Appendix K: Review of Biodiesel and Renewable Diesel Use Considerations

Oregon Low Carbon Fuel Standards Report

BACKGROUND

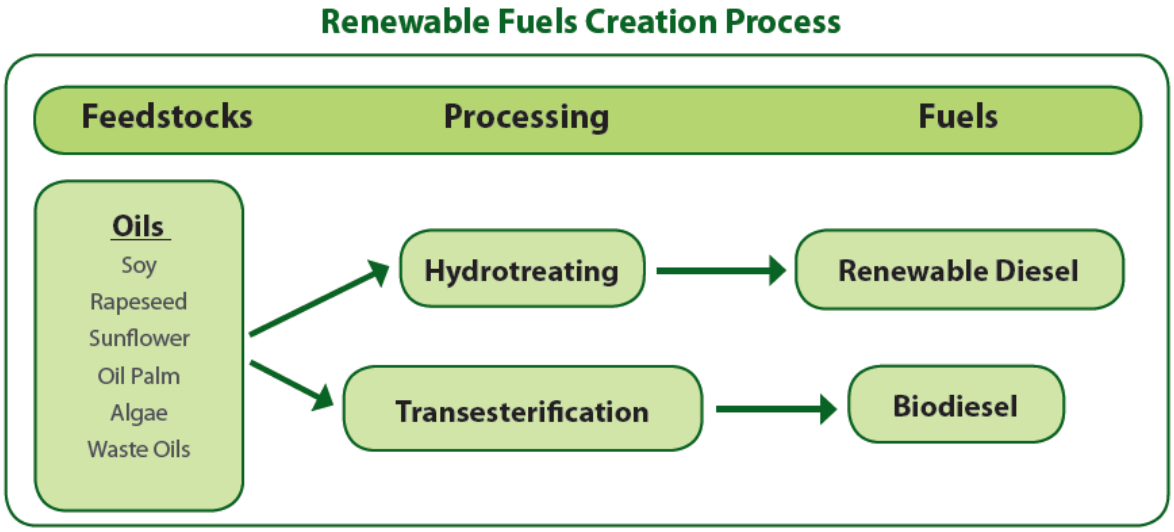
What are renewable fuels?

According to the Environmental Protection Agency's new Renewable Fuel Standard, renewable fuels are defined as motor vehicle fuels produced from plant or animal products or wastes. Within this definition, two distinct forms of diesel fuel are specified: biodiesel and renewable diesel. Each is defined according to the process by which it is produced. The term "biodiesel" is often used very broadly to refer to any blend of conventional petroleum diesel with any renewable diesel product. In order to avoid confusion, the term biodiesel should be used in reference to pure biodiesel fuel meeting the ASTM D6571 standard. Mixtures of biodiesel with petroleum should be referred to as biodiesel blends (i.e. B20, as explained below in the section titled, *What is a biodiesel blend?*).

What is biodiesel? Biodiesel is a diesel fuel alternative that is made from renewable resources, such as vegetable oils or animal fats. The most common feedstock for biodiesel in the US is soybean oil, although palm oil, canola oil, poultry renderings, beef tallow, and waste grease also may be used to make biodiesel. Biodiesel is made through a chemical process called transesterfication, whereby vegetable oil is mixed with methanol in the presence of a catalyst (sodium hydroxide) to produce a diesel fuel alternative. The resulting liquid must then be further processed to remove glycerin and excess methanol. To be designated as biodiesel the alternative fuel must meet the American Society of Testing Materials (ASTM) D6751 quality standards (discussed below), compliance with which assures that biodiesel may be used in low percentage blends without causing problems for the diesel engine. Low percentage blends of high-quality biodiesel may be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel is biodegradable, nontoxic, and essentially free of sulfur and aromatics.

What is renewable diesel? Renewable diesel is a diesel fuel alternative that is made from renewable resources, such as vegetable oils or animal fats. Renewable diesel is sometimes referred to as second or third generation biodiesel, depending upon the production process utilized. The primary differences between biodiesel and renewable diesel are the technologies used to make the fuel and the molecules that are ultimately produced. Whereas, biodiesel is made using a chemical reaction called transesterfication, renewable diesel is made using a thermal or other chemical reaction. There are currently two processing means for producing renewable diesel: stand alone and co-processing. Co-processed renewable diesel is diesel fuel produced from animal fats and/or vegetable oil by blending with petroleum feedstock and hydrotreating within an existing petroleum refinery. It has been in commercial production in the United States and Ireland since 2005, and is sold as diesel fuel. The resulting diesel fuel product is a fully fungible fuel that can be transported via pipeline.

The most significant difference between biodiesel and renewable diesel is that renewable diesel can meet the ASTM D975 quality standard, which is the existing standard for on-road diesel fuel. Renewable diesel has been subjected to rigorous on-road fleet testing during the Canada's Alberta Renewable Diesel Demonstration project in December 2007 through September 2008.[1] Preliminary information indicates that renewable diesel may have advantages over biodiesel for the end-user. These advantages may include a higher energy content and better cold weather performance compared to biodiesel.



What is a biodiesel blend? Both biodiesel and renewable diesel are blend stocks that are typically mixed with petroleum diesel fuel to produce a biodiesel/renewable diesel blend. Biodiesel (or neat biodiesel) refers to the pure fuel before blending with diesel fuel. Biodiesel and renewable blends are denoted as, "BXX" or "RXX" with "XX" representing the percentage of biodiesel contained in the blend (*i.e.*, B10 is 10% biodiesel, 90% petroleum diesel or R10 which is 10% renewable diesel, 90% petroleum diesel).

Unless specifically noted, when the term biodiesel is used in the remainder of this document it is referring to both biodiesel and renewable diesel synonymously.

TRUCKS:

OPERABILITY/PERFORMANCE

Are there advantages to using biodiesel? As defined earlier, Biodiesel offers significant environmental benefits, which are discussed in more detail below. Biodiesel also may be used to increase the lubricity of diesel fuel. A B2 blend may be sufficient to restore the lubricity lost in

1 Alberta Renewable Diesel Demonstration, http://www.renewablediesel.ca

the Ultra Low Sulfur Diesel (ULSD) refining process. Standard lubricating additives may be used with renewable diesel.

How will biodiesel affect fuel economy? Neat biodiesel (B100) has about a 9% lower energy content (BTU content) than petroleum-based diesel. A B5 blend would likely reduce fuel economy by less than one percent and may not be measurable in an individual truck. Use of a B20 blend is expected to reduce fuel economy by two percent when compared to ultra low sulfur diesel. Across the entire fleet the use of biodiesel will require end-users to purchase more fuel to perform the same amount of work. Renewable diesel proponents have indicated that there is no difference in the BTU value of renewable diesel when compared to petroleum-based diesel.

Will biodiesel work in all climates? Biodiesel offers reduced cold weather performance compared to ultra-low-sulfur diesel. While the cloud point and pour point of petroleum diesel fuel varies greatly, generally ULSD will turn gelatinous at 16ºF. B100 derived from soy bean oil will typically turn gelatinous at 32ºF. B20 will raise the cloud point of the base fuel by 3º - 10ºF. Low percentage blends (<B5) should perform comparably to petroleum based diesel. Different feedstocks will have different cold weather performance capabilities. Biodiesel derived from canola oil will have better cold-flow properties than biodiesel derived from soy. Biodiesel derived from animal tallow will have poor cold weather performance compared to soy-based biodiesel. Canada's largest cold-weather demonstration of renewable diesel has shown that levels less than 5% by volume of canola-derived renewable diesel blended with petroleum diesel will work. It can be blended, distributed and used without problems, even in a bitter Alberta winter, using normal commercial facilities.

Will biodiesel require any additional vehicle maintenance? Biodiesel blends tend to act like a solvent and will clean out the sediment that naturally accumulates in diesel fuel systems. For this reason, use of biodiesel will require end-users to closely monitor their fuel filters and likely will require a fuel filter change that coincides with the initial introduction of biodiesel. Subsequent fuel filter changes may need to occur ahead of regularly scheduled maintenance until the fuel system is free from accumulated sediment. Biodiesel tends to attract water in fuel tanks and storage systems and may require replacement of hose and sealing equipment due to incompatibility with some older engines. As for other renewable diesel fuels, many of the challenges related to the fuel system and injectors should be alleviated since they are pure hydrocarbons which have similar performance to petroleum diesel.

Will biodiesel affect the vehicle or equipment warranty? All diesel engine Original Equipment Manufacturers (OEMs) warranty the product they make – engines. They warranty their engines against defects in "material or workmanship." If there is a problem with an engine part or with engine operation due to an error in manufacturing or assembly within the prescribed warranty period, the problem will be covered by the engine company. They do not warrant the fuel that is used in the engines.

Typically, an engine company will define what fuel the engine was designed for and will recommend the use of that fuel to their customers in their owner's manuals. Engine companies do not manufacture fuel or fuel components. Therefore, engine companies do not warranty fuel - whether that fuel is biodiesel, renewable diesel or petroleum diesel fuel. Since engine

manufacturers warranty the materials and workmanship of their engines, they do not warranty fuel of any kind. If there are engine problems caused by a fuel (again, whether that fuel is petroleum diesel fuel, renewable diesel fuel or biodiesel fuel) 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 (biodiesel, petroleum diesel, or a blend of both) should stand behind its products and cover any fuel quality problems if they occur.

Therefore, the most important aspect regarding engine warranties and biodiesel or renewable diesel is whether an engine manufacturer will void its parts and workmanship warranty when biodiesel or renewable diesel is used, and whether the fuel producer or marketer will stand behind its fuels should problems occur.

Most major engine companies have stated formally that the use of blends up to B20 will not void their parts and workmanship warranties provided that the biodiesel used conforms to the ASTM D6751 standard and it is blended with diesel fuel that meets ASTM D975 specifications[2]. This includes blends below 20% biodiesel, such as the 2% biodiesel blends that are becoming more common. Several statements from the engine companies are available on websites; a good website is the National Biodiesel Board website. It is anticipated that the entire industry will incorporate the ASTM biodiesel standard into their owner's manuals over time. Renewable diesel that meets the ASTM D975 specifications will have no impact on manufacturers' warranties.

Are certain materials incompatible with biodiesel? Natural rubber, nitrile and butyl rubber are particularly susceptible to degradation when exposed to high percentage biodiesel blends. Also, copper, bronze, brass, tin, lead and zinc can cause deposit formations. The use of these materials and coatings must be avoided for fuel tanks and fuel lines. OEMs recommend that questions or concerns regarding the use of biodiesel or biodiesel blends be directed to the vehicle manufacturer to determine if any of the OEM-supplied engine components are at risk of voiding warranty coverage in order to prevent engine or vehicle damage.

QUALITY

Are there accepted biodiesel specifications to measure its suitability for use in a truck? The only accepted biodiesel specification in the US is the ASTM D6751 specifications applicable to neat biodiesel (B100). ASTM is in the process of developing specifications for specific biodiesel blends; however, this process is not yet complete. The incorporation of biodiesel that meets the ASTM D6751 specifications into ULSD in amounts up to 5% should produce a high quality biodiesel blend that is suitable for use in heavy duty diesel engines.

Are there fuel quality issues associated with biodiesel? Quality control is one of the most significant challenges facing biodiesel distribution in the United States. It is relatively easy to make biodiesel; however, it is rather difficult to consistently manufacture high quality biodiesel. Biodiesel producers are a diverse group. Some facilities look like modern petroleum refineries

2 The National Biodiesel Board, http://www.biodiesel.org

and have deployed quality controls including on-site testing laboratories. Other producers utilize small batch systems where quality may vary significantly from batch-to-batch. In 2006, the National Renewable Energy Laboratory conducted a random survey of biodiesel producers and found that 50% of the samples taken failed to meet the applicable ASTM quality specifications.[3]

How does the buyer know whether biodiesel meets the specification? Short of sending a sample to a fuel testing laboratory, there is no way for the end-user to tell whether biodiesel blends meet the appropriate quality standards. For this reason, it is important to purchase biodiesel only from producers or distributors that are committed to producing on-spec product. Many biodiesel producers are testing each batch of fuel and can furnish a purchaser with a certificate of analysis that demonstrates compliance with the applicable ASTM specifications.

The National Biodiesel Board, the trade association for the biodiesel industry, has formed the National Biodiesel Accreditation Commission (NBAC) to audit fuel producers and marketers in order to improve the quality of biodiesel production and handling throughout marketing channels in the US NBAC issues a 'Certified Biodiesel Marketer' seal of approval for biodiesel marketers that have met all requirements of fuel accreditation audits and a quality assurance program called BQ-9000. Companies that are BQ-9000 certified have demonstrated that they are capable of consistently producing high quality biodiesel and have implemented quality assurance controls. This seal of approval will provide added assurance to customers, as well as engine manufacturers, that the biodiesel marketed by these companies meets the ASTM standards for biodiesel and that the fuel supplier will stand behind its products. The steps taken by the biodiesel industry to work with the engine companies and to ensure that fuel meets the newly accepted ASTM standards provides confidence to users and engine manufacturers that their biodiesel experiences will be positive and trouble-free.

Who is responsible for enforcement of the biodiesel standard?[4] Biodiesel quality enforcement can occur at several different levels (e.g. federal and state). Unfortunately, there hasn't been a concerted push to ensure biodiesel quality through an enforcement program.

Biodiesel has been registered for sale as a motor vehicle fuel with the US Environmental Protection Agency. As such, EPA has the legal authority to ensure that all biodiesel offered for sale complies with the ASTM D6751 specifications. The sale of off-spec biodiesel is a violation of the Clean Air Act and subjects the person to civil penalties not to exceed $32,500 per violation.

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3 2006 B100 Quality Survey Results, Milestone Report, http://www.nrel.gov/docs/fy07osti/41549.pdf

4 Minnesota Biodiesel Program, http://www.mda.state.mn.us/renewable/biodiesel.aspx

- American Trucking Associations, http://www.truckline.com
- Top Crop Manager, http://www.topcropmanager.com/content/view/4991/60/
- National Renewable Energy Laboratory, http://www.nrel.gov
- U.S. Environmental Protection Agency, www.epa.gov/OMS/models/biodsl.htm

Only biodiesel that meets ASTM D6751 is eligible for the $1 per gallon federal tax credit. As such, the IRS has the legal authority to pursue individuals claiming the tax credit on biodiesel that does not comply with the ASTM D6751 specifications.

Finally, each state, usually through its department of weights and measures, has the authority to ensure that fuel dispensed meets applicable requirements. Most states have not devoted the resources necessary to create a robust on-spec biodiesel inspection and enforcement program, with the Minnesota Biodiesel Program being the exception.

What resources are available to address potential biodiesel quality issues? Damages caused by off-spec biodiesel are difficult to prove for a variety of reasons, including the fact that the damage may not occur immediately upon refueling and the fuel used in an individual truck may be purchased from several different suppliers. If an end-user can identify that a particular problem was caused by a specific biodiesel provider, the end-user may initiate a legal claim against that fuel provider.[5] In addition, EPA, the IRS, and the appropriate state enforcement authority should be notified.

ENVIRONMENTAL ISSUES

What impact does biodiesel have on tailpipe emissions? Biodiesel offers numerous environmental benefits, including reduced particulate matter and hydrocarbon emissions. A life cycle analysis of biodiesel shows that the fuel significantly reduces greenhouse gas emissions.[6] There is an ongoing debate as to the impact biodiesel has on nitrogen oxide emissions, with EPA concluding that biodiesel causes a slight increase in the emissions of this ozone precursor. Neat biodiesel contains no hazardous materials and biodegrades more rapidly than ULSD.

Emission Type	B100	B20	B2
PM	(47%)	(20%)	(2.2%)
NOx	+10%	+2%	+0.2%
CO	(48%)	(12%)	(1.3%)
CO2[1]	(71%)	(14%)	(1.4%)
HC	(67%)	(20%)	(2.2%)

Locomotives:

In May 2004, the US EPA published the Clean Air Nonroad Diesel Rule, designed to dramatically reduce soot and emissions from construction, agricultural and industrial diesel-powered equipment. Locomotive and marine engines were exempted from certain engine modification requirements in the rule (the EPA later proposed a program specific to these

5 U.S. Environmental Protection Agency, www.epa.gov/OMS/models/biodsl.htm

6 EPA's biodiesel emissions analysis program, http://www.epa.gov/OMS/models/biodsl.htm

engines). However, locomotive and marine engines are required to comply with the fuel section of the 2004 ruling. According to the EPA, the rule reduces nonroad diesel fuel sulfur levels in two steps.

Locomotive and marine diesel fuel was first reduced from uncontrolled levels to the low-sulfur diesel level of 500 parts per million (ppm) starting in June 2007, and the second step to ultra-low sulfur diesel (15 ppm cap) will go into effect in June 2012 (all other nonroad diesel engines must comply at the 15 ppm level in June 2010). The decreased lubricity of low-sulfur diesel could be an opportunity for the biodiesel industry to access this market. "Indications are that low concentrations of biodiesel might be sufficient to raise the lubricity to acceptable levels," the EPA ruling reads. "Thus, we believe that biodiesel is a feasible technology that could help support today's clean diesel fuel program."[7]

So far, few trains use biodiesel or renewable diesel, though there have been experiments in some passenger-train systems in Europe and US shortline railroads.

British Train Operating Company Virgin Trains in June of 2007 claimed to have run the world's first "biodiesel train", which was converted to run on a blended fuel which is 20% biodiesel processed from biological sources including rapeseed (Canola), soybean and palm oil.[8] During a six-month trial, the train ran from Birmingham to Scotland, across South Wales, North East England, the North West, the West Country, the South West and the South coast. The experiment has been organized by Virgin Trains, the Association of Train Operating Companies and the Rail Safety and Standards Board.

On September 15, 2007, the Royal Train completed its first ever journey run on 100% biodiesel fuel supplied by Green Fuels Ltd. His Royal Highness, The Prince of Wales, and Green Fuels managing director, James Hygate, were the first passengers on a train fueled entirely by biodiesel fuel. Since 2007 the Royal Train has operated successfully on B100 (100% biodiesel).

Similarly, one of the first biodiesel tests on locomotives in the Northwest took place during the summer of 2008 when a state-owned short-line railroad (Eastern Washington Gateway Railroad) in Eastern Washington ran a test of a 25% biodiesel / 75% petroleum diesel blend, purchasing fuel from a biodiesel producer seated along the railroad tracks. The train will be powered by biodiesel made in part from canola grown in agricultural regions through which the short line runs.[9]

Also in 2007, Disneyland began running their southern California amusement park trains on B98 biodiesel blends (98% biodiesel). The program was discontinued in 2008 due to storage issues, but in January 2009 it was announced that the park would then be running all trains on biodiesel

7 Railroad Switch, Biodiesel Magazine, March 2007, http://www.biodieselmagazine.com/article.jsp?article_id=1506
8 BBC News, June 2007, http://news.bbc.co.uk/2/hi/uk_news/6729115.stm
9 Biodiesel will drive Eastern Washington train during summer long test, http://seattletimes.nwsource.com/html/localnews/2008011135_biodiesel22.html

manufactured from its own used cooking oils. This is a change from running the trains on soy-based biodiesel.[10]

In November 2009 the first cold weather use of biodiesel by a railroad in real world conditions will be used to power the Canadian cold-weather rail service, putting to test issues on the feasibility of using the fuel as biodiesel is known to have a slightly higher freezing point than standard diesel. The industry-leading pilot project is a partnership with Natural Resources Canada under the National Renewable Diesel Demonstration Initiative with the Northern American railway company Canadian Pacific. The project will be conducted under the National Renewable Diesel Demonstration Initiative which provides opportunities for real-world testing and performance evaluation ahead of Canadian regulatory action.

The five-month test cycle will see Canadian Pacific operating four General Electric AC4400 diesel locomotives with FDL-16 engines in captive service between Calgary and Edmonton. The company will conduct detailed mechanical examinations of the locomotives. The information gathered from the testing will be used to determine if a biodiesel mixture of five percent (B5) has any significant adverse effects on a locomotive in cold-climate operation. Effects on reliability, possible changes to the overhaul or maintenance work scope and reviews of specific components on the locomotives will also be monitored.

"Rail is already the most efficient means to move goods long-haul. This initiative positions Canadian Pacific to make a lasting impact by further reducing our network's environmental footprint," said Fred Green, Canadian Pacific's president and chief executive. Apart from General Electric, Calgary-based fuel supplier 4Refuels is also cooperating with Canadian Pacific on the testing phase. Testing began in early November and will continue until the end of March 2010. The Canadian government plans to regulate an average five percent renewable fuel content based on the national gasoline pool by 2010. A requirement for an average two percent renewable content in diesel fuel and heating oil by 2011 or earlier is also being considered for implementation, subject to technical feasibility.[11]

Presenting the proof that biodiesel works in rail applications seems to be a recurring theme. However, there are other issues that are unique to the rail industry, such as fuel supply (getting sufficient quantities in key fueling locations) and the unique nature of their engines. Rail engines are made using copper, which is more flexible than steel and can better handle the vibrations. Railroad companies must know how biodiesel reacts to the copper in these engines.

Proof will need to come from further field testing. Unlike the trucking industry—where a lot has been tested—in following the literature of the railroad industry there is limited information regarding commercial trials which highlights the importance of following the recent pilots mentioned above.

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10 Disneyland trains, http://www.upi.com/Top_News/2009/01/29/Disneyland-trains-running-on-biodiesel/UPI-10151233252145/

11 National Renewable Diesel Demonstration Initiative, http://oee.nrcan.gc.ca/transportation/alternative-fuels/programs/nrddi/background.cfm?attr=8