A Technical Guide from the Minnesota Department of Commerce State Energy Office Summer 2003

BIODIESEL BASICS

Biodiesel is the trade name for a new alternative fuel product to replace petroleum diesel (petrodiesel) fuel. It is commonly manufactured from vegetable oils, such as soybeans, or waste restaurant greases. Just as ethanol can be blended with gasoline, biodiesel can be blended with petrodiesel. Pure biodiesel, also called "100%" or "neat" biodiesel and abbreviated B100, can be used full strength or blended with petrodiesel in varying percentages, commonly as a 20% blend (B20) or a 2% blend (B2). Biodiesel can be used in the same transportation, heating, and electricity generating applications as petrodiesel.

Officially, biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to ASTM specifications for use in diesel engines. Biodiesel refers to the pure fuel before blending with diesel fuel. Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (ie: B20 is 20% biodiesel, 80% petroleum diesel).

Biodiesel fuel has several advantages over petrodiesel: It is safer, less polluting, and is valuable as a rural economic development tool. It is less toxic than table salt and biodegrades as fast as sugar. It is less flammable than petrodiesel, can be made from renewable or waste resources, produces less air pollution when burned, and contributes to the local economy.

Minnesota soybean farmers support making biodiesel using soybean oil. It takes about 7.3 pounds of soybean oil to produce a gallon of biodiesel (one bushel of soybeans produces about 1.6 gallons of biodiesel, 1.0 gallons of glycerin, and 48 pounds of soybean meal).

MAKING BIODIESEL

Biodiesel is produced from vegetable oil through a refining process called transesterification—a chemical process that mixes vegetable oil with an alcohol and a base, commonly methanol and lye. The chemical reaction creates biodiesel and glycerin, a component of soap, which are then separated. Biodiesel used for transportation must be produced to meet the ASTM International biodiesel specification.

Because biodiesel is produced from a contained chemical reaction (while ethanol is produced from the distillation of corn or other starches), biodiesel facilities will generally be smaller, less energy intensive, and have less vapor and odor emissions than ethanol plants. They will likely be located in soybean growing areas of the state, perhaps in conjunction with a soybean crushing facility that produces the soybean oil.

It also takes less energy to produce biodiesel. For every unit of energy you put into growing soybeans and producing biodiesel, you will get 3.2 units of equivalent biodiesel energy. In contrast, ethanol's "energy balance" is 1.3. Like the corn used for ethanol, additional products and feedstocks are also made from the soybeans, in addition to the biodiesel.

USES FOR BIODIESEL

Biodiesel can generally be used in nearly any application that petrodiesel is used—transportation, electricity generation, and heating. Examples include bus fleets and heavy-

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duty trucks, marine vessels such as ferries, construction and agricultural vehicles, home heating oil systems, electric generation, and even aviation.

Biodiesel is registered with the Environmental Protection Agency as a legal motor fuel for sale and distribution and meets clean diesel standards established by the California Air Resources Board (CARB). Biodiesel blends greater than 20 percent (B20 or greater) have been designated as an alternative fuel by the Department of Energy (DOE) and the US Department of Transportation (DOT).

PURCHASING BIODIESEL

Biodiesel fuel costs the least when purchased in large quantities over longer contract periods and delivered directly to the end user from the production facility. Biodiesel can also be purchased from a traditional petrodiesel fuel distributor. Pure biodiesel purchased in bulk will likely cost between $1.50-$2.00 per gallon. If petrodiesel is $1.50 per gallon and B100 is $2.00 per gallon, a B20 blend would cost an additional $0.10 per gallon. A B2 blend would cost an additional $0.01 per gallon. Prices will vary by feedstock and production facility. Biodiesel can also be purchased in 55-gallon drums at a significantly higher cost for a small number of demonstration or test vehicles.

The Minnesota Soybean Growers Association reports that many rural fuel stations are selling 2% biodiesel blends (B2). Local diesel fuel distributors are becoming familiar with biodiesel and can deliver various percentage blends. The National Biodiesel Board also maintains a contact list of manufacturers of biodiesel for direct purchase. Currently, there are about 180 biodiesel fueling locations around rural Minnesota offering blended or straight biodiesel.

BIODIESEL'S EFFECT ON ENGINES

Blends of up to 20% biodiesel can be used in nearly all diesel equipment and are compatible with most storage and distribution equipment. These low level blends (20% and less) don't require any engine modifications and can provide the same payload capacity and mileage range as diesel.

Users should be aware that biodiesel has a solvent effect that may release deposits accumulated on tank walls and pipes from previous diesel fuel storage. The release of deposits may clog filters initially and precautions should be taken. Ensure that only fuel meeting the biodiesel specification is used.

Higher blends, even pure biodiesel (100% biodiesel, or B100), can be used in many engines built since 1994 with little or no modification. Transportation and storage, however, require special management. Material compatibility and warrantee issues have not yet been resolved with higher blends.

In general, the standard storage and handling procedures used for petroleum diesel can be used for biodiesel. The fuel should be stored in a clean, dry, dark environment. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene and teflon. Copper, brass, lead, tin, and zinc should be avoided.

Engine manufacturers warranty the materials and workmanship of their engines but do not warranty fuel of any kind. If there are engine problems caused by a fuel, either petrodiesel or biodiesel, these problems are not related to the materials or workmanship of the engine, but are the responsibility of the

fuel supplier and not the engine manufacturer. Any reputable fuel supplier should stand behind its products and cover any fuel quality problems if they occur. Most major engine companies have stated formally that the use of ASTM specified biodiesel blends up to B20 will not void their parts and workmanship warranties.

COLD WEATHER OPERATION

B100 has a significantly higher cold-filter plugging point (CFPP) than petroleum diesel; therefore, using B100 during the coldest 3 to 4 months of the year in Minnesota is not recommended for outdoor applications, such as transportation. Biodiesel blends (B20 or less) have been used successfully year-round in vehicles in Minnesota, including International Falls. The CFPP for a B20 mixture might vary from -5 to -15°F, while winter blends of petrodiesel might range from -15 to -45°F. Just as petroleum diesel blends change during the seasons, the percentage of biodiesel used may be changed as well for B20 blends or greater.

Existing measures taken for petrodiesel in cold weather should also be taken with biodiesel, such as:

- Blending with No. 1 diesel, which is lighter and more volatile;
- Using a cold-flow enhancing additive;
- Using a heater to warm the fuel tank, filter, or lines;
- Indoor storage and overnight parking.

HEALTH, SAFETY, AND EMISSIONS

Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. It is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act Amendments.

Pure biodiesel or biodiesel blends are safer to store, handle and use than conventional diesel fuel since it has a higher flashpoint. The flash point of a fuel is defined as the temperature to which the fuel must be heated to produce a mixture that will ignite when exposed to a spark or flame.

The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter compared to emissions from conventional diesel fuel. In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to petrodiesel. These reductions increase as the amount of biodiesel blended into diesel fuel increases.

Emissions of nitrogen oxides (contributes to low level ozone) are either slightly reduced or slightly increased depending on the duty cycle of the engine and testing methods used. Some biodiesel produces more nitrogen oxides than others, and some additives have shown promise in modifying the increases. More research is needed to resolve this issue.

A 1998 biodiesel lifecycle study, jointly sponsored by the U.S. Department of Energy and the U.S. Department of Agriculture, concluded biodiesel reduces net carbon dioxide emissions by 78 percent compared to petroleum diesel. This is due to biodiesel's closed carbon cycle. The carbon dioxide released into the atmosphere when biodiesel is burned is recycled by growing plants, which are later processed into fuel.

The U.S. Environmental Protection Agency is promulgating rules for the reduction of sulfur in diesel fuel from 500 ppm to less than 15 ppm in June 2006. Reducing sulfur levels will increase the effectiveness and applicability of new diesel pollution control equipment but sulfur also acts as a lubricant to extend engine life. Low blends of biodiesel in low-sulfur diesel fuels can be used to offset the removal of sulfur.

FEDERAL AND STATE POLICIES SUPPORT BIODIESEL

Biodiesel blends of B20 or greater are considered an alternative fuel for the purposes of fulfilling the requirements of the Energy Policy Act of 1992 (EPAct). Under EPAct, federal, state, and fuel provider fleets are required to purchase at least 75 percent of their new light-duty vehicles as alternative fuel vehicles. As an alternative, using 450 gallons of pure biodiesel (or 2,250 gallons of B20) gains a fleet an equivalent credit. Federal agencies are also under Executive Order to reduce petroleum consumption by 20 percent (from 1999 levels) through efficiency and alternative fuel use by 2005.

The U.S. Department of Energy Clean Cities program promotes the voluntary use of alternative fuels, including biodiesel. The Twin Cities Clean Cities Coalition works to promote the national programs and projects at the local level.

The U.S. Department of Agriculture's Bioenergy Program has a component to reduce the costs of new biodiesel production facilities through their Farm Service Agency (FSA) and is funded by USDA's Commodity Credit Corporation.

Minnesota law requires that all diesel fuel sold in the state for use in internal combustion engines contain 2 percent biodiesel by volume if two of three conditions occur (first and second or first and third):

- the biodiesel is produced in-state
- additional federal or state incentives are available
- it is after June 30, 2005

Engines on railroads, at nuclear power plants, and at mining facilities are exempt. It is estimated that this will require approximately 16 million gallons of B100 for blending.

Minnesota statute 16C.135 directs state agencies, to the extent practical, to use alternative fuels, including biodiesel, in state vehicles.

MINNESOTA RESEARCH AND DEMONSTRATION

Hennepin County snowplows, suburban Twin Cities school district buses, national park vehicles in International Falls, and suburban cities have all used B20 blends for extended periods. The city of Brooklyn Park fuels all of their diesel vehicles and equipment with B20 blends year round and other metropolitan cities are looking into aggregating their demand to reduce the price of using biodiesel blends.

In addition, the University of Minnesota Center for Diesel Research is extensively researching biodiesel for use in mining, transportation, and more recently, electricity generation. The Department of Commerce Weights and Measures Division is working on developing easier testing procedures for determining the percentage blend of biodiesel for verifying future state biodiesel requirements.

TECHNICAL INFORMATION

Selected Fuel Properties for Diesel and Biodiesel Fuels

Fuel Property	Diesel	Biodiesel
Fuel Standard	ASTM D975	ASTM D6751
Fuel composition	C10-C21 HC	C12-C22 FAME
Lower Heating Value, Btu/gal	131,295	117,093
Kin. Viscosity, @ 40 °C	1.3-4.1	1.9-6.0
Specific Gravity kg/l @ 60 °F	0.85	0.88
Density, lb/gal @ 15°C	7.079	7.328
Water, ppm by wt	161	.05% max
Carbon, wt %	87	77
Hydrogen, wt %	13	12
Oxygen, by dif. wt %	0	11
Sulfur, wt %	.05 max	0.0 - 0.0024
Boiling Point, °C	188-343	182-338
Flash Point, °C	60-80	100-170
Cloud Point, °C	-15 to 5	-3 to 12
Pour Point, °C	-35 to -15	-15 to 10
Cetane Number	40-55	48-65
Stoichiometric Air/Fuel Ratio wt/wt	15	13.8
BOCLE Scuff, grams	3,600	>7,000
HFRR, microns	685	314

Source: U.S. Department of Energy, Biodiesel Handling and Use Guidelines, NREL/TP-580-30004

ASTM International D6751 Biodiesel Specifications

Property	Limits
Flash Point (closed cup)	130.0 °C min
Water and sediment	0.050 % volume max
Kinematic viscosity, 40°C	1.9-6.0 mm2/s
Sulfated ash	0.020 % mass max
Sulfur	0.05 % mass max
Copper strip corrosion	No.3 max
Cetane number	47 min
Cloud point	Report °C
Carbon residue	0.050 % mass max
Acid number	0.80 mg KOH/g max
Free glycerin	0.020 % mass
Total glycerin	0.240 % mass
Phosphorus content	0.001 % mass max
Distillation temperature	360 °C max

Source: U.S. Department of Energy Alternative Fuels Data Center, www.afdc.doe.gov

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FOR MORE INFORMATION

ASTM International:
www.astm.org

Minnesota Department of Commerce Energy Information Center:
www.commerce.state.mn.us

Minnesota Department of Agriculture:
www.mda.state.mn.us/ams/biodiesel/default.htm

Minnesota Soybean Growers Association:
www.mnsoybean.org

National Biodiesel Board:
www.biodiesel.org

Twin Cities Clean Cities Coalition:
www.cleanairchoice.org

University of Minnesota Center for Diesel Research:
www.me.umn.edu/centers/cdr

U.S. Department of Agriculture Bioenergy Program:
www.fsa.usda.gov/daco/bio_daco.htm

U.S. Department of Energy Clean Cities Program:
www.ccities.doe.gov

U.S. Department of Energy Energy Policy Act Requirements:
www.ott.doe.gov/epact

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