Investigation of Biodistillates as Potential Blend Stocks for Transportation Fuels

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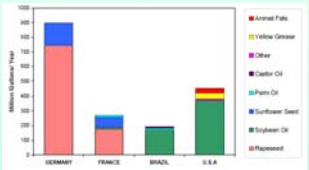
Objectives

Literature Review: Assess the state-of-knowledge regarding biofuels as blending materials for ultra-low sulfur diesel (ULSD) fuel in transportation applications.

Topics investigated:

- policy drivers
- biofuel feedstocks
- fuel production technologies
- fuel properties and specifications
- in-use handling and performance
- exhaust emissions
- life cycle impacts

Feedstocks and Volumes

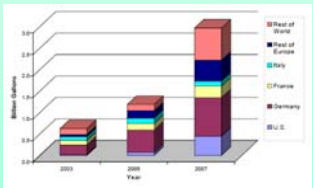


Europe – dominated by rapeseed

U.S. – dominated by soybean oil

Increasing interest in non-edible feedstocks:

- Jatropha, Karanja, Camelina, etc.
- Algae



Global biodistillate production is approx. 3 billion gallons/year (bg/y)

Most biodiesel is blended with petroleum diesel to produce biodiesel blends:

- 20% blend, called B20, is typical

Future growth of biodistillates is limited by feedstock availability and cost.

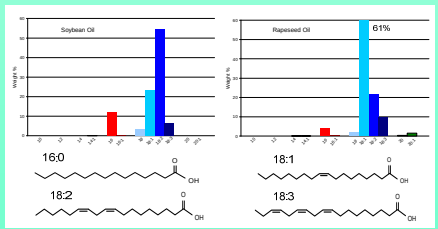
- Approximately 80% of total biodiesel cost is attributed to feedstock.
- Overcapacity is currently a major problem.
- Growing interest in non-conventional feedstocks.

Properties and Specifications

Biodiesel is composed of fatty acid methyl esters (FAME)

Properties and performance of biodiesel are determined by the fuel's chemical composition – especially:

- fatty acid chain length
- degree of unsaturation in the fatty acid chain.



Several standard-setting organizations have developed sets of standard specifications to define acceptable quality biodistillate fuels:

- US - ASTM D 6751
- Europe – EN 14214

Specifications are meant to ensure high purity products, free of contaminants and unreacted starting materials that could otherwise lead to poor performance.

Typical Properties of Petroleum Diesel and Biodistillate Fuels

Property	No. 2 Petroleum ULSD	Biodiesel (FAME)	Renewable Diesel
Carbon, wt%	86.8	76.2	84.9
Hydrogen,wt%	13.2	12.6	15.1
Oxygen,wt%	0.0	11.2	0.0
Specific Gravity	0.85	0.88	0.78
Cetane No.	40-45	45-55	70-90
T_{90}, °C	300-330	330-360	290-300
Viscosity,mm^2/sec. @ 40°C	2-3	4-5	3-4
Energy Content (LHV)			
Mass basis, MJ/kg	43	39	44
Mass basis, BTU/lb.	18,500	16,600	18,900
Vol. basis, 1000 BTU/gal	130	121	122

Biodiesel contains about 11% oxygen, and has lower mass energy content than petroleum diesel. Renewable diesel contains no oxygen, and has mass energy content similar to petroleum diesel.

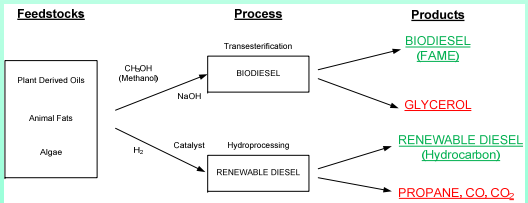
Production Technologies

Biodiesel is produced by transesterification of triglycerides (vegetable oils and animal fats) using an alcohol and a catalyst.

- Methanol is the most common alcohol – produces fatty acid methyl esters (FAME).
- Glycerol is unavoidable by-product of transesterification. Complete removal of glycerol is critical to meeting fuel specifications.

Renewable diesel is produced by hydroprocessing of the same triglyceride feedstocks

- Process is typically conducted within a petroleum refinery.
- Process does not require an alcohol, and does not produce glycerol.



Emissions Effects

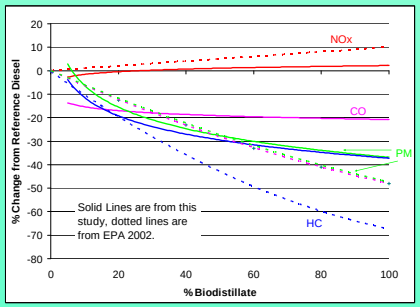
Diesel vehicles are a significant source of both NOx and PM emissions and, to a lesser extent, CO, HC, and other toxic species. Solid lines in the graph below show logarithmic best fit curves based on reported heavy-duty results from 94 studies over the past 8 years. Dotted lines represent results from a similar EPA study in 2002.

Many variables influence emissions results:

- type of engine
- engine operating conditions
- biodistillate sources
- emissions control technologies

In general, biodistillates reduce CO, HC, and PM emissions, but have little effect on NOx

Emissions effects appear smaller than previously reported.



In-Use Performance

Use of biodiesel often requires extra "housekeeping" precautions

- Concerns due to water solubility, oxidative stability, and low temperature operability
- Most problems can be avoided by: (1) strict adherence to specifications and (2) limiting blends to B20 and below

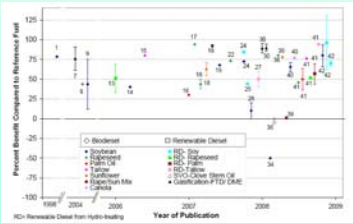
Life-Cycle Assessments

Life-cycle assessments (LCA) are used to evaluate energy and environmental impacts (especially greenhouse gas emissions) that result from all stages of a product's life, from manufacturing through disposal.

- Overall energy benefit, or energy return (ER) of the entire process is determined by dividing the heating value of the fuel by total life-cycle energy inputs.
- Most life-cycle studies report ER values of biodistillates in the range of 2-4.

LCA results for GHG emissions expressed as relative global warming potential (GWP) compared to conventional diesel.

- Most life-cycle studies report biodistillate GWP benefits of 10-90%
- A few studies report no GWP benefit, primarily due to assumptions of high N_2O emissions.
- Indirect land use changes are not included in most LCA studies to-date.



Summary

- Policy Drivers: U.S. Energy Independence and Security Act of 2007 requires 0.5 bg/y of biomass-based diesel fuel by 2009, ramping up to 1.0 bg/y by 2012.
- Biodiesel Volumes and Feedstocks: Approximately 3 bg/y of biodiesel is produced today, with most being used as blends with petroleum diesel (e.g. B20) Rapeseed oil is the dominant feedstock in Europe; soybean oil is the dominant feedstock in the U.S.
- Biodistillate Production Technologies: Biodiesel is commonly produced by transesterification of vegetable oil and animal fats with methanol. Renewable diesel is produced by hydroprocessing of the same triglyceride feedstocks.
- Fuel Properties and Specs.: Standard-setting organizations have established specifications to ensure satisfactory quality of biodistillates in the marketplace.
- In-Use Performance: Extra "housekeeping" may be necessary when dealing with biodiesel. Oxidative stability and low temperature operability are two items of concern.
- Emissions Effects: Biodistillates blends provide exhaust emissions reduction benefits for CO, HC, and PM. The NOx emissions effects are smaller and difficult to discern.
- Life-Cycle Assessments: Life-cycle studies show substantial benefits of biodistillates compared to petroleum diesel in terms of energy return (ER) and GHG reductions. However, results are highly variable, depending upon the LCA model assumptions.

Acknowledgements

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