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Recent Trends and Applications of Bio Diesel

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Abstract
In current scenario, populations continue to increase, It will meets energy demands has become an increasing concern for world scenario and one such solution is to utilize Biodiesel as an alternative fuel is explored, along with his desirable fuel characteristics. The technological requirements for process and production of Biodiesel being comparatively less cumbersome and its ability to fuel an existing diesel vehicle with no or minor modifications also make it a promising alternate fuel and it is discussed. This report also covers attributes like emissions, feed stocks, production method, latest trends and the advantages and disadvantages of the Biodiesel. Pollution reduction is now major issue for changing world situations and it is discussed how exactly Biodiesel meet with the solution.

Keywords: biodiesel, emissions, petro diesel

1. INTRODUCTION

India imported about 2/3rd of its petroleum requirements last year, which involved a cost of approximately Rs. 80,000 crores in foreign exchange. Even 5% replacement of petroleum fuel by bio-fuels can help India save Rs.4000 crores per year in foreign exchange. It is utmost important that the options for substitution of petroleum fuels be explored to control this rapidly growing import bill. With the stock of fossil fuels diminishing throughout the world and demand for energy based comforts and mobility ever increasing, time is ripe that we strike a balance between energy security and energy usage. Moreover having uplifted to such a sphere of engineering excellence, reverting back to the ages of the bull carts will prove next to impossible thereby compelling us to search for a variety of alternative fuels to derive energy to cater to our needs. Several sources of energy, especially for driving the automotives are being developed and tested. This report presents detailed information on Biodiesel together with its emission benefits. The prospect of Biodiesel as an alternative to conventional fuels like gasoline and diesel and the experience of other countries are also mentioned.

2. BIODIESEL

Biodiesel is the name for a variety of ester-based oxygenated fuels derived from natural, renewable biological sources such as vegetable oils. Biodiesel operates in compression ignition engines like petroleum diesel thereby requiring no essential engine modifications. Moreover it can maintain the payload capacity and range of conventional diesel. Biodiesel fuel can be made from new or used vegetable oils and animal fats. Unlike fossil diesel, pure Biodiesel is biodegradable, nontoxic and essentially free of sulphur and aromatics. The concept of using vegetable oil as a fuel dates back to 1895 when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil.

2.1 Production

Vegetable oils can be chemically reacted with an alcohol (methanol or ethanol is the usual choice) to produce chemical compounds known as esters. Biodiesel is the name given to these esters when they are proposed for use as fuel. Currently Biodiesel is produced by a process called transesterification where the vegetable oil or animal fat is first filtered, then processed with alkali to remove free fatty acids. It is then mixed with an alcohol (usually methanol or ethanol) and a catalyst (usually sodium or potassium hydroxide). This transesterification process can also be carried out in presence of acid catalyst. The only problem with acid catalyzed process is that it is very slow. Generally base catalyzed process takes about 2 hours for completion while acid catalyzed process is much slower than this at about 700 C. The oil's triglycerides react to form esters and glycerol, which are then separated from each other and purified. The yield of transesterification process is same for both, acid catalyzed and base catalyzed processes. Yield of process affected, Freedman B. et al. (1984), mainly by oil to alcohol ratio. For all practical purposes 100% excess alcohol is used. But more than this use of alcohol lead to problems during separation of glycerol. Glycerol obtained as by product is used pharmaceutical industry.

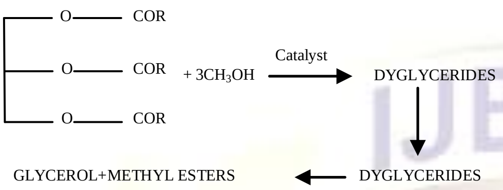
Waste animal fats and used frying oil, peanuts, cottonseed, sunflower seeds and canola are some of the potential feedstock for Biodiesel. Esters made from all the above feed stocks can be used successfully as automotive fuel, although they may differ slightly in terms of energy content, cetane number and other physical properties. The general process of Biodiesel production is depicted in Figure-1. The reaction occurring while production of Biodiesel is shown below:

Vegetable oil + Methanol $\xleftrightarrow{NaOH}$ FAEE (Biodeiesel) + Glycerol

OR

Vegetable oil + Ethanol $\xleftrightarrow{NaOH}$ FAEE (Biodeiesel) + Glycerol

Actual Mechanism is as Below



A fat or oil is reacted with an alcohol (say methanol) in the presence of a catalyst to produce glycerin and methyl esters or Biodiesel. The methanol is charged in excess to assist in quick conversion and recovered for reuse. The catalyst is usually sodium or potassium hydroxide, which has already been mixed with the methanol. Biodiesel is generally prepared by batch process but now a day, Ma F. et al. (1999), continuous process is developed and it is being used in the Europe.

Table 1- A typical input and output streams is shown below

Input streams	**Amount**
Refined oil	1000 Kg
Methanol	107 Kg
KOH 88%	10 Kg
Acid (H2SO4,HCl,Acetic)	8 Kg
Water	17 Kg
Output streams	**Amount**
Biodiesel	1000 Kg
Glycerin 88%	125 Kg
Fertilizer	23 Kg

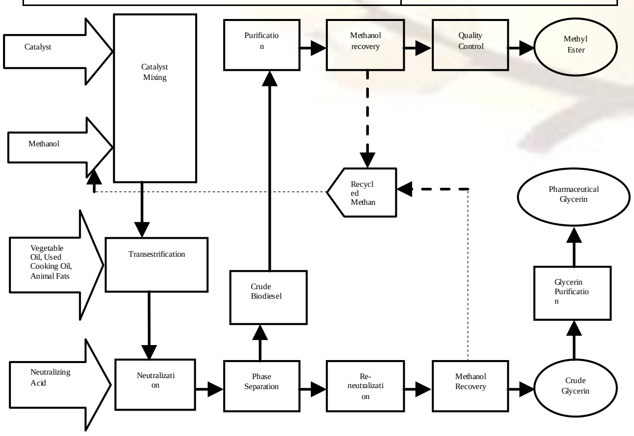


Fig 1, General Process of Biodiesel Production

2.2 Characteristics of Biodiesel

Density of Biodiesel is same as that of, Tat M.E et al. (2000), conventional diesel. Biodiesel as automotive fuel has similar properties to petrodiesel 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 petrodiesel. The viscosity of Biodiesel is higher, Geller D.P et al. (2000), than that of conventional 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. This extra oxygen contain results in complete combustion of fuel. The use of Biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. Emissions of nitrogen dioxides are either slightly reduced or slightly increased depending on the duty cycle or testing methods. Biodiesel eliminates the sulphur fraction (as there is no sulphur in the fuel), while the soluble or hydrogen fraction stays the same or is increased. Table-2 shows reduction in emissions with different blends of Biodiesel:

Table 2, Emissions from engine using Biodiesel

Biodiesel Fuel	**NOx**	**CO**	**VOC**
B20	+2.4%	-13.1%	-17.9%
B100	+13.2%	-42.7%	-63.2%

(Source:- Kinsat J.A. (2003))

The life-cycle production and use of Biodiesel produces approximately 80% less carbon dioxide and almost 100% less sulphur dioxide compared to conventional diesel. But emissions of NOx appear to increase from Biodiesel. NOx increases with the increase in concentration of Biodiesel in the mixture of Biodiesel and petrodiesel. This increase in NOx may be due to the high temperature generated in the fairly complete combustion process on account of adequate presence of oxygen in the fuel. This increase in NOx emissions may be neutralized by the efficient use of NOx control technologies, which fits better with almost nil sulphur Biodiesel then conventional diesel containing sulphur.

2.3 Emissions of Greenhouse Gas

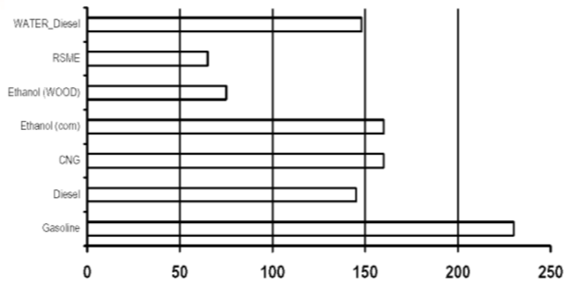


Fig-2: Life Cycle Analysis-Green House Gas Emissions of Different Fuels

1. (CO_2+CO_2 Equivalent of the other pollutants CH_4 and N_20)
2. Biodiesel CO_2 Cycle
3. No Fossile CO_2 Released

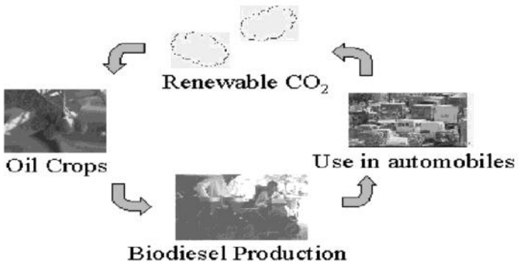


Fig 3, Biodiesel Greenhouse Gas Life Cycle

Life cycle analysis for various fuels including biofuels is diagrammatically represented in Figure-2, which shows that Biodiesel (RSME) has the lowest Greenhouse emissions followed by ethanol from wood. There is large difference in Greenhouse gas (CO2), Poitrat E. (2002), emissions during combustion of diesel than Biodiesel. Greenhouse gas life cycle is shown in the figure-3; this shows how Biodiesel helps to keep balance in environment.

2.4 Storage & Infrastructure

In general, the standard storage and handling procedures used for petroleum diesel may be-used for Biodiesel. The care needs to be taken to avoid temperature extremes. Acceptable storage tank materials include mild steel, stainless steel, and fluorinated polyethylene and fluorinated polypropylene.

Biodiesel has a solvent effect, which releases the deposits accumulated on tanks and pipes, which previously have been used for diesel. These deposits can be expected to clog filters initially and precautions should be taken for this. Biodiesel over time will soften and degrade certain types of elastomers and natural rubber compounds. Materials like bronze, brass, copper, lead, tin and zinc may oxidize the diesel or Biodiesel fuels and create sediments.

It is desirable to change all components, which are not Biodiesel compatible to aluminum or stainless steel. The B20 can be stored in the storage tanks where conventional diesel is stored, without any modifications. With increase in Biodiesel concentration problem starts to arise. It may also be noted that most, Bondioli P. et. al, (1995), of the new generation vehicles can take Biodiesel without any materials compatibility problems as they are already tuned to using low sulphur diesel, Biodiesel etc.

Table 3, Selected Fuel Properties for Petrodiesel & Biodiesel

Fuel Property	Petrodiesel	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
BOCLE Scuff, gm	3,600	>7,000
HFRR, microns	685	314

2.5 Lubricity of Biodiesel

Biodiesel blends offer superior lubricating properties, increases the lubricity of fuel by 65% when 1% Biodiesel is blended with conventional diesel fuel, which may reduce engine wear and extend the life of fuel injection systems. Tests with two leading lubricity measuring systems-the BOCLE machine and the HFRR machine-show Biodiesel blends offer better lubricating properties than conventional petroleum diesel. Viscosity is major problem for using Biodiesel as lubricity enhancer. Some, additives are used to increase viscosity of fuel. The result of a lubricity test done by Exxon with petrodiesel and Biodiesel blends is given in Table-4 and results from US army tests are shown in graph-1. From graph-1 we can say that lubricity of engine increases substantially with Biodiesel concentration.

Table 4, Lubricity Results (HFRR Machine)

Fuel Type	Scar	Friction	Film %
Conventional low sulphur diesel	492	0.24	32
Blend (80% petrodiesel + 20% Biodiesel)	193	0.13	93
Blend (70% petrodiesel + 30% Biodiesel)	206	0.13	93
Petrodiesel + 1000 ppm lubricity additive	192	0.13	82
Petrodiesel + 500 ppm lubricity additive	215	0.14	94
Petrodiesel + 300 ppm lubricity additive	188	0.13	93

Source: Exxon & Interchem Environmental Inc.

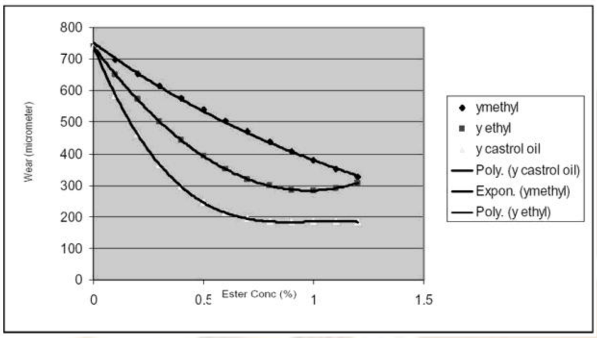


Fig 4, Graph-1[source:- Drown D.C. et. al, 2001]

3. BIODIESEL - A BOON FOR MANKIND

The **benefits** of Biodiesel are:

1. The lifecycle production and use of Biodiesel produces approximately 80% less CO_2 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.
2. Biodiesel is the only alternative fuel that runs in any conventional, unmodified diesel engine.
3. Needs no change in refueling infrastructures and spare part inventories.
4. Diesel skilled mechanics can easily attend to Biodiesel engines.
5. 100% domestic fuel. Neat Biodiesel fuel is non-toxic and biodegradable.
6. Cetane number is significantly higher than that of conventional diesel fuel.
7. Lubricity is improved over that of conventional diesel fuel.
8. "SHE" (Safety, Health and Environment) are prime most priority for a chemical engineer, and on this front too Biodiesel is better than ULSD as the flash point of Biodiesel is higher than fossil based ULSD i.e. 300 degrees versus about 125 degrees Fahrenheit for regular diesel.
9. Catalyst used for production i.e. NaOH or KOH is very cheap.
10. Biodiesel is prepared at temperatures of range 35°C to 60°C and at atmospheric pressure. So the process is not at all energy intensive and that's why the manufacturing cost is so less.
11. Biodiesel can be stored in tanks where conventional diesel is stored.
12. If the washing is carried using H3PO4 and the catalyst used in manufacturing process is KOH then the wash liquid can prove to be an excellent fertilizer this will help to reduce price of Biodiesel.
13. By starting production of Biodiesel there will be increase in employment at villages due plantation of oils seeds and in oil industry.
14. As Biodiesel is prepared from vegetable oils, so for more production of Biodiesel more production of oil seeds is required which will lead to more green coverage and hence result in improved ecology.

3.1 Disadvantages of Biodiesel

Some of the disadvantages of Biodiesel are:

1. Quality of Biodiesel depends on the blend thus quality can be tampered.
2. 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.
3. There may be problems of winter compatibility as pour point is high.
4. It is found that NOx emissions from Biodiesel are more than that of conventional diesel
5. Fuel with higher blends of Biodiesel causes damage to rubber components in the conventional diesel engine.
6. Main disadvantage of Biodiesel is high cost, which is creating main hurdle in its commercialization. Price of Biodiesel is 1.5 to 2 times higher than conventional diesel depending on type of feedstock and scale of operation.

	Diesel	CNG	LNG	Methanol	Ethanol	Bio-diesel
Vehicle cost	10	5	5	5	5	10
Infrastructure	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 acceptance	5	8	8	8	9	8
Funding assistance	1	10	2	0	2	2
Training cost	10	5	5	5	5	10
Fuel availability	10	10	5	5	8	6
Fuel quality	9	5	10	8	8	9
Fuel price stability	6	8	8	6	6	6
Total	98	74	73	61	66	96

Table-5: Comparison of Biodiesel with CNG, LNG, Ethanol and Methanol
[Source: - Chemical weekly March 18, 2003]

Table 5, shows a various comparison of biodiesel with other substitute for conventional diesel. There are many other fuels which are considered as substitute for conventional diesel. We have seen advantages of Biodiesel over conventional diesel. Following Table-5 depicts how Biodiesel is superior in comparison with other substitute fuel.

3.2 Prospective feedstock in India

Biodiesel is prepared by using different feedstock such as edible oils, non-edible oils, frying oils (or waste vegetable oils) and mutton or beef tallow. Edible oils because of their high price are not possible to use as feedstock. Also 60-70% edible oils we import from various countries. Thus, high prices and less availability is major obstacle in commercialization. But, non-edible oils are most suitable for India because of its large production and lower price.

Currently lot of research is going on for using non-edible oils as raw material. Oil can be extracted from a variety of plants and oilseeds. Under Indian condition only such plant sources can be considered for Biodiesel production which are not edible oil in appreciable quantity and which can be grown on large-scale on wastelands. Moreover, some plants and seeds in India have tremendous medicinal value, considering these plants for Biodiesel production may not be a viable and wise option. Considering all the above options, probable Biodiesel yielding trees in India are:

- Jatropha curcas or Ratanjot
- Pongamia pinnata or Karanj
- Calophyllum inophyllum or Nagchampa
- Hevea brasiliensis or Rubber seeds
- Calotropis gigantia or Ark
- Euphorbia tirucalli or Sher; and
- Boswellia ovalifololata.

All the above prospective plant candidates as Biodiesel yielding sources, Jatropha curcas stands at the top and sufficient information on this plant is already available. One hectare Jatropha plantation with 4400 plants per hectare under rain fed conditions can yield about 1500 liters of oil. It is estimated that about 3 million hectares plantation is required to produce oil for 10% replacement of petrodiesel.

The residue oil cake after extraction of oil from Jatropha can be used a-s organic fertilizers. It is also estimated that one acre of Jatropha plantation could produce oil sufficient to meet the energy requirement of a family of 5 members and the oil cake left out when used as fertilizer could cater to one acre. The fact that Jatropha can be grown in any wastelands with less irrigation gives it a distinct advantage for consideration as the prime

Biodiesel feedstock in Indian conditions. Also, castor oil is better option, as in its production India is number one in the world. Also, Biodiesel prepared from it increases lubricity to, Hass M.J. et al. (2000), much larger extent than from any other vegetable oil Another possible feedstock for production of Biodiesel is “Acid oils or (soapstock)”.Generally during refining of vegetable oils, about 4-6% soap stock is formed. Some oils like “Rice bran oil”, give about 10-20 % soapstock. If we are able to collect all this soap stock from oils refineries in India then that can be good feedstock for Biodiesel production.

It is found that India produced about 18,000,000 tons of vegetable oils in the year 2001-2002. Also, India ranked first in world for production of castor oil, safflower oil and sesame oil, Hegde D.M., (2002), in the year 2002. This shows that India can reduce its dependence on the other countries for energy.

In addition to this soapstock which obtained during refining of oils can be used as feedstock. Main advantage of using soapstock is its low price, about 1/10 of refined oil. If we use KOH as catalyst, Hodgson A.S., (1995), while refining and H_2SO_4 or H_3PO_4 acid then it will give value added product which can be used as, Daniels R., (1995), a fertilizer. Thus it can help to reduce price of Biodiesel.

3.3 Biodiesel Initiatives in India

India has great potential for production of bio-fuels like bio-ethanol and Biodiesel from non-edible oil seeds. From about 100 varieties of oil seeds, only 10-12 varieties have been tapped so far. The annual estimated potential is about 20 million tons per annum. Wild crops cultivated in the wasteland also form a source of Biodiesel production in India. According to the Economic Survey of Government of India, out of the cultivated land area, about 100-150 million hectares are classified as waste and degraded land and most of that land is under the control of government and its agencies.

If government starts production of non-edible oils even on 10% of wasteland then India can produce about 4-5 million metric tons per annum. Thus, given a demand-based market, India can easily tap its potential and produce Biodiesel in a large scale. Table-6 depicts the annual production of non-edible oil seeds in India.

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Table 6, Non-edible oil potential in India

Sr.No.	Oil	Oil potential tonns
1	Neem	100000
2	Karanja	55000
3	Kusum	25000
4	Ratanjyot	15000
5	Pilu	17000
6	Tumba	21000
7	Sal	180000
8	Mahua	180000
9	Mango	45000
10	Phulware	3000
11	Kokum	500
12	Simrouba	----
13	Jojoba	----
14	Chullu	110
15	Rice bran	474000

[Source:-Kumar S. et al. (2003)]

In recent years trials on automobiles using Biodiesel have been conducted by institutes like IOC (R&D), IIT, Delhi etc. IOC (R&D) has already set up a Biodiesel production facility of 60 kg/day at Faridabad. Also, they have started collaboration with Indian Railways. Indian railways agreed to plant oil seed trees in between the railway tracks. Indian railways aiming to replace 10% of its annual consumption in few years span. The move is aimed at reducing the dependence on hydrocarbons by the railways, the second largest in the world under a single management. The decision to adopt biodiesel was taken after a successful run of super-fast Shatabdi Express locomotive proved its efficacy. Mahindra & Mahindra Ltd. has a pilot plant utilizing Karanj for Biodiesel in Mumbai. Production of Biodiesel unlike petrodiesel is relatively a less cumbersome process and therefore large scale production can be undertaken with a short lead time.

4. BIODIESEL APPLICATIONS

On-road Vehicles: Practically every diesel engine powered vehicle on the roads. (Millions of miles were logged on biodiesel in EU nations) .

Off-road Vehicles: Naturol fuel can be used for off road construction, mining, and farm machinery.

Marine Vessels: Naturol fuel can be used in marine engines safely. Marine use is especially attractive due to the elimination of any possibility for contamination of waterways.

Stationary Power Generation: With new power generation capacity coming online, Naturol biodiesel makes an attractive choice to meet the regulations. Many stationary application are permitted sources requiring exhaust emission control system, which will work well with biodiesel but will not work with diesel fuel.

Boiler Fuel: With natural gas prices rising high, biodiesel can be substituted easily for natural gas with minor changes necessary to the burner train.

Hybrid Vehicles: With many states now mandating hybrid electric vehicles (including the fuel cell hybrid), biodiesel will make excellent reforming fuel.

Agriculture Adjuvants: Biodiesel is used as a carrier for pesticides and fertilizer in agriculture sprays due to it being non-toxic and biodegradable.

Solvents: Biodiesel can be used as industrial solvents and as a replacement of high VOC containing petroleum solvents. With regulations driving the VOC contents lowers for solvents used in industries, biodiesel offers an attractive solution.. Other solvent applications are household cleaning agents.

Lubricity Agent/Additive: Naturol biodiesel can also be used as a lubricity agent/enhancer in many applications. It is especially useful in marine applications where water contamination with petroleum lubricity agents can create problems. With the low-sulfur fuel regulation of future, biodiesel can be used as a lubricity additive. A 1-2% biodiesel added to diesel fuel can increase diesel lubricity by 65%.

Fuel Additive: Biodiesel can also be used as a diesel fuel additive for the purpose of keeping the injectors, pumps and other combustion components clean. A 1-2% blend should be sufficient for this purpose.

5. CONCLUSION

The Biodiesel program on the national level is achieved and will have a very positive impact on the upliftment of the rural economy and has very large employment generating potential. It also fulfils strategic needs of a country like India, which has large dependence on the imported crude. Bio-diesel is an attested and proven low emission fuel, which is accepted world over by engine manufacturers, is safe to handle and require no separate infrastructure for its distribution and marketing. Biodiesel is a viable alternative to petroleum diesel and has successfully introduced in several countries in the world. Price of Biodiesel is higher than that of conventional diesel; government should give subsidy to promote production of Biodiesel. So, government need to give about Rs.20 subsidy per kg of Biodiesel produced. Since, prices of vegetable oils are relatively high in Asia. This is the potential challenge to Biodiesel. From this point view, Biodiesel can be used most effectively as a supplement to other energy forms, not as a primary source. By bringing lot of wasteland under cultivation India can become independent for energy.

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