

Insulation Overview

“Knowing too little about the subject, people are often proud to announce that their home meets code requirements, as if that was like acing a test, instead of what it is: the lowest possible passing grade. Where “minimum” sounds like “maximum,” “better” sounds like overdoing it. So we’ve been stuck insulating most of our buildings at the C-minus level or less for a long time.”

Tod Benson, Bensonwood in *Insulation Choices*,
Building Green

The Usual Considerations:

Lowest bid, quickest construction/renovation time => least costly or quickest installation choices.

But in a time of severe weather events and questions about built infrastructure resiliency, **there are other considerations.**

Alex Wilson, founder of Building Green:

“Given the uncertainty about future costs of energy and the security of having a building that will maintain livable conditions in the event of extended power outages or interruptions in heating fuel, it often makes sense to invest significantly more in energy efficiency than a simple “payback” analysis might suggest.”

Three kinds of heat loss

- Convection is molecules of gas or water moving through space. Addressed through air sealing.
- Heat loss also occurs through radiation, energy moving through space. Reflective materials have low emissivity – dark materials high. Radiant barriers make sense in situations where there is a large thermal difference between surfaces. The radiant barrier must face an air space to work.
- R value is about conduction, heat moving from one molecule to another. Addressed through insulation.

R and U Values

- R-value measures resistance to heat flow.
- U factor or U value is the inverse: ($U = 1/R$), a measure of heat flow through a material.
- Higher R-values are better (more insulating). Lower U-factors are better.
- R-values typically refer to the product or insulation material, U-values typically refer to the assembly that includes the insulation material.
- A product or assembly's R or U value may degrade over time ("drift").
- Be wary of "NASA-tested", you want earth-bound values.

Types of Insulation

- Putting insulating beads in or boards on concrete, pouring concrete into insulation forms (ICF)
- Structural Insulated Panels
- Foamboard: Polystyrene, Polyisocyanurate
- Sprayed or blown-in: Polyurethane foam, fiberglass, damp cellulose, mineral wool, cementitious, phenolic
- Blankets, batts, rolls: fiberglass, mineral (rock or slag) wool, plastic fibers, natural fibers
- Radiant, reflective materials
- Expanded cork board, straw, vermiculite, perlite
- Foamglas, silica aerogel, vacuum panel

<http://energy.gov/energysaver/articles/types-insulation> Useful information from DOE

- “In the United States, two varieties of solid, precast autoclaved concrete masonry units are now available: autoclaved aerated concrete (AAC) and autoclaved cellular concrete (ACC). This material contains about 80% air by volume and has been commonly used in Europe since the late 1940s. Autoclaved concrete has *ten times the insulating value of conventional concrete*. The R-1.1 per inch blocks are large, light, and easily sawed, nailed, and shaped with ordinary tools. The material absorbs water readily, so it requires protection from moisture.”

One major disadvantage of phenolic foam is that it can shrink up to 2% after curing, which makes it less popular today.

Cementitious foam costs about as much as polyurethane foam, is nontoxic and nonflammable, and is made from minerals (like magnesium oxide) extracted from seawater.

Like polyiso foam, the R-value of closed-cell polyurethane insulation can drop over time as some of the low-conductivity gas escapes and air replaces it in a phenomenon known as thermal drift. Most thermal drift occurs within the first two years after the insulation material is manufactured, after which the R-value remains unchanged unless the foam is damaged.

The thermal resistance or R-value of polystyrene foam board depends on its density, and ranges from R-3.8 to R-5.0 per inch. Polystyrene loose-fill or bead insulation typically has a lower R-value (around R-2.3 per inch) compared to the foam board.

(Wool) can hold large quantities of water, which is an advantage for use in some walls, but repeated wetting and drying can leach out the borate. The thermal resistance or R-value of sheep's wool batts is about R-3.5 per inch, similar to other fibrous insulation types.

From Building Green, *Insulation Choices.*

Table 2: Global Warming Potential of Common Insulation Materials

Insulation Material	R-value R/inch	Density lb/ft ³	Emb. E MJ/kg	Emb. Carbon kgCO ₂ /kg	Emb. Carbon kgCO ₂ /ft ² -R	Blowing Agent (GWP)	Bl. Agent kg/kg foam	Blowing Agent GWP/bd-ft	Lifetime GWP/ft ² -R
Cellulose (dense-pack)	3.7	3.0	2.1	0.106	0.0033	None	0	N/A	0.0033
Fiberglass batt	3.3	1.0	28	1.44	0.0165	None	0	N/A	0.0165
Rigid mineral wool	4.0	4.0	17	1.2	0.0455	None	0	N/A	0.0455
Polyisocyanurate	6.0	1.5	72	3.0	0.0284	Pentane (GWP=7)	0.05	0.02	0.0317
Spray polyurethane foam (SPF) – closed-cell (HFC-blown)	6.0	2.0	72	3.0	0.0379	HFC-245fa (GWP=1,030)	0.11	8.68	1.48
SPF – closed-cell (water-blown)	5.0	2.0	72	3.0	0.0455	Water (CO ₂) (GWP=1)	0	0	0.0455
SPF – open-cell (water-blown)	3.7	0.5	72	3.0	0.0154	Water (CO ₂) (GWP=1)	0	0	0.0154
Expanded polystyrene (EPS)	3.9	1.0	89	2.5	0.0307	Pentane (GWP=7)	0.06	0.02	0.036
Extruded polystyrene (XPS)	5.0	2.0	89	2.5	0.0379	HFC-134a ¹ (GWP=1,430)	0.08	8.67	1.77

1. While XPS manufacturers have not updated their MSDS data to reflect post-HCFC blowing agents, all U.S. manufacturers are assumed to be using HFC-134a.

Blowing Agents and Global Warming

“Global Warming payback” is rapid for insulation materials produced without HFC blowing agents.

Example from Building Green: “If you start with a 2x6 wall insulated with cellulose, and add one inch of XPS (R-5), the GWP payback of that added XPS is about 36 years; adding two inches of XPS increases the payback to 46 years; and with four inches the payback jumps to 65 years.”

Table 1: Ozone-Depleting Potential and Global Warming Potential of Blowing Agents Used in Foam Insulation

Type of Insulation	Blowing Agent	Atmospheric Lifetime (yr)	ODP ¹	GWP ²
Polyisocyanurate				
Original	CFC-11	45	1	4,750
2nd Generation	HCFC-141 b	9.3	0.11	725
3rd Generation	Pentane, cyclopentane	A few days	0	7 ³
Spray Polyurethane				
Original	CFC-11	45	1	4,750
2nd Generation	HCFC-141 b	9.3	0.11	725
3rd Generation	HFC-245fa	7.2	0	1,030
3rd Generation	CO ²	Variable	0	1
Extruded Polystyrene (XPS)				
Original	CFC-12	100	1	10,900
2nd Generation	HCFC-142b	17.9	0.065	2,310
3rd Generation	HFC-134a	13.8	0	1,430

1. Ozone-depletion potential values from U.S. EPA using Montreal Protocol sources. ODP values are relative to CFC-11, which is defined as having a value of 1.0.
2. Global warming potential (GWP) values from EPA using IPCC Fourth Assessment Report values; 100-year time horizon assumed. GWP values are relative to CO₂, which is defined as having a value of 1.0.
3. From L.D. Danny Harvey, "Net climatic impact of solid foam insulation produced with halocarbon and non-halocarbon blowing agents" in *Building and Environment*, August 2007 (Vol. 42, Issue 8).

Flame Retardants

- Polystyrene insulation (both XPS and EPS) is produced with HBCD (hexabromocyclododecane) flame retardant at concentrations.
- Banned as a persistent organic pollutant under Stockholm Convention
- EU Substance of Very High Concern
- EPA's DfE: "HBCD also presents human health concerns based on animal test results indicating potential reproductive, developmental, and neurological effects. People may be exposed to HBCD from products and dust in the home and workplace, as well as its presence in the environment."

DfE's Alternatives Report

- “Only two chemicals were identified as viable alternatives to HBCD in EPS and XPS foam: a butadiene styrene brominated copolymer (CAS RN 1195978-93-8) and a tetrabromobisphenol A (TBBPA)-bis brominated ether derivative (CAS RN 97416-84-7). Only two alternatives were identified for evaluation in this report because flame retardants for EPS and XPS foam must allow the material to comply with fire safety codes while not compromising the performance of the foam. Both alternatives are brominated. No non-brominated flame retardants are known to be compatible in polystyrene manufacturing and associated flame tests.”

New Fire Protection Ideas

- The Safer Insulation Solution workgroup

- Green Science Policy Institute
- Building Green
- Development Center for Appropriate Technology

Is lobbying to change code to allow the use of insulation without toxic flame retardants if behind a thermal barrier, concrete or masonry.

Other discussions involve the possibility of using of sprinklers in lieu of flame retardants.

Concerns about the accuracy of flame tests have also been raised (horizontal and vertical testing, smoke/smolder flame testing, not taking account of melting effect)

Other flame retardants commonly used

- Phosphate-based flame retardants (most polyisocyanurate and spray polyurethane foam) considered less hazardous than halogenated compounds, although phosphate-based flame retardants often contain chlorine - TCPP (Tris(chloropropyl) phosphate) is 33% chlorine.
- Cellulose and cotton insulation typically treated with borates, some cellulose with less-expensive ammonium sulfate (more corrosive). You may see this statement: “Borates are not considered hazardous to humans.” Actually, EPA’s 2006 Tolerance Reassessment found toxicity, but levels of concern where low. Some workplace irritation and effects on infants have been noted. EU REACH candidate list as potentially toxic. Boron is considered a limited, finite resource.

No fire retardants necessary

- **Fiberglass**
- **Mineral (or rock) wool**
- **Wool**
- **Foamglas**
- **AirKrete**

Formaldehyde

- Phenol formaldehyde (PF) has been widely used as a binder in fiberglass and mineral wool insulation. Most of the chemical is driven off in manufacturing by heating the spun fibers, but there is some residual. Those with sensitivities can be affected.
- Offgassing from insulation is lower than from particleboard manufactured with urea formaldehyde (UF) binders.
- Formaldehyde is a “known human carcinogen” as well as a respiratory irritant.

Johns-Manville 's entire fiberglass insulation product line now uses an acrylic binder.

Knauf Insulation (EcoBatt) is produced with a biobased binder (EcoSe Technology). “While the exact composition of this binder has not been divulged, Knauf claims it contains a plant-based material that contains no formaldehyde.” (*Building Green*)

In 2010, CertainTeed announced its own “Sustainable Insulation,” also made with a non-formaldehyde, proprietary, plant-based binder. “As of early 2011, this non-formaldehyde line was available only in California and western Canada.”

Owens Corning now provides a formaldehyde-free product: EcoTouch Fiberglas, made with PureFiber, (proprietary, plant-based).

Guardian Building Products recently announced its launch of formaldehyde-free insulation using ecoGuard Technology.

Polystyrene

- Ethylene and benzene => ethylbenzene => dehydrogenated to form styrene. Once polymerized, you can drink your coffee in it.
 - Process produces benzene and toluene byproducts.
 - Benzene is a known human carcinogen as well as a developmental and reproductive toxicant.
 - Ethylbenzene is a known human carcinogen.
 - Toluene is a developmental toxicant.
 - Styrene is a hazardous air pollutant, a possible carcinogen, and an endocrine disruptor.

Respirable Fibers

- Could they become embedded in lungs and cause cancer like asbestos? This possibility considered for fiberglass and mineral wool fibers but no current determination as such. However, all respirable fibers can be respiratory irritants.
- Fiber shedding and respiratory irritation are also concerns for cellulose and cotton.
- Installers should use respiratory protection.

Isocyanates in Spray Polyurethane Foam

- OSHA national emphasis program
- Most serious workplace asthmagen
- SPF Alliance formed to train applicators, BPI and Air Barriers Association training, ACC online health and safety information. Supplied-air respirators, dermal protection
- Foam used in one-part cans or kits may not be applied with appropriate protection
- Ventilation, curing times, safe zones necessary
- Other workers at the site, neighbors
- Particulates after it cures and is shaved down
- Value of Medical Monitoring
- Amine smells
- Soy replacement of Polyols, not isocyanates

Other considerations

- Insects (eat cellulose, tunnel through foam)
- Compressive strength, structural component
- Polyiso and SPF are *thermoset*, XPS and EPS are *thermoplastics*, which will melt, more dangerous in a fire
- Availability
- Ability to work with the material
- Familiarity of the contractor with the material
- Costs: can be highly variable by region, size of the project, and transportation costs.
- Need for training
- Difficulty when not done right
- Ability to work with space in the future
- Durability
- Whether it works as an air sealer as well (spray in fiberglass will, batts may not)
- Spray foam can decay from exposure to UV

Water

- Can cause degradation, loss of insulating quality, provide home for pests, mold
- XPS, rigid mineral wool, foamglas do well, closed cell SPF, higher-density EPS
- Fiberglass ok if it can dry out, big R-value drop if doesn't
- Cellulose can slump, "lose loft", and borates wash out. Cotton in batts may do better