Biodiesel: The Sustainability Dimensions

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By Al Kurki,
Amanda Hill,
and Mike Morris
NCAT Program
Specialists

Biodiesel is a renewable and environmentally friendly fuel. This publication surveys many dimensions of biodiesel production and use. Net energy balance, sustainable bioenergy crops, scale of production, consumer access, and the economics of biodiesel are all critical when discussing a sustainable energy future for this country. Above all, increased fuel efficiency and increased diesel engine use in the United States will be needed in order for biodiesel to become a meaningful part of our energy future.

Contents

Sunflowers. Photo courtesy of USDA ARS.

Introduction

Biodiesel offers well-publicized environmental, economic, and national security benefits. Biodiesel combustion emits fewer regulated and non-regulated pollutants than petrodiesel (with the possible exception of nitrogen oxides). Further, its lubricity extends engine life, and it is a biodegradable product.

Biodiesel could benefit farmers and rural communities, depending on ownership of production facilities and the mix and marketability of useful co-products. And biodiesel could reduce dependence on foreign oil and associated fluctuations in availability and price.

This publication addresses the sustainability dimensions of biodiesel production and use. These dimensions include the net energy balance of biodiesel relative to other fuels and the link between raising bioenergy crops and sustainable, soil-building practices. Other considerations include the qualities of different biodiesel feedstocks and the economics of production and use. This publication also raises other issues, such as access, scale and ownership of production, co-product development, and the extent to which biodiesel and other biofuels can effectively replace petroleum fuels.

All dimensions of biodiesel production and use are fundamentally intertwined with each other and with the topic of environmental sustainablility. To isolate and address any single aspect of biodiesel invites reference to others.

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Background and Context

The Bigger Picture

The United States consumes transportation fuels at an extremely high rate per capita compared to other industrialized countries. In 2001, for example, 522 gallons of petroleum transportation fuels were expended for every man, woman, and child in this country—compared to 421 gallons per capita in Canada, 211 gallons in Germany, and 196 gallons in Japan. (1)

Two major policy and practical changes must occur for biodiesel to have a real impact on this country's energy future:

- A national commitment to energy efficiency in every facet of American life. This may include community redesign, broad changes in food production and delivery systems, greater commitment to mass transit, and increased mileage efficiency for vehicles.
- A massive conversion from gasoline-powered autos and light trucks to cleaner-burning diesel autos. This sort of change is not without precedent. U.S. farmers switched from gasoline to diesel powered farm equipment in the late 1970s and '80s—an important factor in agriculture's big energy use reduction since the 1970s. Major automakers (General Motors, Toyota, Ford, and Daimler-Chrysler) plan to produce more diesel-powered cars for the U.S. market in the years ahead.

Most farmers and ranchers operate against tight margins. Capturing energy efficiencies and making the best use of biofuels may be nearly impossible without retooling current food production and distribution systems. For example, when food is shipped over shorter distances, energy consumption and freight costs are reduced. Creating local markets for locally grown foods can accomplish this. Rotating nitrogen-producing or phosphorous-availing crops with cash crops can save energy on the farm. Changing tillage methods or technologies, and properly scaling equipment to the farm operation can also save energy. These changes may be important precursors to the cost-effective production of biodiesel.

Related ATTRA Publications

Anaerobic Digestion of Animal Wastes: Factors to Consider

Biodiesel—a Primer

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Organic Soybean Production

Sustainable Corn and Soybean Production

Oilseed Processing for Small-Scale Producers

Moving Beyond Conventional Cash Cropping

Biodiesel as a Transportation Fuel

Simply put, biodiesel is the product of mixing vegetable oil or animal fat with alcohol (usually methanol or ethanol) and a catalyst, usually lye. Glycerin is the main by-product.

Biodiesel performs very similarly to low-sulfur petroleum-based diesel in terms of power, torque, and fuel efficiency, and does not require major engine modifications. Joshua Tickell, the author of several books on biodiesel, claims it contains about 12 percent less energy than petrodiesel (biodiesel = 37 megajoules per kilogram vs. petrodiesel = 42 megajoules per kilogram). This is partially offset by a seven percent average increase in combustion efficiency of biodiesel. No overall perceived decrease in performance is noted for most vehicles using biodiesel, even though, on average, there is five percent less torque, power, and fuel efficiency. (2)

Biodiesel is considered a safer fuel than petrodiesel. Biodiesel has a high flashpoint of over 300ºF (150ºC), compared to 125ºF (52ºC) for petrodiesel. The flashpoint is the temperature at which a fuel's vapor can be ignited. Biodiesel also has a relatively high boiling point and is generally considered safer to handle.

Modern diesel fuels are injected into a highly compressed chamber where combustion occurs without a spark plug. Biodiesel reacts more rapidly in the chamber with less combustion delay than most petrodiesel fuels and is, therefore, assigned a higher cetane number—the measure of ignition quality. Many of biodiesel's emission benefits stem from its high ignition quality. (3)

Biodiesel can be produced from virtually any kind of vegetable oil—new or used. The U.S. Department of Energy estimates that about 26.7 million gallons of biodiesel were sold in 2003. Total U.S. diesel consumption that year was more than 39.9 billion gallons. (4)

Qualities and Quantities of Biodiesel and Biodiesel Feedstocks

At cold temperatures, diesel fuels form wax crystals that cloud the product and affect fuel performance. This temperature threshold is called the ***cloud point*** and occurs at 20º F (-7ºC) for most commonly used grades of petrodiesel. Biodiesel fuels generally have a cloud point between 25 and 60ºF (4 to 16ºC), depending on the amount of free fatty acids in the product. Waste vegetable oil contains more free fatty acids (FFAs) than virgin oils. Free fatty acids raise the cloud point of the fuel, so biodiesel made from used cooking oil or animal fat will cloud at higher temperatures than biodiesel made from new vegetable oil feedstock.

The American Society for Testing and Materials (ASTM) recommended in 1996 that biodiesel have a cloud point of at most 38º F. The cloud point can be lowered with winterizing additives formulated for diesel fuels. Biodiesel blends such as B20 (20 percent biodiesel/80 percent petrodiesel) typically require no action beyond that necessary for ordinary petrodiesel. (5)

The United States produces approximately 3 to 5 billion gallons of waste vegetable oil every year in restaurants. (7, 8) Much of this product goes to landfills; some is used in the soap and cosmetics industry. Waste cooking oil could contribute only a small percentage of total U.S. diesel demand. Converting this waste into a relatively low-cost resource, however, reduces the environmental degradation and costs of disposal in landfills.

The quantity of biodiesel produced from crops is also limited. If rapeseed were grown on every acre of cropland available in the United States in 2002, an estimated 36.3 billion gallons of oil could be produced—very close to current national demand. (6) But of course it is not practical to use all available farmland to produce transportation fuels. Moreover, very serious ethical issues are raised by sacrificing croplands for vehicle fuel in a world where people are hungry and populations are growing. (For a discussion of the "food vs. fuel" controversy, see the Web site Journey to Forever, *www.journeytoforever.org*.)

Charles L. Peterson, PhD., of the University of Idaho, notes that 37 million acres of cropland were reported idle in 2002. That acreage might meet 11 percent of U.S. diesel demand with 3.7 billion gallons of vegetable oil. Practical use of idle land would be less than the 37 million acres, though, because much of the acreage is highly erodible, dry, and has poor soils.

Ninety percent of the biodiesel virgin oil feedstock in the United States in 2001 was from soybeans. There are many reasons why soybean draws most of the market share as a biodiesel feedstock. Soy is a versatile, nitrogen-fixing crop that yields oil and food for humans and livestock. Soybean meal is of higher market value than soy oil. Consequently, soy oil is a low-priced byproduct available in relatively large volumes. Cur-

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The Chemistry of Biodiesel

Transesterification is the term used to describe the transformation of vegetable oil into biodiesel. Vegetable oil is made up of three esters attached to a glycerin molecule—a triglyceride. An ester is a hydrocarbon chain available to bond with another molecule. During transesterification, the esters in vegetable oil are separated from the glycerin molecule, resulting in the byproduct glycerin. The esters then attach to alcohol molecules (either methanol or ethanol) to form biodiesel. In order to prompt the esters to break from the glycerin and bond with the alcohol, a catalyst (sodium hydroxide or potassium hydroxide) must be used. The glycerin byproduct can be further processed to make soap.

Free fatty acids are present in vegetable oil when it has been used in cooking. When free fatty acids are present, as in waste vegetable oil, more base catalyst is required to neutralize the FFAs, which renders the biodiesel fit for use. (Adapted from *From the Fryer to the Fuel Tank* by Joshua Tickell)


Soybeans. Photo courtesy of USDA ARS.

rently, it is a cheaper virgin feedstock than other oilseeds. The processing and distribution infrastructure for soybeans is already in place, with more capacity being added as more biodiesel production facilities come online.

However, the list of the top thirty plant species with the highest oil yield per acre for biodiesel doesn't even include soybeans. Of the more common commodity-style crops that can be raised for biofuels in this country, soy ranks as only the eighth best oil-yielding crop.

This may be good news for farmers who don't or can't grow soybeans on their farms. Rapeseed *(brassica napus)* rates as the highest yielding oil source in this country at 122 gallons per acre. Sunflower has the third best yield on this shorter U.S. list at 98 gallons per acre, followed by safflower (80 gallons per acre) at fourth, and mustard, rated seventh (59 gallons per acre). Table 1 shows the oil yields in gallons per acre. (One gallon of oil = 7.3 pounds.) (4) Please keep in mind as you examine this table that the yields will vary in different agroclimatic zones.

Table 1: OIL PRODUCING CROPS

Adapted from Joshua Tickell, *From the Fryer to the Fuel Tank: The Complete Guide to Using Vegetable Oil as an Alternative Fuel.* 3rd Ed. 2000.

Plant	Latin Name	Gal Oil/ Acre	Plant	Latin Name	Gal Oil/ Acre
Oil Palm	*Elaeis guineensis*	610	Rice	Oriza sativa L.	85
Macauba Palm	*Acrocomia aculeata*	461	Buffalo Gourd	*Cucurbita foetidissima*	81
Pequi	*Caryocar brasiliense*	383	Safflower	*Carthamus tinctorius*	80
Buriti Palm	*Mauritia flexuosa*	335	Crambe	*Crambe abyssinica*	72
Oiticia	*Licania rigida*	307	Sesame	*Sesamum indicum*	71
Coconut	*Cocos nucifera*	276	Camelina	*Camelina sativa*	60
Avocado	*Persea americana*	270	Mustard	*Brassica alba*	59
Brazil Nut	*Bertholletia excelsa*	245	Coriander	*Coriandrum sativum*	55
Macadamia Nut	*Macadamia terniflora*	230	Pumpkin Seed	*Cucurbita pepo*	55
Jatropa	*Jatropha curcas*	194	Euphorbia	*Euphorbia lagascae*	54
Babassu Palm	*Orbignya martiana*	188	Hazelnut	*Corylus avellana*	49
Jojoba	*Simmondsia chinensis*	186	Linseed	*Linum usitatissimum*	49
Pecan	*Carya illinoensis*	183	Coffee	*Coffea arabica*	47
Bacuri	*Platonia insignis*	146	Soybean	*Glycine max*	46
Castor Bean	*Ricinus communis*	145	Hemp	*Cannabis sativa*	37
Gopher Plant	*Euphorbia lathyris*	137	Cotton	*Gossypium hirsutum*	33
Piassava	*Attalea funifera*	136	Calendula	*Calendula officinalis*	31
Olive Tree	*Olea europaea*	124	Kenaf	*Hibiscus cannabinus L.*	28
Rapeseed	*Brassica napus*	122	Rubber Seed	*Hevea brasiliensis*	26
Opium Poppy	*Papaver somniferum*	119	Lupine	*Lupinus albus*	24
Peanut	*Ariachis hypogaea*	109	Palm	*Erythea salvadorensis*	23
Cocoa	*Theobroma cacao*	105	Oat	*Avena sativa*	22
Sunflower	*Helianthus annuus*	98	Cashew Nut	*Anacardium occidentale*	18
Tung Oil Tree	*Aleurites fordii*	96	Corn	*Zea mays*	18

Rotational Benefits of Oilseed Crops Other than Soybeans

Higher-yielding oil crops like safflower, mustards, and sunflower have significant rotational benefits. For example, deep safflower and sunflower roots help break up hardpan and improve soil tilth. Canola and rapeseed make soil nutrients available for succeeding years' crops. Oil-yielding brassicas such as mustards, canola, and rapeseed help reduce soil-borne diseases and pathogens. Table 2 shows the rotational benefits of certain oilseed crops.

Table 2: ROTATIONAL BENEFITS OF OILSEED CROPS
See References section for sources.

Oil Seed Crop	Yield (Gal Oil/ Acre)	Rotational Benefits	Management Practices
Rapeseed/Canola	122	Both are cool season crops. Attract hoverflies whose larvae prey on aphids. Has value as green manure because it makes phosphorus available for subsequent year's crops and initial research shows it inhibits growth of small weed seeds. Can serve as a nutrient catch crop. Provides weed control at high seeding rates. Canola is edible version of rapeseed, winter and spring varieties are available. Winter varieties are not as winter hardy as winter small grains (wheat, barley). Tap root breaks up hardpan. Good rotation crop, breaking cycles of weeds, disease and insect pests. Mellows soil.	Sclerotinia-susceptible. Should not be grown within five years of sunflower.
Peanut	109	Peanuts are often grown in rotation with other crops to replace soil nitrogen and decrease the need for synthetic fertilizers.	
Sunflower	98	Catch crop for nutrients, breaks up hardpan and compacted soil, may reduce fusarium when used in rotation with grain crops, can serve as a windbreak. Row-cropping provides opportunity for mechanical weed control during growing season.	Susceptible to sclerotinia and should be grown once very five years. Should not be raised in short rotations with crucifers.
Safflower	80	Breaks up hardpan and compacted soil with its deep roots.	
Crambe	72	Cool season crop—similar to canola, but more disease resistant and is tolerant of flea beetle damage.	
Camelina	60	Cool season crop—a crucifer like canola, rape, mustard, and crambe. Has allelopathic effects and it is somewhat drought resistant. It fairly weed competitive when winter or very early spring seeded.	
Mustard	59	Primarily a cool season crop. Nutrient catch crop. Has nematicidal properties that reduce soil-borne pathogens. Can smother weeds and has allelopathic effects on weeds.	Sclerotinia-susceptible. Should not be grown within five years of sunflower.
Flaxseed/Linseed	49	A good crop for interseeding or to sow following a competitive crop onto clean field. Not weed competitive on its own. It is a light feeder.	
Soy	46	Fixes nitrogen, although most of the nitrogen is removed with the bean harvest.	Poor choice for controlling erosion or building organic matter levels.
Lupine	24	Moderate nitrogen fixer, takes up soil phosphorus—making it available for subsequent crops, reduces erosion and crop disease, deep taproots can open and aerate soil.	
Oat	22	Erosion control, enhances soil life, and adds organic matter. Serves as a catch crop and a nurse crop, can be used for weed control in rotations, crop residue reduces nitrogen leaching.	

Canola. Photo courtesy of USDA ARS.

State agricultural experiment stations, Extension Service or the Natural Resource Conservation Service (NRCS) may have information on specific oilseed crops that can be raised in certain locales and the best rotations for soil-building and pest suppression benefits. Sustainable agriculture groups are often helpful, since they may have farmer members who have experience raising brassicas or other oilseed crops in rotation. Rotational benefits are also outlined in other sources listed in the **References** section of this publication.

The Energy Balance of Biodiesel Compared to Ethanol and Petroleum Diesel

A debate within scientific and policy circles centers on the net energy balance of various ethanol and biodiesel feedstocks. The energy balance is "a comparison of the energy stored in a fuel to the energy required to grow, process and distribute that fuel." (7) In this publication we use the most commonly quoted energy balance statistics available at press time.

Biodiesel provides a positive energy balance, according to most sources: for every unit of energy needed to produce biodiesel, 2.5 to 3.2 units of energy are gained. Evidence suggests virgin oil from sources other than soy may have an even higher energy content. Overall, biodiesel is said to have the highest energy yield of any liquid fuel. According to the Minnesota Department of Agriculture Web site (8):

- Biodiesel provides an energy yield of 3.2 (soybean oil).
- Bioethanol provides an energy yield of 1.34.
- Petrodiesel provides an energy yield of .843.
- Petro gasoline provides an energy yield of .805.

Economics of Biodiesel Production and Use

Many studies have been conducted on the potential macroeconomic benefits of large-scale biodiesel production in various locations around the country. These studies also give some indication of the potential economic impacts across the nation. According to the Hampel Oil Distributors' Biodiesel Fact Sheet (9), three major economic benefits would accrue to a state (in this case, Iowa) from the increased use of biodiesel:

1) Biodiesel expands demand for soybean oil, which raises the price processors pay for soybeans.

2) Soybean farmers near the biodiesel plant receive slightly higher prices for soybeans.

3) The presence of a facility that creates energy from soybeans adds value to the state's industrial and income base.

The University of Missouri estimates that 100 million gallons of biodiesel production could generate an approximate $8.34 million increase in personal income and more than 6,000 temporary or permanent jobs in a metropolitan region. (10) Another study predicts a 100 million-gallon biofuels plant could generate a one-time economic boost of $250 to $359 million during the construction phase.

Additionally, the local economic base is projected to expand by $250 million through annual direct spending of $140 million. More than 100 new full-time jobs would be created at the plant and more than 1,500 indirect jobs in the state, and annual community household income in the area would increase by $50 million.

A 1998 USDA economic study estimated that a sustained national market for 100 million gallons of biodiesel could increase the value of the U.S. soybean crop by more than $250 million and increase soybean oil prices by 14 percent. A 70 million gallon demand would add 10 to 18 cents per bushel to the price of soybeans. (11)

The cost of the vegetable oil feedstock is the single largest factor in biodiesel production costs. In 2004, wholesale biodiesel costs ranged between $1.25 and $2.50 per gallon, before taxes, depending on transportation, distribution, and feedstock costs.

Commercially produced biodiesel has to meet the ASTM D-6751 quality standard. Some biodiesel users and "home brewers" are willing to accept tradeoffs in small-scale production. Waste vegetable oil can be used to make biodiesel, and is often available free or at low-cost compared to virgin feedstocks.

Straight vegetable oil (SVO) can also be used as a fuel, but there are risks. It is much more viscous than either petrodiesel or biodiesel and must be filtered to five microns and heated to at least 140°F before use in diesel engines. It doesn't burn the same in the engine and many studies have found that it can cause lacquering and other kinds of engine damage.

If you are tempted to try SVO, a professional engine conversion is strongly recommended. This conversion often includes installing a second fuel tank, allowing you to start and shut down on biodiesel or petrodiesel. The basic idea is to use only preheated SVO and to clear your fuel lines before shutting down the vehicle.

The economics of producing and using biodiesel on a small scale are outlined in ATTRA's publication *Biodiesel - a Primer* (12) and in other sources, such as Maria "Mark" Alovert's excellent *Biodiesel Homebrew Guide.* (13) The examples outlined in *Biodiesel: a Primer* demonstrate that a five-gallon batch of biodiesel yields a much different economy of scale than does a 250-gallon run.

The "Bulk Commodity Treadmill"

Large plots of undifferentiated plant species grown on the same ground year after year or in very short rotations are known as *monocultures.* The negative environmental aspects of monocultures are well researched and proven. The same holds true for any oilseed crop considered for biodiesel. Monoculture crop production can deplete the soil of organic matter and essential nutrients, which can result in soil compaction, erosion, or downstream nutrient loading. Monocultures also create more insect, pathogen, and weed management challenges.

Monocultures exhibit an economic dimension as well—at what point does any cash crop become an undifferentiated bulk commodity raised in such high volumes that it doesn't have enough value for growers to turn a profit? Many farmers and ranchers are raising more diverse, higher-value food crops and animals because they perceive that subsidized, bulk commodity production is economically unsustainable for them. This is a factor to consider in producing biofuel crops as well.

Ownership and Design of Biodiesel Production

Ownership and design of biodiesel production is also related to feedstock price and a fair rate of return to farmers. Farmer ownership of at least part of the production process beyond the farm gate keeps more dollars in farmers' pockets and in the local community. This has been proven time and again, most recently in the Midwest with etha-

Mustard. Photo courtesy of USDA ARS.

Entrepreneurs and scientists in Montana discovered that a biodiesel plant could not pay farmers a sustained fair price for their bioenergy crops (canola or industrial rape) unless the co-products could be manufactured and sold.

nol production. According to David Morris of the Institute for Local Self-Reliance, "If farmers own the ethanol plants; that is, if they own a share of the manufacturing facility that converts their raw material into a finished product, they can receive dividends of 20-30 cents per gallon." (14)

Another dimension related to farmers making a reasonable profit is the value of biodiesel co-products. For example, entrepreneurs and scientists in Montana considering biodiesel development in that state discovered that a biodiesel plant could not pay farmers a sustained fair price for their bioenergy crops (canola or industrial rape) unless the co-products could be manufactured and sold.

This means that a *biorefinery* is probably the most economically sustainable means of larger-scale biodiesel production. Within this production design or paradigm, the crude vegetable oil pressed from bioenergy crops is the base for all sorts of products, ranging from relatively lower value biodiesel to biolubricants for motors. The crop pressings have potential value as biopesticides and animal feed. Table 3 shows some of the possible co-products of biodiesel. (15)

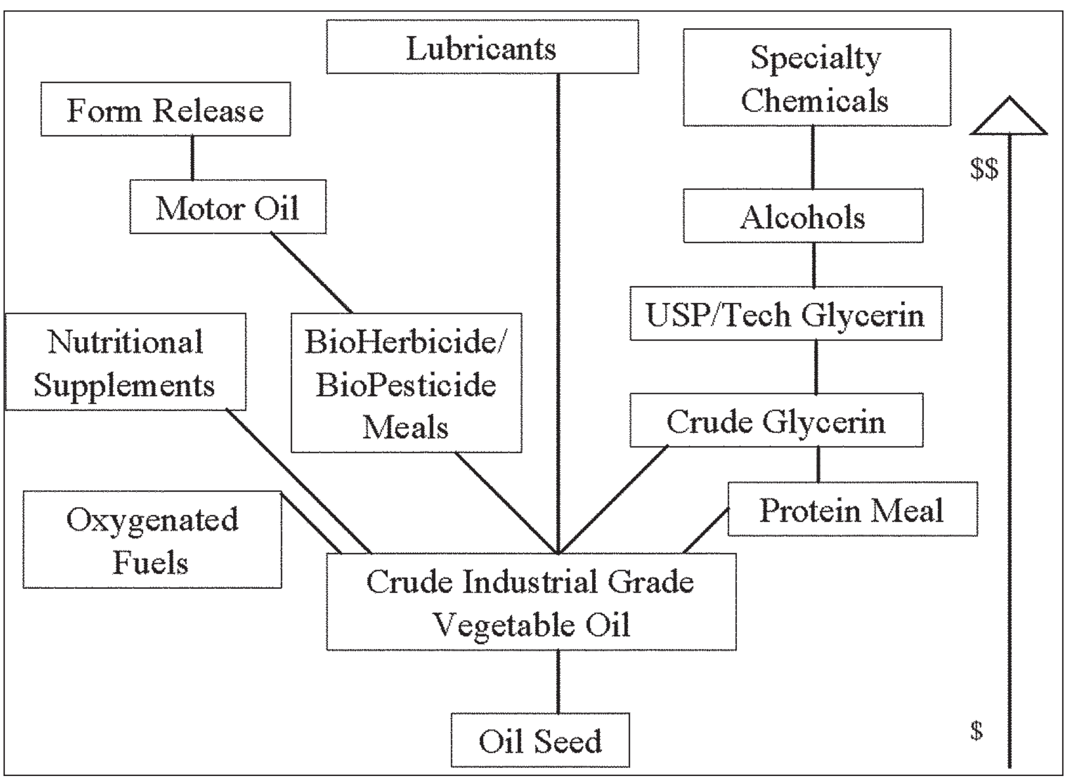
Biorefineries are not a new concept. They are, in fact, similar to petroleum refineries. However, their process complexities, capitalization, and permitting requirements go far beyond making biodiesel in the garage or farm shop.

Scale of Biodiesel Production

In the Kansas-based Land Institute's Sunshine Farm project, researchers concluded that farm-scale biodiesel production might not be cost effective for farmers to pursue individually, but that some level of community-scale biodiesel production with standards satisfactory to engine manufacturers would be more feasible. (16) Individuals would each have to spend too much energy and resources to produce biodiesel on a farm. Small community-scale biodiesel production would likely produce more biodiesel for less effort. That scale of production was not precisely defined in the Land Institute report. Far more research and documented practical experience in biodiesel production in dispersed, near-farm, and community-level settings is needed.

Larger scale biodiesel production is progressing rather quickly. In July 2005, 35 biodiesel production plants were online in the United States. Many new plants have begun production, with an expected increase in production to more than 100 million gallons by the end of 2005. The new plants range in initial production capacity from about 5 million gallons per year (MGY) at a plant in Indiana to a pro-

Table 3: VALUE ADDED TREE
Adopted from Paul Miller's *Value Added Tree in A Biobased Vision for Montana and the Pacific Northwest.* 2003.



posed 30 MGY plant in Iowa. (17, 18) Archer Daniels-Midland has plans for a 50 MGY plant in North Dakota (using canola), and Cargill plans a 37.5 MGY plant in Iowa.

Scale is a strong determinant of who can afford to own all or part of a plant or biorefinery, bear the risks, and accrue the benefits of that ownership. For example, the 5 MGY Indiana plant will cost approximately $10 million. The new plant is expected to expand capacity to 30 MGY over time. A planned 20 MGY plant in Wisconsin is expected cost 10 to 15 million dollars. (19)

Photo courtesy of USDA ARS.

Access to Biodiesel

Biodiesel is currently available in most states that produce oilseed crops, and many farmers use biodiesel as a means of fostering production and raising public awareness. Nonetheless, farmers' access to biodiesel for farm use is another dimension that requires consideration and raises potential for a sad irony.

Farmers who raise crops for biodiesel in isolated rural areas may not have ready access to the finished fuel. Unless farmers intend to make biodiesel on location, or a larger scale local biodiesel production facility is online, many farmers find they cannot use the fuel they are working to create.

On its Web site, the National Biodiesel Board lists about 50 suppliers to contact to have biodiesel shipped across the U.S. Almost every state has at least one pump station that offers some blend of biodiesel, though not necessarily within practical distance for most potential customers. The site posts a map of retail outlets for biodiesel across the country. The board recommends asking regional fuel distributors to get more biodiesel supplied locally. (20)

Conclusion

Resources are available to help farmers and consumers determine the best means to manage the advantages biodiesel has to offer. Biodiesel has "tailpipe benefits" and holds great promise as a sustainable energy source, if several sustainability principles are treated seriously:

1. Capture as much energy efficiency as possible on and off the farm, to reduce transportation fuel demand, reduce production costs, and improve energy balance.
2. Convert as much waste as possible into a useable resource, such as converting waste vegetable oil into fuel.
3. Put oil-producing crops and high-quality agricultural lands to their highest and most sustainable use, which will often be food production instead of energy production.
4. Raise bioenergy crops that enhance soil and water resources.
5. Create a range of diverse opportunities for biodiesel production in terms of the scale, design, and ownership so farmers and rural communities can share in the economic benefits.

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Web Resources

National Biodiesel Board
www.biodiesel.org

Veggie Van Home Page
www.veggievan.org

Biodiesel America
www.biodieselamerica.org

Journey to Forever
http://journeytoforever.org/biodiesel.html

DOE Energy Efficiency and Renewable Energy Alternative Fuels Data Center
www.eere.energy.gov/afdc/altfuel/biodiesel.html

Minnesota Department of Agriculture Diversification Options—Crops
http://mda.state.mn.us/mgo.crops/default.htm

Saskatchewan Food and Agriculture Cropping Decisions
http://agr.sk.ca/docs/econ/econ_farm_man/production/cereals/cropdecisions99.asp

Biodiesel and Straight Vegetable Oil Kits for Vehicles, Biodiesel Coops, Producers and More
www.ecobusinesslinks.com/biodiesel.htm

Notes

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By Al Kurki, Amanda Hill and Mike Morris
NCAT Program Specialists

Paul Driscoll, Editor
Amy Smith, Production

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