

U.S. and European Activities Promote Biobased Industrial Products

The search for new industrial uses of agricultural materials is occurring in many countries. In the United States, projects funded by USDA's Alternative Agricultural Research and Commercialization Center and Cooperative State Research Service, Office of Agricultural Materials have begun to yield results. USDA's Agricultural Research Service continues to expand its technology transfer activities. Projects at the U.S. Department of Energy focus on developing high-volume chemicals from biomass. The European Union and its member countries are investing in research and demonstration projects, like the Biorefinery Concept in Denmark.

Updates: USDA's AARC Center

In fiscal year 1994, USDA's Alternative Agricultural Research and Commercialization (AARC) Center received \$9 million for new industrial-uses projects. The Center issued a competitive request for proposals in June 1993 for fiscal 1994 and received 160 proposals. Of these, the AARC Board chose 47 to develop into full proposals. Twenty projects were selected. Half of these have been funded, with negotiations continuing on the rest. Some of the projects funded thus far include: stress-skin construction panels made from compressed wheat straw by Agri-board Industries L.C. (Fairfield, IA); oil-absorbent booms and socks, which contain natural bacteria to bioremediate the oil, produced by Environmental Remediation Technologies (Clinton, MS); and a new biological fungicide, which uses ground bark or crop and grass residues as the carrier, manufactured by Innovative Biosystems, Inc., (Moscow, ID). Criteria used in awarding funds include:

- economic viability,
- private financial participation,
- potential market size,
- potential for job creation and rural development (especially in economically distressed rural areas),
- State or local government participation,
- likelihood of reducing federal commodity support outlays,
- likely impact on the environment,
- lack of adequate private funding,
- viability without continued assistance,
- and eventual ability to repay the AARC revolving fund.

The projects funded in fiscal 1993 have begun to yield results. Gridcore Systems International (Carlsbad, CA) is selling its composite material made from kenaf, wood fibers, and/or recycled corrugated containers to "The Gap" clothing stores. Sales of Ogallala Down comforters and pillows, made with milkweed floss and goose and duck down, by Natural Fibers Corporation (Ogallala, NE) are up and the company is nearing the break-even point.

Five major European automobile manufacturers are now recommending the rapeseed-oil lubricants made by

International Lubricants, Inc., (Seattle, WA) to their customers. The company's sales have grown 70 percent per year for the last 4 years. CCT Corporation (Carlsbad, CA) is awaiting approval from the U.S. Environmental Protection Agency (EPA) so it can commercially manufacture its granular matrix that will contain a biopesticide for use on corn. Hobbs Bonded Fibers (Mexia, TX) is now selling oil-absorbent pads made from low-grade wool on a commercial scale. Leahy Wolf Company (Franklin Park, IL) has a biodegradable, concrete-form release agent made from industrial rapeseed oil on the market.

Phenix Composites (Mankato, MN) has started commercial production and made initial sales of its "Environ" composite construction panels that are made from recycled newspaper, soybean meal, and binders. Aquinas Technologies (St. Louis, MO) has introduced a summertime windshield washer fluid made with ethanol and will soon add a winter product.

CSRS's Office of Agricultural Materials Consolidates Program in Fiscal 1994

In fiscal 1994, USDA's Cooperative State Research Service, Office of Agricultural Materials received \$3.2 million to fund projects developing industrial uses of agricultural crops and materials. Some of the projects include development of: hesperaloe as a new "hard" fiber, industrial oilseeds such as crambe and lesquerella, hypoallergenic latex and other products from guayule, and industrial products from wheat. The joint USDA-U.S. Department of Defense (DOD) program received \$4.7 million in fiscal 1993 and \$2.5 million is anticipated in fiscal 1994. This program is targeting the development of biodiesel and other environmentally friendly fuels and lubricants; biodegradable, oil-selective adsorbents; nylons and epoxies from vegetable oils; natural biocides; and low volatile-organic-compound (VOC) paints and coatings.

Lesquerella made its public debut at a field day in Maricopa, AZ, on April 19, 1994. At the Field Day, research presentations ranged from plant breeding and germplasm development, production practices, and successful feeding trials of the meal, to product research and development. Lesquerella oil is similar to castor oil, except that its

hydroxy fatty acid has two more carbon atoms than castor, which may make lesquerella oil superior to castor oil in some applications, particularly in cosmetics. Lesquerella research and commercialization is being supported by the Office of Agricultural Materials, using DOD funds, and by the AARC Center. In the 1994/95 growing season, selected farmers are expected to grow test fields of lesquerella.

Hypoallergenic surgical gloves and other rubber products can potentially be manufactured from guayule latex (see the December 1993 issue of this report for more information). This is good news for people who are allergic to the proteins in Hevea rubber products. Research has been accepted for publication that demonstrates antibodies against proteins in Hevea rubber products do not recognize guayule latex proteins. Related research is under way to prepare sufficient guayule latex for material fabrication and testing by commercial firms. The long-term guayule rubber program administered by the Office of Agricultural Materials is achieving some of its major goals by testing prototype tires on U.S. Army trucks in Yuma, AZ, and on Navy aircraft at Patuxent, MD, this summer.

In 1994/95, yield trials will be conducted in Arizona, Texas, Oregon, and Puerto Rico on vernonia, a plant with epoxy-containing oil. The variety being tested is only six generations from a natural hybrid, which will flower in the short days of temperate North America. The epoxy oil may be used to make low-VOC paints and specialized plastics.

Agricultural Research Service's Technology Transfer Accelerates

In fiscal 1993, USDA's Agricultural Research Service (ARS) more than doubled the number of joint agreements signed with industry to develop ARS technology. The number of Cooperative Research and Development Agreements (CRADA's) in 1993 reached 59, compared to 37 a year earlier. In fiscal 1993, ARS issued 25 licenses to private companies to develop ARS-patented discoveries. Overall, ARS accounts for about 80 percent of USDA's patents. Approximately two-fifths of ARS licenses are for industrial uses. For example, ARS licensed technology that is used to manufacture printing inks from 100-percent vegetable oil to Franks Research Laboratory (Oklahoma City, OK).

When technology is transferred, it helps rural communities grow and creates jobs. For example, Central Illinois Manufacturing Company (Bement, IL) increased its employment to 120 and sales to \$10 million by selling fuel filters that use a cornstarch-based adsorbent developed by ARS. Canadian Harvest USA built a milling plant in Cambridge, MN, and hired 60 people to work there. The company makes low-calorie, high-fiber baking products with ingredients isolated from oat hulls, using ARS technology (see the special article on ethanol coproducts).

In fiscal 1994, ARS received \$79.5 million for research and development of new uses for agricultural commodities. Of this, \$45.3 million is allocated to new, nonfood uses and \$34.2 million to new foods and processing systems. Examples of ARS's nonfood research include programs on improving microorganisms for bioconversion, such as for ethanol and biomolecular fermentation; utilizing agricultural products in plastics, fibers, and membranes; and identifying and extracting biologically active chemicals such as enzymes, pharmaceuticals, and antibiotics.

Past ARS research efforts have resulted in patents on the use of cross-linked starch in biodegradable plastics, colored soy-ink, super-slurper, soy-oil-based nylons, guayule-based rubber, wrinkle-free cotton, penicillin, and many others. Recent research efforts have resulted in the major new dietary product, Oattrim, which is modified oatstarch and soluble fibers. Other discoveries include new, heat-sensitive cotton for use in military and sporting goods. Genetic engineering efforts are producing improved yeast for ethanol fermentation, ways to ferment orange peels to ethanol, and new biopolymers from amino acids and fermented sugars. Soyoil research has resulted in new processes for modifying waste fatty acids into industrial-processing additives and as components in cosmetics, detergents, plastics, and coatings. Research underway on corn and wheat proteins is resulting in new ways to chemically and enzymatically modify their reactive properties to open up new uses as plastics, membranes, and oxygen barriers.

Department of Energy Expands Its Renewable Fuel and Chemical Programs

The Biological and Chemical Technologies Research Program in the U.S. Department of Energy's (DOE) Office of Industrial Technologies has recently concluded a technical and market analysis of the current top-50 commodity chemicals produced in the United States. This analysis is being used to evaluate additional research and development opportunities using biomass feedstocks for the production of high-volume chemicals. The study compiled information on various economic, environmental, and energy characteristics of the chemicals, for example, capital intensity, market share trends, and energy consumption for processing and feedstocks.

Nineteen chemicals were identified as possible targets for replacement by biomass feedstocks. Several are among the top-50 U.S. chemical products. Gasification and pyrolysis were targeted as likely process routes for production. A copy of *A Chemicals and Petroleum Refinery Initiative to Impact the Top 50 Commodity Chemicals Produced in the United States* is available through the Program Manager, David Boron, (202) 586-0080.

The Alternative Feedstocks Program, also administered by DOE's Office of Industrial Technologies, has recently

added a project to develop life-cycle-analysis (LCA) decision tools to help direct research and development priorities and options for chemicals from renewable resources. This project is a cooperative effort between EPA and DOE's Idaho National Engineering Laboratory. The goal is to integrate the LCA module with production-facility economic software developed by the National Renewable Energy Laboratory to incorporate market realities into setting priorities for technology development.

Funding for research and development of chemicals from renewable resources and related chemical processing technologies within DOE's Alternative Feedstocks and Biological Technologies Research Program is being targeted for a 20- to 30-percent increase in fiscal 1995 over the \$7.86 million received in fiscal 1994. The additional funds will support pilot plant activities and further process development, which will be conducted in partnership with industry.

DOE, USDA, DOD, and other federal agencies are cosponsoring the Biobased Products EXPO '94 in December 1994. The EXPO is an opportunity for technology developers, potential investors, and customers to see what is new in industrial uses of agricultural and forestry materials. EXPO '92 attracted over 450 participants and more than 100 exhibits of science, technology, and new products. For information on attending or exhibiting at the EXPO, see Upcoming Events at the end of this article. The proposed deadline for exhibitor applications is the end of August.

Denmark's Biorefinery Concept

The most concerted efforts outside the United States to find new industrial uses of agricultural materials are in the European Union (EU). Indeed, the approaches in the EU and its member countries to developing new uses differ from the U.S. approach, and in general receive more public-sector support.

For example, agricultural and industry interests in Denmark entered into an arrangement in 1990 with five other European countries, plus other parties, to develop new uses for agricultural materials. The group will complete the first phase of its effort by the end of this year. Specifically, the group is developing and testing technologies that treat and fractionate key crops to isolate new products, especially for nonfood uses. The total budget for this effort is \$9 million. Other European nations and the EU also have programs to develop new industrial uses of agricultural materials.

The Danish-led group is focusing on wheat and oilseeds, primarily rapeseed. The overall purpose is to break these crops down into all relevant components and examine their market potential, given today's changing industry and consumer needs. The effort represents a comprehensive, vertically integrated approach--harvesting, transportation,

storage, processing, and market development. Called the Biorefinery Concept (figure 1), it encompasses farmers as well as marketers of the final products--food, feed, energy, and other industrial uses. Major players include the Green Center, Novo-Nordisk, Westfalia Separator, and the Institute of Agricultural Economics, among others (figure 2).

In the pilot plant, different separation technologies and product lines for all parts of the plant were examined. The group readily admits, however, that its product-development component is the weakest link. Industry partners are interested in improving the efficiency of current product lines. Upgrading the value of byproducts or finding markets for current waste streams is of primary interest to farmers and farm organizations involved in the project. In the next phase, a full-scale demonstration project is planned, which is the last step before establishing commercial plants.

Initial economic analysis suggests that the Biorefinery Concept should be feasible for wheat. The products are broken out as Bioraf I, which includes products from whole wheat, and Bioraf II, which includes products from wheat straw (figure 3).

European Efforts Set to Expand

In general, Europeans are ahead of the United States in coordinating their research, development, and demonstration activities in exploring opportunities for new industrial uses for agricultural materials. However, interaction with new startup entrepreneurs is minimal. The Europeans do not have a program like USDA's AARC Center that emphasizes market pull instead of technology push. Some Europeans would like to explore a similar organization but are not sure their politicians are ready for it. However, the Europeans do plan to expand aggressively into the demonstration phase of these programs--not only for wheat and rapeseed, but also for alternative crops like kenaf, elephant grass, hemp, and rapeseed-based biodiesel.

In the fourth framework program, just getting underway, the EU is planning to spend the equivalent of \$117 million over 4 years in the nonfood, new-uses arena, which does not include support from member countries or industry. When this support is included, the total will be two to three times the EU contribution.

The comprehensive nature of the EU's program is stimulating the diversification of agriculture. Production, processing, end use, demonstration, and information transfer are all handled under one umbrella framework. U.S. government and industry are working to find ways to share information with the Europeans on how best to convert renewable materials into useful products. Both sides of the Atlantic are interested in reducing the price-depressing effects of overproduction, and when each side succeeds, both benefit. A possible transatlantic conference

Figure 1

The Biorefinery Concept

Agriculture

Farm 1

Farm 2

Farm 3

Farm n

Harvest,
transport,
and
intermediate
storage

Intermediate
storage and
pretreatment

The biorefinery

Fractionation/combination/
upgrading
- mechanical
- chemical
- biochemical

Intermediate
products
Industrial
raw materials

Industry

Paper, textiles,
fiberboard,
composites

Plastics, paint,
lubricants, chemical
and pharmaceutical
products

Food

Feed

Energy

Source: The Whole Crop Biorefinery Project, Mid-Term Assessment, Morten Gylling, Bioraf Denmark Foundation, Aakirkeby, Denmark, October 1993.

Figure 2

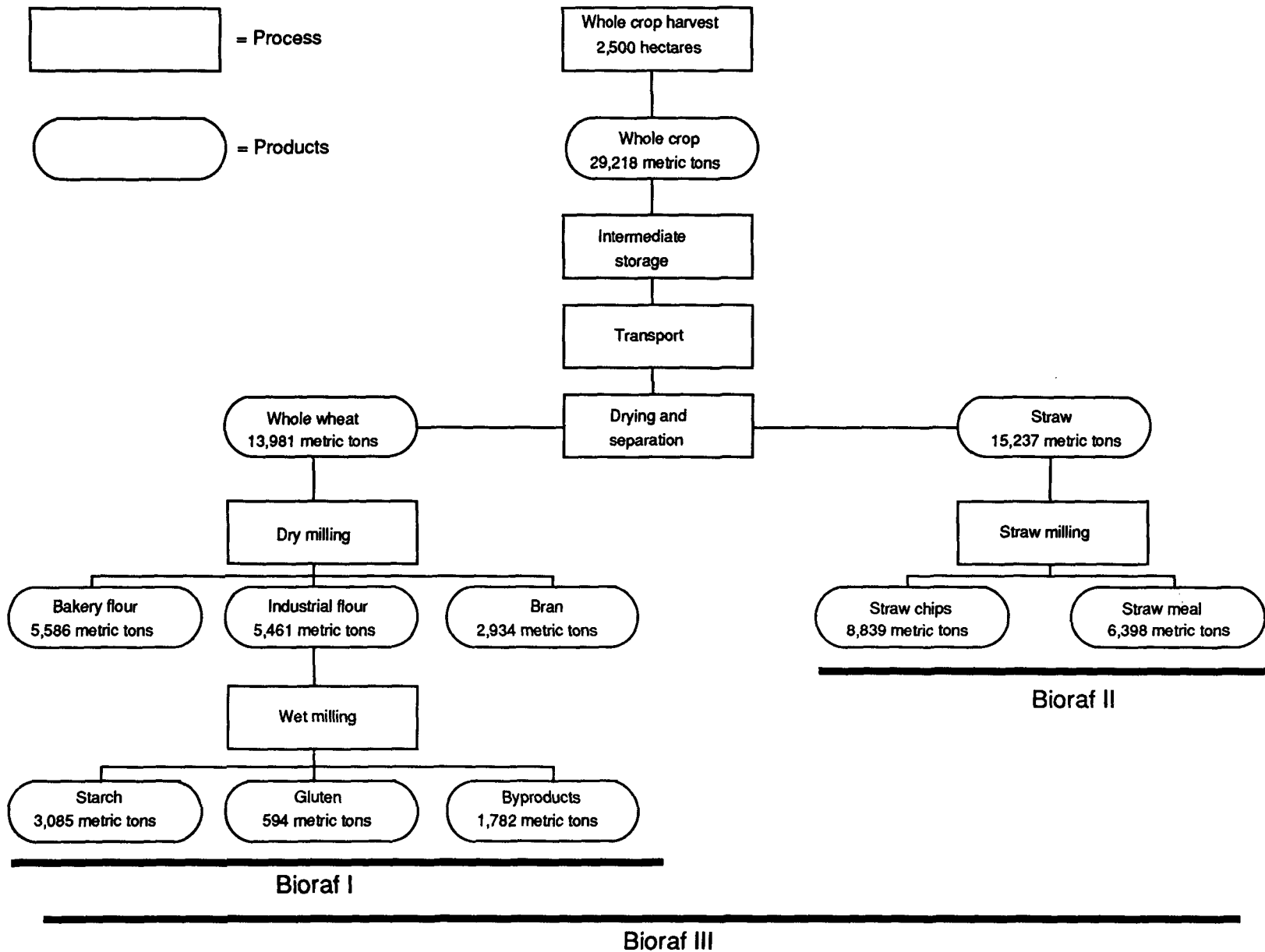
Activities and Participants of the European Whole-Crop Biorefinery Project

	Elements in the biorefinery production system	Activity	Participants	
			Partners and associates	Subcontractors
MODEL OF FULL-SCALE BIOREFINERY SYSTEM Technology, mass balances, cost relations	Plant breeding and selection	1. Selection and development of suitable plant species	Green Center, Denmark Institute of Crop Science, France Braunschweig, Germany	Research Service for Soil and Plant Sciences, Denmark
	Cultivation, harvesting, and transport	—	—	—
	Intermediate storage	2. Intermediate storage, separation and drying of whole crops	Biotechnological Institute, Denmark Teagasc, Ireland	Brdr. Westrup, Denmark
	Drying, dry separation	—	—	—
	Fractionation	3. Integrated upgrading of wheat and barley to starch and feed ingredients	United Milling Systems, Denmark	Vioryl, Greece
		4. Production and analysis of fiber fractions from straw and biomass	United Milling Systems, Denmark National Technical University of Athens, Greece	Brdr. Westrup, Denmark
		5. Enzymatic extraction of oil, protein, and starch Integration of fractionation techniques	Novo-Nordisk, Denmark United Milling Systems, Denmark Westfalia Separator, Germany	Institute of Chemistry and the Royal Veterinarian and Agricultural University, Denmark
	Use of outlets, marketing	Product tests and market surveys included in above activities	—	—
	Data registration, integration, economic feasibility	6. Systems analysis and economic assessment of the Integrated Biorefinery System	Institute of Agricultural Economics, Denmark Silsoe Research Institute, United Kingdom	—

Source: The Whole Crop Biorefinery Project, Mid-Term Assessment, Morten Gylling, Bioraf Denmark Foundation, Aakirkeby, Denmark, October 1993.

Figure 3

Bioraf Model of Whole Crop Wheat ^{1/}



1/ All amounts are on a dry-matter basis.

Source: The Whole Crop Biorefinery Project, Mid-Term Assessment, Morten Gylling, Bioraf Denmark Foundation, Aakirkeby, Denmark, October 1993.

on value-added industrial uses in the spring of 1995 is under consideration. [Greg Gajewski (202) 219-0085 and Paul O'Connell (202) 401-4860]

Upcoming Events

July 11-13, 1994, SERBEP Wood Recycling Conference and Exhibition: Opportunities for Waste Generators and Solid Waste Facilities in the Southeast, Charlottesville, VA, sponsored by the Southeastern Regional Biomass Energy Program (SERBEP). For information, contact C. T. Donovan Associates, Inc., P.O. Box 5665, Burlington, VT, 05402, (802) 658-9385.

July 15, 1994, SERBEP Biogas Recovery and Use Workshop at the Northside Wastewater Treatment Plant, Durham, NC, sponsored by the Southeastern Biomass Energy Program. For information, contact John Wander, Wander Associates, 1933 Rockingham St., McLean, VA, 22101, (703) 533-8333.

July 15, 1994, Alternative Feedstocks Program, Rockville, MD, sponsored by the U.S. Department of Energy and its national laboratories. For information, contact Joan Ross, National Renewable Energy Laboratory, Golden, CO, (303) 231-1412, fax (303) 231-1905.

July 24-29, 1994, Annual Meeting of the Council on Forest Engineering, Portland and Corvallis, OR. For information, contact Loren Kellog, Department of Forest Engineering, 213 Peavy Hall, Oregon State University, Corvallis, OR, 97331-5706, (503) 737-2836.

September 26-30, 1994, First North American Conference and Exhibition: Emerging Clean Air Technologies and Business Opportunities, Toronto, Ontario, sponsored by Environment Canada. For information, contact Raymond Klicius, Environment Canada, Technology Development Branch, Ottawa, Ontario, K1A 0H3, (819) 953-8717.

September 26-30, 1994, Ninth International Conference on Jojoba and Its Uses and the Association for the

Advancement of Industrial Crops Annual Meeting, Catamarca, Argentina, sponsored by the Latin American Jojoba Association and the Association for the Advancement of Industrial Crops. For information, contact James Brown, International Flora Technologies, Ltd., 2295 S. Coconino Drive, Apache Junction, AZ, 85220, (602) 983-7909.

October 1994, Eighth European Conference on Biomass for Energy. For information, contact Dr. G. Grassi, Commission of the European Communities, DG XII, Brussels, Belgium, fax 32-2-296-3024.

October 2-6, 1994, Bioenergy '94, Reno, NV, sponsored by the Western Regional Biomass Energy Program (WRBEP). For information, contact David Swanson (WRBEP program manager), c/o Western Area Power Administration, A7100, P.O. Box 3402, Golden, CO, 80401, (303) 275-1706.

October 3-7, 1994, BioResource Business Opportunities: Profit From a Sustainable Future (BioResources '94 conference), Bangalore, India, sponsored by Biomass Users Network, International Energy Initiative, Stockholm Environment Institute, and the Commonwealth Science Council. For information, contact LaRocco Associates, 2 Erie Street, Montclair, NJ, 07042, (201) 509-7900.

October 10-12, 1994, Animal Coproducts '94, Kansas City, MO, sponsored by USDA's Cooperative State Research Service, Kansas Department of Agriculture, businesses, and other organizations. For information, contact Raymond Burns, Kansas Department of Agriculture, 901 S. Kansas Ave., Topeka, KS, 66612-1282, (913) 296-1907.

December 5-7, 1994, Biobased Products EXPO '94, trade show and conference, Kansas City, MO, sponsored by the New Uses Council, U.S. Department of Energy, U.S. Department of Agriculture, and the U.S. Department of Defense. For information, contact Barbara Detwiler, Science Applications International Corporation, 1710 Goodridge Drive, MS-2-2-5, McLean, VA, 22102, (703) 734-4081, fax 703-356-4056.