Crambe, Industrial Rapeseed, and Tung Provide Valuable Oils

In 1996, crambe is again being grown commercially, while industrial rapeseed acreage is down from previous years. Tung oil is being produced in the United States for the first time since 1973. Glycerine markets remain tight, as demand continues to outpace supply. Biodiesel commercialization faces a number of regulatory and market challenges in the United States.

Crambe Again in Commercial Production

The American Renewable Oilseed Association (AROA), an organization of crambe growers, contracted with 145 farmers in 1996 to grow 22,000 acres of crambe. No commercial acreage was planted in 1995 because much of the crambe oil produced in 1994 had not been sold prior to spring planting. Commercial crambe production began in North Dakota in 1990, and U.S. acreage peaked in 1993 at 57,683 acres (table 4). (See the June 1993 and the September 1995 issues of this report for more information on crambe supply and uses.)

All of the 1996 acreage is in North Dakota. As of mid-July, about 19,000 acres were in good to excellent condition. There is no predetermined contract price this year, but producers are likely to receive between 11.5 and 12 cents per pound of seed harvested. The crop will be toll processed by Archer Daniels Midland at its Enderlin, North Dakota, oilseed crushing plant. AROA has contracted with Witco Corporation, headquartered in Greenwich, Connecticut, to buy the crambe oil and will market the crambe meal to feed manufacturers for beef finishing rations.

AROA has set up a separate steering committee and business to develop a production, processing, and marketing infrastructure for novel oilseeds in the Northern Great Plains. The grower-owned company, AgGrow Oils, plans to offer stock to growers this December, construct a 200-ton-per-day crushing facility in 1997, and begin operation with the 1997 crop. Negotiations are underway that include contracting for 30,000 to 60,000 acres of crambe annually and other novel oilseeds such as high-oleic sunflower and safflower, flax, and possibly specialty canolas.

Table 4--Crambe acreage, United States, 1990-96 1/

Year	Planted area	Yield 2/	Production
	Acres	Pounds/acre	1,000 pounds
1990	2,359 3/	988	2,330 4/
1991	4,475 3/	1,153	5,160 4/
1992	23,204 5/	1,057	24,538 4/
1993	57,683 5/	972	56,090
1994	43,925 3/	1,350	59,200 6/
1995	400 7/	N.A.	N.A.
1996	22,000 3/	N.A.	N.A.

N.A. = Not available. 1/ Commercial acreage. 2/ North Dakota only. 3/ Contracted acreage. 4/ Net crop crushed. 5/ Acreage certified by the Farm Service Agency. 6/ Estimated. 7/ Acreage planted in 1995 was for seed production only.

Source: North Dakota State University.

U.S. Industrial Rapeseed Production Declines

Like crambe oil, industrial rapeseed oil contains high amounts of erucic acid. To meet industry requirements, industrial rapeseed oil must contain at least 45 percent erucic acid. In contrast, canola and other special types of rapeseed, such as high-lauric canola, have been bred or genetically engineered to contain different fatty acids in their oils. Canola oil is used for edible consumption and, according to Food and Drug Administration standards, must contain less than 2 percent erucic acid. Canola is the name generally applied to rapeseed that has low amounts of erucic acid in its oil and low levels of glucosinolates in its meal.

Cross pollination can occur if industrial rapeseed and canola are planted in adjacent fields, resulting in an oil with an intermediate erucic acid content that would be useless for either application. Visually, the seeds of the two types are identical; only testing can differentiate their characteristics. In the Pacific Northwest, where both types are grown, a couple of States have designated production regions to address the cross-pollination issue. Idaho established six production areas in 1986 and Washington State finalized rules and regulations for 12 production districts in 1988.

Industrial rapeseed has been grown in the Pacific Northwest for over 40 years. It was also produced in the South during the late 1980's and early 1990's. Harvested acreage of industrial rapeseed has declined from 19,400 acres in 1987/88 to 2,400 in 1995/96 (table 5). During the same period, domestic production has dropped from 22 million pounds to an estimated 3 million pounds.

In the Pacific Northwest, industrial rapeseed is produced for birdseed and oil. Historically, birdseed has accounted for at least 50 percent of production, according to Andrew Thostenson, a former merchandiser with Spectrum Crop Development, a canola and rapeseed merchandizing firm in Clarkston, Washington. After becoming familiar with canola, birdseed manufacturers now buy either industrial rapeseed or canola, whichever is cheaper.

The only known U.S. crusher of industrial rapeseed is Koch Agricultural Services of Great Falls, Montana. According to Steve Chambers, a marketing manager for the company, Koch contracts for seed and buys it on the open

Table 5--Industrial rapeseed, acreage planted, harvested, yield, production, and value, United States, 1987-95

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 pounds	Million dollars
1987	20.0	19.4	22.7	21,981	N.A.
1988	13.5	13.1	24.1	15,822	N.A.
1989	14.0	13.6	28.2	19,143	2.01
1990	15.0	14.6	31.2	22,717	2.33
1991	18.2	15.6	20.7	16,146	1.63
1992	12.0	9.8	29.5	14,455	1.45
1993	7.2	6.1	24.4	7,442	0.76
1994 1/	7.4	6.7	37.6	12,596	1.29
1995 2/	2.5	2.4	25.1	3,012	0.38

N.A. = Not available. 1/ Preliminary. 2/ Forecast.

market. In addition, unprocessed seed is exported to Japan, where it is crushed and the oil used as lubricants in the steel manufacturing industry and the meal used as fertilizer.

The Market for Erucic-Acid Oils Remains Tight

Charles Leonard, an oleochemical industry expert, estimates world consumption of high-erucic-acid oils for industrial applications at about 125 million pounds per year, with the United States accounting for about 35 million pounds. This is up from a 1991 industry estimate of 25 to 30 million pounds for the U.S. share. Other major industrial users are Europe and Japan.

Two 1996 articles in the *Chemical Marketing Reporter,* quoting industry sources, estimate the U.S. supply of industrial rapeseed oil at about 5 million pounds of domestic production and around 25 to 30 million pounds shipped in from Canada and Europe (*1*, *2*). This is similar to USDA estimates of industrial-rapeseed-oil production and imports for the late 1980's and early 1990's (table 19). However, according to USDA figures, U.S. rapeseed oil production has declined from 5.7 million pounds in 1991/92 to an estimated 836,000 pounds in 1995/96, while imports have averaged 9.8 million pounds during the same period.

Although no data are available from industry sources or USDA on U.S. crambe-oil production, crambe oil reportedly gained acceptance in the U.S. high-erucic-acid market in the early 1990's when Humko Chemical, a division of Witco Corporation, began relying on it as a domestic source of erucic acid. Humko currently uses both industrial rapeseed and crambe oils (*4*), but supplies of crambe oil are reported as limited.

World supplies of high-erucic acid oils have tightened in the last few years as older rapeseed varieties have been replaced with canola types. For example, Poland and the former East Germany historically have been heavy producers of industrial rapeseed oil because much was used for edible purposes. However, since the breakup of the Eastern Bloc, industrial rapeseed has yielded to canola because industrial rapeseed oil cannot be sold to European Union countries for edible purposes. Erucic acid-containing rapeseed varieties are now considered specialty crops in Canada and Europe. China, Russia, and India, however, still use high-erucic acid rapeseed oil for human consumption.

World supplies of industrial rapeseed oil are expected to remain tight. Although Canadian production is fairly stable, European production is below expectations again this year. According to a spokesman for Croda Universal, Inc., which is headquartered in the United Kingdom, the 1996 European harvest of industrial rapeseed will be 1,000 hectares short of what is needed (*1*). The U.S. market for high-erucic-acid oils will likely be served mostly by domestic production and imports from Canada. Calgene Chemical, a subsidiary of Calgene, Inc., of Davis, California, has an agreement with CanAmera Foods of Oakville, Ontario (North America's largest rapeseed processor) to distribute some of CanAmera's industrial rapeseed oil in the United States.

Prices for erucic-acid oils have increased as supplies have tightened (*1*, *2*). Higher world prices have been felt in erucic-acid product markets. Three producers of erucamide—Witco Corporation, Croda Universal, Inc., and Akzo Nobel Chemicals, Inc.—raised the prices of their erucamide products by 20 cents per pound in April and May 1995 due in part to high prices of high-erucic-acid oils. Because of current high prices and the prospects of continued tight supplies, the companies increased their erucamide prices again in May and June 1996, Akzo by 8 cents per pound and Witco and Croda by 25 cents per pound. While U.S.-based Witco uses both crambe and industrial rapeseed oils, the other two manufacturers use only industrial rapeseed oil.

High-Erucic-Acid Oils Have Traditional And Emerging Uses

The primary market for high-erucic-acid oils is erucamide. Plastic-film manufacturers have used erucamide for decades in bread wrappers and garbage bags. It lubricates the extruding machine during manufacture of thin plastic films. After processing, the erucamide migrates to the surface of the films and keeps them from clinging together. Two cheaper amides, stearamide and oleamide, cannot individually provide the critical properties that erucamide does. Therefore, erucamide is preferred, even at about twice the price.

Charles Leonard estimates that 48 million pounds of high-erucic-acid oils are used worldwide in making about 15 million pounds of erucamide per year (table 6). Erucamide is sold by a half dozen oleochemical producers in the United States, Europe, and Asia. Witco is the largest worldwide producer and marketer, supplying product from its Memphis, Tennessee, production facility. Leonard esti-

Table 6--Estimated worldwide use of high-erucic-acid oils for industrial applications

Derivative	Application	Volume of oil used	Volume of derivative produced
		1,000 pounds	
Erucamide	Slip agent	48,000	15,000
Erucyl alcohol	Emollient	30,000	10,000
Various fatty nitrogen derivatives	Hair care and textile softening	18,000	6,000
Behenyl alcohol	Pour point depressant	18,000	6,000
Esters and others	Lubricants	6,000	4,000-5,000
Gyceryl tribehenate	Food emulsifier	2,500-3,000	2,500-3,000
Silver behenate	Photography	~750	~250
Total		123,250-123,750	43,750-45,250

Source: Charles Leonard, "Sources and Commercial Applications of High-Erucic Vegetable Oils," Lipid Technology, July/August 1994.

mates that erucamide market growth roughly parallels the growth of polyolefin film sales, which in recent years has ranged from 4 to 6 percent per year.

Cationic surfactants that function as active ingredients in personal-care products, laundry softeners, and other household products appear to be an up-and-coming use for high-erucic-acid oils. Some companies in Japan and the United States are using cationic surfactants derived from 22-carbon fatty acids, such as those found in rapeseed, crambe, and meadowfoam oils, as the active ingredient in hair conditioners. At least two U.S. companies are doing research in this area. An estimated 18 million pounds of high-erucic-acid oils are used worldwide to manufacture roughly 6 million pounds of cationic surfactants.

Because rapeseed and crambe oils have a high degree of lubricity, they also are used either directly as lubricants or in lubricant formulations. They are used as spinning lubricants in the textile, steel, and shipping industries; as cutting, metal-forming, rolling, fabricating, and drilling oils; and as marine lubes. For example, Calgene Chemical offers a line of erucic-acid esters to the textile and automotive fluids industries. International Lubricants, Inc., of Seattle, Washington, sells erucic-acid-oil-based automatic transmission fluid additives, cutting oils, hydraulic oils, and power steering fluids. The transmission fluid additives are currently used by five European automobile manufacturers and U.S. transmission repair shops, and are newly available in retail auto parts stores.

One of the selling points of the erucic-acid-oil products offered by International Lubricants is their enhanced biodegradability compared to their petroleum-based counterparts. Thus, they are said to be more environmentally friendly. Several companies are reportedly in the market for industrial rapeseed and canola oils for lubricant applications because of their environmental attributes, which has caused a recent increase in demand (*2*).

Another use of erucic-acid oils in response to environmental concerns is in the production of concrete mold-release agents. Leahy-Wolf Company of Franklin Park, Illinois, has developed and patented a biodegradable concrete-release agent based on industrial rapeseed oil, and is marketing it through U.S. distributors. Construction companies and precasters of concrete structures, such as sewer pipes, vaults, and bunkers, coat their molds and forms with release agents to facilitate the release of the hardened concrete. Often these compounds, which are traditionally petroleum-based, leach out of the mold or concrete and end up in the groundwater. Construction firms and precasters have had to modify their operations, however, to meet increasingly strict State and local regulations that limit the release of petroleum-based chemicals into the environment.

Tung Oil Production Begins Again In the United States

Tung oil, a nonedible vegetable oil, is scheduled to be produced again in the United States beginning in December 1996. The sole U.S. producer will be American Tung Oil Corporation (ATO) of Lumberton, Mississippi. ATO was created 4 years ago by Blake Hanson of Industrial Oil Products (IOP) of Woodbury, New York, to revive domestic production of tung oil, which has not occurred since March 1973. IOP is the largest supplier of tung oil in the Western Hemisphere.

Tung oil, produced from the fruit (nut) of the tung tree, contains mainly eleostearic fatty acid, with smaller amounts of oleic, linoleic, and palmitic fatty acids. Tung oil's physical and chemical properties make it useful as a protective coating, solvent, and/or drying agent in various paints, varnishes, lacquers, resins, fiberboard, concrete sealers, electronic circuit boards, and printing inks. Its superior drying properties allow it to be sold at a price premium compared to other vegetable drying oils such as linseed oil (tables 37 and 40). Various new applications for tung oil and its byproducts also are being developed for use in products such as cosmetics, insecticides, and lubricants.

Tung oil is produced commercially mostly in subtropical regions, primarily in China and South America. Tung oil production is small compared with that of many other vegetable oils. Estimated world production averages 50,000 metric tons a year. Major producers include China (about 42,000 metric tons), Paraguay (about 4,000 metric tons), Argentina (about 3,000 metric tons), and Brazil (about 1,000 tons) (*3*).

The world supply of tung oil can be very volatile, as tung orchards can be greatly affected by adverse weather conditions and by age of the orchards. Though hearty, fast growing, and naturally resistant to disease and insects (tung trees require no fungicides or pesticides), tung trees are very sensitive to temperature levels during fruit-set. There is also some concern that aging orchards in South America

Table 7--U.S. imports of tung oil and its fractions, volume and value, by country, 1991-95

Country	1991	1992	1993	1994	1995
			Metric tons		
Argentina	2,380	3,455	2,137	1,627	2,797
Paraguay	3,085	823	1,557	2,526	1,235
China	179	318	546	1,206	379
Brazil	0	400	0	0	0
Other	0	0	30	42	16
Total	5,645	4,996	4,270	5,401	4,427
			Thousand dollars		
Argentina	2,584	6,828	4,175	1,881	2,739
Paraguay	3,051	825	2,801	2,438	1,044
China	206	709	926	1,201	382
Brazil	0	525	0	0	0
Other	0	0	70	43	18
Total	5,841	8,888	7,971	5,563	4,182

Source: U.S. Department of Commerce, Bureau of the Census.

may be losing productivity. In addition, Brazil produces primarily for domestic consumption and China uses as much as 25,000 metric tons of oil per year (*3*). A poor crop in any of the major producing countries often leads to volatile tung oil prices.

The current U.S. tung oil market is supplied largely by Argentina and Paraguay. During 1991-95, 50 percent of U.S. imports of tung oil came from Argentina, another 37 percent from Paraguay, and 11 percent from China (table 7). Small South American crops in 1991/92 and 1992/93 led to extremely high tung oil prices in the United States from mid-1992 through most of 1993 (table 40). Good crops in South America and China in 1993/94 helped prices decline in 1994. Decreased demand from Japan and Europe in 1994 and 1995 helped keep U.S. tung oil prices down, despite smaller crops the last two seasons.

However, U.S. tung oil prices have increased slightly this summer, and may rise even further, as South America and China are anticipating relatively small crops again this season. In addition, a lower supply of Chinese tung oil and renewed Japanese demand due to a strengthening economy are likely to put more upward pressure on prices for South American tung oil. How far prices will rise remains to be seen, but the market's continued volatility will likely encourage some companies to use other natural and synthetic alternatives in their product formulations.

Tung Production Is Centered in Mississippi

ATO is confident its revitalization of domestic production will help stabilize tung oil supply and prices. The company is currently planting its initial goal of 5,000 acres of tung trees, 500 acres of which will be company owned, and the rest contracted with individual growers. Current production of tung nuts is from several hundred acres of 3- to 4-year-old trees in southern Mississippi, although ATO is open to contracting with growers in other parts of the U.S. production region (a 100-mile wide area along the Gulf Coast extending from north central Florida into eastern Texas). The oil will be extracted at ATO's Tung Ridge Ranch mill near Poplarville, Mississippi, and will be distributed by IOP.

Blake Hanson, president of IOP, projects U.S. production for 1996 to be about 50,000 pounds of oil, which will have little impact on world markets. However, Mr. Hanson notes that as trees reach production maturity in about 4 to 5 years (when they will be 7 to 8 years old), the United States will be a significant producer of tung oil. He projects that in 5 years, U.S. production will be about 2 million pounds of oil. In 8 years, if all 5,000 acres are planted and producing, production could be over 4 million pounds. These trees could sustain commercial production for about 25 years, unless destroyed by natural disaster.

Prior U.S. production of tung oil occurred between the late 1930's and 1972, peaking in 1958 at 44.8 million pounds. Indicative of the tung oil industry, production during this period varied greatly from year to year, due primarily to the crop's natural bearing cycle and late frosts during budding. Weather will still be an important factor in this current production effort. However, higher fruit yields than were realized in previous decades are anticipated due to the use of heavy bearing varieties and improved farming methods. Harvesting costs will be reduced by mechanical harvesting, which is not used internationally and was not employed in the United States until the late 1960's. In addition, ATO plans to store surplus tung oil during years of over-production in an attempt to stabilize market prices during years of under-production. Under proper conditions, tung oil can be stored for several years.

Tung Oil Market Has Changed

The U.S. market for tung oil has changed dramatically during the past half-century. U.S. industrial use of tung oil peaked in 1947 at 130.4 million pounds, with over 75 percent used by the paint and varnish industry, and about 10 percent used by the resins industry. However, in the late 1940's, as the protective coatings industries shifted to lower cost substitutes, including synthetics and other oils, domestic consumption of tung oil declined dramatically. By 1961, domestic use had fallen to around 35.9 million pounds, with 73 percent consumed by the paint and varnish industry and 15 percent by the resins industry.

A general shift from the use of vegetable oil-based paints, which often require petrochemical solvents to reduce paint viscosity, in favor of water-based latex paints since the 1960's, contributed to a further decline in the use of tung oil. In 1994, domestic use was estimated at 9.3 million pounds, with 71 percent consumed by the resins and plastics industry, and 13 percent by the paint and varnish industry (table 30). The 1995 estimate for domestic use of tung oil is 20.2 million pounds, but this, according to industry sources, is likely overstated. One industry source estimates current tung oil use at around 10 million pounds, broken down as follows: 40 percent in paints, varnishes, and wood coatings; 40 percent in inks and overprint varnishes for graphic arts; 14 percent in fiberboard and other building materials; and 6 percent in miscellaneous items like caulk, concrete sealers, and brakepads (*3*).

Current and future uses of tung oil depend on several factors, including various regulations in the Clean Air Act Amendments of 1990 (CAAA) that require coatings manufacturers to reduce volatile organic compounds (VOC's) in their formulations. Petrochemicals such as toluene, xylene, methyl ethyl ketone, and methyl isobutyl ketone must be eliminated entirely. Chlorinated solvents must be removed from formulations because of their ozone-damaging potential. Because of these regulations, many companies are formulating new products, a number of which use tung oil because of its good drying ability and inherent solvency. However, these regulations have also caused the phaseout of some older tung-oil-containing products that include petrochemical solvents, which contain VOC's. Therefore, the net effects of CAAA regulations for the coatings industries will continue to play a major role in tung oil consumption. (For more information on VOC's and solvent replacements, see the fats and oils section of the June 1994 issue of this report).

In addition to air quality regulations, future uses of tung oil are likely to depend upon market stabilization, price reduction, and the development of new uses and new modified-tung oil products. Lower prices and the success of these new products will be vital to increasing the demand for tung oil.

Glycerine Uses Continue To Expand

Glycerine is a byproduct of producing soaps, fatty acids, and fatty esters from the triglycerides in vegetable oils and animal fats. Primary sources of glycerine include tallow, palm kernel oil, and coconut oil. Dow Chemical is presently the only U.S. manufacturer producing synthetic glycerine from petrochemicals.

Although the terms glycerine, glycerin, and glycerol often are used interchangeably, subtle differences in their definitions do exist. Glycerine is the commonly used commercial name in the United States for products whose principal component is glycerol. Glycerin refers to purified commercial products containing 95 percent or more of glycerol. Glycerol is the chemical compound 1,2,3-propanetriol.

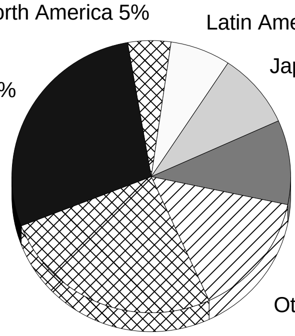
Worldwide production and consumption of glycerine is estimated at 1.5 billion pounds in 1995, up 10 percent from a year earlier. Europe and the United States account for over half of the consumption volume (figure 3). The supply of natural glycerine is directly related to fatty-acid and fatty-ester production. More sources of byproduct glycerine have been identified in recent years as uses for vegetable oils have increased, including processes for manufacturing biodiesel, fat substitutes, and polyols. In Europe, an estimated 100 million pounds of glycerine is currently produced in biodiesel production plants.

In 1995, the United States had an estimated glycerine production capacity of 522.5 million pounds. Roughly 25 percent of that is synthetic glycerine. Procter & Gamble and Dow Chemical are the two largest U.S. producers. In the United States, eight natural glycerine producers, including Procter & Gamble, currently have 15 production plants in operation. Dow has one synthetic glycerine plant.

Glycerine is used in over 1,500 applications and end products. It has an extensive list of traditional uses that include drugs, cosmetics, resins, polymers, explosives, toothpaste, tobacco processing, paints, paper manufacturing, lubricants, textiles, and rubber (see the December 1993 issue of this report for more information). Pharmaceuticals, toothpaste, and personal-care products were major uses in 1995 (figure 4), and more applications are being developed all the time. For example, because of its environmentally friendly characteristics, glycerine has potential in new-generation fabric softeners, deicing fluids, and drilling fluids.

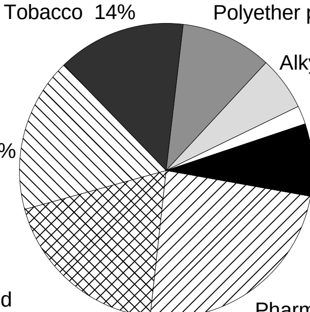
The glycerine market has been tight since 1992. While world production has increased, rising demand continues to outpace supply. Glycerine competes with sorbitol and propylene glycol in food, beverage, and tobacco applications, but these and other glycerine substitutes may not be readily accepted by consumers because of their taste. Although tight supply conditions are expected to continue, declining cellophane and explosive use will compensate for some of the projected growth in newly identified applications, such as fabric softeners, sports drinks, and

Figure 3
Estimated World Consumption of Glycerine, By Country, 1995 1/



1/ Worldwide glycerine production and consumption is estimated at 1.5 billion pounds in 1995.
Source: Irshad Ahmed, Booz-Allen and Hamilton Inc., McLean, Virginia, July 1996.

Figure 4
Estimated End Uses of Glycerine In the United States, 1995 1/



1/ U.S. glycerine production capacity is estimated at 522.5 million pounds in 1995.
Source: Irshad Ahmed, Booz-Allen & Hamilton Inc., McLean, Virginia, July 1996.

deicing fluids.

Glycerine prices fluctuate widely, depending on supply and demand factors. Historically, glycerine prices have ranged from 51 cents to $1.08 per pound. Current prices are between $1.05 and $1.08 per pound. High 1996 prices are due to a worldwide shortage of glycerine estimated at roughly 100 million pounds. Demand is strong because of new applications, an unwillingness on the part of end-product manufacturers to switch to substitutes, and environmental pressures to enhance end-product biodegradability.

To satisfy the rising demand for glycerine, producers are boosting capacity by an estimated 50 million pounds through expansion and debottlenecking of existing facilities. Henkel Corporation, which is headquartered in Germany, is investing $60 million to add 10 to 20 percent to its worldwide glycerine capacity.

U.S. demand in 1995 is estimated at 420 million pounds. The market is expected to grow 3 to 4 percent per year through 2000, higher than its historical growth rate of 2 to 3 percent per year, due to a wide variety of newer applications and product lines. By the year 2000, demand is projected to reach 500 million pounds. Glycerine prices are expected to remain high because of continued increases in demand.

Fuel and Environmental Regulations Offer Challenges for Biodiesel

One potential source of glycerine in the United States is biodiesel. However, despite new market opportunities for alternative fuels created by CAAA and the Energy Policy Act of 1992 (EPACT), biodiesel commercialization still faces a number of regulatory and market barriers.

One challenge stems from EPACT's alternative-fuel, motor-fleet regulations that require Federal, State, and alternative fuel providers to increase their purchases of alternative-fueled vehicles. In a March 1996 final rule on the Alternative Fuel Transportation Program, the U.S. Department of Energy (DOE) concluded that neat (100 percent) biodiesel meets EPACT's criteria as an alternative fuel for this program (*5*). However, biodiesel is an expensive fuel and to lower its cost, potential users want to blend it with petroleum diesel. The most common blend used today is a mixture of 20-percent biodiesel and 80-percent petroleum diesel (B20). However, B20 vehicles have been disqualified from the Program based on the March 1996 final rule. In the absence of a special ruling on B20 or some other blend, it is unlikely that an immediate demand for biodiesel will be created through the Alternative Fuel Transportation Program. Biodiesel advocates are working with DOE to establish an appropriate blend level that will qualify as an alternative fuel.

Like most fuel producers, manufacturers of biodiesel and biodiesel blends have to meet CAAA fuel-property definitions and satisfy health-effect requirements. Hence, another regulatory hurdle stems from the U.S. Environmental Protection Agency's (EPA) current rule-making process of defining a standard diesel fuel. This definition will enable fuel manufacturers to determine whether their diesel fuels are substantially similar (sub-sim) to EPA's definition of diesel fuel in terms of chemical composition. When the final rule is implemented, most fuel manufacturers, including those of biodiesel and biodiesel blends, must either be able to prove that their fuels are sub-sim to the diesel standard or receive a waiver under CAAA Section 211(f). If fuel manufacturers are able to show that biodiesel has the same emission characteristics and the same engine degradation properties as EPA's definition of diesel fuel, they may be able to get a waiver for biodiesel. EPA expects to propose definitions for diesel fuel in December 1996, with an expected final rule in December 1997.

Biodiesel producers also have to overcome the potential public-health-effect data requirements under CAAA Section 211(b) and (c). These provisions require manufacturers to gather preliminary research data on their fuels to evaluate the potentially harmful human health effects of fuel emissions and submit this information to EPA by May 1997. Biodiesel analysts are currently conducting research that will help biodiesel comply with both the sub-sim and health-effect requirements. Negative findings from these data could delay commercialization and require the biodiesel industry to conduct a new round of expensive health-effect testing to address EPA concerns.

Another regulatory challenge for biodiesel relates to EPA's requirements on implementing particulate matter (PM) standards for pre-1994-model-year urban buses in areas with a 1980 population of more than 750,000. Finalized in 1993, the Urban Bus Retrofit Rebuild Program is designed to reduce PM exhaust emissions from older-model urban buses. Although the standards were to become effective when engines are rebuilt or replaced after January 1, 1995, EPA delayed enforcement for 1 year.

EPA has developed two compliance options to provide some flexibility to bus operators in meeting the new PM standards. The standards in both options are based on what PM reductions can be achieved by equipment certified by EPA. The first option requires an operator to install certified PM-reduction equipment on each of their buses when bus engines are rebuilt or replaced. (An urban bus engine generally undergoes two or three rebuilds during its 15-year lifetime.) The second option requires that PM levels for the entire bus fleet be below a yearly average target level at the beginning of each year. This target level can be calculated by urban bus operators through a computer program provided by EPA. Average target levels will vary by engine age and PM-reduction requirements for the various engine types within the fleet.

To date, five technologies in the form of rebuild kits and/or catalytic converters have been certified by EPA for the Urban Bus Retrofit Rebuild Program. In June 1995, Twin Rivers Technologies, a Massachusetts-based company, submitted a certification package to EPA different from the five technologies. This package aims to lower PM in some bus engines through the combined use of B20 and a catalytic converter. Even with EPA certification, the B20 package still faces an economic challenge, because under the first compliance option, the certified rebuild kits and catalytic converters are cheaper to use than the B20 package. Biodiesel may have a better opportunity under the second option, depending on how the B20 package affects fleet operators' average PM target levels.

Additional Research Is Needed

Research is needed to help biodiesel comply with government regulations, including exploring its environmental and health benefits and economic feasibility. USDA, DOE, and the National Biodiesel Board (NBB) have been working together to investigate these topics. For example, representatives from these organizations, along with university and other researchers, recently attended a biodiesel workshop at Mammoth Hot Springs, Wyoming, May 21-22, 1996. DOE, through its Pacific Northwest and Alaska Regional Bioenergy Program, and the University of Idaho's National Center for Advanced Transportation Technology sponsored the event, entitled Commercialization of Biodiesel: Environmental and Health Effects Workshop. The workshop's purpose was to assess the health and environmental effects associated with emissions from compression ignition engines and to identify the benefits to be gained by using biodiesel.

Workshop participants agreed that, when compared to petroleum diesel, neat biodiesel generally offers the following known environmental and health benefits: biodegradability; reductions in soot, greenhouse gases, and some emission levels; and a positive energy balance. Several other benefits were identified, such as reduced toxicity and lower amounts of ozone precursors and mutagenic and carcinogenic compounds. However, additional data are needed to verify these potential benefits and how they change when blended with petroleum diesel. Workshop organizers hope to use these known and potential environmental and health benefits to help meet CAAA health-effect data requirements and as an education campaign to boost biodiesel commercialization.

An important opportunity to show biodiesel's net environmental benefits will be an analysis of biodiesel's life-cycle. The main purpose of this joint USDA-DOE study is to compare the environmental effects of biodiesel versus petroleum diesel. Life-cycle analysis accounts for all production activities and raw materials involved in producing a product. For example, with biodiesel, the analysis begins with assessing the environmental effects of growing soybeans, including the production of seed, fertilizer, and other inputs used on the farm. After the inputs aspect is analyzed, the environmental effects are then examined through the product's manufacturing, followed by consumption, and finally the waste stage (recycling or disposal). A final report is expected before the end of the year. [*Crambe and industrial rapeseed*: Lewrene Glaser, ERS, (202) 219-0091, lkglaser@econ.ag.gov. *Tung*: Charles Plummer, ERS, (202) 219-0717, cplummer@econ.ag.gov, and Sandra Pyles, ERS. *Glycerine*: Irshad Ahmed, Booz-Allen & Hamilton, (703) 917-2060, 71332.3160@compuserve.com. *Biodiesel*: Anton Raneses, ERS, (202) 219-0752, araneses@econ.ag.gov; Jim Duffield, ERS/OENU, (202) 501-6255, duffield@econ.ag.gov; Leroy Watson, NBB, (202) 331-7373; and Craig Chase, Technical and Engineering Management, (307) 527-6912, 104723.623@compuserve.com.]

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