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Biodiesel - Processing, Economics & Potential in India

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1. INTRODUCTION

Fossil fuels are hundreds of millions of years old, but in the last 200 years consumption has increased rapidly, leaving fossil fuel reserves depleted and climate change seriously impacted. Reserves are becoming harder to locate, and resources won't last forever with finite supply of fossil fuels. The amount we use now simply isn't sustainable, and the problem is getting worse as the global population increases. Globally, current consumption is equivalent of over 11 billion tonnes of oil from fossil fuels every year. Crude oil reserves are vanishing at a rate of more than 4 billion tonnes a year – so estimates show that at current rate crude oil is going to vanish in next 53 year.

India is third largest oil user of the world, India may further observe surge in domestic diesel consumption amidst economic slowdown seeing rising oil and fuel prices. Analysts at Fitch Solutions and consultants Wood Mackenzie forecast India's diesel demand to rise in 2019 by 5.7% and 6.4%, respectively, from 2018. Data from Ministry of Petroleum indicated that the country consumed a record 6.9 million tonnes of diesel a month in 2018, or about 1.7 million barrels per day (bpd).

Bio-Diesel is an eco-friendly, alternative diesel fuel prepared from domestic renewable resources i.e. vegetable oils and animal fats. These natural oils and fats are made up mainly of triglycerides. These triglycerides when reacted chemically with lower alcohols in presence of a catalyst result in fatty acid ester. These esters show striking similarity to petroleum derived diesel and are called "Bio-Diesel" (PCRA). The history of biodiesel goes back to the era of development of diesel engine by Mr.Rudolph Diesel in 1890s. He suggested of using vegetable oils as biofuel in the diesel engine in the remote areas where diesel is not available. In-fact, in late 1800s, Corn derived ethanol was first used to power early cars such as Henry Ford's Model-T. But, modern biodiesel fuel, which is made by converting (trans-esterification) Vegetable oils into compounds called fatty acid methyl esters, has its roots in research conducted in the 1930s in Belgium. And, the Pacific Biodiesel became one of the first biodiesel plants in the United States in 1996, establishing a biodiesel production operation to recycle used cooking oil into biodiesel on the island Maui in Hawaii (Kishore Chandra Swain, 2014).

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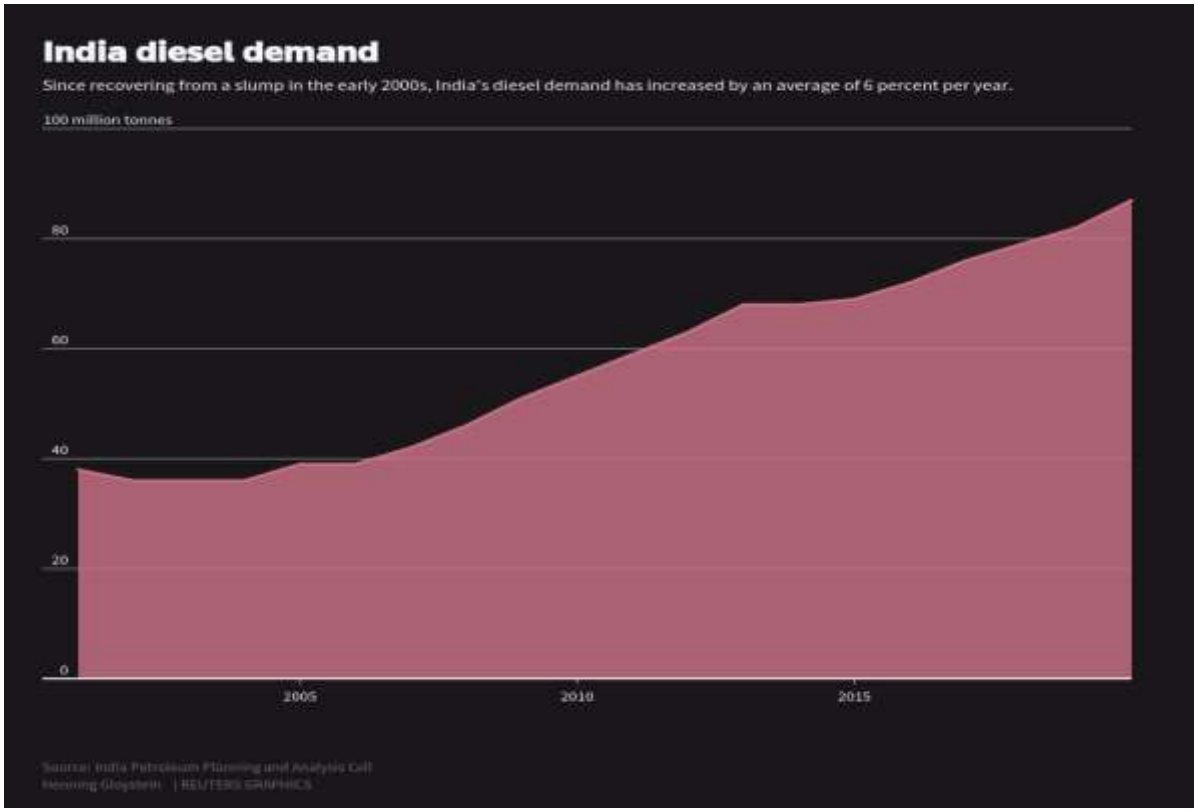

Source: Indian Petroleum and Analysis Cell

Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulphur and aromatics (Zafar, 2017). It is usually used as a petroleum diesel additive to reduce levels of particulates, carbon monoxide, hydrocarbons and toxics from diesel-powered vehicles. When used as an additive, the resulting diesel fuel may be called B5, B10 or B20, representing the percentage of the biodiesel that is blended with petroleum diesel (PCRA, 2014).
Biodiesel is produced through a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. The biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel or used as a neat fuel (100% biodiesel). There are three basic routes to biodiesel production from oils and fats:

- Base catalyzed trans-esterification of the oil
- Direct acid catalyzed trans-esterification of the oil
- Conversion of the oil to its fatty acids and then to biodiesel.

National Biodiesel Mission (2009)
Government of India launched ambitious project to encourage biodiesel production and consumption in 2009. The mission identified Jatropha curcas as the most suitable tree borne oilseed for biodiesel production. The planning commission set the target to bring 13 million

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of land under the forest cover of Jatropha cultivation by end the end of 11th five year plan. Several public institutions, state biofuel boards, state agricultural universities and cooperative sectors are also supporting the biofuel mission in different capacities.

Currently Jatropah occupies hardly 1 million ha of land, and 65-70% of the land is less than 3 year old. Several corporations, petroleum companies and private companies have entered into a memorandum of understanding (MoU) with state governments to establish and promote Jatropha plantations on government-owned wastelands or contract farming with small and medium farmer. However, only a few states have been able to actively promote Jatropha plantations despite government incentives.

Non availability of the feed stock coupled with less investment in the research & development of the product has resulted in serious hurdle in front of the government to achieve its target of the mission. Another major drawback has been difficulty to produce large scale Jatropha, with better yields and draught resistance variety.

Lack of specific markets for the produce that did not encourage the plantation of the plant. Middle men took most the seeds directly from the produce and sold it further to the processing units at higher commissions. The Jatropha seed distribution channels are currently underdeveloped as sufficient numbers of processing industries are not operating. The lack of assured supplies of feedstock supply has hampered efforts by the private sector to set up biodiesel plants in India.

National Policy on Biofuels (2018)

In order to promote biofuels in the country, a National Policy on Biofuels was made by Ministry of New and Renewable Energy during the year 2009.

Globally, biofuels have caught the attention in last decade and it is imperative to keep up with the pace of developments in the field of biofuels. Biofuels in India are of strategic importance as it augers well with the ongoing initiatives of the Government such as Make in India, Swachh Bharat Abhiyan, Skill Development and offers great opportunity to integrate with the ambitious targets of doubling of Farmers Income, Import Reduction, Employment Generation, Waste to Wealth Creation. Biofuels programme in India has been largely impacted due to the sustained and quantum non-availability of domestic feedstock for biofuel production which needs to be addressed.

Features:

- The Policy categorises biofuels into three categories to enable extension of appropriate financial and fiscal incentives under each category.
- First generation biofuels: These are made from food sources such as sugar, starch, vegetable oil, or animal fats using conventional technology. Common first-generation biofuels include Bioalcohols, Biodiesel, Vegetable oil, Bioethers, Biogas.
- Second generation biofuels: These are produced from non-food crops or portions of food crops that are not edible and considered as wastes, e.g. stems, husks, wood chips, and fruit skins and peeling.
- Thermochemical reactions or biochemical conversion process is used for producing such fuels. Examples include cellulose ethanol, biodiesel. It is reported that these biofuels emit

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less greenhouse gases when compared to first generation biofuels.

- Third generation biofuels: These are produced from micro-organisms like algae. Example- Butanol. Micro-organisms like algae can be grown using land and water unsuitable for food production, therefore reducing the strain on already depleted water sources. One disadvantage is that fertilizers used in the production of such crops lead to environment pollution.
- Fourth Generation Biofuels: In the production of these fuels, crops that are genetically engineered to take in high amounts of carbon are grown and harvested as biomass. The crops are then converted into
  fuel using second generation techniques. The fuel is pre-combusted and the carbon is captured. Then the carbon is geo-sequestered, meaning that the carbon is stored in depleted oil or gas fields or in unmineable coal seams. Some of these fuels are considered as carbon negative as their production pulls out carbon from environment.
- The Policy expands the scope of raw material for ethanol production by allowing use of Sugarcane Juice, Sugar containing materials like Sugar Beet, Sweet Sorghum, Starch containing materials like Corn, Cassava, Damaged food grains like wheat, broken rice, Rotten Potatoes, unfit for human consumption for ethanol production.
- Farmers are at a risk of not getting appropriate price for their produce during the surplus production phase. Taking this into account, the Policy allows use of surplus food grains for production of ethanol for blending with petrol with the approval of National Biofuel Coordination Committee.
- With a thrust on Advanced Biofuels, the Policy indicates a viability gap
  funding scheme for 2G ethanol Bio refineries of □5000 crore in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels.
- The Policy encourages setting up of supply chain mechanisms for biodiesel production from non-edible oilseeds, Used Cooking Oil, short gestation crops.
- Government has imposed ban on import and export of the biofuel which includes ethyl alcohol, petroleum oil and oils obtained from bituminous minerals, bio-diesel and mixtures. Trading can be done in these products only under license permit.
- Goods and Service Tax (GST) was reduced on biodiesel from 18% to 5%.

Table 1 Oil Yield Capacity of various oil seeds

S No.	**Crop type**	**Oil yield potential (‘000 l/ha)**
1	Microalgae	47.5-142.5
2	Oil Palm	6.0
3	Jatropha	2.0
4	Canola	1.25
5	Rapeseed	1.2

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6	Sunflower	1.0
7	Soybean	0.5
8	Corn	0.2

Source: Rapier R (2012) Renewable Energy-Facts and Figures. Energy traders report.

Processing of Biodiesel

- Process steps
  - Feedstock pre treatment
  - Reactions
  - Product purification
- Reactions
  - Transesterification
  - Base-catalysed transesterification mechanism
- Production methods
  - Supercritical process
  - Ultra- and high-shear in-line and batch reactors
  - Ultrasonic reactor method
  - Lipase-catalyzed method
  - Volatile fatty acids from anaerobic digestion of waste streams

Biodiesel production is the process of producing the biofuel, biodiesel, through the chemical reactions of transesterification and esterification. This involves vegetable or animal fats and oils being reacted with short-chain alcohols (typically methanol or ethanol). The alcohols used should be of low molecular weight. Ethanol is the most used because of its low cost, however, greater conversions into biodiesel can be reached using methanol. Although the trans esterification reaction can be catalyzed by either acids or bases, the base-catalyzed reaction is more common. This path has lower reaction times and catalyst cost than those acid catalysis.

The process steps are as follows:

1. Feedstock pre-treatment: Common feedstock used in biodiesel production includes yellow grease (recycled vegetable oil), "virgin" vegetable oil, and tallow. Recycled oil is processed to remove impurities from cooking, storage, and handling, such as dirt, charred food, and water. Degumming to remove phospholipids and other plant matter is common, though refinement processes vary. Water is removed as its presence during basecatalyzed transesterification will cause the triglycerides to hydrolyze, producing soap instead of biodiesel.
2. Reactions: Base-catalyzed transesterification reacts lipids (fats and oils) with alcohol (typically methanol or ethanol) to produce biodiesel and an impure coproduct, glycerol. If the feedstock oil is used or has a high acid content, acid-catalyzed esterification can be used to react fatty acids with alcohol to produce biodiesel. Other methods, such as fixed-bed reactors, supercritical reactors, and ultrasonic reactors, forgo or decrease the use of chemical catalysts.

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3. Product Purification: Products of the reaction include not only biodiesel, but also by-products, soap, glycerol, excess alcohol, and trace amounts of water. All of these by-products must be removed to meet the standards, but the order of removal is process dependent. The density of glycerol is greater than that of biodiesel, and this property difference is exploited to separate the bulk of the glycerol coproduces. Residual methanol is typically recovered by distillation and reused. Soaps can be removed or converted into acids. Residual water is also removed from the fuel.

Table 2 Types of Bio Product and Technique used

Raw material	Technique	Product	Product type
Vegetable oil and animal fat	Hydrotreatment	Biodiesel	Hydro-treated biodiesel
Algae	Fermentation, extraction and Esterification	Biodiesel etc.	Algal biodiesel
Lignocellulosic material	Advanced hydrolysis & fermentation	Biomass-to-liqui ds (BTL): Fischer-Tropsch (FT) diesel synthetic (bio) diesel	Synthetic biodiesel
Lignocellulosic material	Advance hydrolysis and fermentation	Cellulosic bioethanol	Bioethanol

Economics of Jatropha Oil

Dorado et al. (2006) studied and approach to the economics of two vegetable oil based biofuels in Spain. This study identified that the price of the feedstock was one of the most significant factor. Also, glycerol was found to be a valuable by-product that could reduce the final manufacturing costs of the process up to
6.5 per cent, depending on the raw feedstock used. Biodiesel can only compete with diesel fuel prices if the feed cost is taken care of. Planning Commission of India (2004) has calculated the cost of biodiesel for Jatropha biodiesel considering seed at □6 per kg and worked out the cost to be 20 per litre (which is expected at least aGer 4 years of plantation from then). Dindorkar (2006) studied on the production and energy balance of biodiesel and its performance in CI engine. Economics were calculated for biodiesel production using small scale domestic PKV Biodiesel processor. The cost of biodiesel was found □29.31 per litre of biodiesel considering seed cost 5/kg by Samodini S. Nevase et al. in 2012. The cost of JEE was found to be □ 28.64 per liter (by reducing cost of by products) when the cost of Jatropha oil was a □ 26/kg and that of seed cost was □ 6/kg. Biodiesel is gaining acceptable worldwide as a solution for problem of

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environmental degradation, energy security, restricting imports, rural employment and attaining better agricultural economy.

2. CONCLUSION

India's dependency on the crude oil for the purpose of diesel is rising at a very high rate; this is resulting not only in large demand for forex but also rising rate of pollution. Both on the economic as well as environmental ground, Biofuel can be considered as a feasible substitute for it. Current production of the biodiesel is not enough to fulfil the need of the green economy. India has signed several MoU's and International commitment to develop more of greener fuel by 2030.
National Biodiesel Mission was launched in 2009 to capture the potential of the country in the production & processing of biodiesel using the Jatropha. The plant has properties to grown even in dry land and yield good quality.
Production of biodiesel from it can reduce the cost of diesel to the end consumer on an average by 30%, given environmental benefits and blended approach. It failed as it was not able to increase the size under the Jatropha cultivation as there was no proper market for the same.

National Biofuel Mission is launched in 2018 to realize the potential of bio fuels. Several incentives are given to promote the domestic production including financial assistance, Export & Import ban, Land reforms, and government assistance. It is aimed to B20 variant of the biodiesel by 2025,
experiments have been carried out in Gujrat to carry 100% Biodiesel and have caused a great success for the mission.

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