Soy-Based Materials and Green Building Construction Technologies

Soy materials for building construction are renewable, environmentally friendly and ideal for green building. Benefits as compared to petrochemical and other material stocks show a range of performance and environmental benefits.

Soy is a versatile plant, offering a range of uses in our society. Myriad food products are derived from soy protein. The use of soy-based ink has become a popular alternative to standard inks, in part because it is seen as safer, greener and healthier than traditional inks. Even more significant, building professionals can use soy-based products for building design and construction uses, as an alternative to other building materials made with petrochemicals.

Interest in biobased construction materials is growing rapidly. Understanding the performance attributes of soy-based materials gives building teams a better understanding of how soy is used for a wide range of building products and construction-related applications.

Green benefits of soy-based materials

Among the most significant recent advances in building technology is the use of soy-derived building products as an alternative to petrochemical-based materials and finishes. Beyond soy ink, the products can be used in many areas of building and include adhesives, plastics, insulation, barriers, sealants and coatings. In addition, many lubricants and solvents used in building mechanical systems can be made with soy. Last, soy is increasingly used for biodiesel, which may be part of a building's fuel mix.

Life-Cycle Benefits of Soy

Rigorous studies of the impact of U.S. soybean applications demonstrate valuable life-cycle contributions by employing soy for non-food uses, including building construction materials.

In 2010, the United Soybean Board (USB) released a peer-reviewed update of the life-cycle inventory (LCI) databases for soybean production and processing into four key soy-derived feedstocks for industrial products: (1) methyl soyate, (2) soy lube base stock, (3) soy polyol and (4) soy resin.

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Renewable resource. Because it is a food crop, is soy a limited resource for construction? Not at all. According to experts in agriculture and economics, soy is abundant and rapidly renewable – and a sensible alternative to limited petroleum-based and mineral products. Currently, production levels have reached about 20 billion pounds of crude soybean oil each year in the United States alone, a figure that increases each year. The global supply of refined vegetable oil is estimated at more than 140 million metric tons. New uses for construction materials and building are growing rapidly, but they are not a significant impact on the supply of soybean oil for food uses.

Low toxicity. Construction materials produced from soy share another valuable benefit: a healthier profile than petroleum and chemical substances. Soy-based products tend to be low in volatile organic compounds (VOCs), and soy helps replace materials with undesirable components such as urea-formaldehyde in wood products, ammonia (urea), methanol and the like.

A good example is the growing use of ***soy adhesives*** in making plywood. These strong, effective adhesives are drop-in replacements for urea-formaldehyde adhesives, which emit (off-gas) formaldehyde into building indoor air; unhealthy concentrations of formaldehyde indoors can contribute to "sick building syndrome." Due to its sustainable traits and association with healthy environments, ***soy plywood*** is increasingly used in such areas as wall construction, casework, flooring and furnishings.

The use of soy-related products is competitive on cost, and the materials are widely available through lumber suppliers. With this success, similar soy adhesives are being developed for oriented strand board (OSB), particleboard and medium-density fiberboard (MDF).

Life-Cycle Benefits of Soy

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The LCI's cradle-to-gate scope – from soybean farming through product processing – found major greenhouse gas (GHG) reductions through soybean production, which scrubs carbon during the plant growth phase.

- The release of nitrous oxide (N20) was found to be 85 percent less than the current U.S. LCI Database shows.
- About 20 percent less direct energy is needed for soybean farming today as compared to 1998 levels, thanks to reduced diesel and gasoline usage.
- Energy consumption for soybean processing has been reduced by 45 percent since 1998.
- **A life-cycle impact assessment** (LCIA) in the USB study showed that all four soy-derived feedstocks significantly reduce greenhouse-gas emissions and fossil fuel use as compared to petroleum-based equivalents.

The peer-reviewed USB life-cycle study presents further evidence of the energy and environmental benefits of U.S. soybean farming and processing.

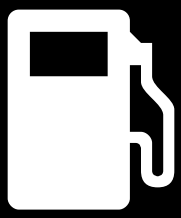
The results confirm why manufacturers are increasingly using soy for "green chemistry" to support a wide array of biobased products, including construction adhesives, sealants and spray-foam insulation.

Environmental contribution. Yet the primary benefit of soy-based adhesives is that the products are inherently green. That's true in green building use, but it is also the nature of the renewable resource itself. First, as soy plants grow, they remove greenhouse gases from the atmosphere; in the United States alone, the total cultivation of 3.36 billion bushels of soybeans in 2009 eliminated the carbon equivalent of 21 million automobiles.

Second, as a renewable, low-toxicity resource that contributes to good indoor environmental quality (IEQ), soy materials contribute to meeting the requirements for the new International Green Construction Code (IGCC), ASHRAE's Standard 189.1, California's state green-building code CalGreen and the U.S. Green Building Council's LEED certification system.

Third, in the LEED standards, for example, the use of soy-based materials can help achieve credits in a variety of categories, including Materials & Resources (MR), Indoor Environmental Quality (IEQ) and, in some cases, Innovation in Design. Beyond these, many soy-based products help meet criteria for the EPA's Energy Star program, or the Cool Roof Rating Council's database. In addition, a recent life-cycle inventory was conducted to help compare soy-derived feedstocks against their petrochemical equivalents, with very positive results (see "Life Cycle Benefits of Soy," page 1).

"U.S. soy already delivers environmental and energy benefits," said John Cooper, a USB director and soybean farmer in Wynne, Arkansas. "It's exciting to see the trends point to even more in the future."



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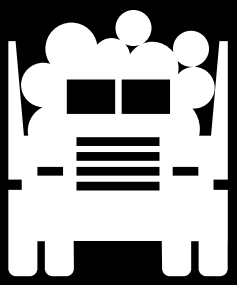
Applications Uncover Advantages

Recent projects using soy-derived materials include the four-story headquarters for Heifer International in Little Rock, Arkansas. The semicircular office building, designed as a durable, 100-year structure, targeted a 55 percent energy reduction as compared to comparable structures. Materials included a ***soy-based spray foam*** for insulation and barrier protection. The project earned platinum certification under LEED-NC, and was selected by the American Institute of Architects (AIA) as a Top Ten Green Project by the AIA Committee on the Environment.

In another example, a building team used wood adhesives that include soybean meal. For a military office project in Virginia, Fort Lee's Building 11108, the cabinets built and installed throughout the building emit no formaldehyde. They are made with a hardwood plywood manufactured with a ***soy-based, formaldehyde-free adhesive.*** The 15,000-square-foot, single-story building now has about 25 cabinet units scattered through seven locations in the facility. All of these cabinets are constructed with the zero-formaldehyde products, removing a known human carcinogen that can cause eye, nose and throat irritation as well as respiratory problems, according to the U.S. Environmental Protection Agency (EPA).



CASE STUDY

Meeting Formaldehyde Rules with Soy-Based Wood

Recent federal rules limiting formaldehyde emissions from pressed wood products have led to more use of soy-based wood adhesives.

In response, companies, including Columbia Forest Products, have developed formaldehyde-free plywood technologies.

According to the United Soybean Board, "Using soy-based adhesives and other biobased products reduces reliance on foreign petrochemicals and can help improve the environment by reducing VOC emissions." Wood panels using soy adhesives also perform well, displaying better water resistance than formaldehyde plywood with equal or better strength and durability, according to Columbia Forest Products.

To make the panels, the company uses about 15 million pounds of flour processed from U.S. soybeans annually. Soy flour is a rapidly renewable resource, and its use in manufacturing architectural and construction products is growing, according to the United Soybean Board.

Current Use of Soy Materials in Construction

Increasingly, these examples of green building are becoming not the exception, but rather the rule. Methods and materials are becoming more abundant for applying soy-derived products in construction techniques, some with multiple advantages over conventional approaches. Highlights of the product universe include

1 Soybean oil in adhesives, coatings, solvents and the like. Similar to linseed oil, soy oils have good drying properties and are valuable for making alkyd resins for inks, paints and industrial coatings. In recent years, however, soybean oil has shown promise in waterborne paints and architectural coatings. One manufacturer, Sherwin-Williams, uses hybrid soy resins for a line of sustainable interior paints; another, Rust-Oleum, offers a line of soy-based wood stains. In addition, a new generation of metal coatings, "cool roof" coatings, and concrete stains and sealers – all based on soy technologies – bring the market low-VOC, renewable product choices.

2 Plywood, and molded pre-engineered wood. Soy adhesives offer numerous properties that make them ideal for creating wood panels and structural timber composites. First, the adhesives' resistance to heat and fire makes them valuable as a binder for particleboard and fiberboard, but also in structural joints for wood beams, joists and any assembly joinery. Second, they tend to be lighter than conventional manufactured wood products. Third, the products share the benefits of using soy as a base material: zero formaldehyde, low VOCs and a renewable base resource. Several manufacturers have introduced products with soy-based urethanes and other adhesives as a substitute for petrochemical-based polyols. Wood composites with soy-based adhesives help eliminate phenols, ureas and formaldehyde that come from natural gas and petroleum.

CASE STUDY

Paints with Soy Components Reduce VOC Levels

The desire for safer and more sustainable chemicals, processes and products for building construction has led to increased attention on the benefits of soy in coatings and sealants.

Companies are developing new paints and stains using soybean oils, including a new water-based acrylic alkyd paint by Sherwin-Williams made with soy oil and recycled plastic bottles (PET). The resulting formula reduce volatile organic compounds (VOCs) by 60 percent, says the company.

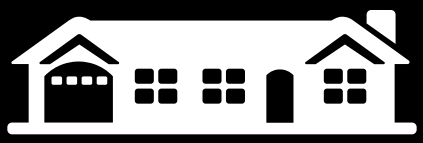
Soybean oil promotes film formation, gloss, flexibility and cure. The soy-based paint formulations are shown to dry quickly "with less yellowing and improved shelf life with water cleanup" as compared to other paints, say industrial experts.

continued

3 Use in roofing shingles. Soy has also been introduced as a base material for producing an alternative to asphalt cement, which constitutes about 28 percent of the materials for roof shingles. Some manufacturers and contractors are recycling used shingles, a valuable material reuse strategy, using solvents that are about 25 percent soy based. The reduced asphaltic content is considered a promising way to cut project costs, as primary asphalt prices have quadrupled in the last decade alone.

4 A world of alternative plastics. One of the most promising areas of development is the use of soy-derived materials in creating strong, beneficial construction plastics. Four areas are worthy of focus: spray foams, carpet backing, soy foams for furniture and high-density soy foams for decorative materials. In all cases, soy offers an alternative to petrochemical components, which are limited resources that historically rise in cost. Soy polyols can be used for polyurethane and as a base material for thermoset plastics, such as composites. Performance factors such as weight, strength and durability are equivalent, and the cost of the soy-based products is trending downward.

- Polyurethane-based products based on soy polyols include carpet backing and backing for outdoor carpet and artificial turf. The soy feedstocks replace styrene butadiene and polyvinyl chloride (PVC) backings, reducing not only VOC production but also the total flammability of the flooring.



CASE STUDY

Paints with Soy Components Reduce VOC Levels

Using 320,000 pounds of soybean oil in conjunction with 250,000 pounds of PET allowed the manufacturer to offset more than 800,000 pounds of VOCs, solvents and other petroleum-based feedstock.

Recognizing the benefits to building occupants, last year the U.S. Environmental Protection Agency gave the product developers a 2011 Presidential Green Chemistry Award.

- Spray-foam insulation based on soy plastics made and installed by several manufacturers delivers a high R-value and a good barrier for air and moisture. The product is typically applied as a system, sprayed into enclosures, on roofs, or into floor and roof assemblies.
- For furnishings, built-in seating and other uses, flexible soy foam enjoys a growing market in the architectural and construction industry. It is already used extensively in the automotive and furniture industries.
- Last, soy plastics technology is employed for high-density, rigid molded foams that can substitute for molded polyurethane products. These are used as insulation or as decorative trims, panels and accessories.

5 Other building products and materials. These include soy solvents now used in product manufacture, which will in the future also be a more commonly specified items or contractor products. Soy solvents offer reduced ozone depletion potential (ODP) as compared to conventional petroleum-based solvents, and they are considered nonhazardous. At this time, the building team can ask for soy solvents, soy adhesives and other soy-based materials as an alternate specification.

One of the most promising areas of development is the use of soy-derived materials in creating strong, beneficial construction plastics.

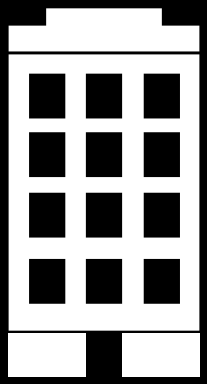
The Green Benefits of Soy in Building

While the myriad product offerings using established, effective soy-based material technologies make them increasingly attractive to building teams, there are other market drivers. Most important are the contributions to green building and sustainable design techniques. For soy-based adhesives, for example, a life-cycle analysis reveals a variety of environmental benefits along the supply chain. Soy solvents offer reduced ODP and other benefits as a "nonhazardous product" specification.

The USGBC's LEED certification system can reward the use of soy-derived base materials, including finished products and base materials such as resins and solvents, in its **Materials and Resources** (MR) section, which seeks to "transform material use and disposal through the use of products, materials and processes that possess attributes associated with lower environmental impacts." Soy does that on a number of levels, with life-cycle impact assessments for four major soy-based feedstocks significantly reducing greenhouse gas emissions and using less fossil fuel in their manufacture. Other benefits of soy for achieving MR credits include:

- Use of a rapidly renewable resource.
- Avoiding chemicals of concern.
- Good life-cycle assessment (LCA) scores.

A second credit area that benefits from soy-based materials is the Indoor Environmental Quality (IEQ) category, which "promotes strategies that improve indoor air as well as those that provide access to natural daylight and views and improve acoustics." Here as well, soy can help with such credits as IEQ 4.1, which establishes thresholds for material emissions and VOC levels, as well as 4.4, which rewards the use of wood products that don't have added urea-formaldehyde. In these and other credits, soy contributes to better IEQ – and higher certification levels.



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More Benefits for the Building Team

The advantages of using soy-based materials and finishes go far beyond LEED certification, although the ratings are a major market driver. For example, interest in improved indoor air quality (IAQ) and reduced use of "chemicals of concern" and material offgassing have prompted the adoption of more soy-based compounds useful in making architectural paints. In some cases, soy oil is an additive to existing latex formulations, reducing VOC levels, or it is the foundation for a completely novel polymer formulation.

The increased us of Health Product Declarations (HPDs) for building materials will also benefit soy-derived oils, adhesives as well as resins and plastics. Similar to environmental product declarations (EPDs), which describe the life-cycle environmental characteristics of products, HPDs describe not just the product's material makeup but also how base materials impact human health. With reduced VOCs and toxicity levels, soy-derived materials will grow with increased interest in HPDs.

A second area that bodes well for soy is the quantifying of building performance. In many cases, the soy specification provides equivalent or enhanced performance of the life of the building. Soy-based waterborne latex paints, for example, have been tested to deliver high-performance sealing and reduced deterioration as compared to commonly used latex coatings. Improvements have been reported recently in hydrolytic stability (shelf life) and yellowing, as well as ease of application, speed of finished product drying, and cleanup. The products are cost-competitive and abundant, and deliver the lowest possible VOC levels in the category. In terms of use and application, contractors note they are no different from traditional latex paints.

In some cases, the soy-based materials deliver increased strength and even new attributes that allow for greater design freedom. Biobased composites, for example, are shown to provide very good heat resistance, as well as high strength and adhesion capacities. The composites are also very lightweight, and can be molded into complex shapes during the manufacturing or construction process.

Similar benefits have been noted for soy-based thermoset plastics, made with either soy oil and fiberglass or soy meal and natural fibers. Soy oil is used in making unsaturated polyester resins, which are used to make molded composites like tub and shower surrounds. Soy meal combined with natural fibers such as wood, kenaf and jute produces a **lightweight**, engineered composite for molding into a variety of shapes, such as corrugated panels, that can be cut and shaped like wood with excellent screw-holding properties.

The testing of structural engineered wood using soy adhesives is another success story. Soy-derived adhesives have been found to offer superior heat resistance, prolonging the structural integrity of the wood structure in a fire, and soy proteins are serve as a robust binder in renewable, plant-fiber composite particleboard and MDF. The products have a **high strength-to-weight ratio** and – like all soy-based materials – are completely formaldehyde-free.

Best of all, novel and established soy-related building materials have been shown to be **cost effective** and even compete in price with most available materials. In some cases, a slight price premium is offset by the clear benefits to improved occupant health and green building standards. Most important, the prices tend to be stable in spite of commodity price fluctuations, for example for soy flour. The reason is simple: An abundant, rapidly renewable resource, soy is long on supply and a stable market for the long term.

An abundant, renewable resource that is healthier for building occupants and versatile and durable for construction uses? The simple soybean sounds like a winning ingredient – ripe for growth in the world of building design and construction.

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