BIODIESEL
AN ALTERNATIVE VEHICLES FUEL; ANALYTICAL VIEW

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1. Introduction

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(1).

Rudolf Diesel's prime model, a single 10ft (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(2). Diesel later demonstrated his engine at the World Fair in Paris, France in 1898. This engine stood as an example of Diesel's vision because it was powered by peanut oil—a biofuel. He believed that the utilization of a biomass fuel was the real future of his engine. In a 1912 speech, Rudolf Diesel said, (1) "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."

Rudolf Diesel was not the only inventor to believe that biomass fuels would be the mainstay of the transportation industry. Henry Ford designed his automobiles, beginning with the 1908 Model T(1), to use ethanol. Ford was so convinced that renewable resources were the key to the success of his automobiles that he built a plant to make ethanol in the Midwest and formed a partnership with Standard Oil to sell it in their distributing stations.

During the 1920's, this biofuel was 25% of Standard Oil's sales in that area. With the growth of the petroleum industry Standard Oil cast its future with fossil fuels. Ford continued to promote the use of ethanol through the 1930's. The petroleum industry undercut the biofuel sales and by 1940 the plant was closed due to the low prices of petroleum.

Diesel engine manufacturers altered their engines to utilize the lower viscosity of the fossil fuel (petroleum diesel) 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.

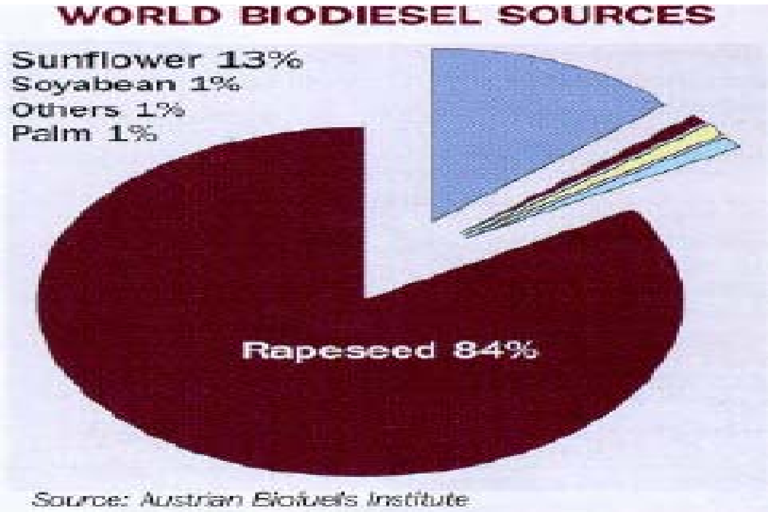
At the beginning of World War II, the groundwork for our current perceptions of biofuels was in place[(1)]. **First**, the diesel engine had been modified, enabling it to use petroleum Diesel. **Second**, the petroleum industry had established a market with very low prices for a residual product. **Third**, a major biomass industry was being shut down. Corn farmers were unable to organize at that time and provide a potential product to replace hemp as a biomass resource. Finally, industries with immense wealth behind them were acting in concert to push forward their own agenda - that of making more wealth for themselves. It is interesting to note that, during World War II, both the Allies and Nazi Germany utilized biomass fuels in their machines. Despite its use during World War II, biofuels remained in the obscurity to which they had been forced.

Post World War II the petroleum industries quietly bought the trolley car systems that ran on electricity and were a major part of the transportation infrastructure system. They dismantled them. The trolleys were then sporadically replaced with diesel buses. These industries also pushed the government to build roads, highways, and freeways, so the automobiles they produced had a place to operate. This newly created transportation infrastructure was built with public funds, supporting and aiding the growth and strength of the petroleum, automobile, and related industries[(1)].

Only recently have environmental impact concerns and a decreasing cost differential made biomass fuels such as biodiesel which is a growing alternative.

2. What is biodiesel?

Biodiesel is defined as the mono-alkyl esters of fatty acids[3] derived from vegetable oils or animal fats. In simple terms, Biodiesel is the product you get when a vegetable oil or animal fat is chemically reacted with an alcohol to produce a new compound that is known as a fatty acid alkyl ester.



A catalyst such as sodium or potassium hydroxide is required. Glycerol is produced as a byproduct.

The approximate proportions of the reaction are: [4]

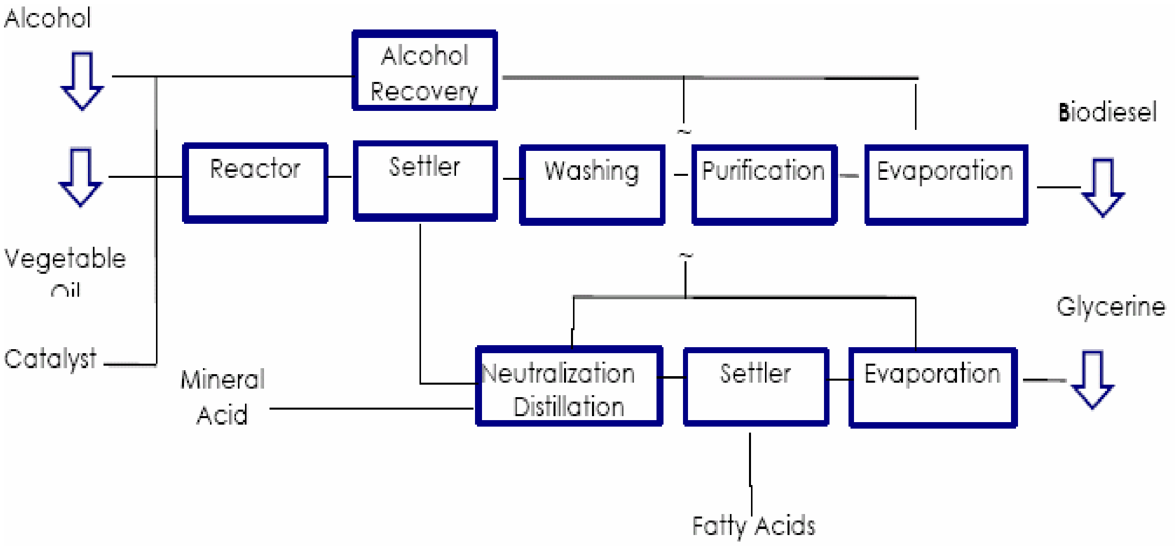
100 lbs of oil + 10 lbs of methanol ….. 100 lbs of Biodiesel + 10 lbs of glycerol

Soybean oil and methanol are the most popular feedstocks in the United States. Biodiesel from soybeans is sometimes called soy diesel, methyl soyate, or soy methyl esters (SME). In Europe, most Biodiesel is made from rapeseed oil and methanol and it is known as rapeseed methyl esters (RME).

3. How is Biodiesel made? [5]

Biodiesel fuel can be made from new or used vegetable oils and animal fats. Fats and oils are chemically reacted with an alcohol (methanol is the usual choice) to produce chemical compounds known as fatty acid methyl esters. Biodiesel is the name given to these esters when they are intended for use as fuel.

Biodiesel can be produced by a variety of esterification technologies. The oils and fats are filtered and preprocessed to remove water and contaminates. If free fatty acids are present, they can be removed or transformed into biodiesel using special pretreatment technologies. The pretreated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium or potassium hydroxide). The oil molecules (triglycerides) are broken apart and reformed into esters and glycerol, which are then separated from each other and purified.



Approximately 55% of the Biodiesel industry can use any fat or oil feedstock, including recycled cooking grease. The remaining percentage is limited to vegetable oils, the least expensive of which is soy oil.

4. Why Biodiesel:

- It is a renewable resource, based on soybean and other oil crops that are grown anew each year.
- Biodiesel has been demonstrated to have significant environmental benefits in terms of decreased global warming impacts, reduced emissions. Various studies have concluded that using 1 kg of biodiesel leads to the reduction of some 2.5 kg of CO_2 [(6)]. Pure biodiesel is biodegradable, nontoxic and essentially free of sulfur and aromatics. Biodiesel used in a 20 percent blend

with petroleum diesel and a catalytic converter will cut air pollution. Particulate matter is reduced 31 percent, carbon monoxide by 21 percent and total hydrocarbons by 47 percent. Biodiesel used in a blend will also reduce sulfur emissions and aromatics. Using 100% biodiesel further reduces emissions and carcinogenic compounds.

- Biodiesel offers fleet operators a safer, cleaner alternative to petroleum diesel. It requires no engine modifications or changes in the fuel handling and delivery systems. Biodiesel delivers similar torque, horsepower and miles per gallon.
- Biodiesel production also plays a useful role in agriculture. The arable raw materials needed for biodiesel production may be grown on set-aside land, land which would otherwise be taken out of production.

5. How is biodiesel used?

Biodiesel as fuel applications can be divided into 3 categories[(7)]:

1. Pure fuel (B100)

Biodiesel can be used in its pure form, also known as *neat* biodiesel, or B100. This is the approach that provides the most reduction in exhaust particulates, unburned hydrocarbons, and carbon monoxide. It is also the best way to use biodiesel when its non-toxicity and biodegradability are important. Marine applications may be important for B100.

2. Blends (typically20-50%)

Biodiesel will blend with petroleum-based diesel fuel in any proportion so it is common to use blends of 20 to 50% biodiesel in 80 to 50% normal diesel fuel. Blends reduce the cost impact of biodiesel while retaining some of the emissions reduction. Most of the emission reductions appear to be proportional to the percentage of biodiesel used.

3.As an additive, 1-2% (BO2) :

Tests for lubricity have shown that biodiesel is a very effective lubricity enhancer. Even as little as 0.25% can have a measurable impact and 1-2% is enough to convert a very poor lubricity fuel into an acceptable fuel. Although these levels are too low to have any impact on the Cetane number of the fuel or the emissions from the engine, the lubricity provides a significant advantage at a modest cost.

6. How Biodiesel Works ?

Biodiesel runs in any unmodified diesel engine. There is no “engine conversion” typical of other alternative fuels. The diesel engine can run on biodiesel because it operates on the principle of compression ignition whereby air is compressed and then fuel is sprayed into the ultra-hot, ultra-pressured combustion chamber. Unlike gasoline engines, which use a spark to ignite the fuel/air mixture, diesel engines actually use fuel to ignite hot air. This simple process allows the diesel engine to run on thick fuels. Since biodiesel is chemically similar to petroleum diesel fuel, you can pour biodiesel right into the fuel tank of any diesel vehicle (8).

7. Biodiesel quality, standards and properties (9)

Biodiesel is a clear amber-yellow liquid with a viscosity similar to petroleum diesel. Much of the world uses a system known as the "BD factor" to state the amount of biodiesel in any fuel mix. For example, 20% biodiesel is labeled BD20. Pure biodiesel, 100%, is referred to as BD100. In the United States, a similar system is used, but the "D" is dropped (B100, B20, B5, etc.).

The international standard for biodiesel is ISO 14214. Another is the ASTM International 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.

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 older vehicles (prior to 1992). Biodiesel is a better solvent than petrodiesel and has been known to break down deposits of residue in the fuel lines of vehicles which usually run on petroleum. Fuel filters may become clogged with particulates if a quick transition to pure biodiesel is made, but the biodiesel cleans the engine in the process.

The standards make sure that the following important factors in the fuel production process are satisfied: Complete reaction, Removal of glycerin, Removal of catalyst, Removal of alcohol and the absence of free fatty acids.

ASTM Specification (D6751) for B100 [(9)]

Property	**ASTM Method**	**Limits**	**Units**
Flash Point	D93	130 min.	Degrees C
Water & Sediment	D2709	0.050 max.	% Volume
Kinematic Viscosity (40 C)	D445	1.9-6.0	mm^2/sec
Sulfated Ash	D874	0.020 max.	% mass
Sulphur	D5453	0.05 max.	% mass
Cetane	D613	47 min.	
Cloud Point	D2500	Report	Degrees C
Carbon Residue (100% Sample)	D4530*	0.050 max.	% mass
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass
Phosphorous Content	D4951	0.001 max.	% mass

*The carbon residue shall be run out on the 100% sample

8. Characteristics of Biodiesel[(9)]

Biodiesel as automotive fuel has similar properties to petroleum diesel and as such can be directly used in existing diesel engines with no or minor modifications. It can be used alone or mixed in any ratio with petroleum diesel. The most common blend is B20, a mix of 20% biodiesel with 80%

petroleum diesel. Biodiesel has 11% oxygen by weight and essentially contains no sulphur or aromatics.

Selected Fuel Properties for Petroleum Diesel & Biodiesel [9]

Fuel Property	**Petroleum diesel**	**Biodiesel**
Fuel Standard	ASTM D975	ASTM PS121
Fuel Composition	C10-C21 HC	C12-C22 FAME
Lower Heating Value, Btu/gal	131,295	117,093
Kin. Viscosity, @40 C	1.3-4.1	1.9-6.0
Specific Gravity, kg/l @ 60 F	0.85	0.88
Density, lb/gal @ 15 C	7.079	7.328
Water, ppm by wt.	161	0.05% max.
Carbon, wt%	87	77
Hydrogen, wt%	13	12
Oxygen by dif. Wt%	0	11
Sulphur, wt%	0.05 max.	0.00-0.0024
Boiling Point, Degrees C	188-343	182-338
Flash Point, Degrees C	60-80	100-170
Cloud Point, Degrees C	-15 to 5	-3 to 12
Pour Point, Degrees C	-35 to -15	-15 to 10
Cetane Number	40-55	48-65
Stoichometric Air/Fuel Ratio	15	13.8

The major fuel characteristics include ignition quality commonly expressed by the cetane number; fuel stability, indicated by carbon residue and accelerated stability; low temperature flow performance, indicated by fuel cloud point; and fuel energy content from lower heating value in BTU/gallon.

1. Ignition quality

One of the primary advantages of diesel is its high cetane rating which allows the fuel to auto ignite when sufficiently compressed. The cetane rating is a number indicating the ability of fuel to self ignite, the higher the number, the easier it self-ignites. The reported cetane numbers for biodiesel range between 46 and 51. depending on the feedstock used to make the ester.

2. Fuel Stability

The stability of the fuel is described by carbon residue and accelerated stability: blends up to 30 percent are still within the satisfactory range .

3. Low Temperature Performance

Biodiesel is somewhat more viscous than petroleum diesel. This is not of major concern for biodiesel as long as routine measures, which are used to ensure the flow of petroleum diesel, are employed, but cold weather additives are being explored.

4. Fuel Energy Content

Biodiesel has a significantly lower heating value (BTU/gallon) than diesel fuel (12.5% lower). Because this is essentially a straight line blending function, the heating value of the blend is proportional to the biodiesel concentration. However, the density of biodiesel is greater than diesel fuel, so the effect on energy density (BTU/gallon) is not as great. Therefore, because diesel engines inject fuel by volume, not mass, the impact of the lower heating value of biodiesel will not be as great.

9. Advantages of biodiesel

- The lifecycle production and use of biodiesel produces approximately 80% less carbon dioxide emissions, and almost 100% less sulphur dioxide. Combustion of biodiesel alone produces over a 90% reduction in total unburned hydrocarbons, and a 75-90% reduction in aromatic hydrocarbons. Biodiesel further provides significant reductions in particulates and carbon monoxide than conventional diesel fuel.

- Need no change in refueling infrastructures and spare part inventories.
- Maintains the payload capacity and range of conventional diesel engines.
- Diesel skilled mechanics can easily attend to biodiesel engines.
- 100% domestic fuel.
- Neat biodiesel fuel is non-toxic and biodegradable. Based on Ames Mutagenicity tests, biodiesel provides a 90% reduction in cancer risks.
- Cetane number is significantly higher than that of conventional diesel. Lubricity is improved over that of conventional diesel fuel.
- Has a high flash point of about 300 F compared to that of conventional diesel, which has a flash point of 125 F.

10. Disadvantages of biodiesel

- Quality of biodiesel depends on the blend, thus quality can be tampered.
- Biodiesel has excellent solvent properties. Any deposits in the filters and in the delivery systems may be dissolved by biodiesel and result in need for replacement of the filters.
- There may be problems of winter operatibility.
- Spills of biodiesel can decolorize any painted surface if left for long.
- Neat biodiesel demands compatible elastomers (hoses, gaskets, etc.).

11. Biodiesel Performance[10]

Operationally, biodiesel performs very similar to low sulfur diesel in terms of power, torque, and fuel without major modification of engines or infrastructure.

Biodiesel offers similar power to diesel fuel*:*

One of the major advantages of biodiesel is the fact that it can be used in existing engines and fuel injection equipment with little impact to operating performance. Biodiesel has a higher cetane number than diesel fuel. In over 15 million miles of in-field demonstrations biodiesel showed similar fuel consumption, horsepower, torque, and haulage rates as conventional diesel fuel.

Biodiesel provides significant lubricity

Improvement over petroleum diesel fuel*:* Lubricity results of biodiesel and petroleum diesel using industry test methods indicate that there is a marked improvement in lubricity when biodiesel is added to conventional diesel fuel.

Compatibility of Biodiesel with engine components:

In general, biodiesel will soften and degrade certain types of elastomers and natural rubber compounds over time. Using high percent blends can impact fuel system components (primarily fuel hoses and fuel pump seals), that contain elastomer compounds incompatible with biodiesel. Manufacturers recommend that natural or butyl rubbers not be allowed to come in contact with pure biodiesel. Biodiesel will lead to degradation of these materials over time, although the effect is lessened with biodiesel blends. If a fuel system does contain these materials and users wish to fuel with pure biodiesel, replacement with compatible elastomers is recommended.

Biodiesel in cold weather:

Cold weather can cloud and even gel any diesel fuel, including biodiesel. Users of a 20 percent biodiesel blend will experience an increase of the cold flow properties (cold filter plugging point, cloud point, pour point) of approximately 3 to 5° Fahrenheit. Precautions employed for petroleum diesel are needed for fueling with 20 percent blends. Neat (100 percent) biodiesel will gel faster than petroleum diesel in cold weather operations. Solutions for winter operability with neat biodiesel are much the same as that for low-sulfur petroleum diesel (i.e. utilization of fuel heaters, and storage of the vehicle in or near a building).These same solutions work well with biodiesel blends, as do the use of cold flow improvement additives.

Infrastructure:

In general, the standard storage and handling procedures used for petroleum diesel should be used for biodiesel. The fuel should be stored in a clean, dry, dark environment. Temperature extremes should be avoided. Acceptable storage tank materials include mild steel, stainless steel, fluorinated polyethylene, and fluorinated polypropylene. Biodiesel has a solvent effect which releases the deposits accumulated on tank walls and pipes, which previously have been used for diesel. These deposits can be expected to clog filters initially and precautions should be taken to allow for this.

12. BIODIESEL & ENVIRONMENT(7)

BIODIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL(7)

Emission Type	B100	B20
Total Unburned Hydrocarbons	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
NOx	+13%	+2%
Sulfates	-100%	-20%
PAH (Polycyclic Aromatic Hydrocarbons)	-80%	-13%
nPAH (nitrated PAH’s)	-90%	-50%

- *The overall ozone (smog) forming potential of biodiesel is less than diesel fuel*. The ozone forming potential of the hydrocarbon emissions was nearly 50 percent less than that measured for diesel fuel.
- *Sulfur emissions are essentially eliminated with pure biodiesel*. The exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel were essentially eliminated compared to sulfur oxides and sulfates from diesel.
- *Criteria pollutants are reduced with biodiesel use*. The use of biodiesel in an unmodified Cummins N14 diesel engine resulted in substantial reductions of unburned hydrocarbons, carbon monoxide, and particulate matter. Emissions of nitrogen oxides were slightly increased.
- *Carbon Monoxide:* The exhaust emissions of carbon monoxide from biodiesel were 50 percent lower than carbon monoxide emissions from diesel.
- *Particulate Matter*: Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from biodiesel were 30 percent lower than overall particulate matter emissions from diesel.
- *Hydrocarbons* : The exhaust emissions of total hydrocarbons (a contributing factor in the localized formation of smog and ozone) were 93 percent lower for biodiesel than diesel fuel.
- *Nitrogen Oxides* : NOx emissions from biodiesel increase or decrease depending on the engine family and testing procedures. NOx emissions (a contributing factor in the localized formation of smog and ozone) from pure (100%) biodiesel increased by 13 percent. However, biodiesel's lack of sulfur allows the use of NOx control technologies that cannot be used with conventional diesel. So, biodiesel NOx emissions can be effectively managed and efficiently eliminated as a concern of the fuel's use.
- *Biodiesel reduces the health risks associated with petroleum diesel*. Biodiesel emissions showed decreased levels of PAH and nitrated PAH compounds which have been identified as potential cancer causing

compounds. In the recent testing, PAH compounds were reduced by 75 to 85 percent, with the exception of benzo(a)anthracene, which was reduced by roughly 50 percent. Targeted nPAH compounds were also reduced dramatically with biodiesel fuel, with 2-nitrofluorene and 1-nitropyrene reduced by 90 percent, and the rest of the nPAH compounds reduced to only trace levels.

13. Biodiesel Fleet Economics[(11)&(12)] (*Biodiesel Price*)

The major economic factor to consider for input costs of biodiesel production is the feedstock, which is about 80 percent of the total operating cost. It takes around 7.5 pounds of fat or oil to produce a gallon of biodiesel. If a feedstock is 20 cents per pound, the feedstock cost alone is nearly $1.50 per gallon. Other important costs including plant overhead, labor and methanol must be added to the feedstock cost to determine the total cost per gallon in biodiesel production.

Biodiesel in the United States is currently marketed at a premium compared to petroleum diesel. Therefore US fuel costs are greater than petroleum diesel for fleet managers that use a biodiesel blend. Although biodiesel is more expensive in the United States on a per gallon basis, there are no significant infrastructure changes or incremental maintenance costs associated with its use. This contrasts to the significant capital investments that must be made in vehicle modifications and fueling infrastructure for other alternative fuels. Three independent studies have confirmed that biodiesel blends (i.e. B20) are cost competitive with other alternative fuel options when compared on a vehicle life cycle basis[(11)].

A study[(11)]completed by the University of Georgia provided a cost comparison for operating a transit fleet on three different alternative fuels (biodiesel blends, compressed natural gas, and methanol). Utilizing a 5% discount rate, the present value per bus per mile was calculated for the total cost of a transit fleet over an expected 30 year life cycle. Diesel buses had the lowest cost per mile (24.7¢). Costs for biodiesel blends ranged from 37.5 to

42¢ per mile. Compressed natural gas costs varied from 37.5 to 42 cents per mile, while methanol's cost was 73.6¢ per mile. This study indicated that biodiesel blends have the potential to compete with CNG and methanol as fuels for urban fleets.

Similar conclusions[12] have been reached by urban transit managers. Bi-State Development Agency is the transit authority in the City of St. Louis, MO which operates over 700 buses that consume over 6 million gallons of diesel fuel annually. Lyle Howard, Quality Assurance Manager for Bi-State, has documented the advantages and disadvantages of various alternative fuels.

Bi-State has used B20 for two years in a documented research program. Conclusions from that work include:

- biodiesel is a viable motor fuel
- performance and fuel economy were unchanged with B20
- exhaust emission improved dramatically
- the fuel was fully compatible with vehicle and fuel dispensing equipment

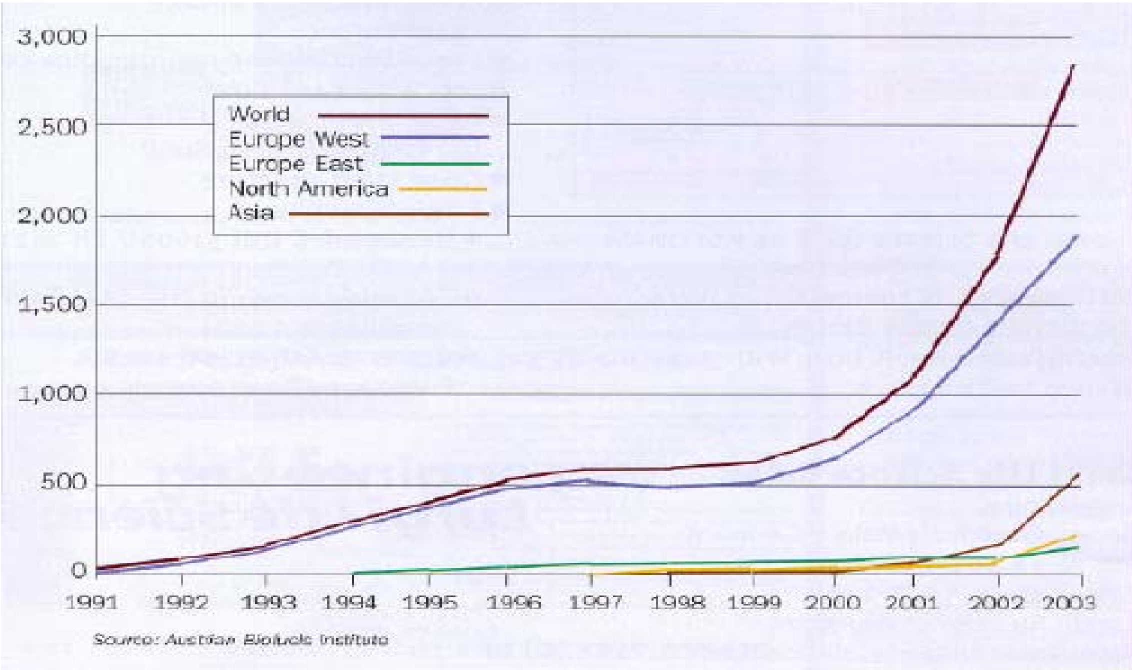
Mr. Howard compared alternative fuels on the following evaluation criteria; vehicle cost, infrastructure cost, safety, operating cost, reliability, customer acceptance, funding assistance, training costs, fuel availability, fuel quality, and fuel price stability. Fuels were evaluated on a scale of 1 to 10 with 10 being most desirable. The following table compares B20 with diesel fuel, compressed natural gas, liquefied natural gas, methanol, and ethanol[12].

	Diesel	CNG	LNG	Methan ol	Ethanol	B20
Vehicle Cost	10	5	5	5	5	10
Infrastructure Cost	10	2	5	5	5	10
Safety	7	4	3	1	3	8
Operating Range	10	5	10	10	10	10
Operating Cost	10	5	7	5	5	7
Reliability	10	7	5	3	3	10
Customer Accept.	5	8	8	8	9	8
Funds Assistance	1	10	2	0	2	2
Training Costs	10	5	5	5	5	10
Fuel Availability	10	10	5	5	5	6
Fuel Quality	9	5	10	8	8	9
Price Stability	6	8	8	6	6	6
TOTALS	**98**	**74**	**73**	**61**	**66**	**96**

Ref. BIODIESEL VS. OTHER ALTERNATE FUELS, MARCH 15, 1994, Prepared By: Lyle Howard, Manager of Quality Assurance, Bi-State Development Agency, St. Louis, MO 63102

14. Biodiesel News Around The World

World production of biodiesel



14.1. Biodiesel in Europe

Biodiesel production in Europe is growing, and is becoming an important part of the European market for rapeseed. Annual biodiesel output is now over a million tons per year and requires the input of an estimated 2.7 million tons of oilseed. Biodiesel is not cost competitive with petroleum diesel without subsidies or tax incentives except in cases where petroleum prices are high in the extreme and vegetable oil prices are low. Biodiesel has a major advantage over petroleum diesel in that it is derived from renewable resources; thus, on a net basis, fewer greenhouse gases such as carbon dioxide are emitted into the atmosphere. The

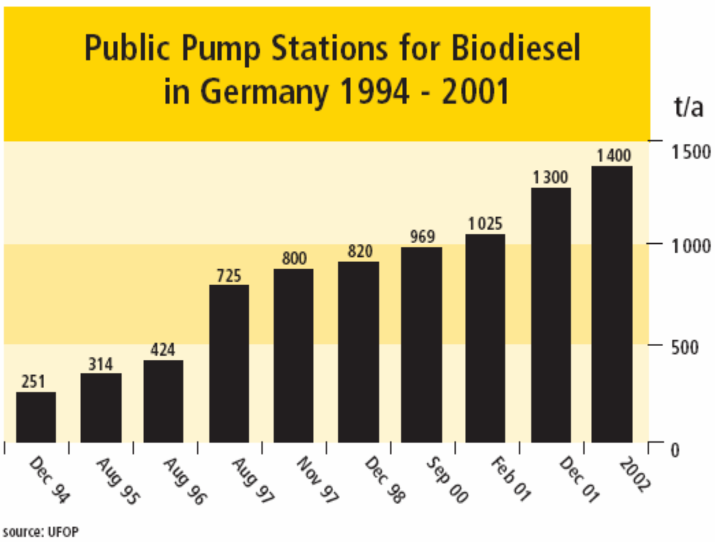
European Union:
Estimated Biodiesel Production, 2002

Country	(1000 metric tons)
Germany	450
France	366
Italy	210
Austria	25
Denmark	10
United Kingdom	3
Sweden	1
Total	1065

Source: European Biodiesel Board

political support for the production and consumption of biodiesel and renewable fuels appear to be present to expand the biodiesel industry[(13)].

European production of biodiesel has increased rapidly during the last several years and is now concentrated primarily in three countries. According to the European Biodiesel Board in Brussels, Germany produced an estimated 450,000 metric tons in 2002, France produced 366,000 tons, and Italy produced 210,000 tons.



Investments are planned in Poland and the Czech Republic has also completed a programme to set up 16 small biodiesel plants.

Industrial scale production of biodiesel in Europe began in 1992 and capacities almost doubled between 1996 and 2001. Today, EU installed capacity stands at around 1.6M tones/year and biodiesel is attracting more and more investors.

This is particularly true for Germany, where the biodiesel market has been boosted by high gas oil prices and increased levels of carbon tax. If planned projects are finalized, German production will increase to one million tones by 2003, mostly in former east Germany, pushing EU production capacities close to 2-2.5M tones in the medium term.

14.1.1.EU regulatory framework

The EU biodiesel industry developed chiefly as a result of the 1992 EU Common Agricultural Policy (CAP) reform, which capped oilseed growing areas on the continent. This encouraged the European Commission to draft a first regulation on set-aside land for non-food uses and to co-finance the first esterification plants in Europe. Various EU programmes and regulations have also supported the development of biodiesel. An EU Directive, for example, has enabled EU member countries to detax biodiesel production up to a given quota, considering these as "pilot projects".

Specific national legislation include:

- **France and Italy** - biodiesel (pure or blends) are de-taxed within a quota (320,000 tones and 300,000 tones respectively).
- **Germany** - unblended biodiesel is free of tax and there are no quantity limitations.
- **UK** - the April 2002 government budget has stated that biodiesel will have an excise tax rate 20p lower than ultra low sulphur diesel. This is awaiting royal assent, expected in June or July, 2002
- **Austria and Sweden** have developed similar specific biodiesel legislation

As of 1995, western European biodiesel production capacity was over 1.1 million tones per year largely produced through the transesterification process. This adds over 80,000 tones of glycerine by-product to the market annually. This has created a glut of glycerine on the market. In fact, Germany is limiting production of biodiesel using the transesterification process because of an excess supply of glycerine. One method of disposal of the excess glycerine is incineration, however this wastes a manufactured product, creates an environmental risk and results in additional costs. Germany is now focusing on biodiesel production using the cold pressed rapeseed method to avoid the excess glycerine problem.

14.1.2. Biodiesel in Japan In early 1995 Japan decided to explore the feasibility of biodiesel by initiating a three year study. A new biodiesel plant was to be constructed with its feedstock being recycled vegetable oils collected in the Tokyo area, estimated at 0.2 Mt annually.

14.1.3. Biodiesel in the United States United States interest in biodiesel was stimulated by the Clean Air Act of 1990 combined with regulations requiring reduced sulphur content in diesel fuel and reduced diesel exhaust emissions. The Energy Policy Act of 1992 established a goal of replacing 10 percent of motor fuels with non-petroleum alternatives by the 2000 and increasing to 30 percent by the year 2010. By 1995, 10 percent of all federal vehicles were to be using alternative fuels to set an example for the private automotive and fuel industries.

There is, however, a strong petroleum industry lobby opposed to the promotion and usage of alternative fuels. Despite this, use of biodiesel in the U.S. is increasing, particularly in urban bus fleets.

Extensive testing in the U.S. has concentrated on biodiesel produced from soybeans. A number of public transit fleets have been using biodiesel. Tests indicate production costs for biodiesel are 2.5 times that of petroleum diesel.

14.1.4. Biodiesel in Canada[(14)]: In the early 1990s, Canadian canola production increased in response to higher market prices relative to cereal grains and increasing grain handling and transportation costs. Canola production may have peaked in 1994 and 1995 given current yields, the suitable land base and crop rotational requirements. However, higher yields due to new Brassica Juncia varieties and improved chemical weed control may further increase production in the medium-term.

Most of Canada's exportable canola supplies are purchased by Japan. The remainder of the crop is crushed for domestic consumption or export, primarily to the United States. Biodiesel production in Canada would require displacement from higher priced food uses. There is potential for the use of lower quality canola oils from overheated or frost damaged seed without any ill affects on the quality of the biodiesel.

Canadian biodiesel technology has focused on the hydro-treating method using a conventional refining process similar to the petroleum industry. This method produces cetane (used as a booster for diesel fuel), naphtha (used as a gasoline supplement), and other products (usable as power burner fuels). The high cetane portion (super cetane), when blended about 5 to 10 percent by volume with diesel, enhances engine performance in diesel the way octane does in gasoline.

Diesel fuel with the biodiesel cetane booster is called green diesel. Emission and engine performance tests indicate that green diesel performance is similar to conventional diesel blends with commercial nitrate-based enhancers. Therefore, super cetane may find a potential market as a replacement for commercial nitrate-type diesel fuel additives.

14.1.5. CHINA: Work has begun on a 600,000 tones/year biofuel plant in Jilin province which will turn 1.92 Mtonne of maize into ethanol. The joint venture between China National Petroleum Corporation (CNPC), the Jilin Grain Group and trading group China Resources Corp will supply CNPC with fuel to blend with gasoline.

14.1.6. INDIA: Indian Oil Corporation (IOC) began in January 2004, field trials of running buses on biodiesel – diesel doped with 5% Biodiesel made from non-edible oils. Haryana Roadways buses would be used for the project. About 450 kilolitres of biodiesel would be used in the pilot project. Vehicle engines would not require any modification for use of bio-diesel. Already automobile manufacturers have tried biodiesel mix as fuel for their vehicles.

14.1.7. LITHUANIA: Rapsoila company has started constructing a biofuels plant in the Mazeikiai region at a cost of US$4.6M. Production of rapeseed oil methyl ester is expected to begin in January 2003. The plant's planned production capacity is 100,000 tones/year.

14.1.8. AUSTRALIA: The government has announced a US$2.8M two year study to investigate market barriers to the increased use of biofuels. The study will develop a strategy to increase biofuels production to 350M liters/year by 2010.. This target was announced by the government in last year's election campaign.

15. BIODIESEL – FUEL FOR THE FUTURE

Biodiesel and BioEthanol will become a vital part of the energy supply in the near future. The introduction of biofuels into the motor fuel market, will be the most immediate and most efficient way to meet the obligations of the 'Kyoto

Protocol '-which is the United Nations framework convention on climate change -in order to reduce greenhouse gas emissions.

For example, The 'EU Biofuels Regulation' intends to raise the market usage of biofuels from 2% in 2005 to a remarkable 5.75% in 2010 in the transport fuel market. This is equivalent to a market potential of approximately 14 million tons of biofuels by 2010. The construction of large scale production units will be inevitably necessary. In the US, the production is projected to reach 5.6 billion gallons of BioEthanol by 2008 and 1.0 billion gallons of Biodiesel in the same period [15].

Actionplan of the EU-Commission: Bio Fuel Production in the EU

Year/ Minimum Share (each 1998)	Gasoline-Consumption	Diesel-Consumption	Total
2005/2,00%	2341	2532	4873
2006/2,75%	3219	3482	6701
2007/3,50%	4096	4431	8527
2008/4,25%	4974	5381	10355
2009/5,00%	5852	6331	12183
2010/5,75%	6730	7280	14010

All notes in 1000 t, Basis: Fuel Consumption 1998
References: EU-Commission (KOM (2001) 547 fin.)

16. BIODIESEL IN EGYPT

Egypt is heavy consumer of diesel, and this consumption is expected to increase with faster rate in the near future to satisfy the demand required for development process. At the same time, Egypt has large side-arable land as well as good climatic conditions in large parts of the area to account for large biomass production each year.

We can benefit from unutilized public land, field boundaries and fallow lands of farmers to plant trees for biomass production. There are many tree species which bear seeds rich in oil. Of these, some promising tree species have been evaluated and it has been found that there are a number of them such as *Jatropha curcas* which would be very suitable in our conditions.

These will also be planted in public lands such as along the railways, roads and irrigation canals.

16.1. Why biodiesel in Egypt:

1. Biodiesel is one of the superior fuel for vehicles from the environmental point of view
2. Use of biodiesel becomes compelling in view of the tightening of automotive vehicle emission standards
3. Addressing global concern relating to containing Carbon emissions for mitigation of climate change
4. Providing nutrients to soil, by using oil cake as manure.
5. Reducing the consumption of diesel
6. Greening the country through *Jatropha curcas* plantation.
7. Generation of gainful employment to the people.

Proposed Jatropha Plantation[16] *:* Jatropha curcas has been found the most suitable tree specie in Egypt for the reasons summarized below:

- It can be grown as a quick yielding plant even in adverse land situations viz. degraded and barren lands, dry and drought prone areas, marginal lands. It can be planted on fallow lands and along farmers field boundaries as hedge because it does not grow too tall as well as on vacant lands along side railways, highways, irrigation canals and unused lands in townships etc.

- The cost of plantation is largely incurred in the first year and improved planting material can make a huge difference in yield.
- Raising Jatropha plant and its maintenance creates jobs for the rural poor, particularly the landless.
- It has multiple uses and after the extraction of oil from the seeds, the oil cake left behind is an excellent organic manure, the bio mass of Jatropha curcas enriches the soil and it can also be put to other uses.
- Retains soil moisture and improve land capability and environment.
- Jatropha adds to the capital stock of the farmers and the community, for sustainable generation of income and employment.

If we look to the ***Economics of Jatropha biodiesel***, we can take into consideration the Indian case. In India, it is estimated that cost of Biodiesel produced by trans-esterification of oil obtained from Jatropha Curcas oil-seeds shall be approximately same as that of petroleum diesel.

The by-products of Biodiesel from Jatropha seed are the seed oil cake and glycerol, which have good commercial value. The seed oil cake is very good compost being rich in plant nutrients. It can also yield biogas, which can be used for cooking and the residue will be used as compost. Hence oil cake will fetch good price. Glycerol is produced as a by product in the trans-esterification of oil. These by-products shall reduce the cost of Biodiesel to make it at par with petroleum diesel.

The cost components of Biodiesel are: the price of seed, seed collection and oil extraction, trans-esterification of oil, transport of seed and oil. As mentioned earlier, cost recovery will be through sale of oil-cake and of glycerol.

16.2.Work done in Egypt in the field of biodiesel production:

The ministry of environment in cooperation with ministry of agriculture imported Jatropha seeds from India five years ago, and cultivated in the southern part of Egypt and irrigated by treated sewage water. The cultivation has been very successful since Jatropha seeds need hot weather, beside the sewage water gave it power where it contains organic materials.*(ref. MR. M. Reyadh-undersecretary of state for afforestation-ministry of agriculture and land reclamation).*

One of British companies- engaged in the manufacture of biodiesel manufacturing plants, development and sourcing of biodiesel raw material- presented a proposal to the ministry of environment to cultivated thousands fadan with Jatropha seeds using sewage water in order to produce biodiesel.

An Egyptian team from ministry of petroleum (EGPC & MISR PETROLEUM COMPANY) made study on the Egyptian Jatropha seeds after extracting the oil and they concluded that its properties are very similar to the international ones, and they got 20% by weight oil from the seeds.

17. Recommendations:

- A National Mission on Biodiesel should be launched immediately with the objective of producing biodiesel .
- As its Phase I, a demonstration project may be taken up.
- the Jatropha seeds should be the base of this demo project where it has high oil content, has very small gestation period, is hardy, grows on good and degraded lands and in low and high rainfall areas, the seed comes in non rainy season and the tree is not very high making collection of seed convenient.

18. Conclusions :

- It is clear that it is important for Egypt to start production and use of Biodiesel to achieve the objectives of emission standards, regeneration of degraded lands, poverty alleviation, employment generation, better use of natural resources etc.

- Reviewing the international experiences of biodiesel show that biodiesel cost is a little bit higher than petroleum diesel –in case of low oil prices-, but with marketing byproducts of the production process, taking the environmental benefits into consideration and the reduction in importing diesel bill, will make Biodiesel economically feasible and a strategic option.

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