Biodiesel

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Biodiesel sample

Biodiesel is a biofuel made from renewable materials such as vegetable oils or animal fats. It is biodegradable and non-toxic, and has significantly fewer emissions than petroleum-based diesel (petro-diesel) when burned. Biodiesel functions in current diesel engines, and is a possible candidate to replace fossil fuels as the world's primary transport energy source.

With a flash point of 160 °C, Biodiesel is classified as a non-flammable liquid by the Occupational Safety and Health Administration. This property makes a vehicle fueled by pure biodiesel far safer in an accident than one powered by petroleum diesel or the explosively combustible gasoline. Precautions should be taken in very cold climates, where biodiesel may gel at higher temperatures than petroleum diesel.

Biodiesel can be distributed using today's infrastructure, and its use and production is increasing rapidly (especially in Europe, the United States, and Asia). Fuel stations are beginning to make biodiesel available to consumers, and a growing number of transport fleets use it as an additive in their fuel. Biodiesel is generally more expensive to purchase than petroleum diesel, although this differential may diminish due to economies of scale, the rising cost of petroleum, and government subsidization favoring the use of biodiesel.Contents

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History

Transesterification of a vegetable oil was conducted as early as 1853, by scientists E. Duffy and J. Patrick, many years before the first diesel engine became functional. Rudolf Diesel's prime model, a single 10 ft (3 m) iron cylinder with a flywheel at its base, ran on its own power for the first time in Augsburg, Germany on August 10, 1893. In remembrance of this event, August 10 has been declared International Biodiesel Day. Diesel later demonstrated his engine and received the "Grand Prix" (highest prize) at the World Fair in Paris, France in 1900. This engine stood as an example of Diesel's vision because it was powered by peanut oil—a biofuel, though not strictly biodiesel, since it was not transesterified. He believed that the utilization of a biomass fuel was the real future of his engine. In a 1912 speech, Rudolf Diesel said, "the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time." [1]

During the 1920s, diesel engine manufacturers altered their engines to utilize the lower viscosity of the fossil fuel (petrodiesel) rather than vegetable oil, a biomass fuel. The petroleum industries were able to make inroads in fuel markets because their fuel was much cheaper to produce than the biomass alternatives. The result was, for many years, a near elimination of the biomass fuel production infrastructure. Only recently have environmental impact concerns and a

decreasing cost differential made biomass fuels such as biodiesel a growing alternative.

The revival of biodiesel production started with farm co-operatives in the 1980s in Austria, but in 1991 the first industrial-scale plant opened in Aschach, also in Austria, with a capacity in excess of 10,000 m³ per year. Throughout the 1990s, plants were opened in many European countries, including the Czech Republic, France, Germany, Sweden. At the same time, nations in other parts of world also saw local production of biodiesel starting up and by 1998, the Austrian Biofuels institute identified 21 countries with commercial biodiesel projects.

In the 1990s, France launched the local production of biodiesel fuel (known locally as diester) obtained by the transesterification of rapeseed oil. It is mixed to the proportion of 5% into regular diesel fuel, and to the proportion of 30% into the diesel fuel used by some captive fleets (public transportation). Renault, Peugeot, and other manufacturers have certified truck engines for use with up to this partial biodiesel. Experiments with 50% biodiesel are underway.

From 1978 to 1996, the U.S. National Renewable Energy Laboratory experimented with using algae as a biodiesel source in the "Aquatic Species Program". A recent paper from Michael Briggs at the UNH Biodiesel Group, offers estimates for the realistic replacement of all vehicular fuel with biodiesel by utilizing algae that has a greater than 50% natural oil content, which he suggests can be grown on algae ponds at wastewater treatment plants. [2]

Meanwhile, independent results have shown that GreenFuel Technologies[3], a Cambridge, MA company founded by Isaac Berzin, has been successful in producing biodiesel growing algae on flue gas emissions from power plant smokestacks. Using a patented algae bioreactor, GreenFuel utilizes microalgae and a process of photomodulation to reduce emissions: 40 percent less CO2 and 86 percent less nitrous oxide. This oil-rich algae can then be extracted from the system and processed into biodiesel, and the dried remainder further reprocessed to create ethanol. The company is testing their method at the MIT cogeneration facility and at an undisclosed 1000-megawatt power facility in the southwestern U.S. [4][edit]

Fuel quality, standards and properties

Biodiesel is a clear amber-yellow liquid with a viscosity similar to petrodiesel, the industry term for diesel produced from petroleum. It can be used as an additive in formulations of diesel to increase the lubricity of pure ultra-low sulfur petrodiesel (ULSD) fuel. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix, in contrast to the "BA" system used for bioalcohol mixes. For example, 20% biodiesel is labeled B20. Pure biodiesel, 100%, is referred to as B100.

The common international standard for biodiesel is EN 14214.

There are additional national specifications. The standard ASTM D 6751, which is the most common standard referenced in the United States. In Germany, the requirements for biodiesels are fixed in a DIN standard. There are standards for three different varieties of biodiesel, which are made of different oils:
- RME (rapeseed methyl ester, according to DIN E 51606)
- PME (vegetable methyl ester, purely vegetable products, according to DIN E 51606)
- FME (fat methyl ester, vegetable and animal products, according to DIN V 51606)

The standards ensure that the following important factors in the fuel production process are satisfied:
- Complete reaction.
- Removal of glycerin.
- Removal of catalyst.
- Removal of alcohol.
- Absence of free fatty acids.

Basic industrial tests to determine whether the products conform to the standards typically include gas chromatography, a test that verifies only the more important of the variables above. More complete testings are more expensive. Fuel meeting the quality standards is very non-toxic, with a toxicity rating (LD50) of greater than 50 ml/kg. This toxicity rating would mean that an average 60 kg person would need to consume more than 3 litres to cause death 50% of the time, making biodiesel ten times less toxic than table salt.

Biodiesel can be mixed with petroleum diesel at any concentration in most modern engines, although it has the disadvantage of degrading rubber gaskets and hoses in vehicles manufactured before 1992. Biodiesel is a better solvent than petrodiesel and has been known to break down deposits of residue in the fuel lines of vehicles that have previously been run on petroleum. Fuel filters may become clogged with particulates if a quick transition to pure biodiesel is made, but biodiesel cleans the engine in the process.

In a study at a U.S. military base, a biodiesel blend was used as a replacement for heating oil at housing on the base. Due to the solvent power of biodiesel, residues that had been present in fuel tanks for decades were dissolved. The particulate component of the residues caused repeated clogging of fuel strainers, requiring repeated replacement,

cleaning, and in some cases installation of higher capacity filters. Due to the relatively smaller surface area and service life of fuel tanks in motor vehicles and mobile equipment, filter clogging is less prevalent but still a factor to be considered.

Environmental benefits in comparison to petroleum based fuels include:
- Biodiesel reduces emissions of carbon monoxide (CO) by approximately 50% and carbon dioxide by 78.45% on a net lifecycle basis because the carbon in biodiesel emissions is recycled from carbon that was already in the atmosphere, rather than being new carbon from petroleum that was sequestered in the earth's crust. (Sheehan, 1998)
- Biodiesel contains fewer aromatic hydrocarbons: benzofluoranthene: 56% reduction; Benzopyrenes: 71% reduction.
- It also eliminates sulfur emissions (SO2), because biodiesel does not include sulfur.
- Biodiesel reduces by as much as 65% the emission of particulates, small particles of solid combustion products. This reduces cancer risks by up to 94% according to testing sponsored by the Department of Energy.
- Biodiesel does produce more NOx emissions than petrodiesel, but these emissions can be reduced through the use of catalytic converters. The increase in NOx emmisions may also be due to the higher cetane rating of biodiesel. Properly designed and tuned engines may eliminate this increase.
- Biodiesel has a higher cetane rating than petrodiesel, and therefore ignites more rapidly when injected into the engine. It also has the highest BTU content of any alternative fuel in its pure form (B100).
- Biodiesel is biodegradable and non-toxic - tests sponsored by the United States Departement of Agriculture confrim biodiesel is less toxic than table salt and biodegrades as fast as sugar.
- Biodiesel is the only alternative fuel to have successfully completed the Health Effects Testing requirements of the Clean Air Act (1990).

Pure biodiesel (B100) can be used in any petroleum diesel engine, though it is more commonly used in lower concentrations. Some areas have mandated ultra-low sulfur petrodiesel, which reduces the natural viscosity and lubricity of the fuel due to the removal of sulfur and certain other materials. Additives are required to make ULSD properly flow in engines, making biodiesel one popular alternative. Ranges as low as 2% (B2) have been shown to restore lubricity. Many municipalities have started using 5% biodiesel (B5) in snow-removal equipment and other systems. Since biodiesel is more often used in a blend with petroleum diesel, there are fewer formal studies about the effects on pure biodiesel in unmodified engines and vehicles in day-to-day use. Fuel meeting the standards and engine parts that can withstand the greater solvent properties of biodiesel is expected to--and in reported cases does--run without any additional problems than the use of petroleum diesel. The flash point of biodiesel (150 °C) is significantly higher than that of petroleum diesel (64 °C) or gasoline (−45 °C). The gel point of biodiesel varies depending on the proportion of different types of esters contained. However, most biodiesel, including that made from soybean oil, has a somewhat higher gel and cloud point than petroleum diesel. In practice this often requires the heating of storage tanks, especially in cooler climates.[edit]

Production

Main article: Biodiesel production

Chemically, biodiesel comprises a mix of mono-alkyl esters of long chain fatty acids. The most common form uses methanol to produce methyl esters as it is the cheapest alcohol available, though ethanol can be used to produce an ethyl ester biodiesel and higher alcohols such as isopropanol and butanol have also been used. Using alcohols of higher molecular weights improves the cold flow properties of the resulting ester, at the cost of a less efficient transesterification reaction. A byproduct of the transesterification process is the production of glycerol. A lipid transesterification production process is used to convert the base oil to the desired esters. Any Free fatty acids (FFAs) in the base oil are either converted to soap and removed from the process, or they are esterified (yielding more biodiesel) using an acidic catalyst. After this processing, unlike straight vegetable oil, biodiesel has combustion properties very similar to those of petroleum diesel, and can replace it in most current uses.[edit]

Base oils

Soybeans are used as a source of biodiesel

A variety of biolipids can be used to produce biodiesel. These include:
- Virgin oil feedstock; rapeseed and soybean oils are most commonly used, though other crops such as mustard, palm oil, hemp and even algae show promise;
- waste vegetable oil (WVO);
- Animal fats including tallow, lard, yellow grease and as a byproduct from the production of Omega-3 fatty acids from fish oil.

Worldwide production of vegetable oil and animal fat is not yet sufficient to replace liquid fossil fuel use. Furthermore, some environmental groups (notably the Natural Resources Defense Council), object to the vast amount of farming and the resulting over-fertilization, pesticide use, and land use conversion that would be needed to produce the additional vegetable oil.

Many advocates suggest that waste vegetable oil is the best source of oil to produce biodiesel. However, the available

supply is drastically less than the amount of petroleum-based fuel that is burned for transportation and home heating in the world. According to the United States Environmental Protection Agency (EPA), restaurants in the US produce about 300 million US gallons (1,000,000 m^3) of waste cooking oil annually.[5] Although it is economically profitable to use WVO to produce biodiesel, it is even more profitable to convert WVO into other products such as soap. Hence, most WVO that is not dumped into landfills is used for these other purposes. Animal fats are similarly limited in supply, and it would not be efficient to raise animals simply for their fat. However, producing biodiesel with animal fat that would have otherwise been discarded could replace a small percentage of petroleum diesel usage.

The estimated transportation fuel and home heating oil use in the United States is about 230,000 million US gallons (0.87 km^3) (Briggs, 2004). Waste vegetable oil and animal fats would not be enough to meet this demand. In the United States, estimated production of vegetable oil for all uses is about 23,600 million pounds (10,700,000 t) or 3,000 million US gallons (11,000,000 m^3)), and estimated production of animal fat is 11,638 million pounds (5,279,000 t). (Van Gerpen, 2004)

For a truly renewable source of oil, crops or other similar cultivatable sources would have to be considered. Plants utilize photosynthesis to convert solar energy into chemical energy. It is this chemical energy that biodiesel stores and is released when it is burned. Therefore plants can offer a sustainable oil source for biodiesel production. Different plants produce usable oil at different rates. Some studies have shown the following annual production:
- Soybean: 40 to 50 US gal/acre (40 to 50 m^3/km^2)
- Rapeseed: 110 to 145 US gal/acre (100 to 140 m^3/km^2)
- Mustard: 140 US gal/acre (130 m^3/km^2)
- Jatropha: 175 US gal/acre (160 m^3/km^2)
- Palm oil: 650 US gal/acre (610 m^3/km^2) [6]
- Algae: 10,000 to 20,000 US gal/acre (10,000 to 20,000 m^3/km^2)

There is ongoing research into finding more suitable crops and improving oil yield. Using the current yields, vast amounts of land and fresh water would be needed to produce enough oil to completely replace fossil fuel usage.

Soybeans are not a very efficient crop solely for the production of biodiesel, but their common use in the United States for food products has led to soybean biodiesel becoming the primary source for biodiesel in that country. Soybean producers have lobbied to increase awareness of soybean biodiesel, expanding the market for their product.

In Europe, rapeseed is the most common base oil used in biodiesel production. In India and southeast Asia, the Jatropha tree is used as a significant fuel source, and it is also planted for watershed protection and other environmental restoration efforts.

Malaysia and Indonesia are starting pilot-scale production from palm oil. Palm oil so far proved to be efficient as biodiesel.

Specially bred mustard varieties can produce reasonably high oil yields, and have the added benefit that the meal leftover after the oil has been pressed out can act as an effective and biodegradable pesticide.

The production of algae to harvest oil for biodiesel has not been undertaken on a commercial scale, but working feasibility studies have been conducted to arrive at the above yield estimate. In addition to a high yield, this solution does not compete with agriculture for food, requiring neither farmland nor fresh water.[edit]

Efficiency and economic arguments

According to a study written by Drs. Van Dyne and Raymer for the Tennessee Valley Authority, the average US farm consumes fuel at the rate of 82 litres per hectare (8.75 US gallons per acre) of land to produce one crop. However, average crops of rapeseed produce oil at an average rate of 1,029 L/ha (110 US gal/acre), and high-yield rapeseed fields produce about 1,356 L/ha (145 US gal/acre). The ratio of input to output in these cases is roughly 1:12.5 and 1:16.5. Photosynthesis is known to have an efficiency rate of about 16% and if the entire mass of a crop is utilized for energy production, the overall efficiency of this chain is known to be about 1%. This does not compare favorably to solar cells combined with an electric drive train. Biodiesel outcompetes solar cells in cost and ease of deployment. However, these statistics by themselves are not enough to show whether such a change makes economic sense.

Additional factors must be taken into account, such as: the fuel equivalent of the energy required for processing, the yield of fuel from raw oil, the return on cultivating food, and the relative cost of biodiesel versus petrodiesel. A 1998 joint study by the U.S. Department of Energy (DOE) and the U.S. Department of Agriculture (USDA) traced many of the various costs involved in the production of biodiesel and found that overall, it yields 3.2 units of fuel product energy for every unit of fossil fuel energy consumed. [7] That measure is referred to as the energy yield. A comparison to petroleum diesel, petroleum gasoline and bioethanol using the USDA numbers can be found at the Minnesota Department of Agriculture website[8] In the comparison petroleum diesel fuel is found to have a 0.843 energy yield, along with 0.805 for petroleum gasoline, and 1.34 for bioethanol. The 1998 study used soybean oil primarily as the base oil to calculate the energy yields. It is conceivable that higher oil yielding crops could increase the energy yield of biodiesel. The debate over the

energy balance of biodiesel is ongoing, however.

Some nations and regions that have pondered transitioning fully to biofuels have found that doing so would require immense tracts of land if traditional crops are used. Considering only traditional plants and analyzing the amount of biodiesel that can be produced per unit area of cultivated land, some have concluded that it is likely that the United States, with one of the highest per capita energy demands of any country, does not have enough arable land to fuel all of the nation's vehicles. Other developed and developing nations may be in better situations, although many regions cannot afford to divert land away from food production. For third world countries, biodiesel sources that use marginal land could make more sense, e.g. honge nuts [9] grown along roads.

More recent studies using a species of algae that has oil contents of as high as 50% have concluded that as little as 28,000 km² or 0.3% of the land area of the US could be utilized to produce enough biodiesel to replace all transportation fuel the country currently utilizes. Further encouragement comes from the fact that the land that could be most effective in growing the algae is desert land with high solar irradiation, but lower economic value for other uses and that the algae could utilize farm waste and excess CO2 from factories to help speed the growth of the algae. [10]

The direct source of the energy content of biodiesel is solar energy captured by plants during photosynthesis. The website biodiesel.co.uk[11]discusses the positive energy balance of biodiesel:When straw was left in the field, biodiesel production was strongly energy positive, yielding 1 GJ biodiesel for every 0.561 GJ of energy input (a yield/cost ratio of 1.78). When straw was burned as fuel and oilseed rapemeal was used as a fertilizer, the yield/cost ratio for biodiesel production was even better (3.71). In other words, for every unit of energy input to produce biodiesel, the output was 3.71 units (the difference of 2.71 units would be from solar energy).

Biodiesel is becoming of interest to companies interested in commercial scale production as well as the more usual home brew biodiesel user and the user of straight vegetable oil or waste vegetable oil in diesel engines. Homemade biodiesel processors are many and varied.[edit]

Availability

Bus running on soybean biodiesel.[edit]

Australia

With around 100 million litres (26.5 million US Gallons) annual production capacity, commercial biodiesel production is still in its relative infancy in Australia. However many new production plants are being built around the nation. The future growth of the biodiesel industry in Australia is limited by feedstock availability and also by the relatively low price of petroleum diesel fuel. Many city and regional councils are already using B20. All of the public transport trains and most of the public transport buses in Adelaide, South Australia have been operating on a B5 blend since March 2005.[edit]

Austria

As one of the pioneers in the rediscovery of biodiesel, Austria has a well developed biofuels industry with a production capacity in excess of 100,000 m³ per year [12]. Biodiesel is available at filling stations in various parts of the country in different levels of blend. Large parts of the public transport in the Austrian city of Graz operate on biodiesel.[edit]

Brazil

Brazil opened a commercial biodiesel refinery in March 2005. It is capable of producing 12,000 m³ (3.2 million US gallons) per year of biodiesel fuel. Feedstocks can be a variety of sunflower seeds, soybeans, or castor beans. The finished product will be currently a blend of gas oil with 2% biodiesel and, after 2011, 5% biodiesel, both usable in unmodified diesel engines. As of 2005, there were 3 refineries and 7 that are planned to open. The three factories were capable of producing 45,6 million of litres per year.[edit]

Belgium

In Belgium, there are refineries in Ertvelde (by the company Oléon) and at Feluy.[edit]

Canada

Rothsay of Ville Ste Catherine, Quebec produces 35,000 m³ of biodiesel a year [13]. Ocean Nutrition of Mulgrave, Nova Scotia produces 6 million gallons (23,000 m³) of fatty acid ethyl esters annually as a byproduct of its Omega-3 fatty acid processing. They use this byproduct for power and Halifax-based Wilson Fuels take the surplus and offer blended biodiesel for use in transportation and heating fuel. Halifax Regional Municipality has converted its bus fleet, with a future demand of 7,500 m³ of BD20, reducing biodiesel content in low temperatures to avoid gelation issues but possibly increasing to B50 in summer, and 3,000 m³ split between B20 and B100 for building heat. The municipality forecasts a

greenhouse gas reduction of over 9,000 tonnes CO2 equivalents (4,250 tonnes from fleet use and 5,000 tonnes from building heating) if fully implemented. The Province of Nova Scotia uses biodiesel in some buildings for heating. Private sector uptake is slow due to a lack of price differential with petroleum fuel and a lack of federal and provincial tax rebating. Wilson Fuels have opened a biodiesel station in Moncton, New Brunswick.

Manitoba has seen a rush of building in bio-diesel plants in 2005 and 2006. The first plant was built in June of 2005 called Bifrost Bio-Diesel in Arborg, Manitoba.

Biodiesel is being made by individual farmers for their own use.

BioFuel Canada Ltd www.biofuelcanada.ca has small scale affordable plants for Farmers and off road users.[edit]

Czech Republic

Czech production of biodiesel was already above 60,000 m³ per year by the early 1990s and is now even larger [14]. Many of the plants are very large, including one in Olomouc which produces almost 40,000 m³ per year. From the summer of 2004, the Czech producers of biodiesel for blend receive a subsidy of roughly CEK 9.50/kg. All Skoda diesels built since 1996 are warrantied to use biodiesel.[edit]

Germany

According to the Union zur Förderung von Öl- und Proteinpflanzen UFOP[15](Union to promote oil- and protein plants), in 2004 the sale of biodiesel through German gas stations rose to 375,000 m³, although it is currently only available at selected outlets. In 2004, 45 percent of all biodiesel sales went directly to large end users, such as trucking companies.

Production capacity for biodiesel, for the most part produced from rapeseed, is expected to rise in 2006 to over 2,000,000 m³ per year. Sales in Germany have doubled to 376.6 million litres (about 99 million US gallons) from 2002 to 2004. This amount is sufficient to meet the average yearly consumption of well over 300,000 automobiles. Diesel engines have become increasingly popular in Germany and almost half of all newly manufactured cars are diesel powered. This is in part due to the greater efficiency of diesel engines, the desire by consumers to use environmentally friendlier technologies and lower taxes on diesel fuel that make it cheaper than gasoline.

With 1,900 sales points, equal to one in every ten public gas stations, biodiesel is the first alternative fuel to be available nationwide. The industry is expecting a surge in demand since the authorisation at the beginning of 2004, through European Union legislation, of a maximum 5 percent biodiesel addition to conventional diesel fuel. In Germany biodiesel is also sold cheaper in comparison to fossil diesel fuel.[edit]

India

Biodiesel is now being produced locally in India for use in three-wheeler motor rickshaws. These engines actually run on regular diesel fuel or CNG, but in the past kerosene was used because it was far cheaper, and worked just as well. However, kerosene was dirty and wasn't as clean-burning. Biodiesel is rapidly replacing both kerosene and diesel as a more efficient, cheap, and clean alternative.[edit]

United Kingdom

Biodiesel is sold by a small number of filling stations in B5 and B100 blend [16] and some farmers have been using small plants to create their own biodiesel for farm machinery since the 1990s, but the first large scale plant, capable of producing 50 million litres (13 million US gallons) a year, opened in Scotland in 2005 [17]. Biodiesel is treated like any other vehicle fuel in the UK and the paperwork required to register as a producer is a major limiting factor to growth in the market.[edit]

United States

Biodiesel is commercially available in most oilseed-producing states in the United States. As of 2005, it is somewhat more expensive than fossil diesel, though it is still commonly produced in relatively small quantities (in comparison to petroleum products and ethanol). Many farmers who raise oilseeds use a biodiesel blend in tractors and equipment as a matter of policy, to foster production of biodiesel and raise public awareness. It is sometimes easier to find biodiesel in rural areas than in cities. Similarly, some agribusinesses and others with ties to oilseed farming use biodiesel for public relations reasons. As of 2003 some tax credits are available in the U.S. for using biodiesel. In 2004 almost 30 million US gallons (110,000 m³) of commercially produced biodiesel were sold in the U.S., up from less than 0.1 million US gallons (380 m³) in 1998. Due to increasing pollution control requirements and tax relief, the U.S. market is expected to grow to 1 or 2 billion US gallons (4,000,000 to 8,000,000 m³) by 2010. The price of biodiesel in the United States has come down from an average $3.50 per US gallon ($0.92/l) in 1997 to $1.85 per US gallon ($0.49/l) in 2002. This appears

economically viable with current petrodiesel prices, which as of 09/19/05 varied from 264.8 cents to 306 cents.

A pilot project in Unalaska/Dutch Harbor, Alaska is producing fish oil biodiesel from the local fish processing industry in conjunction with the University of Alaska Fairbanks. It is rarely economic to ship the fish oil elsewhere and Alaskan communities are heavily dependent on diesel power generation. The local factories project 3.5 million tonnes of fish oil annually.

In 2005, U.S. entertainer Willie Nelson was selling B20 Biodiesel in four states under the name BioWillie. By late 2005 it was available at 13 gas stations and truck stops (mainly in Texas). Most purchasers were truck drivers. It was also used to fuel the buses and trucks for Mr. Nelson's tours as well as his personal automobiles [18].

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- Economy_and_business#Commodities
- Alcohol fuel (including gasohol)
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- Ethylester biodiesel
- Hydrogen car
- List of diesel automobiles
- Renewable energy
- Straight vegetable oil (SVO)
- Thermal depolymerization
- Future energy development [edit]

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- ^ EPA: OSWER: OSWER Innovations Pilot: Reducing Production Costs and Nitrogen Oxide (NOx) Emissions from Biodiesel. URL accessed on November 2, 2005. [edit]

External links
- Learn to Make Biodiesel - A Collaborative Biodiesel Tutorial
- B100 Supply - Biodiesel Homebrewing Supplies, Books, Kits, Scales, Labware and more
- Utah Biodiesel Supply - Biodiesel Homebrewing Supplies, Equipment, & Information
- Biodiesel Warehouse - Biodiesel Processor's, Homebrewing Equipment, Diesel Generators, & More
- http://www.biofuelcanada.ca/
- http://www.biodiesel.org/ U.S. National Biodiesel Board (NBB) mirror of http://www.nbb.org/
- http://www.biodiesel.org.au/
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- San Francisco Biofuels Cooperative - Access, Advocacy, Education
- Soy biodiesel
- Biodiesel Fuel Testing, B100 & ASTM D6751 Biodiesel
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Specifications
- Alternative fuels index
- What is Biodiesel? (biofuel.be)
- A forum for biodiesel and grease cars
- Bio-power, a Trade Association of local producers of biodiesel in the UK
- Biodiesel and vegetable oil news, sites, events, conversion kits, FAQs, etc.
- Biodiesel article on CBC website
- Northwest Biodiesel Network(USA)-an advocacy group
- Biodiesel Info from a Vermont/New Hampshire/New York Biodiesel Supplier.
- Halifax Regional Municipality's experiences with biodiesel
- Halifax Herald article on Ocean Nutrition/Wilson Fuels biodiesel in Nova Scotia, Canada
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