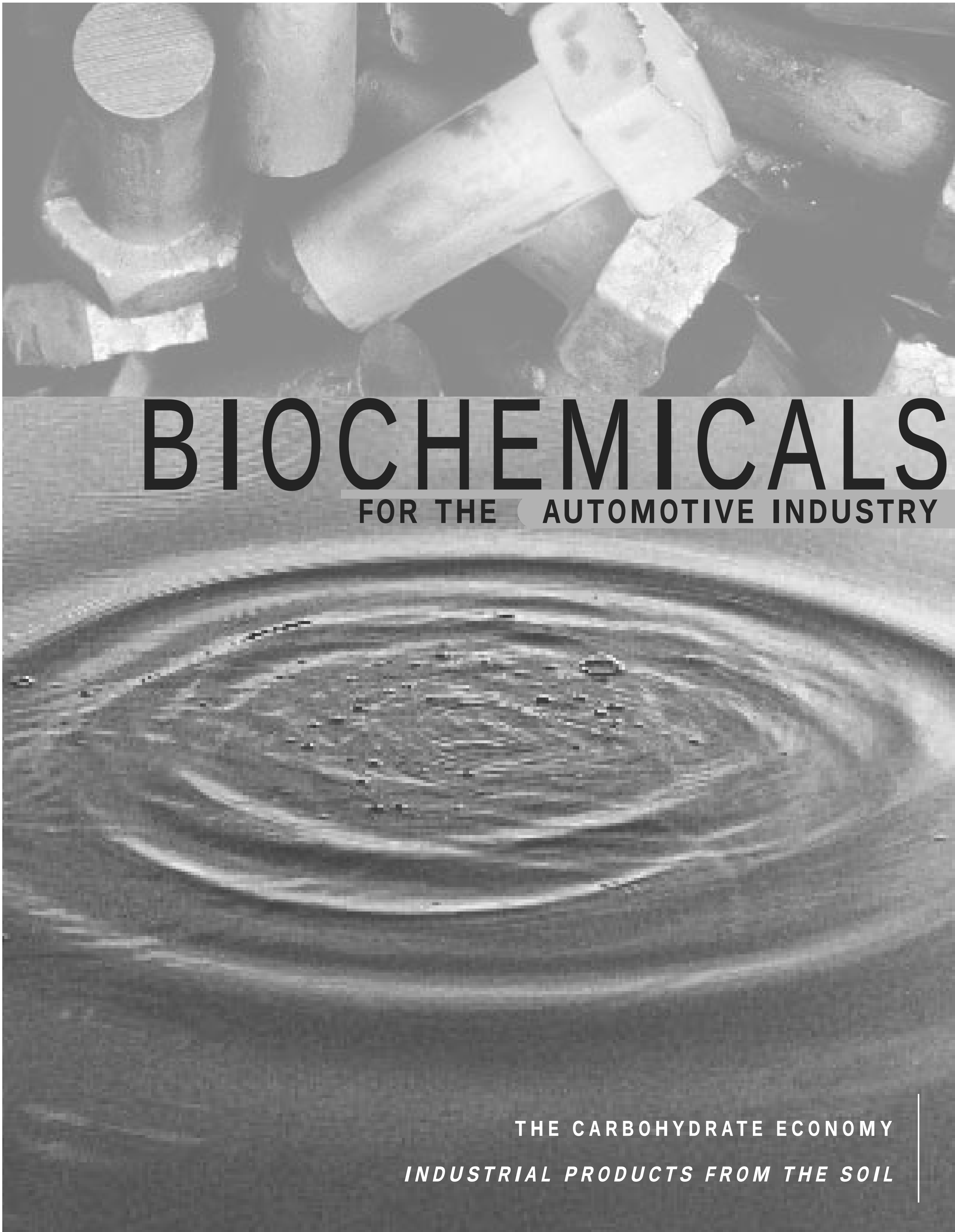
BIOCHEMICALS
FOR THE AUTOMOTIVE INDUSTRY



THE CARBOHYDRATE ECONOMY

INDUSTRIAL PRODUCTS FROM THE SOIL

INTRODUCTION

The U.S. automotive industry is the largest manufacturing industry in North America. In 1996, almost one million people were employed in manufacturing automobiles, and an additional six million people work in allied automotive industries.

The automotive industry is also the nation's largest consumer of raw materials. Over 60 percent of the oil, 50 percent of the rubber, 65 percent of the iron, 50 percent of carpeting, and 20 percent of all electronics and aluminum produced in the United States each year ends up in our cars and trucks.

Given its size, it's not surprising that the automotive industry is also one of our largest polluters. In 1995, about 315 million pounds of toxic compounds were transferred or released into the environment by the automotive industry. Over 54 percent of these chemicals were released in the Great Lakes Basin, which is home to 40 percent of the 4,500 U.S. automotive production facilities.

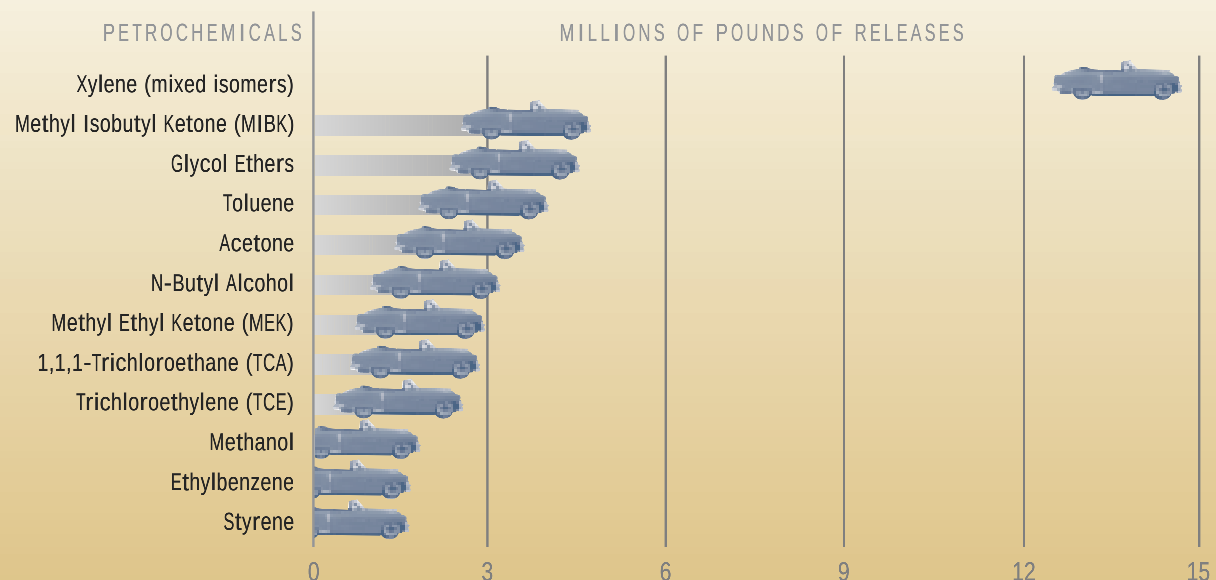
Figure 1 shows the top ten polluting chemicals in the automotive industry. All ten are petroleum-derived. These chemicals are commonly used for cleaning and degreasing, painting or finishing operations, and as chemical components in adhesives, paints and coatings. The greatest portion of these chemicals are emitted during painting and finishing operations.

Plant matter-based materials, such as biochemicals and natural fibers have several advantages over fossil fuel derivatives:

Environmental Advantages: The public benefits from biochemicals through reduced pollution. Utilizing materials abundant in nature dramatically reduces the amount of pollution generated from the extraction and processing of crude oil. Products derived from plant matter are highly biodegradable and in most cases can be disposed of safely and inexpensively.

Manufacturing Advantages: The private sector benefits from biochemicals in several ways. Biochemicals provide an environmental compliance tool for manufacturers. Increasingly stringent regulations regarding the use and disposal

FIGURE 1. This graph illustrates the top polluting chemicals from the EPA's Toxic Release Inventory (SIC 3711, 3713, 3714). The totals include both transfers and releases. Transfers refer to chemicals in waste brought to off-site locations for further processing or disposal. Most of the releases were in the form or volatile organic compounds (VOCs). VOCs cause ground-level ozone, leading to the formation of smog and causing related health hazards.



What is a carbohydrate economy?

New technologies, new laws and an increasingly environmentally aware public are ushering in a new materials base for the 21st century—plant matter. Corn. Soybeans. Beets. Wheat. Alfalfa. Grasses. We call it a "carbohydrate economy."

One hundred years ago, most of our fuels, construction materials, clothes, inks, paints, and even synthetic fibers and chemicals were made from plant matter. Then petroleum flooded the economy and a new industrial era began. By the 1980's, less than 5 percent of our industrial products and fuels came from biological materials. Now industry may be moving away from the oil derrick and towards the silo for its supplies, as new technologies lower the cost of deriving products from plant matter and environmental regulations raise the cost of extracting, processing, using and disposing of fossil fuel derived products.

CONTENTS

of petroleum-based chemicals are raising the administrative cost of these materials for manufacturers. For example, Southern California signed a rule into law on July 11, 1997, forcing over 19,000 area businesses to switch to low-smog degreasers (less than 50g of petroleum per liter) by January 1999; expecting to cost the businesses $21 million annually.

Substituting biochemicals can be a permanent solution to the regulatory problem.

In the past, manufacturers have often substituted a petrochemical not on the Toxic Release Inventory (TRI) to avoid environmental regulations only to discover that a later version of the TRI included the substitute petrochemical. Substituting biochemicals can be a permanent solution to the regulatory problem. Also, biochemicals tend to be far less toxic than petrochemicals, creating safer work environments for employees. The economics of replacing petrochemicals with biochemicals are increasingly favorable. Not only can a manufacturer save money by avoiding costly permits and compliance penalties, there is also a dramatic reduction in hazardous waste disposal costs. Companies using biochemicals in their manufacturing processes also can appeal to "green" consumers, an increasing portion of the market.

This report identifies companies and products that use naturally-derived materials in the following operations: cleaning/degreasing, paint stripping, paint application, automotive fluids and assembly of automotive components. The companies highlighted in this report were selected because they offer biochemical-derived substitutes and their products are commercially available to automotive companies. ILSR, which monitors this emerging industry, believes that this report contains a significant portion of the companies manufacturing biological products for the automotive industry. Every month more companies and products enter this burgeoning market. This report serves simply as a snapshot of the industry in mid 1997. ■

Biochemical-Based Cleaning And Degreasing Operations

Newly-developed biochemicals (chemicals derived from plant matter) have begun to enter the solvent market as cost-effective, environmentally-sound alternatives to petroleum-based chemicals.

Inland Technologies *(Tacoma, WA)* manufactures a wide variety of terpene-based cleaning solvents and degreasers that are derived from citrus fruits. The terpene d-limonene is the primary component of Inland's solvent line.

Citra-Safe®, an evaporative solvent widely used in hand-wipe applications, was originally developed for the aerospace industry as a low-VOC substitute for MEK, TCE, and toluene. It is specifically formulated for surface preparation and general solvent cleaning. Citra-Safe® has been used in the automotive industry as a parts cleaner to prepare surfaces for paint and coating application. This product is not regulated by the EPA's Toxic Release Inventory or as a Hazardous Air Pollutant (HAP). Citra-Safe® sells for $3.99/lb, high compared to the price of competing petrochemical solvents that range from $0.46/lb for MEK to $1.07/lb for TCE.[1] However, the higher initial purchase cost of Citra-Safe® is offset by its cleaning efficiency. Citra-Safe® can clean three times the amount of equipment as a comparable quantity of MEK, making it cost-competitive and reducing the disposal volume.[2]

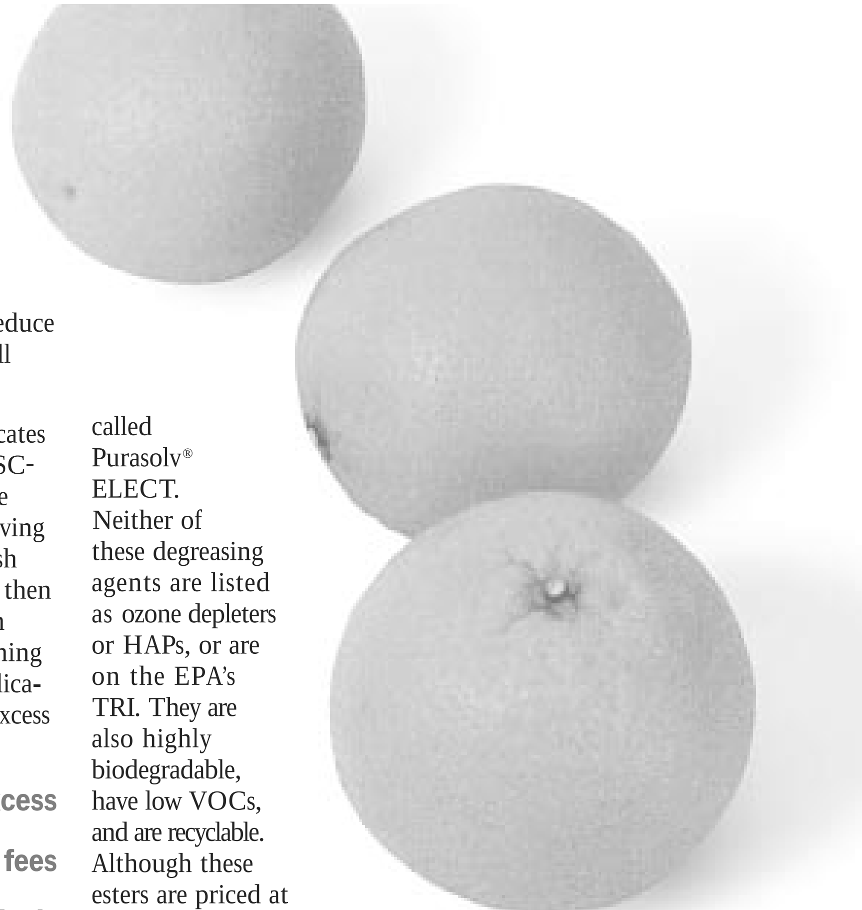
…the higher initial purchase cost of Citra-Safe® is offset by its cleaning efficiency. Citra-Safe® can clean three times the amount of equipment as a comparable quantity of MEK, making it cost-competitive and reducing the disposal volume.

Inland also markets Breakthrough® and Skysol®, solvents designed for dip-tank applications. Breakthrough® has low-VOCs, low toxicity, and is a non-regulated solvent designed for parts cleaning and degreasing. It removes oils, grease, inks, wax, and other deposits from metal surfaces. Skysol® is a cleaning solvent and degreaser designed for parts cleaning in dip-tank applications. In addition to these cleaners, both of which have applications in the automotive industry, Inland manufactures a mild caustic soap for cleaning engine blocks, called Freedom Clean®.

Gemtek Products *(Phoenix, AZ)* markets a cleaner and degreaser with a corn-derived alcohol base. This product, called SC-1000®, is a blend of colloids, sequesterants, surfactants, and wetting agents. It is a water-soluble product that is attracted to oils, fats and grease.

SC-1000® does not contain any chlorinated solvents or petroleum-based derivatives and does not contribute to VOCs. Therefore, it is not listed on the EPA's TRI or as a HAP. Its applications in the automotive industry include degreasing engine blocks and parts, cleaning exterior and interior components, removing soils from glass and vinyl, and working as a hand cleaner.

SC-1000® is typically applied using a spray method, followed by a high-pressure water rinse, and is also used in dip tanks and pressure washers. It removes contaminants in 3-5 minutes, leaving no residue. SC-1000® sells for approximately $1.43/lb; however, because it is typically diluted to a 1:10 solvent to water ratio for effective cleaning and degreasing, its "actual" cost is $0.14/lb. In dip tanks, a 2-5% solution is typical, at a cost of approximately



$0.04/lb. Petroleum-based degreasers sell for $0.46/lb (MEK), $0.60/lb (TCE), $0.76/lb (xylene) and $1.07/lb (TCA).[3] SC-1000® is also fully filterable, reusable, and recyclable. This is very important for manufacturers seeking to reduce downstream pollution and decrease overall disposal volumes.

A California-based company, which fabricates a line of metallic auto parts, switched to SC-1000® to clean parts between two separate process stages that involve welding. By leaving SC-1000® on the part between stages, flash rusting is prevented. Next step cleaning is then accomplished by a simple rinse with clean water. SC-1000® is used again as the cleaning agent prior to final paint and plating applications. The company estimates savings in excess

The company estimates savings in excess of $100,000 per year in disposal fees paid previously (a 50% reduction). Auto manufacturers currently using Gemtek products include Mercedes Benz, General Motors, Toyota, Nissan, KAR Products, and Cummins Diesel.

of $100,000 per year in disposal fees paid previously (a 50% reduction).[4] Auto manufacturers currently using Gemtek products include Mercedes Benz, General Motors, Toyota, Nissan, KAR Products, and Cummins Diesel.

Purac America *(Lincolnshire, IL)* manufactures cleaning solvents based on lactic acid esters, which are derived from the fermentation of sugars. One of the products in their solvent line, Purasolv® ELS, has proven highly efficient for degreasing metal surfaces.

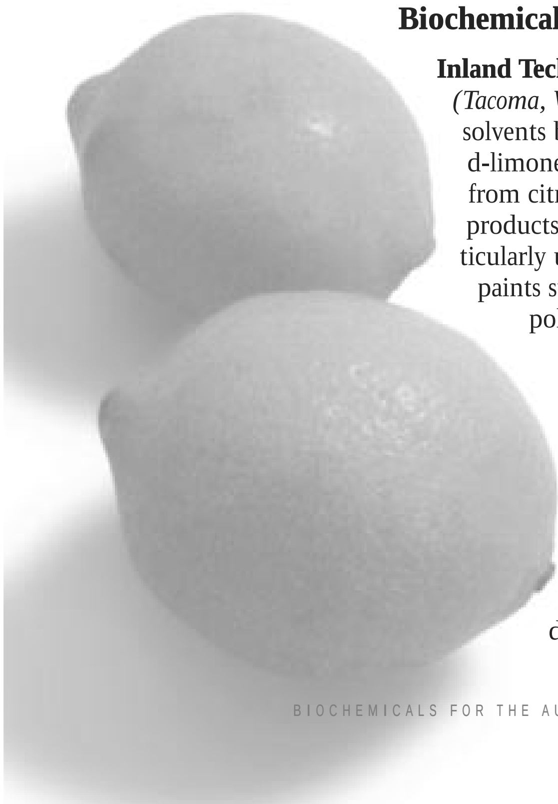
Purasolv® ELS leaves a hydrophilic metal surface which allows for superior adhesion properties for coatings. Purac also markets a degreaser designed for immersion application, called Purasolv® ELECT. Neither of these degreasing agents are listed as ozone depleters or HAPs, or are on the EPA's TRI. They are also highly biodegradable, have low VOCs, and are recyclable. Although these esters are priced at $1.43/lb, the solvents are cost competitive with petrochemical degreasing agents, due to a higher use efficiency (less volume required for effective cleaning). The company is also selling a lower grade of ethyl lactate for half the cost, or approximately $0.70/lb.[5] Purac recently discovered that the lower grade of ethyl lactate performed just as well in cleaning and degreasing applications as the highly pure form, and is less expensive to produce. This greatly improves the economics of using this product as a substitute for petroleum-based solvents.

Ag Environmental Products *(Lenexa, KS)* uses soy methyl esters, which are derived from soybean oil, as the primary components of the SoyGold® line of cleaning and degreasing solvents. The solvents effectively remove heavy grease and oils from automotive parts and engines. SoyGold® solvents are very low VOC (<14%), relatively non-toxic, readily biodegradable, and highly compatible with other solvent systems. They are not regulated by the EPA and are not considered HAPs. The solvents sell for $0.95/lb, comparable to some of the petrochemical solvents SoyGold® replaces.[6] ■

Biochemical Alternatives For Paint Stripping Operations

Paint removal operations commonly use chemical stripping agents such as methylene chloride. Although petrochemical stripping can effectively remove paints and other coatings, the chemicals used are generally toxic and hazardous to workers' health.

Methylene chloride is listed on the EPA's Toxic Release Inventory (TRI), and is also considered to be a hazardous air pollutant (HAP) and ozone depleter. The increasing regulatory pressure to reduce the use of hazardous chemicals, such as the pending phase-out of methylene chloride, is forcing companies to identify alternative, cost-competitive stripping agents that meet performance criteria. Biochemical-based stripping agents are a safe, commercially-viable alternative to chemical strippers.



Biochemical Strippers

Inland Technologies

(Tacoma, WA) markets cleaning solvents based on the terpene d-limonene, which is derived from citrus fruits. One of its products, X-Caliber®, is particularly useful for stripping paints such as polyurethanes, polyamides, latex, and polystyrene, as well as for cleaning paint guns and lines. It contains no chlorinated hydrocarbons, aromatic hydrocarbons, or petroleum distillates.

In 1993, the Los Alamos National Laboratory tested twenty leading solvent substitutes. It found X-Caliber® to be the most efficient and versatile, an excellent paint stripper, as well as a good substitute for methylene chloride and acetone. The only limitation noted was that X-Caliber® has a slower evaporation rate than acetone, requiring an extended drying time. At $5.70/pound, X-Caliber® costs more than methylene chloride ($0.43/lb). However, because X-Caliber® is ten times less volatile than methylene chloride, its true *use cost* is only $0.57/pound. In addition, X-Caliber® has a contaminant-loading capacity four to six times greater than methylene chloride.

Citrex® is another of Inland's terpene-based strippers. This cleaning and stripping agent can remove a variety of contaminants, including paints, coatings, carbon, grease, fuel residues,

In 1993, the Los Alamos National Laboratory tested twenty leading solvent substitutes. It found X-Caliber® to be the most efficient and versatile, an excellent paint stripper, as well as a good substitute for methylene chloride and acetone.

and resins. Its stripping performance equals those of traditional cold-tank compounds, such as methylene chloride and dichlorobenzene, but Citrex® has none of the toxicity or disposal problems associated with them.

Citrex® contains no chlorinated solvents. Its components are not listed on the EPA's TRI, nor are they SARA reportable. Citrex® can be safely used on both ferrous and non-ferrous metals, as well as sensitive metals such as aluminum, magnesium, and titanium. It sells for

$5.70/lb; however, like X-Caliber,® its high level of cleaning efficiency makes its price comparable to other stripping agents.[7]

Gaylord Chemical *(Slidell, LA)*, is the world's leading producer of dimethylsulfoxide (DMSO), which is derived from natural raw wood lignin, or black liquor, a byproduct of paper milling. Gaylord manufacturers DMSO from lignin produced by Gaylord Container's pulp and paper mill in Bogaluse, LA. DMSO is a powerful organic solvent that is used for stripping paints, coatings, and adhesives. It can replace listed petrochemical solvents such as methylene chloride, n-methyl pyrrolidone (NMP), and dimethylformamide (DMF). DMSO is not listed on the TRI, nor as a hazardous air pollutant (HAP). It costs $0.96/lb, comparable to solvents of similar strength, such as NMP and DMF ($0.83-$1.85/lb). DMSO also has a low toxicity, creating a safer work environment.[8]

Blasting Technologies Using Natural Materials

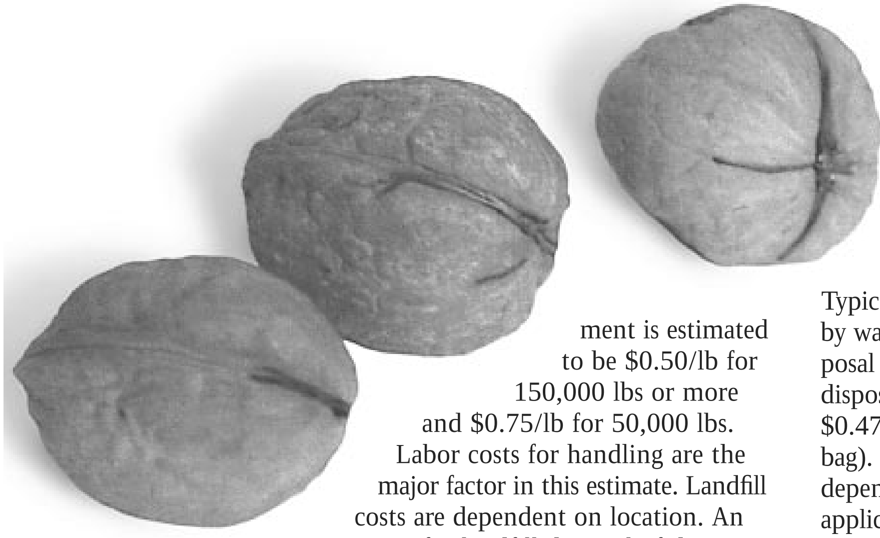
CAE Electronics *(Alpharetta, GA)* patented an abrasive stripping process, EnviroStrip,® using wheat starch as the blasting media. Using low-pressure air, the process propels particles of crystallized wheat starch at a painted surface. The coating is stripped away by a combination of impact and abrasion. Wheat starch blasting can remove a variety of coatings, paints, adhesives, sealants, and composites. Its gentle stripping action can remove individual coating layers, such as removing a topcoat while leaving the primer intact.

Wheat starch-blasting has several advantages over chemical stripping. It uses non-toxic, biodegradable media derived from a renewable agricultural product, rather than petroleum, reducing the consumption of non-renewable resources.

To strip paint from its rare Porsches, Aase Bros, Inc. of Anaheim, CA, prefers to use walnut hull blasting rather than chemical stripping because it does not distort the metal. Although the process is slower and rather dusty, it produces significantly less waste than does chemical stripping.

A completely dry stripping process, wheat starch-blasting generates no wastewater. Furthermore, the wheat starch can be collected and reused for numerous blasting cycles. When the media is finally spent, it can be disposed of via landfilling, incineration, or biological treatment.

DOT Technologies developed a biological treatment process that will effectively treat contaminated starch stripping waste. The system is a four-step process: 1) starch liquification using an alpha-amylase enzyme; 2) removal of paint solids via filtration; 3) metal extraction via ion exchange; 4) aerobic starch digestion. This is a batch digester process that converts the starch waste to carbon dioxide and water. The filtered paint organic compounds are reduced and metals can be recovered. The waste volume requiring subsequent disposal is estimated to be only 5% of the original volume. Biodegradation is most economical when spent media volume is greater than 50,000 lbs. The cost of the biological treat-



ment is estimated to be $0.50/lb for 150,000 lbs or more and $0.75/lb for 50,000 lbs. Labor costs for handling are the major factor in this estimate. Landfill costs are dependent on location. An estimate for landfill disposal of dry hazardous waste ranges from $1.75-3.25/lb. Incineration cost for dry waste is estimated at $1.50/lb. Capital costs for a wheat starch-blasting system vary, depending upon applications, but a plastic media-blasting system can be modified to utilize wheat starch for approximately $10,000. Wheat starch media costs between $1.60-1.70/lb, and can be reused in the system for 15-20 cycles. The operating

Carbon dioxide blasting, another alternative stripping process, converts liquid CO_2 to dry ice flakes (or pellets), which are then projected by compressed air onto a targeted surface… effectively remov[ing] paints, sealants, carbon, grease, oil, flux, and adhesives.

costs for wheat starch-blasting systems have been estimated to be 50% less than chemical paint stripping (e.g. methylene chloride). Wheat starch-blasting also produces 85% less waste sludge than chemical stripping, substantially reducing disposal costs.[9]

Walnut Hull-Blasting is another paint removal process that uses a naturally-derived abrasive media. This process is used primarily for specialty paint-removal applications, such as automotive restoration. To strip paint from its rare Porsches, Aase Bros, Inc. of Anaheim, CA, prefers to use walnut hull blasting rather than chemical stripping because it does not distort the metal. Although the process is slower and rather dusty, it produces significantly less waste than does chemical stripping.

Typically, less than 10% of the dust generated by walnut hull blasting requires a special disposal method (i.e., landfill), thereby reducing disposal costs.[10] Walnut hulls cost between $0.47/lb (50 lb bag) and $0.007/lb (2,000 lb bag). The blasting system costs $1,000-25,000, depending on the size of the unit and type of application. For example, a 53 cubic feet blasting unit costs approximately $25,000.[11]

Carbon dioxide (CO_2) can also be used for paint stripping. The majority of CO_2 produced in the United States is a byproduct of chemical manufacturing, particularly the manufacture of ammonia. However, the production of ethanol by fermentation is the fastest growing source of CO_2 for industrial uses. Archer Daniels Midland, the largest manufacturer of ethanol by fermentation in the United States, is the fifth largest producer of carbon dioxide.

Carbon dioxide blasting, another alternative stripping process, converts liquid CO_2 to dry ice flakes (or pellets), which are then projected by compressed air onto a targeted surface. As the dry ice pellets strike the surface, they induce a thermal shock between the coating and the underlying substrate, weakening the bonds between the two layers. Immediately after impact, the pellets vaporize, releasing CO_2 gas along the surface and dislodging the coating (or contaminant) from the substrate. CO_2 blasting effectively removes paints, sealants, carbon, grease, oil, flux, and adhesives. Waste disposal is minimal, because the CO_2 pellets disintegrate. Thus, only the coating or contaminant residue remains after blasting. Also, the CO_2 stripping is 80-90% faster than chemical stripping.

CO_2 pellet blasting systems can be purchased for $25,000-$50,000, or rented for $1,500-$2,500/month. The pellets cost $0.10/lb to $0.50/lb (price based on delivery distance). For $50,000-$130,000, a manufacturer can purchase a pelletizer and make pellets on-site, reducing the cost of the pellets to $0.10-0.15/lb.[12] ■

Biochemical Alternatives For Spray Paint Applications

One of the greatest challenges facing the automotive industry is maintaining regulatory compliance without sacrificing quality. Spray painting processes have been heavily scrutinized because of their high emission of volatile organic compounds (VOCs). The main culprits in spray painting are highly volatile and hazardous solvents, such as toluene, methyl ethyl ketone, and 1,1,1-trichloroethane, which are used in both paint application and clean-up.

A new, alternative-spray painting technique uses supercritical carbon dioxide (CO_2) rather than hazardous solvents. It is the only biochemical substitution method for spray painting that can effectively reduce solvent emissions while increasing transfer efficiency. It was first used in the automotive industry in 1994.

When CO_2 is heated to 88°F and compressed to 1100 psi, it acts like a solvent and can be used for thinning viscous coatings to the desired level for application. Because of its solvent-like properties, CO_2 can replace hazardous hydrocarbon solvents. A conventional hydrocarbon-based coating emits 4.0 pounds of VOCs per gallon, compared to a CO_2 coating, which emits less than 2.3 pounds of VOCs per gallon.

Solvent use can be reduced by 50-85%; and use of hazardous air pollutants (HAPs), such as xylene and toluene, can be completely eliminated in some cases. CO_2 can also improve coating quality and lower material consumption and operating costs by eliminating application steps and reducing the amount of coating solids sprayed per part.

It is compatible with a wide variety of thermoplastic and thermosetting polymers, and can be used with ultraviolet coatings, waterborne coatings, and two-package systems (vehicle plus curing agent). The CO_2 process has been used on metal, wood, plastics, and some commercial applications, including automotive topcoats and components, aircrafts, and appliances.[13]

Because it provides greater coverage per gallon than conventional solvents, Unicarb® is more economical.

This CO_2 system, developed by Union Carbide *(Danbury, CT)* and given the tradename Unicarb®, offers numerous performance and economic advantages. Unicarb® creates more uniformly-sized paint particles that are more evenly distributed throughout the spray fan, yielding higher quality films and minimizing overspray. It also allows for either a high film build without running or sagging, or a low film build that is uniform and continuous.

Because it provides greater coverage per gallon than conventional solvents, Unicarb® is more economical. It saves on labor and energy costs by combining or reducing coating systems. Furthermore, the higher efficiency of transferring the coating to the surface reduces solid waste generation and disposal costs. Finally, the manufacturer can reduce its flammable solvent inventory by replacing low flashpoint solvents with nonflammable CO_2.[14]

Unicarb® was first introduced into the wood finishing industry in 1990, when the industry was searching for a new technology to reduce VOC emissions. It then expanded to metal and plastic applications, and was introduced to the automotive industry in 1994.

When CO_2 is heated to 88°F and compressed to 1100 psi, it acts like a solvent and can be used for thinning viscous coatings to the desired level for application. Because of its solvent-like properties, CO_2 can replace hazardous hydrocarbon solvents.

Textron Automotive *(Portsmouth, NH)* was the first to use Unicarb® to paint automotive plastic parts. Textron used Unicarb® to apply moisture-cure urethane clearcoats to vacuum-metallized grilles on the Lincoln Mark VIII. Textron was able to apply the coating in less than half the time required for the HVLP (high-volume, low pressure) method previously used. The coating's gloss and image distinction was increased, and it was rendered acid-etch-resistant. In addition to improving coating quality, Unicarb® replaced 85% of the hydrocarbon solvents, enabling the company to comply with VOC regulations.[15] It is now being used for similar parts of the Chrysler Cirrus and Chevrolet Lumina.

Other automotive companies, such as Ziebart Products Group and SKF, are using Unicarb® to spray automotive finishes (e.g., alkyds, polyesters, and epoxy esters). Unicarb® is licensed to coating formulators and spray applicators worldwide. In North America, coating manufacturers including Red Spot, Lilly Industries, Guardsman, PPG, BASF, and Akzo Nobel are licensed to make Unicarb® coatings.

The specially designed application equipment includes a mixing unit, where the gaseous CO_2 is heated to supercritical temperature and pressurized immediately prior to being added to the paint. The liquid CO_2 is mixed with the paint and applied immediately by manual or automatic electrostatic and non-electrostatic spray guns or robots.

Capital costs for an installed Unicarb® system depend on the size of the system. A one-component, fully-automatic system for automotive clearcoat applications costs approximately $200,000. A similar two-component system can cost up to $250,000. A manual, low-volume system, designed for smaller applications, costs approximately $30,000. Liquid CO_2, purchased in bulk, costs $0.07-$0.09/lb. Companies investing in a Unicarb® system typically receive a return on investment in less than 12 months. ■

Case Study One

When an automotive company applied an acrylic lacquer clearcoat to automotive sport wheels with the Unicarb® system, it reduced solvent emissions by 75%. In addition, transfer efficiency of the coating was nearly doubled, from 30% to 54%, while maintaining film thickness and producing a high quality appearance. This resulted in a 42% reduction in material costs, and a 27% (per part) reduction in overall application costs. Unicarb® reduced the company's waste treatment and removal costs by 75%. Also, by reducing rejects by 25%, Unicarb® saved costly reworking expenses. Payback period for the installed system was less than six months.

Case Study Two

The Unicarb® system was used by one automotive company to apply a thin adhesion-promoter primer layer to automotive components made of thermoplastic polyolefin (TPO). Because TPO is made primarily of polypropylene, it is a difficult substrate for polyurethane coatings to adhere to, and traditionally requires the use of adhesion promoters. However, using the supercritical process, transfer efficiency was increased from 28% to 38%. Coating coverage quadrupled, from 9 parts per gallon (conventional coating) to 36 parts per gallon. With an annual spray line of 1.8 million parts, the company saved $2.5 million in reduced coating application costs alone.[16] ■

BIOCHEMICALS ENHANCE WORKER SAFETY

Biochemicals offer a number of advantages for workers. Most importantly, they significantly reduce the health risks related to petrochemicals. Lower levels of health risk mean that less safety training and protective equipment may be required. Working with less hazardous chemicals reduces the stress associated with accidental spills and contaminations that could lead to uncontrolled reactions. A safer work environment also benefits the manufacturer by reducing work-related injuries or illness related to hazardous chemical exposures. This translates into fewer liability claims and increased productivity.

The following table compares the National Fire Protection Association (NFPA) ratings for components of common petrochemical-based products to components of biochemical-based products. Biochemicals exhibit far less health and safety hazards.

PETROCHEMICALS	HEALTH RATING	FLAMMABILITY RATING
Methyl Isobutyl Ketone (MIBK)	2	3
Methyl Ethyl Ketone (MEK)	1	3
Xylene	2	3
Toluene	2	3
Styrene	2	3

BIOCHEMICALS	HEALTH RATING	FLAMMABILITY RATING
Soybean Oil	0	1
Coconut Oil	0	1
Grain-derived alcohol	0	0
Rapeseed Oil	0	1
Terpene (pinene)	1	0

Note: Ratings from the NFPA and chemical manufacturers.

HEALTH RATING

- 0 = no hazard
- 1 = caution (may irritate)
- 2 = warning (if inhaled/absorbed)
- 3 = corrosive/toxic
- 4 = danger (possibly fatal)

FLAMMABILITY RATING

- 0 = not combustible
- 1 = combustible if heated
- 2 = combustible liquid
- 3 = warning (flammable liquid)
- 4 = danger (extremely flammable liquid/gas)

Biochemically-Derived Automotive Fluids

Though the automotive fluid market is heavily dependent on mineral-based materials, increasing amounts of plant-based components are re-entering the automotive industry.

Transmission Fluid Additives

International Lubricants Inc., (ILI), *(Seattle, WA)* markets a plant matter-based additive for use with automatic transmission fluid (ATF), Lubegard™ ATF Supplement.

Prior to the Endangered Species Act of 1972, sperm whale oil was the transmission additive of choice (a component of Dexron I™). Sperm whale oil has a linear structure comprised of up to 50 carbons. With this additive, the transmission fluid lasted the lifetime of the car.

When Dexron II™ was formulated without sperm whale oil, automatic transmission fluid's life was reduced to 15,000 miles. In order to mimic the characteristics of sperm whale oil, ILI initially used jojoba oil. However, due to jojoba oil's high cost, ILI began researching high erucic acid, which is found in crambe and rapeseed. Erucic acid, comprised of 22 carbons, when esterified and further extended by additional reactions, leads to a compound with comparable properties to sperm whale oil.

Lubegard™ is sold by ILI to retailers, which price a 10 oz. bottle from $10 to $25. The cost for petroleum-based automotive transmission fluid additives, such as DuraLube™, averages $11 for an 8 oz. bottle. An advantage that Lubegard™ has over other competitors is that once the additive is in the tranmission fluid (Dexron II™ or Dexron III™), the fluid performs similar to Dexron I™ and may not

Lubegard™ has been endorsed for solving automatic transmission problems by these European car manufacturers: SAAB, Volvo, Pugeot, and BMW.

need to be changed. (Lubegard™ at least doubles the life of the fluid). In contrast, the manufacturer of DuraLube™ recommends maintaining the same automatic transmission fluid replacement schedule, therefore fluid life is not significantly extended. With the cost of automatic transmission fluid changes ranging from $20 (drain and fill) to $150 (if they drop the transmission pan to fully drain the vehicle), consumers can realize a significant cost savings by using Lubegard.™ [17]

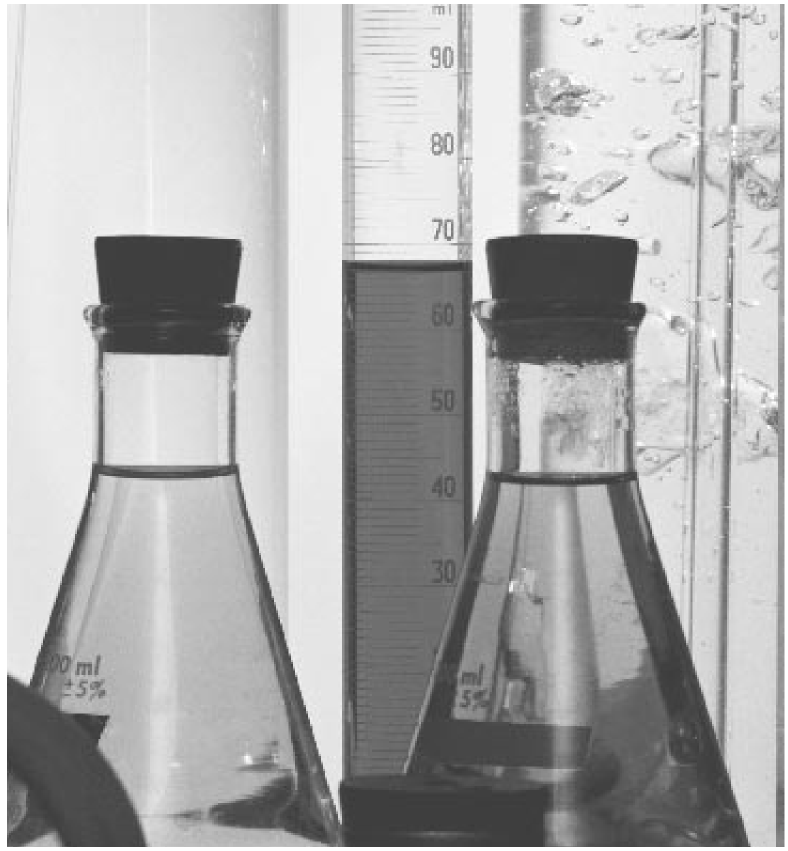
Lubegard™ has been endorsed for solving automatic transmission problems by these European car manufacturers: SAAB, Volvo, Pugeot, and BMW.

Windshield Washer Fluid And Antifreeze

Aquinas Technologies Group, Inc. *(St. Louis, MO)* developed a premium windshield washer fluid which uses corn derived ethanol, called America's Solution.™ Using ethanol as the solvent, it replaces the need for methanol, a petroleum derivative. America's

Solution,™ formulated with 50% ethanol and 50% water, is sold for $1.79/gallon. This price is approximately twice as expensive as methanol-based washer fluid, however it is a less toxic product that also contains an air freshener (which is absorbed through the car's ventilation system) and bug remover in the formulation. Aquinas's largest distributors of America's Solution™ are Grow-Mart and K-Mart, which sold over 50,000 gallons in 1996.

Aquinas also markets RV Premium Antifreeze,™ which also contains ethanol. It is used to winterize mobile or vacation homes, travel trailers, and plumbing in pools and boats. This product contains 10% ethanol and is priced at $3.00/gallon, comparable to other market brands of antifreeze. The largest distributor of RV Premium Antifreeze is K-Mart, which sold over 300,000 gallons in 1996.[18]



Up And Coming Automotive Fluids

Agro Management Group, Inc. *(Colorado Springs, CO)* developed seed-based lubricants that can completely replace petroleum oil in small engines and automobiles. Processed canola oil, combined with several other natural ingredients, keeps engines running cool and smooth without the environmental hazards associated with the disposal of waste petroleum.

This new product, called BIO 25/30, is a crankcase oil designed to operate in 4-cycle engines, such as lawn mowers, pumps, generators and automobiles. Tests conducted on an air-cooled Volkswagon engine demonstrated reduced engine operating temperatures, reduced oil consumption, and reduced engine wear over conventional petroleum oils. A 1970 Ford Mustang is currently being driven over the road to test the product in a high performance engine. BIO 25/30 will also be priced competitively to petroleum oil. The 99.8% biodegradable lubricant will be priced approximately $0.10/gal higher than petroleum oil, however savings in disposal costs should offset this slight premium.[19]

International Polyol Chemicals, Inc. (IPCI), located in Redmond, WA, developed a technology that converts sugar (glucose) into ethylene glycol, the primary ingredient of antifreeze. The least expensive and most readily available feedstock for glucose is corn starch, although other sugars can be utilized including: lactose from cheese whey, sucrose from cane or beet sugar, and pentose from wood pulp liquor.

Processed canola oil, combined with several other natural ingredients, keeps engines running cool and smooth without the environmental hazards associated with the disposal of waste petroleum.

Ground-breaking on IPCI's first U.S. plant is expected to begin this fall with a capacity of 100,000-200,000 tons per year. Additional plants are planned for South Africa and Iceland. Their end products, ethylene glycol and propylene glycol, will be marketed as direct replacements for petroleum-derived products. Propylene glycol's primary automotive market will be in engineered plastics.[20] ■

Natural Fiber Substitutes For Automotive Components

The 2,000 natural materials from which humans have extracted, spun, and woven fibers also have qualities which make them attractive for the automotive engineer. This is true, despite high-technology competition from steel and plastics. Natural materials are good humidity regulators, insulate against heat and noise, and are renewable. Both biodegradable and usually comparatively inexpensive, they rarely present a health risk. And, although normally low in weight, they are extremely strong.

Natural fibers can be used to reinforce synthetic materials. The glass fibers embedded in plastic hinder the environmentally compatible disposal of the used components. For this reason, ecologically more suitable fibers such as flax are already being used in place of fiberglass.

For example, flax or coir can be used to reinforce a thermoplastic material, such as polypropylene. This combination would be stronger and more easily recyclable than plastics reinforced with fiberglass.

Hemp has also been a key natural fiber that is suitable to replace glass fiber, however until recently, its cultivation was illegal in Germany. As of 1996, the cultivation of hemp is again permitted and researchers have determined that its advantages even outweigh those of flax. Hemp fibers are more rigid and can be

NATURAL FIBERS USED IN THE AUTOMOTIVE INDUSTRY[21]

Natural Fiber	Leading Producing Countries	Applications
Banana	Philippines, Uganda, India, Brazil, Ecuador	Reinforcement of polyester resins
Cotton	China, U.S., India, Pakistan, Brazil, Uzbekistan, Turkey, Australia, Turkmenistan, Eqypt, Mexico	Manufacture of interior trims, supports and sound insulation mats
Flax	Canada, China, Argentina, India, Poland, Romania	Manufacture of interior supports; reinforcement of plastics
Hemp	India, Romania, Thailand, China, Hungary, Poland, Turkey, France	Backing for carpets
Jute	India, China, Bangladesh, Brazil	Reinforcement fibers and filling for automotive plastics
Coir	Philippines, Indonesia, India, Mexico, Vietnam	Rubber/hair matting for seats and head-rests; reinforcement fibers for plastics
Ramie	China, Japan, Brazil, India, Taiwan, Philippines	Reinforcement for composite materials; creation of blended fabrics for car textiles
Sisal	Brazil, Tanzania, Angola, Kenya, Madagascar, Mexico	Manufacture of supports for interior; reinforcement for plastics

cultivated without the use of insecticides. In addition, initial investigations have shown that in most criteria, hemp matches and even surpasses flax in terms of performance potential and may even prove to be more economical.

Ramie, a 2.5 meter high Chinese relative of the common stinging nettle, yields fibers which are practically as tear-proof as fiber from glass. Developers in Bremen are currently testing ramie as a possible replacement for interior fittings for the Airbus. The fiber already satisfies one vital requirement for aircraft construction—it is fireproof. The Bremen team were even able to locate a cheesecloth manufacturer in Switzerland that could process the material.

Furthermore, fibers from the leaves, wood, and even the fruit of the banana are bright

Flexiform is already in Mercedes family size C-class cars. It is exceptionally strong, corrosion proof, and is never expected to wear out.

prospects for car components including: interior trim and supports, backing for carpets, and reinforcement for polyester resins.

Mercedes Benz: Leading The Way

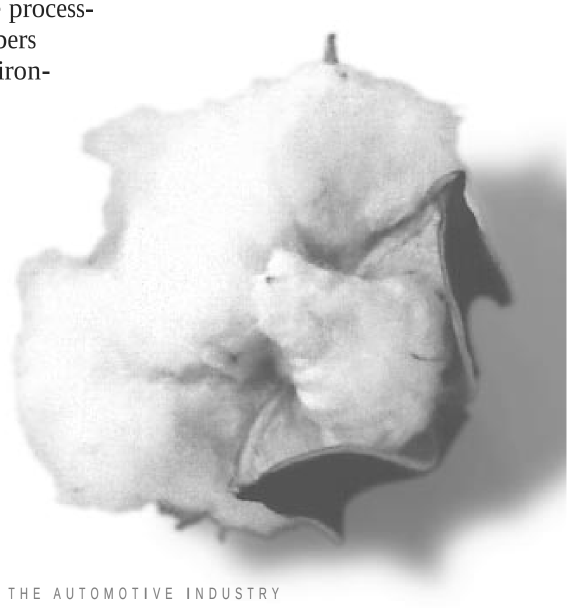
A modern vehicle like a Mercedes-Benz consists of a variety of materials, of which the best known are steel, plastics, glass and rubber. But a closer look underneath the bodywork of the car would reveal an increasing number of new materials which one would not normally associate with car manufacture: cotton, flax, coir (coconut fiber), sisal and latex.

A combination of flax and sisal, called Flexiform, is used for interior trim and acoustic insulation. It is 20% lighter than traditional materials and met rigorous crash-test and quality control standards. In Stuttgart, engineers found that it makes a better door paneling than plastic. Besides being lighter, it does not splinter upon impact in a crash.

It also provides sound insulation. It reduces the weight of a car by one kilogram, reducing fuel consumption. It is also easy to recycle. Flexiform is already in Mercedes family size C-class cars. It is exceptionally strong, corrosion proof, and is never expected to wear out.

Flexiform looks like sacking, because the sisal comes from recycled coffee bean sacks from South America. Bruno Stark, head of Mercedes Recycling Department, claims their car plants are fitting 4,000 Flexiform panels a day—350 tons a year. The flax is harvested in Germany. In 1995, 1700 hectares (4200 acres) of flax was grown in Bavaria, compared to only 2 hectares (5 acres) ten years ago.

The long and short fibers are separated with the long fibers used for linen and the short ones for industrial uses, such as cars. Not only is the processing of the natural fibers easier and more environmentally friendly than synthetic materials, but also offers greater scope for the designers, because the flax /sisal mats can be formed into complicated shapes and curves.

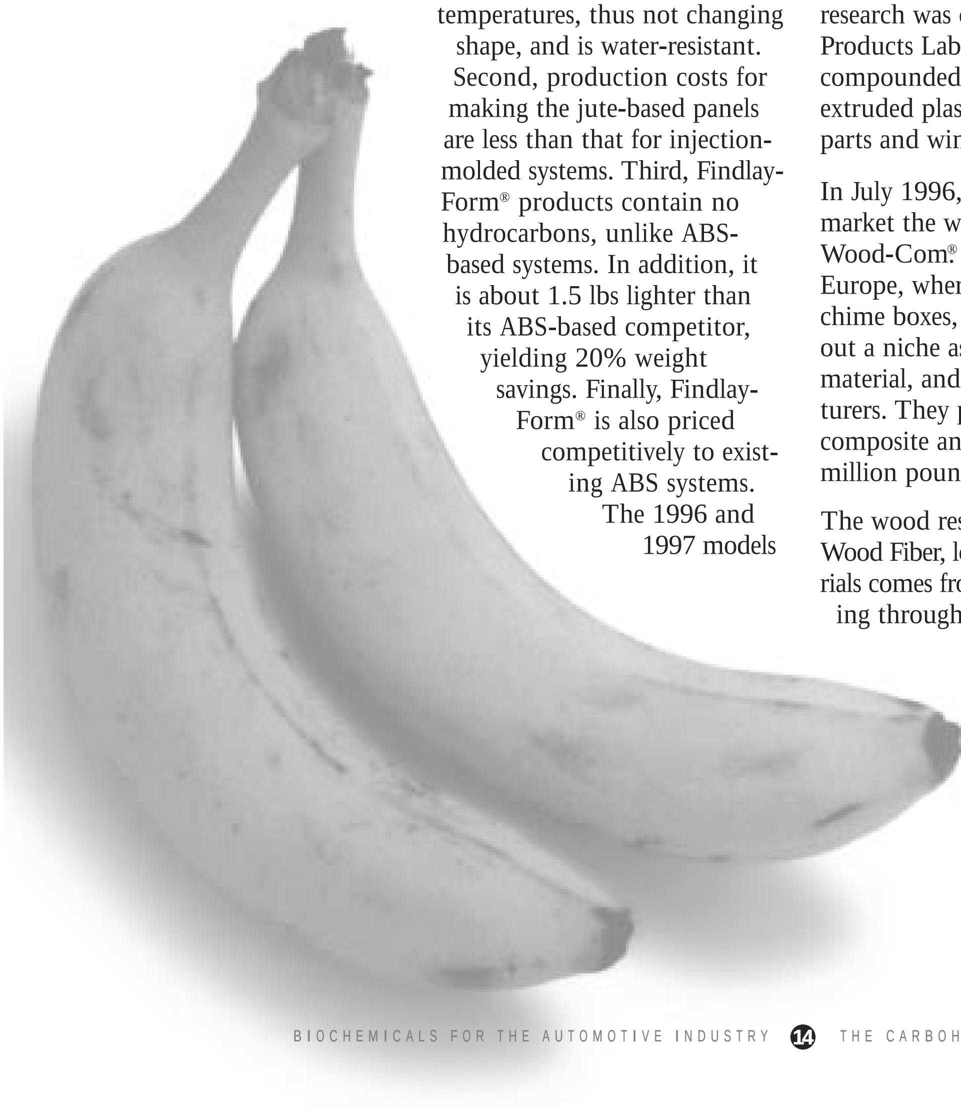


Cotton fibers have been used to make rear parcel shelves in the class C cars. The transmission tunnel, dashboard and lower instrument panel have all been sound-deadened by cotton fleece. A mixture of cotton, coir and latex can also be used in seat cushions.[22]

U.S. Suppliers

Findlay Industries *(Troy, MI)* makes interior trim panels from long-fiber jute, coated with resin, called Findlay-Form®. The product consists of jute fibers, impregnated with a synthetic resin, and compressed into a board with a contoured shape. The jute fiber is imported primarily from Mexico, Bangladesh, and Africa.

Findlay-Form® has a number of advantages over ABS-based door panels. First, it has excellent stability in extreme temperatures, thus not changing shape, and is water-resistant. Second, production costs for making the jute-based panels are less than that for injection-molded systems. Third, Findlay-Form® products contain no hydrocarbons, unlike ABS-based systems. In addition, it is about 1.5 lbs lighter than its ABS-based competitor, yielding 20% weight savings. Finally, Findlay-Form® is also priced competitively to existing ABS systems. The 1996 and 1997 models of Chevrolet's CK Pickup, 4-door Blazer, and Suburban contain door paneling systems made from Findlay-Form®.[23]

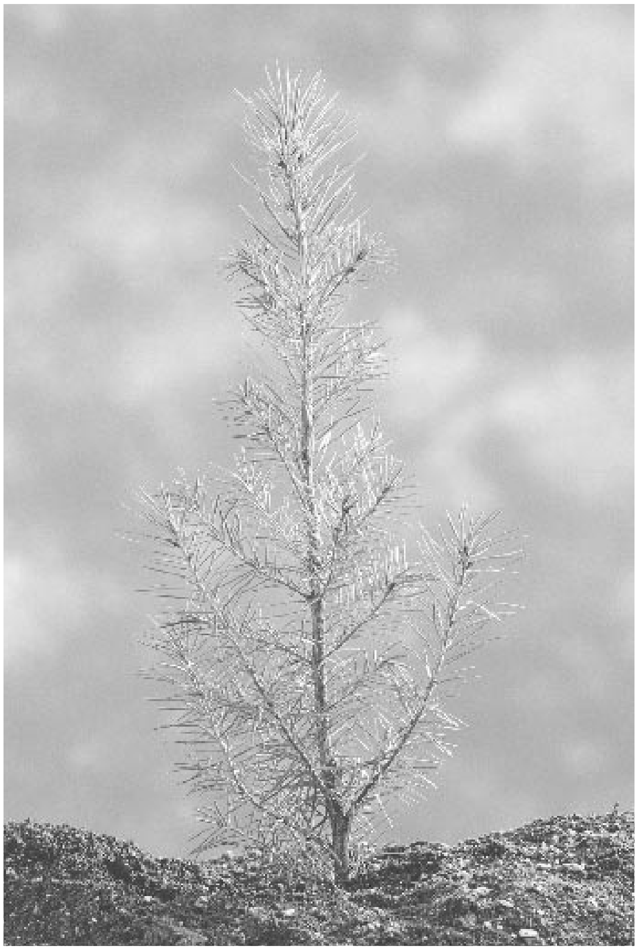


Natural Fiber Composite (NFC) in Baraboo, Wisconsin is marketing plastic composites made from recycled wood and plastic. The research was conducted by USDA's Forest Products Laboratory in Madison, where they compounded wood with injection molded and extruded plastic to manufacture automotive parts and window frames.

Developers in Bremen are currently testing ramie as a possible replacement for interior fittings for the Airbus. The fiber already satisfies one vital requirement for aircraft construction—it is fireproof.

In July 1996, Mike Ford founded NFC to market the wood/plastic composite, called Wood-Com®. The technology has been in Europe, where it is used for door panels, chime boxes, and other parts. NFC has carved out a niche as a supplier of the composite raw material, and custom blends it for manufacturers. They produce 10 million pounds of the composite annually, using approximately 5 million pounds of wood waste per year.

The wood residuals are supplied by American Wood Fiber, located in Schofield, WI. The materials comes from door and window manufacturing throughout Wisconsin and the Midwest, and is ground into wood flour (particle sizes 75-2000 microns). Applications in the automotive industry include chime boxes, speaker brackets, and bracing for seats (support). These products are currently being used in the automotive industry by such companies as the Chrysler Corporation.[24]



Wood-Com® has significant advantages over mineral-filled resins (including talc, calcium carbonate, etc.) including:

- It can be processed at lower temperatures, saving money in energy costs (20% reduction)
- It displaces the amount of polymer needed with wood, lowering production costs by using less polymer.
- Both of these advantages combined lead to decreased cycle times for injection molding applications, which significantly increases production capacity. The composite forms more quickly than the 100% plastic (25% less time to harden).
- Particularly in the automotive industry, these wood fillers are a lower density than traditional mineral fillers, thereby lowering the weight of components by more than one-third. For example, a speaker bracket made with mineral fillers weighs 80 grams, compared to a bracket made with the wood filler weighing only 45 grams.

The average cost of the Wood-Com® material is $0.56/lb, priced competitive to mineral-filled plastics. NFC expects to sell $4.5 million worth of composite in 1997.

Cambridge Industries *(Madison Heights, MI)* uses natural fiber in headliners to replace glass in a urethane-foam sandwich design. This natural fiber-reinforced polypropylene material is called EmpeFlex.™ EmpeFlex™ mats use flax as the natural fiber source, however jute or hemp could also add the desired strength to the headliners. It can be used for door-trim panels, package shelves, garnish moldings, consoles and seat backs. EmpeFlex™ has a number of advantages over fiberglass-reinforced headliners.

- *Lightweight:* Due to its low density and high tensile strength, EmpeFlex™ mats provide a strong product with less material, reducing overall component weight.
- *Safe:* EmpeFlex™ mats do not splinter nor leave sharp corners when impacted, even under extreme temperatures. Using natural fibers also creates a safer work environment as opposed to using additives such as phenolics, which produce emissions, and glass, which is abrasive.
- *Durable, Quiet:* EmpeFlex™ is not only a long lasting thermoplastic product, it also provides a quieter ride due to its sound absorption properties.

The 1996 and 1997 models of Chevrolet's CK Pickup, 4-door Blazer, and Suburban contain door paneling systems made from Findlay-Form.®

- *Cost Effective:* Decorative material and fasteners can be compression molded into EmpeFlex™ mats in a single process step. This simplified process reduces costs, improves cycle time and enhances design flexibility.

- *Recyclable:* At the end of a vehicle's life-cycle, the EmpeFlex™ mat component is disassembled and reground for three potential uses: as material to make additional EmpeFlex™ mat components; injection molded for use in another functional component; or burned, which generates even more energy than was consumed to make the initial component.

Due to its low density and high tensile strength, EmpeFlex™ mats provide a strong product with less material, reducing overall component weight.

EmpeFlex™ is currently being used in Europe by GM, Opel, and BMW, and Cambridge is starting-up a prototype facility in Canandaigua, NY to try to penetrate the U.S. market. This new facility will be capable of producing 250 headliners per day beginning this fall, and will be marketed through C.E. Automotive Trim Systems (CEATS), a joint venture between Cambridge and EMPE Werke (Geretsried, Germany).[25] ■

References

1. Chemical priced quoted from *Chemical Marketing Reporter*, October 7, 1996.
2. Product information provided by Eric Lethe of Inland Technologies, Inc.
3. Chemical prices quoted from *Chemical Marketing Reporter*, October 7, 1996.
4. Product information provided by Bruce Bateman of Gemtek Products.
5. Product information provided by John Ketelaar of Purac America.
6. Product information provided by Bill Ayres of Ag Environmental Products.
7. Product information provided by Eric Lethe of Inland Technologies.
8. Product information provided by Rod Willer of Gaylord Chemical.
9. U.S. Dept. of Defense, "*Wheat Starch Blasting*", Pollution Prevention Technical Library, June 1995.
10. Information provided by Aase Bros, Inc. of Anaheim, CA.
11. Information provided by Phil Hicks of MC Abrasive Cleaning Equipment.
12. NFESC, Pollution Prevention Technical Library, "*CO_2 Blasting Operations*," October 1996.
13. Third Annual Advance Coatings Technology Conference, "*Technical Development of the Supercritical Fluid Spray Method for the Application of Coatings*," November 1993.
14. Product information provided by Rick Woods of Union Carbide.
15. "*Auto Industry Gases Up...*," Industrial Paint & Powder, vol. 71, No. 11, November 1995.
16. Neilson, K.A., "*Decompressive Atomization*," July 1994.
17. Information supplied by Bill Mammel, ILI.
18. Information provided by Aquinas Technology Group.
19. Product information provided by Tim Lambert, Agro Management Group.
20. Information provided by IPCI.
21. Information provided by Mercedes Benz and the *WorldBook Encyclopedia*.
22. Information provided by Mercedes Benz.
23. Information provided by Findlay Industries.
24. Information provided by Mike Ford, Natural Fiber Composites.
25. Information provided by Peter Herrmann, Cambridge Industries.

THE INSTITUTE

I am pleased to present this newest addition to ILSR's growing family of studies on the Carbohydrate Economy. When we first coined that term more than a decade ago, it communicated a vision of a future materials foundation for our economy, one based on carbohydrates rather than hydrocarbons, on agricultural fibers rather than tree fibers, on sustainable industries rather than unsustainable enterprises.

Today that vision is becoming a reality. A new biological economy is emerging.

Our technical reports have highlighted different aspects of the Carbohydrate Economy. The flagship monograph, *The Carbohydrate Economy: Making Chemicals and Industrial Materials from Plant Matter*, revealed the 200 year old battle for supremacy between hydrocarbons like coal, oil and gas and carbohydrates like cotton, oilseeds, grains and grasses and provided a detailed analysis of those product markets where biochemicals are making a significant comeback.

Replacing Petrochemicals With Biochemicals made the qualitative and quantitative case for promoting plant matter-based products as a key element in a comprehensive pollution prevention strategy.

Making Construction Materials From Cellulosic Wastes showed that there is sufficient economically and ecologically recoverable agricultural residue to make significant inroads into the tree fiber market. The study also identified key companies who are pioneers in that emerging industry.

Biochemicals in the Automotive Industry focuses the carbohydrate economy lens on the nation's largest industry. Automobiles constitute the nation's largest consumer of raw materials. They have been the engine, if you will, that powered the mineral economy and could now play an important role in moving us toward a more sustainable economy based on vegetable matter. As with our other reports, this one highlights those companies and products that are leading the way.

Michelle Carstensen, a staff member of ILSR and the author of this report has proven herself remarkably capable of mastering the complex field of biochemicals. A chemist, toxicologist and agricultural scientist by training, her articles in technical journals and her talks before industry organizations are earning her a well-deserved reputation for meticulous research and to-the-point presentations.

We are grateful for the support given our work by the Joyce Foundation and Great Lakes Protection Fund. And we are equally grateful to the many businesses and individuals who have willingly lent their time and expertise to this endeavor.

Dr. David Morris
Vice President

The Institute for Local Self-Reliance (ILSR) is a nonprofit research and educational organization that provides technical assistance and information on environmentally sound economic development strategies. Since 1974, ILSR has worked with citizen groups, governments and private businesses to develop and promote strong local economies and the efficient use of our natural resources.

Contact: Michelle Carstensen
Research Associate, Midwest Office
1313 5th Street SE
Minneapolis, MN 55414
Phone: (612) 379-3815
Fax: (612) 379-3920
E-mail: *michelle@ilsr.org*

National Office
2425 18th Street NW
Washington, DC 20009
Phone: (202) 232-4108
Fax: (202) 332-0463

World-Wide-Web:
http://www.ilsr.org

J6

Printed on chlorine-free, tree-free kenaf paper.
Printed with soy-based ink. Recyclable.