

Biodiesel and Other Renewable Diesel Fuels

Diesel fuel can be produced from biomass via several types of technologies. Some use specific biomass components, while others can convert many forms of biomass into fuel. At present, federal tax incentives apply only to certain biomass-derived diesel fuels; others do not qualify. Understanding the technologies used and resulting products helps to identify eligible fuels.

Defining Renewable Diesel and Biodiesel

According to EPA Act 2005, renewable diesel is diesel fuel derived from biomass, as defined in Section 45K (c)(3), using the process of thermal depolymerization that meets the following:

- Registration requirements for fuels and chemicals established by the Environmental Protection Agency under Section 211 of the Clean Air Act (42 U.S.C. 7545)
- Requirements of the American Society of Testing and Materials (ASTM) D975 or D396.

Biodiesel, on the other hand, is defined as methyl and ethyl esters of fatty acids meeting the requirements of ASTM specification D6751. Biodiesel is also referred to as FAME (fatty acid methyl ester) or, in Europe, as RME (rape seed methyl ester). This definition of biodiesel comes from common usage and energy policy and tax laws of the United States.

Diesel Fuel Basics

Traditional diesel fuels are petroleum distillates rich in paraffinic hydrocarbons. They have boiling ranges as broad as 370° to 780°F, which are suitable

for combustion in a compression ignition engine, such as a diesel engine. ASTM establishes the grade of diesel according to the boiling range, along with allowable ranges of other fuel properties such as cetane number, cloud point, flash point, viscosity, aniline point, sulfur content, water content, ash content, copper strip corrosion, and carbon residue.

Technically, any hydrocarbon distillate material derived from biomass that meets the appropriate ASTM specification can be defined as diesel, or as biodiesel.

Feedstocks for diesel fuels derived from biomass include soybean, rape seed, canola, palm, and waste cooking oils, along with animal fats. Starting oils can also come from algae. Vegetable oils can be used directly as diesel fuels, but their properties such as high viscosity and low volatility cause durability problems in fuel systems.

Various processes convert biomass to diesel fuels. Among these is transesterification of triglycerides, which produces esters. The resulting fuel fits into the definition of biodiesel. Other processes include hydrothermal processing, hydroprocessing, and indirect liquefaction. These processes yield distillates that are not esters. Therefore, they are ineligible for the biodiesel tax credit because they do not meet the definition of biodiesel. They could, however, be eligible for the renewable diesel credit.

Biodiesel

Biodiesel is defined as the mono alkyl esters of long-carbon-chain fatty acids derived from renewable lipid feedstocks. It is produced by transesterification of triglycerides (fatty acids) contained in oil-rich biomass and animal fats. The triglycerides can be converted to esters that have properties more compatible with petroleum diesel fuel. In the base-catalyzed transesterification process, the triglycerides are reacted with an alcohol, either methanol or ethanol, in the presence of an alkaline catalyst, normally potassium hydroxide. This reaction forms methyl or ethyl esters, and glycerin is a byproduct.

Feedstocks such as soybean oil are used for biodiesel and other renewable diesel fuels.



Nebraska Soybean Board/PW00231



In the United States, FAME meeting the requirements of ASTM D6751 can be called biodiesel and is eligible for the biodiesel tax credit.

Renewable Diesel from Hydrothermal Processing

In hydrothermal processing, biomass is reacted in water at an elevated temperature and pressure to form oils and residual solids. Conversion temperatures are typically 570° to 660°F, with pressure sufficient to keep the water primarily as a liquid, 100 to 170 standard atmosphere (atm). Reaction times are on the order of 15 to 30 minutes. After reaction, the organics are separated from the water; a distillate cut suitable for diesel use is produced.

This technology is being commercialized in the United States by Changing World Technologies (CWT). CWT states that its product meets the requirements of ASTM D975 and uses the term “thermal depolymerization” to describe the process. This terminology originated in a patent by P.T. Baskis, and the intent of the renewable diesel tax credit appears to have been to offer an incentive for this product.

Renewable Diesel from Hydroprocessing

A renewable diesel referred to as “green diesel” can be produced from fatty acids by traditional hydroprocessing technology. The starting biomass-derived oils can be the same as for biodiesel or renewable diesel. The triglyceride-containing oils can be hydroprocessed either as a co-feed with petroleum or as a dedicated feed. The product is a premium diesel fuel containing no sulfur and having a cetane number of 90 to 100. An analysis by B. Arena and others indicates that capital and operating costs are substantially lower than those for transesterification. NESTE in Finland is constructing a \$100 million green diesel plant, and Petrobras in Brazil already produces a renewable diesel called H-Bio.

Petroleum refiners use hydroprocessing to remove impurities by treating feeds with hydrogen. Hydroprocessing conversion temperatures are typically 600° to 700°F, pressures are typically 40 to 100 atm, and the reaction times are on the order of 10 to 60 minutes. Solid catalysts are employed to increase certain reaction rates, improve selectivity for certain products, and optimize hydrogen consumption.

Refiners normally do not refer to hydroprocessing as a thermal depolymerization process. Yet all hydroprocessing requires heat and pressure, and all ultimately lead to a reduction in the molecular weight of the feed (except for olefin saturation). In the case of triglyceride-containing oils, the triglyceride molecule is reduced to four hydrocarbon molecules under hydroprocessing conditions: a propane molecule and three hydrocarbon molecules in the C12 to C18 range.

Renewable Diesel from Indirect Liquefaction

A traditional ultra-low sulfur diesel can be produced from any form of biomass by a two-step process. First biomass is converted to a syngas, a gaseous mixture rich in hydrogen and carbon monoxide. Then the syngas is catalytically converted to liquids. The production of liquids is accomplished using Fischer-Tropsch (FT) synthesis. This technology applies to coal, natural gas, and heavy oils.

The proper selection of catalyst and conditions yields a product stream rich in diesel specification distillates. The production of FT liquids is a commercial technology, but most FT diesel today is produced using natural gas. FT diesel fuel can meet the requirements of ASTM D975.

For further reading

American Society for Testing and Materials. *2006 Annual Book of Standards: Volume 5, Petroleum Products and Lubricants, D 396-05 and D975-06*, 2006.

Petroleum-Based Fuels Property Database: <http://www.nrel.gov/vehiclesandfuels/apbf/progs/search1.cgi>. (Contains values for diesel properties and specific ASTM tests, including methods and values for biodiesel and other renewable fuels.)

Baskis, P.T. “Thermal Depolymerization Reforming Process and Apparatus,” U.S. Patent 5,269,947, 1993.

Arena, B.; Holmgren, J.; Marinangeli, R.; Marker, T.; McCall, M.; Petri, J.; Czernik, S.; Elliot, D.; and Shonnard, D. “Opportunities for Biorenewables in Petroleum Refineries,” Rio Oil & Gas Expo and Conference, Instituto Brasileiro de Petroleo e Gas - IBP, IBP1701_06, Sep., 2006.

For more information

Richard Bain
National Bioenergy Center, NREL
richard_bain@nrel.gov
303-384-7765

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

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