SOY-BASED THERMOSET PLASTICS

From construction to automotive manufacturing, soy polyols deliver low cost and high functionality to a variety of markets.

THE PRODUCT

Building materials can be end uses for either soy-based polyurethane and polyester thermoset plastics or both. Examples are components of foam insulation and molded mill work; parts for cars, trucks, trains, planes, tractors, tractor trailers and recreational vehicles; furniture, mattresses, carpet pads and carpet binders; insulation for coolers, water heaters and vending machines; packaging and pallets; materials for ships, boats and flotation devices; industrial insulation and sealing; shoe and boot soles.

MARKET SIZE AND VALUE: SOY POLYOLS FOR POLYURETHANE

Of all the industrial markets for soy polyols, polyurethane foams, binders, coatings, adhesives and sealants hold the greatest potential. Annual 2009 North American product demand for for petrochemial polyols represented an estimated 2.6 billion pounds, with a potential substitution estimate for soy-oil-derived polyols for petrochemical polyols, of about 505-million pounds or 46 million bushels of soybeans. The total polyol market has shrunk due to the reduced demand for consumer durable products brought on by the 2008-09 economic recession. The market demand for polyurethane products should return to its historical growth and pre-recession levels by 2012. Current priority markets for soy-based polyurethanes are listed in the table below (in millions of pounds of product):

	(09E) Polyol Market (mil. lb.)	Current Potential Substitution of Soy Polyols for Petrochemical Polyols (mil. lb.)
Foam	2,030	400
Binders & CAS*	420	85
Other	100	20
Total	**2,551**	**505**

* Coatings, Adhesives, Sealants

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The North American market represents only a third of the global market for polyurethanes, and the ultimate potential for soy polyol utilization could be tripled from the 505-million-plus-pound level.

MARKET SEGMENTS

There are six market segments for polyurethane that can be classified as priorities for soy-based products. They include:

1. *Construction* – Residential and nonresidential buildings insulation, refrigerated buildings, walk-in cooler insulation, molded millwork, laminated insulation board stock, insulated doors and metal panels.
2. *Transportation* – Automotive vehicle and farm equipment component cushioning.
3. *Carpet* – Flexible foam attached cushion and fiber binder coatings.
4. *Furniture and Bedding* – Flexible foam cushioning applications.
5. *Coatings, Adhesives, Sealants* – Window seals, industrial adhesives and protective coatings.
6. *Binders* – Rubber and wood products.

Penetration of the six priority polyol end-use market segments by 2014 is estimated to be (in millions of pounds of polyol products):

Segment	Market size ('09 E) (mil. lb.)	Soy polyol Potential ('14 E) (mil. lb.)
Construction	700	150
Transportation	500	110
Carpet	280	80
Furniture/Bedding	470	100
Other*	600	180
Total	**2,550**	**620**

* Other: footwear, appliance, marine, packaging, foundry, machinery, industrial, misc.

THE CONSTRUCTION MARKET: RIGID FOAM

The construction market segment can be divided into several different sub markets, as named above. Rigid foam normally has two functions: insulation (mainly in the appliance, residential and industrial applications) and structural integrity. The foam is made from low-cost, highly functional polyols and isocyanates with many additives to adjust the formulation for specific end-use properties. Soy-oil polyols have found their greatest utility in the spray foam insulation market and could compete as a reactive component in quantities of up to 30 percent of the polyol portion of the formulation.

THE AUTOMOTIVE MARKET: FLEXIBLE FOAM

Much like the construction industry, the automotive market utilizes both rigid and flexible foams. Soy-based, flexible molded polyurethane foams for seating, headrests, and arm rests are being used in almost all Ford vehicles, and also in select Toyota, Hyundai and Chrysler vehicles.

RELATIVE ECONOMICS

Today, soy polyols are priced competitively with petroleum-based polyols. The polyurethane formulations, which use soy polyols, are competitive with petro-polyol based polyurethane formulations.

REPLACEMENT POTENTIAL

Because manufacturers typically try to optimize the cost performance of their product and meet raw material sustainability needs, soy polyols derived from soybean oil offer polyurethane manufacturers the opportunity to meet both needs. Urethane Soy Systems Company, of Volga, S.D.; BioBased Technologies,

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Inc., of Fayetteville, Ark.; Cargill of Wayzata, Minn.; Dow Chemical of Midland, Mich.; MCPU Polymer Engineering of Corona, Calif.; and Arkema of Bloomington, Minn., have each developed a series of soy-based polyols in the process of being commercially utilized in polyurethane formulations in transportation, furnishing and construction industries.

MARKET SIZE AND VALUE: PLASTIC COMPOSITES

The use of fiber-reinforced thermoset composites in 2009 is estimated to be less than 3.1 billion pounds. Unsaturated polyester resin (41 percent), epoxy resin (6 percent), and polyurethane (3 percent) account for the majority of the resins. Reinforcements (40 percent) and fillers (10 percent) account for the rest. About 30 percent of unsaturated polyester resins are used in color-sensitive applications with no reinforcement, such as highly mineral-filled products for marble or granite-appearing countertops or sinks.

The total amount of unsaturated polyester resin used has decreased from 1.9 billion pounds in 2006 to an estimated 1.0 billion pounds in 2009. This drop is due to economic recession in the major markets. Major markets for thermoset composites are transportation, construction and pleasure marine, representing 70 percent of the total consumption.

INITIAL MARKET ENTRY AND FUTURE OUTLOOK

A collaborative effort has led to a commercial introduction of soy-derived composite products. Collaborators are Ashland Performance Materials (resin), Continental Structural Plastics (sheet molding compound), Ashley Industrial Molding (molded parts), Deere & Company (buyer) and the United Soybean Board (USB). The result is a series of molded parts for the Model 9750 John Deere Harvester™ combine, introduced in August 2003. Deere & Company have further specified soy-derived composite products made from sheet molding compound (SMC) in most of their SMC parts including tractor hoods. Some soy-based composites are also found on Case New Holland equipment.

The basic process consists of a soy-based polyester resin that is converted into SMC using industry-accepted techniques and meeting Deere & Company specifications. More than 285 pounds of soy composite are installed on each combine. The composite material contains the equivalent of 2 bushels of soybeans.

Ashland and its collaborators are working to expand the product offerings into other markets, including construction and transportation. Higher productivity through alternate processes, such as vacuum bag, resin transfer molding and pultrusion, is being examined through potential industrial partners.

Meanwhile, basic product research continues on soy-oil-based resins to improve adaptability to key manufacturing processes that are efficient and economical. Interfacing with other composite raw material suppliers is important so that optimal cure conditions and mechanical properties in the final resins are obtained.

Increasing interest in LEED (Leadership in Energy and Environmental Design) in the construction industry provides the opportunity for soy-derived resins from renewable resources to be used in construction applications. The interest in using renewable resources also enhances the potential for soy-based unsaturated polyester resins in other market areas such as transportation. Polyurethane composites fabricated by the pultrusion process are also being evaluated in the construction industry.

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REPLACEMENT POTENTIAL

Soy oil is an indirect replacement for the glycols (ethylene glycol, propylene glycol, etc.) and soy-based sugars can be fermented to replace the acids (fumaric, maleic, terephthalic) used to produce unsaturated polyester resins. Assuming the total replacement of the portion of the thermoset resin that could be replaced with soy-based ingredients, the total amount would be around 20 million bushels.

Soy oil containing unsaturated polyester resins are being produced by two major chemical companies, Ashland, Inc., and Reichhold, Inc. Other chemical companies have reported developing these soy containing resins, but no commercial activity by others has been announced. Improved reactivity of the resin system containing soy oil is a sought-after property.

Soy-based thermoset composites continue to slowly gain market penetration. Interest in renewable resources drive the interest, but cost parity is a must. Pricing of soy oil compared to petroleum-based products is favorable. Aggressive marketing of the benefits of these resins helps to drive the market penetration.

Another route to producing thermoset unsaturated polyester and epoxy resins from soy oil is from glycerin, which is a byproduct of the biodiesel manufacturing process. The amount of biodiesel produced in the United States will dictate the supply of glycerin, and new found uses will determine its value. The conversion of glycerin for materials to be used in thermoset composites will be driven by the economics of glycerin feedstock and the technology to find economical conversion processes. Solvay and Dow Chemical have both announced making epichlorohydrin for thermoset epoxy from glycerin. Other companies are reported to be converting glycerin into propylene glycol, which is used to make unsaturated polyester resins. Most of these announcements are for overseas plants. Other routes of producing feedstock for thermoset resins from soy meal by fermentation are being investigated. Soy meal, flour and hulls are also being investigated as fillers for thermoset plastics.

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