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Truck and Engine Manufacturers Association
Facts You Should Know About Biomass-Based Diesel Fuels

Fuel is the energy source utilized by engines to generate power. Using the compression ignition process, engines convert a fuel's chemical energy to mechanical energy that propels vehicles or equipment, moves materials, and conducts other forms of work. Biomass-based diesel fuels are an alternative to conventional petroleum derived fuels. Multiple varieties exist, each with unique characteristics requiring the user to understand the truck or engine manufacturer's recommendations regarding their use.

What are biomass-based diesel fuels?

The United States Environmental Protection Agency (EPA) regulations[1] define "*Biomass-based diesel" as* "a renewable fuel that has lifecycle greenhouse gas emissions that are at least 50 percent less than baseline lifecycle greenhouse gas emissions and meets all of the requirements of paragraph (1) of this definition:

(1) (i) Is a transportation fuel, transportation fuel additive, heating oil, or jet fuel.

(ii) Meets the definition of either biodiesel or non-ester renewable diesel.

(iii) Is registered as a motor vehicle fuel or fuel additive under 40 CFR part 79, if the fuel or fuel additive is intended for use in a motor vehicle.

(2) Renewable fuel that is co-processed with petroleum is not biomass-based diesel."

The regulations define "*Biodiesel"* as "a mono-alkyl ester that meets ASTM D 6751 (incorporated by reference, *see* §80.1468)" and "*Non-ester renewable diesel*" or "*renewable diesel"* as "renewable fuel that is not a mono-alkyl ester and that is either:

(1) A fuel or fuel additive that meets the ASTM D 975-13a (incorporated by reference, see §80.1468) Grade No. 1-D or No. 2-D specifications and can be used in an engine designed to operate on conventional diesel fuel; or

(2) A fuel or fuel additive that is registered under 40 CFR part 79 and can be used in an engine designed to operate using conventional diesel fuel."

Therefore, biomass-based diesel fuels can be separated into two distinct types: biodiesel and non-ester renewable diesel. Non-ester renewable diesel is more commonly referred to as "renewable hydrocarbon diesel." Engine manufacturers must evaluate an engine's capability to perform using biodiesel or renewable hydrocarbon diesel fuels. To date, they have not expressed a preference regarding the feedstock used to produce biomass-based diesel fuels. The critical performance factors of any diesel fuel — petroleum-based or biomass-based — are derived from the end product and not from the source or characteristics of the feedstock.

[1] 40 CFR Part 80.1401 Definitions, Regulation of Fuels and Fuel Additives:

The following characteristics distinguish the two types of biomass-based diesel:

Biodiesel:

Biodiesel is often referred to as Fatty Acid Methyl Ester (FAME) or Fatty Acid Ethyl Ester (FAEE) and can be produced from a variety of renewable sources such as soybeans, rapeseed, used cooking oils, or animal fats. The feedstock is processed to create oils, which are then treated with methyl or ethyl alcohol in the presence of a catalyst. In a final step, water and contaminants are removed in order to make a usable stock that can be blended with petroleum diesel fuel and burned in diesel engines. Biodiesel has a specific hydrocarbon structure that contains oxygen molecules, as well as residual glycerides and/or catalyst materials depending upon the production process.

ASTM International has adopted the following technical definition of biodiesel:

> Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to ASTM D6751 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 (e.g., B20 is 20% biodiesel, 80% petroleum-based diesel).

It is important to note that raw vegetable oils are not biodiesel. Raw, unprocessed vegetable oils and animal fats, regardless of blend level, can have significant adverse effects and should not be used as fuel in diesel engines. See EMA's Statement regarding "Use of Raw Vegetable Oils or Animal Fats in Diesel Engines:"

> http://www.truckandenginemanufacturers.org/articles/article.asp?DOCUMENT_ID=12559&F_ARTICLE_ID=9

Renewable Hydrocarbon Diesel:

Renewable hydrocarbon diesel may be produced through different processes using any one of several feedstocks. It is difficult for engine manufacturers to evaluate and approve a fuel defined as renewable hydrocarbon diesel without first determining the feedstock and process utilized for its production. For purposes of this document, the term "renewable hydrocarbon diesel" refers only to fuels produced from the same variety of renewable sources as biodiesel and processed in a manner similar to that used to produce petroleum diesel fuel, including hydro-processing. That process results in a paraffinic hydrocarbon subsequently isomerized to provide acceptable cold flow properties and additized to provide acceptable lubricity. The finished fuel contains virtually no aromatic hydrocarbons and no oxygen. Renewable hydrocarbon diesel can be used as processed or blended with petroleum diesel fuel and burned in diesel engines in accordance with individual engine manufacturer recommendations. In either case, it is important that contaminants and other minor components not be carried over from the feedstock or the production process. Thus, engine manufacturers urge that the same quality controls expected for diesel fuels produced by large refinery type operations be in place for the production of renewable hydrocarbon diesel.

What technical and quality specifications should biomass-based diesel fuels meet?

The fuel and engine industries have developed international standards for diesel fuel through ASTM International (ASTM) in North America and the European Committee for Standardization (CEN) in Europe.

Biodiesel:

Specific fuel standards referred to as ASTM D6751 and EN 14214 have been developed for 100% biodiesel blend stock, generally known as B100. Engine manufacturers typically require all B100 biodiesel blend stock to meet ASTM D6751 or EN 14214 prior to blending with petroleum diesel fuel. ASTM D6751 and EN 14214 establish characteristics and properties designed to ensure that fuels containing biodiesel perform properly. If B100 in a biodiesel blend does not meet one of those standards, the blended fuel may prevent engine start-up, cause fuel-system fouling, damage engine components, or otherwise adversely affect engine performance. Under worst-case conditions, poor quality biodiesel fuel may prevent an engine from running or create the need for expensive engine overhaul and repairs. The ASTM and EN specifications also include limit values for compounds that can influence durability and/or maintenance intervals for emission control system components, such as diesel particulate filters.

Low level biodiesel blends must meet the petroleum-based diesel specifications, ASTM D975 or EN 590, which have been modified to include biodiesel of up to five percent (5%) and seven (7%) respectively. In addition, because of increased interest in B6-B20 blends, ASTM has created a finished fuel specification, ASTM D7467, that establishes requirements for B6-B20 biodiesel blends. Several engine manufacturers also have created fuel specifications or recommendations that are applicable for their engines.

In March 2009, The Worldwide Fuel Charter Committee, comprised of members of EMA, the Alliance of Automobile Manufacturers, the European Automobile Manufacturers Association, and the Japan Automobile Manufacturers Association, published its First Edition of Biodiesel Guidelines. The Guidelines focus on the quality of the blend stock used to make finished biodiesel blends, rather than on the finished fuels themselves. They are intended to guide blenders who produce and use 100% biodiesel and diesel fuel blend stocks to make finished 5% biodiesel blends. A copy of the Guidelines may be downloaded at:
http://www.enginemanufacturers.org/admin/library/upload/1727.pdf

Renewable Hydrocarbon Diesel:

Engine manufacturers recommend that renewable hydrocarbon diesel fuels meet the technical parameters of ASTM D975 or the draft CEN Technical Specification CEN/TS 15940. The draft CEN specification consists of two Classes (Class A and Class B), both of which require improved performance parameters when compared to ASTM D975. However, many engine manufacturers consider D975 and CEN/TS 15940 inadequate to describe limits associated with unspecified contaminants and other minor components.

Can all biomass-based diesel fuels or blends be used in today's compression ignition (diesel) engines?

Today's diesel engines are highly engineered machines in which fuel delivery and combustion are controlled by computer technology designed to achieve required power, performance, efficiency, and emission levels. Having high quality, ultra-low sulfur diesel fuel is

essential to the performance of those engines, especially now that they must meet near-zero emission regulatory limits being implemented by the EPA, the California Air Resources Board (CARB), and other regulatory agencies around the world.

Biomass-based diesel fuels and fuel blends can be used in diesel engines only if they: (i) meet the technical and quality specifications developed by internationally recognized standard-setting organizations to assure proper performance; and (ii) comply with additional limitations established by individual engine manufacturers for the specific engine the fuel is intended to power.

Diesel fuel that does not meet internationally recognized standards is not acceptable at any blend level in that it can prevent the engine from starting or result in damage to engine and/or emission control components, loss of power or fuel efficiency, and excess emissions. In addition to the technical specifications adopted by internationally-recognized standard setting bodies, the biodiesel industry has adopted its own process for assessing the quality of its fuel. Among other things, it has developed and implemented BQ-9000, a voluntary quality assurance program that accredits producers, marketers, laboratories, and retailers of biodiesel and biodiesel blends.

Do engine manufacturers approve the use of biomass-based diesel fuels in their engines?

Biodiesel:

Engine manufacturers and the biodiesel fuel industry have been working together for a number of years to investigate the use of biodiesel fuel in today's engines. Currently, there is very little data regarding the long-term effects of biodiesel fuel blends on engine performance, durability or emissions when those fuel blends are used with advanced diesel engine technologies introduced to meet the latest near zero emission standard requirements. Accordingly, engine manufacturers are cautious in their approval of biodiesel fuel blends for use in their engines. They widely accept the use of a B5 blend of biodiesel and petroleum-based diesel in most engines as long as the B100 used to create the blended fuel meets the ASTM D6751 or EN 14214 standards and the final blend meets the ASTM D975 or EN 590 specifications. Engine manufacturers have approved biodiesel blends between B6 and B20 for certain engine models, provided the fuel meets the finished fuel specification established for B6-B20 blends, ASTM D7467. Most engine manufacturers do not recommend the use of biodiesel blends above B20. In all cases, users should refer to their individual engine manufacturer's technical publications to determine what, if any, blend is acceptable for a particular engine.

Renewable Hydrocarbon Diesel:

Given renewable hydrocarbon diesel's petroleum-like properties, certain engine manufacturers approve renewable hydrocarbon diesel fuel and renewable hydrocarbon diesel fuel blends as long as the finished fuel meets ASTM D975, EN590, or CEN/TS 15940. Some are concerned, however, that neat renewable hydrocarbon fuel or fuel blends having a high percentage of renewable hydrocarbon fuel may cause engine malfunction. Engine manufacturers continue to evaluate renewable hydrocarbon diesel fuel to determine potential concerns and consider additional standard recommendations.

What are engine manufacturers' concerns about the use of biomass-based diesel fuel?

Engine manufacturers have invested billions of dollars in research, development, and re-tooling to provide engines that meet stringent, worldwide emission regulatory requirements and maintain the high performance levels demanded by end users. With the introduction of engines meeting EPA 2010 heavy-duty on-highway and Tier 4 nonroad standards, engine manufacturers have reduced uncontrolled emissions from diesel engines by about 99% compared to pre-2000 engines. That result was achieved in the face of tremendous technical and economic challenges. Engine manufacturers do not want the introduction and use of biomass-based diesel fuels to play a role in reversing the progress achieved to date.

Engines are designed and tested to operate on petroleum-based diesel fuel having standardized properties known and understood by the industry. Engine manufacturers must test and certify their engines with respect to emissions using diesel fuel specified by the applicable regulatory agency. Fuels having significantly different properties from petroleum-based diesel fuels, can, and do, affect the engine's ability to start, provide the desired power output, and achieve the desired emission levels.

If biodiesel fuel is mixed with petroleum-based diesel at blend levels greater than those approved by the engine manufacturer for a specific engine, fuel filter clogging, cold-weather starting problems, fuel quality deterioration, fuel system component damage, and emission control system damage can result. Many of those potential problems can be linked to residual feedstock materials, processing materials, or the basic fuel chemistry associated with the mono-alkyl-ester.

Similarly, if renewable hydrocarbon diesel fuels are produced without process controls and quality checks associated with a petroleum refinery, engine manufacturers are unlikely to approve their use at any blend level.

How does the use of biomass-based diesel fuel affect emissions?

Biodiesel:

Research indicates that when biodiesel fuel is used in diesel engines not having the latest emission controls, engine-out emissions of particulate matter (PM), hydrocarbons (HC) and carbon monoxide (CO) are less than those from engines using petroleum-based diesel fuel. The studies also show that use of biodiesel fuel blends may increase emissions of nitrogen oxides (NOx) from those same engines. Despite some recent reports indicating that NOx may not increase, analyses by EPA show, in fact, that NOx levels vary depending on the biodiesel blend used and the engine duty cycle employed. Both emission increases and decreases tend to be linearly proportional to the blend rate of biodiesel.

In any case, the emission influences of biodiesel are relatively small in comparison to the emission reductions achieved by the latest emission controls required by EPA and CARB for both on-highway and nonroad vehicles and equipment. Any particulate matter, hydrocarbon, and carbon monoxide emission benefits from biodiesel will be significant only for that portion of the existing diesel fleet that is not equipped with exhaust aftertreatment systems. EPA and CARB emission standards require all 2007 and later model year on-highway diesel engines to install aftertreatment devices that reduce particulate emissions to near-zero levels. Similar requirements are being phased-in for most stationary, nonroad, and marine engines. In addition, EPA and CARB emission standards require all 2010 and later model year on-highway diesel engines to

reduce NOx emissions to near zero levels. Because the particulate matter, hydrocarbon, and carbon monoxide emissions from aftertreatment-equipped engines are already near zero, any engine-out emission reductions attributable to the use of biodiesel fuels will be negligible. In addition, analysis of the long-term effects of biodiesel fuel blends on the performance of exhaust aftertreatment systems or ultra-low NOx emission control systems is on-going.

Renewable Hydrocarbon Diesel:

Based on research conducted by CARB, renewable hydrocarbon diesel fuel's high cetane number and low aromatic content result in lower NOx emission levels for pre-2010 on-highway and pre-Tier 4 nonroad engines compared to those from petroleum-based diesel fuels.[2] The influence of renewable hydrocarbon diesel fuel's properties on 2010 and later on-highway and Tier 4 nonroad engines has not been evaluated sufficiently to make similar comparisons.

Does the use of biomass-based diesel fuel affect greenhouse gas (CO_2) emissions?

Because they are produced from renewable sources, biomass-based diesel fuels offer significant benefits in terms of greenhouse gas emissions when compared to petroleum-based diesel fuels. When petroleum-based diesel fuels or fuel blends are burned in compression ignition engines, carbon long trapped in the petroleum is released as new carbon into the atmosphere. Biomass-based diesel fuels, however, are currently produced from crops such as soybeans or rapeseed that take CO_2 out of the air during the growing season. Therefore, when evaluated on a full lifecycle basis, much of the CO_2 released when biomass-based diesel is burned is essentially recycled back into the new crop by the plants and then into more biomass-based diesel fuel. Conversely, the CO_2 from petroleum is not recycled into new petroleum fuel but adds to the net increase of CO_2 in the atmosphere. Ongoing analysis of factors associated with crop production and related land use changes may reduce the CO_2 benefits achievable through increased use of biomass-based diesel fuels. Research to identify new sources of renewable feedstocks, such as algae, are ongoing and their influence on greenhouse gas emissions will be evaluated as they are developed.

Is biomass-based diesel fuel currently in the marketplace? If so, how can I identify it?

Biodiesel:

Biodiesel is being marketed in many regions, including the U.S., the European Union (EU), and others. In the U.S., several states have adopted programs to promote, and, in some cases, mandate the use of biodiesel blends. In the EU, biodiesel blends are mandated in several countries. The ASTM D975 and EN590 diesel fuel specifications include provisions for limited biodiesel blends (B5 and B7 respectively) to be classified as diesel fuel without notice to the user.

The U.S. Federal Trade Commission has adopted regulations imposing labeling requirements for pumps that dispense biodiesel blends between B5 and B20, with pumps dispensing greater than B20 blends required to identify the specific blend level.

[2] Reference CARB Biodiesel and Renewable Diesel Documents: http://www.arb.ca.gov/fuels/diesel/altdiesel/biodocs.htm

Renewable Hydrocarbon Diesel:

In some regions, renewable hydrocarbon diesel fuel with little or no petroleum-based diesel is being marketed for use in diesel engines. The California Air Resources Board recommends increased use of renewable hydrocarbon diesel fuel to meet Low-Carbon Fuel Standard (LCFS) requirements and meet lower NOx emission levels from pre-2010 on-highway or pre-Tier 4 nonroad engines. No special labeling is required for renewable hydrocarbon diesel fuel or blends regardless of blend level.

How does the cost of biomass-based diesel fuel compare to that of petroleum-based diesel?

At current production rates and economies of scale, biomass-based diesel fuel generally costs more per gallon than petroleum-based diesel fuel. The cost depends on the feedstock used, as well as the process used to produce a quality fuel. Because biomass-based diesel is typically more expensive, governments have found it necessary to provide subsidies and incentives to the biomass-based diesel industry so that it can produce a competitively-priced product. The economics of oil and fuels are volatile, and the competitive cost-position of biomass-based diesel fuels may change in the future, particularly if regulation or demand creates greater economies of scale.

What is the outlook for biomass-based diesel fuels?

Biomass-based diesel fuel provides certain benefits related to energy security, expanding markets for agricultural products, and reducing greenhouse gas emissions when lifecycle carbon emissions are considered. All biomass-based diesel fuels provide a means to reduce the use of petroleum-based diesel fuels.

Biodiesel:

Biodiesel has been shown to reduce particulate matter and hydrocarbon emissions when used in diesel engines without particulate controlling aftertreatment. For biodiesel fuels, adherence to B100 and blended fuel specifications that address fuel stability and combustion concerns is critical to the acceptance of biodiesel blends up to B20. Additional performance testing will determine whether biodiesel fuels are acceptable for use in the new near zero emission engine and aftertreatment systems or if specification changes are required to improve compatibility.

Renewable Hydrocarbon Diesel:

Renewable hydrocarbon diesel fuels have been shown to reduce NOx emissions when used in diesel engines without NOx controlling aftertreatment. Renewable hydrocarbon diesel fuels with essentially the same properties as conventional petroleum-based diesel fuel show great promise. Those fuels eliminate certain concerns with biodiesel and have other properties such as high cetane and low aromatic content that may be advantageous. Controls associated with their production process have led to good product consistency. Engine manufacturers continue to evaluate renewable hydrocarbon diesel fuel to determine potential concerns.

What else is important to know about biomass-based diesel fuel?

Engine manufacturers provide guidelines and specifications regarding fuels acceptable for use in a specific engine. Thus, end users should consult their engine manufacturer as to whether use will void the engine manufacturer's commercial warranties.

Biodiesel:

The energy content of neat biodiesel fuel (B100) is eleven percent lower (by volume) than that of petroleum-based diesel. This means that engines must burn more biodiesel fuel than petroleum-based diesel fuel to generate the same amount of work, i.e., fuel-economy of biodiesel is lower. This effect is typically small in B20 and lower blends.

Biodiesel naturally contains oxygen and therefore must be stabilized to avoid storage problems. Depending on the feedstock used, biodiesel also may have a higher cloud point (temperature at which the fuel becomes cloudy or hazy with wax crystals that can plug fuel filters and stop the engine). Biodiesel fuels may require the use of additives to improve those properties. Moreover, traditional petroleum-based diesel additives may need to be modified for use in biodiesel blends.

B100 has been found to be nontoxic and biodegradable.

Biodiesel blends may require a change to the engine manufacturer's recommended engine lubricant maintenance interval. Users should consult their engine manufacturer for information regarding changes required when using biodiesel blends.

The chemical nature of biodiesel blends causes them to attract and incorporate water; thus, care must be taken to assure that biodiesel and water are not mixed together. While it is important to keep the fuel tank full to avoid water vapor and to drain water from the fuel regardless of the fuel used, it is especially important when using biodiesel. To avoid excess water and fuel deterioration issues, vehicles and equipment should be drained of biodiesel blends and filled with petroleum-based diesel if they are not expected to be used for long periods of time.

Because it is a good solvent, biodiesel can remove rust and other deposited material not only from fuel storage tanks and distribution piping, but also from vehicle/equipment fuel tanks. When converting to biodiesel fuels, fuel tanks should be cleaned and maintenance practices adjusted to minimize fuel filter clogging and reduced filter life.

Renewable Hydrocarbon Diesel:

Renewable hydrocarbon diesel fuel has lower density and, therefore, lower energy content when compared to conventional petroleum diesel fuels. To date, however, the influence of the lower energy content on fuel consumption for various blend levels has not been fully evaluated.

Renewable hydrocarbon diesel may have a higher cloud point than petroleum diesel depending on the fuel's processing. It has storage, water holding, and solvency properties very similar to those of petroleum-based diesel fuels and, thus, should not require changes in fuel handling or storage other than those applied to petroleum-based diesel fuels.

Resources

This Fact Sheet and other documents referenced herein can be downloaded from the Truck and Engine Manufacturers Association Website at:

http://www.truckandenginemanufacturers.org/articles/search.asp?F_ARTICLE_ID=9 ;

A general reference document regarding biodiesel storage, handling, and use is available from the National Renewable Energy Laboratory (NREL), NREL/TP-540-43672, published January 2009: http://www.nrel.gov/transportation/news/2008/712.html

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