stratospheric ozone than CFCs, but damaging nonetheless. When it can be done without reducing overall energy performance, avoid all HCFC-based insulation, including extruded polystyrene, polyisocyanurate, and spray polyurethane. Expanded polystyrene or rigid fiberglass can be substituted for extruded polystyrene and polyisocyanurate. HFC-blown polyurethane (SuperGreen Foam), CO2-blown isocyanurate (Icynene), or CO2-blown polyurethane (Resin Technologies when it becomes available) can be substituted for conventional HCFC-blown polyurethane.

- With highly conductive framing systems, avoid thermal bridging by installing a layer of insulating sheathing. With steel framing, for example, it does not make sense to design the walls to accommodate thicker or higher-R-value cavity-fill insulation when the steel will dramatically reduce the average wall R-values; instead, minimize the cavity-fill insulation and spend your budget putting insulative sheathing over the framing.

- Choose high-recycled-content insulation materials. With cavity-fill insulation, cellulose and mineral wool have higher recycled content than fiberglass. Among the different fiberglass products, Schuller International's products have the highest post-consumer recycled content. Among extruded polystyrene products, Amofoam is the only one available with recycled content.

- With built-up roofing systems, install a layer of sheathing between the insulation and the roofing surface so that reroofing is possible without destroying the insulation.

- When substituting fiber insulation materials for boardstock insulation, consider the impact of using more framing material. Boardstock insulation is self-supporting, while cavity-fill fiber insulation materials require a framed cavity. Even though the fiber insulation material might be environmentally superior, when you factor in the additional framing resource required, the advantages may not be as great.

- With most fiber insulation materials, you should install a continuous air barrier between the insulation and the living space to keep fibers out of the indoor air.

- For chemically sensitive individuals, specify a non-offgassing insulation material, such as the new Miraflex fiberglass from Owens Corning, or Air Krete. As additional testing information becomes available, consider Icynene and Greenwood Cotton insulation for these applications.

- Choose an insulation contractor who recycles scrap insulation. Batt insulation scraps and Icynene trimmings can be chopped into loose-fill insulation with a Big Green Machine (TM).

- *Alex Wilson*

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