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Expanding Options

Spray-foam insulation can definitely crank up the performance of your homes—if you make the right choices. Here's what to look for.

By: Fernando Pages Ruiz

If a single product can claim the status of a green building silver bullet, it might be foam insulation. Singlehandedly, these products can almost guarantee the highest practical levels of R-value per inch, effective air sealing, moisture management, and a higher performance as expanding foam usually fills even unseen gaps; plus, foam remains less susceptible to poor-quality installation, with most jobs done by trained applicators.

But with significant cost differences and subtleties in the performance characteristics and environmental impact of various foams, it's important to understand the pros and cons of the basic foam products before choosing the best one for a specific project.

Foam Basics

If you've used a can of foam sealant, you already know the basics: The insulation comes as a sticky, thick liquid that reacts with air, expanding to flood any cavity you squirt it into. Chemical additives in the foam insulation harden the expanding spume into a resilient, solid substance.

Because of this expanding quality, properly applied foam will generally fill every nook in a wall cavity, band joist, floor joist, and attic rafter so that the entire surface has a tight air seal. Given equal R-values, foam delivers about 20% to 40% better overall performance than traditional fiberglass or cellulose insulation, says Rick Duncan, technical director of the Spray Foam Alliance. The reason for this significant difference, despite equal R-values, comes with trained installation and the built-in air seal.

Closed-cell foam insulation also manages moisture well enough to satisfy current ICC code requirements without an added interior vapor retarder in most applications. Perhaps most surprising, closed-cell insulation adds significant structural value, equivalent to about 75% of the ultimate shear strength of a ½-inch sheet of plywood, according to Duncan.

On the other hand, spray-foam installation costs between 100% to 300% more than professionally installed traditional insulation systems. And from a green building perspective, foam gets dismal marks in cradle-to-gate comparison, containing zero to very low renewable material or recycled content, compared to staple insulation products such as cellulose.

Most foam insulation is made with polyurethane, a two-part chemical composition that when blended creates gas bubbles, and then, like epoxy, sets up quickly, trapping the bubbles in a plastic matrix with excellent insulating properties.

For the technical reader, polyurethane foam insulation results from the reaction of diisocyanates blended with polyols. Chemicals, such as catalysts, surfactants, and flame retardants, may be added to control the set time, workability, and flame-spread characteristics of the final product. It's in the details of these chemical additives that foams differentiate themselves in both performance and environmental qualities.

Foams deliver superior insulation and air seal; several meet Greenguard indoor air quality standards and contain the most advanced propellants available with no impact on the ozone layer and improving global warming indices. Bio-based products have entered the foam insulation market to offset some of the negative effects, or at least perceived negative effects, of foam's petroleum pedigree. But some misconceptions exist.

A common misunderstanding is that bio-based spray-foam insulations are made exclusively from rapidly renewable plant sources, such as soybean oil, castor oil, and sucrose-based oils from sugar beets. But most products with bio-based content contain less than 20%; in fact, the USDA's threshold for claiming spray foam is made with renewable, bio-based materials is only 7%. Nevertheless, the inclusion of plant oils reduces the petroleum content of foam insulation; national green standards provide points for the use of foam insulation products that meet the criteria for the USDA's Biobased Affirmative Procurement Program.

A study of the environmental benefit of soy-based polyols commissioned by the United Soybean Board in 2004 concluded that every pound of soy polyol that replaces a pound of petroleum has a positive carbon benefit of 5.6 pounds; however, it remains a minor component of foam insulation and some argue that the water and land consumed in growing crops, such as soybeans, has greater negative environmental impact than the petro savings. Neither camp has conclusive evidence of significant benefit or harm and most claims either way seem geared toward marketing rather than ecology. Overall, insulation of almost every type provides greater environmental benefits than costs.

Open-Cell Vs. Closed-Cell

The real distinction between types of foam insulation focuses on whether they are open- or closed-cell. In general, both are made from the same materials and work in the same way, trapping air or gas in a plastic matrix. The differences start with the "blowing agents" used to create bubbles and end with both varied performance and cost.

Open-cell foam costs slightly less for the same thickness, but offers lower per-inch R-values than closed-cell products. In some instances, this is a disadvantage, but where thickness is less relevant, or where higher R-values are not needed, then open-cell can provide the better choice. It also has some green advantages over closed-cell: The blowing agent used to install open-cell insulation is water, which reacts with air to become CO_2—while closed-cell products use HFCs.

Because CO_2 expands quickly, the bubbles tend to burst before the plastic sets, and hence the "open cells," which produce a spongy, lightweight foam. The industry describes the foam as "half-pound" material, which simply means the foam has a mass that weighs 0.5 pounds per cubic foot. This density yields an R-value of approximately 3.6 per inch, equivalent to most traditional insulations. Because of the open cell structure, open-cell foam allows some vapor to pass through, making it a good choice in hot, humid climates, and under roof sheathing, such as in conditioned attics, where water vapor caught between insulation and sheathing could promote wood rot.

In short, open-cell foam, tested in accordance with ASTM E 283, provides an air barrier with vapor breathability. Water-blown solutions have less environmental impact than the current HFCs used for most closed-cell spray-foam insulation. And open-cell has about twice the noise reduction coefficient in normal frequency ranges as closed-cell foam. Because the blowing agent in open-cell insulation dissipates as it sets, instead of slowly over time, there is no degeneration of the R-value—a minor point given aged closed-cell R-values still trump open-cell R-values by a magnitude of nearly 100%.

Unlike open-cell foam, closed-cell foam uses chemical blowing agents that come in liquid form and become gasses as they are applied. These gasses expand, but not as quickly as CO_2, allowing the polyurethane plastic to set before the bubbles burst. This yields dense foam weighing nearly 2 pounds per cubic foot, and without the capillary characteristics of open-cell, it remains impermeable. The blowing agents used perform like the inert gasses between the panes of high-performance windows, adding to the insulating qualities of the foam. Unlike open-cell foam, closed-cell foam rarely requires any trimming, with little or no jobsite waste.

Closed-cell has more obvious advantages over open-cell, and a slightly higher price tag (20% to 30% for the same thickness). It provides both a vapor and air barrier and offers an aged R-value of a whopping 6.5 per inch. Because of its density and glue-like consistency, it remains very strong, providing both compressive and tensile strength to structure comparable to added sheathing, increasing the racking strength of walls by as much as 300%, according to the NAHB Research Center. Because water does not penetrate or degrade the product, FEMA recommends closed-cell foam as a suitable insulation material for flood regions.

The principle disadvantage of closed-cell foam comes with overkill. If you do not require the extra vapor barrier, structural strength, and R-value per inch, then you may be wasting money. As for the added wall strength, while real and substantial, it's not acknowledged by building codes currently, so you can't reduce the structural bracing as a tradeoff.

Environmental Tradeoffs

With the phase outs of chlorine-based chemicals, third-generation blowing agents such as Forane's HFC-365mfc and Honeywell's HFC-245fa have become widely used in closed-cell foam, lowering concerns about ozone depletion. Although it no longer contains ozone-depleting chemicals, closed-cell foam still poses a high global warming potential (GWP). The average impact of today's closed-cell foam blowing agents approaches 1,000 GWP versus 1 GWP for water-blown open-cell foam.

A recent article in Environmental Building News argues against using HFC-blown closed-cell insulation due to its high GWP. In computer modeling referenced by *EBN*, the results showed that closed-cell spray-foam insulation using HFCs can have lifetime GWP payback lengths of as much as 30 to 60 years with insulation depths from 1 to 4 inches, versus less than one year in all cases for cellulose.

Manufacturer BASF says that the article doesn't take into account the air tightness achieved in a home with closed-cell spray-foam insulation, arguing that the comparative performance advantages of this type of foam in reducing home energy consumption over the lifetime of the product outweigh imbalances at the manufacturing and installation stage. The manufacturer says a third party–verified Eco Efficiency Analysis of its closed-cell polyurethane spray foam (which factored in the production, use, and disposal phases) shows that cellulose insulation has more than twice the GWP than its closed-cell product over its lifecycle; the GWP for fiberglass was four times greater over its lifecycle.

In addition, new blowing agents are in development, with several chemical companies expected to introduce fourth-generation blowing agents within the next two to three years, with zero ozone depletion characteristics and a radically improved climate change profile of less than 15 GWP, according to Duncan. The *EBN* article acknowledges that this would change the equation.

Recycling polyurethane foam presents another challenge. As a thermoset material, it cannot be melted or broken down into its components for reuse. This means that even jobsite waste is hard to recycle, so proper installation with minimum overspray is essential to achieve environmental efficiency. Foam can be shredded and used as packing material or filler, but given that foam sticks to building structures and is difficult to extract and separate from other materials during demolition, the labor, transportation, and processing costs required for reuse are not usually justified.

Toxic Blowing Agents and Fire Proofing

Fully cured polyurethane foam contains no residual off-gassing. Nevertheless, foam insulation contains hazardous chemicals such as benzene and toluene, which pose a potential hazard concern during manufacture, transport, and installation. This is why installers must be trained and wear protective gear—a portion of the blowing agents in closed-cell foam dissipate during installation, releasing VOCs and greenhouse gases during application.

Manufacturers no longer use polybrominated diphenylethers (PBDEs), synthetic fire-resistance chemicals that pose grave health and environmental risks, but concerns remain with their replacement. Many manufacturers now use halogenated retardants that pose a health risk to installers and occupants if the foam burns. Safer chemicals exist, such as triethyl phosphate (TEP), a non-halogenated fire retardant, and some manufacturers are moving in this direction.

Regardless of its petroleum makeup and toxicity during application, foam products provide such compelling durability, air infiltration, moisture management, and energy-saving advantages that their use continues to grow. Manufacturers are working to keep improving their products from an environmental perspective, including a new generation of high-density open-cell, water-blown foam.

Cost remains the most significant market barrier to more prevalent use of foam in the building industry at large, but some contractors have found ways to obtain the advantages of foam while shaving off some of the increased cost. For example, some builders use a hybrid insulation system called “flash and batt,” applying 1 to 2 inches of closed-cell spray foam to a wall cavity first followed by a standard fiberglass batt, cellulose, or, in some cases, even open-cell foam. This provides the air-sealing benefits, with improved R-value, at lower cost. Some builders use foam only in difficult-to-insulate areas, such as rim joists and eaves, where even the best installers have trouble matching the air seal and vapor-retardant qualities of foam.

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